Model intercomparison of maize response to climate change in low-input smallholder cropping systems

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1 Introduction

- Smallholder farming systems are characterized by **poor soil fertility** and **low agricultural input use**; process-based crop growth models can help quantifying the potential impact of climate change on productivity in these systems.
- With limiting conditions (water and nutrients), crop models need to rigorously account for **soil water, nutrient, CO_2, and temperature interactions** when simulating climate change effects.

We performed a **crop model intercomparison** including **29 different maize models:**

1) **How accurately** can these models **simulate observed yield** in diverse smallholder cropping systems ?
2) **How uncertain are the model responses** to changes in **CO_2, temperature and water ?**

2 Methods

Five contrasting experimental sites across sub-Saharan Africa (OPV: Open Pollinated Variety):

		ETHIOPIA	RWANDA	GHANA	MALI	BENIN
SOIL	Soil Texture	clay	sandy loam	clay	loamy sand	loamy sand
	SOC (%) (0-30cm)	0.65	1.65	0.57	0.20	0.28
MANAGEMENT	Cultivar	Hybrid	OPV	OPV	OPV	OPV
	N fertiliser (kg/ha)	87	64	80	85	0
CLIMATE (baseline 1980-2010)	Type of rainy season	unimodal	bimodal	bimodal	unimodal	unimodal
	Temperature (°C)	20.6	21.9	27.6	28.3	25.5
	Rainfall (mm)	938	330*	440*	580	640

*major growing season only

FAO Agro-ecological zones:

- Cool sub-humid
- Warm sub-humid
- Warm semi-arid

29 soil-crop models (some with different soil or crop modules) :
AGRO-IBIS, APSIM, CELSIUS, DSSAT, CROPSYST, DNDC, EPIC, EXPERT-N, GLAM, HERMES, INFOCROP, MAIZSIM, MCWLA - MAIZE, MONICA, PEGASUS, RZWQM2, SALUS, SARRA-H, SIMPLACE-LINTUL, STICS, SWB

1) Model calibration; two experimental years per site

Partial calibration: crop phenology only

Full calibration: experimental yields, in-season biomass, leaf area index and soil water content provided

2) Model sensitivity to climate change; baseline climate compared with:

increased [CO_2] :	**Increased temperature:**	**Modified rainfall :**
450, 540, 630 and **720** ppm	+2, **+4** and +6 °C	**50**, 75, 125 and **150%** of current

3 Results

1) Model simulation of observed yield

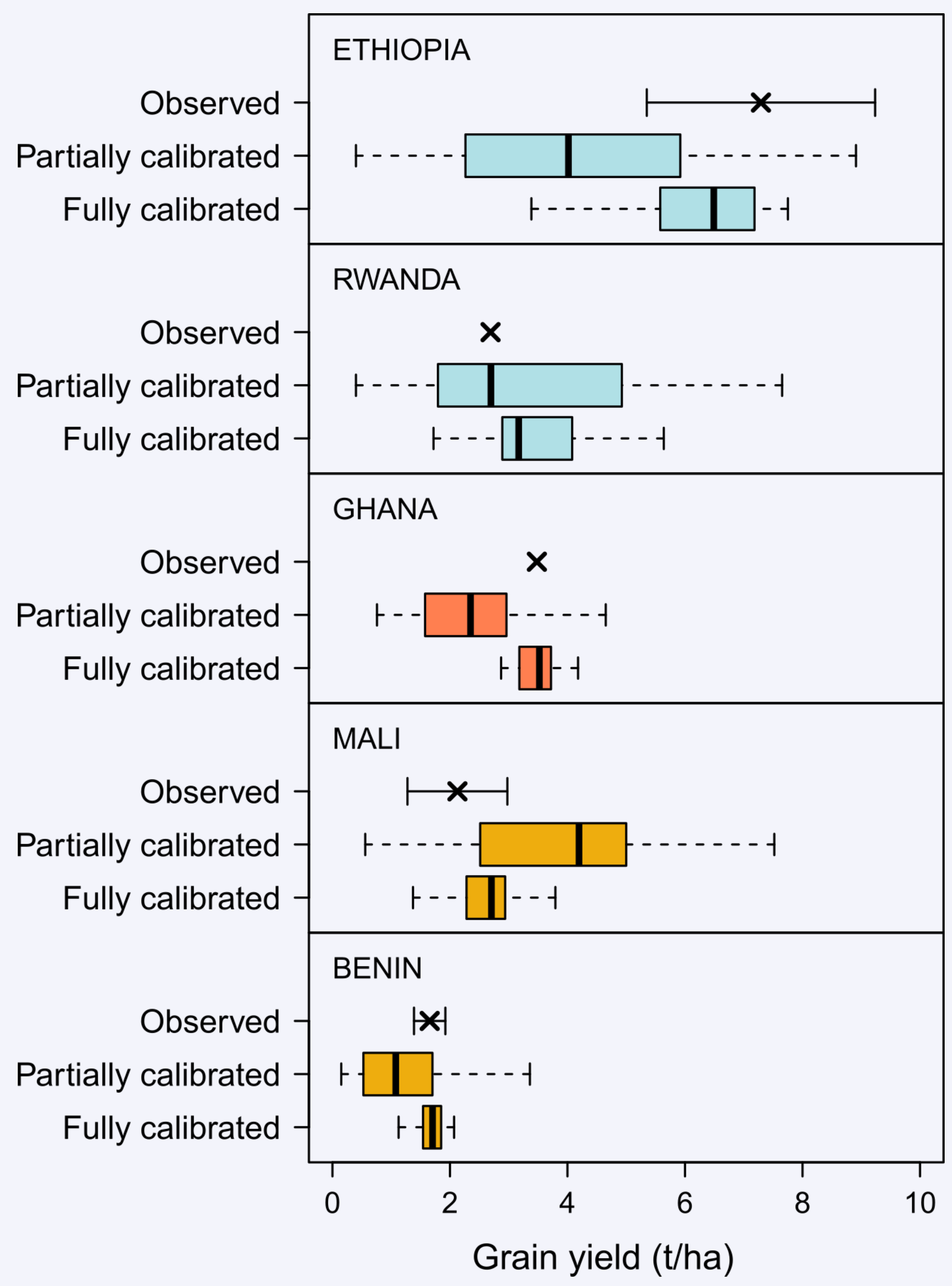

Fig 1. Observed (crosses) and simulated (box plots) grain yields

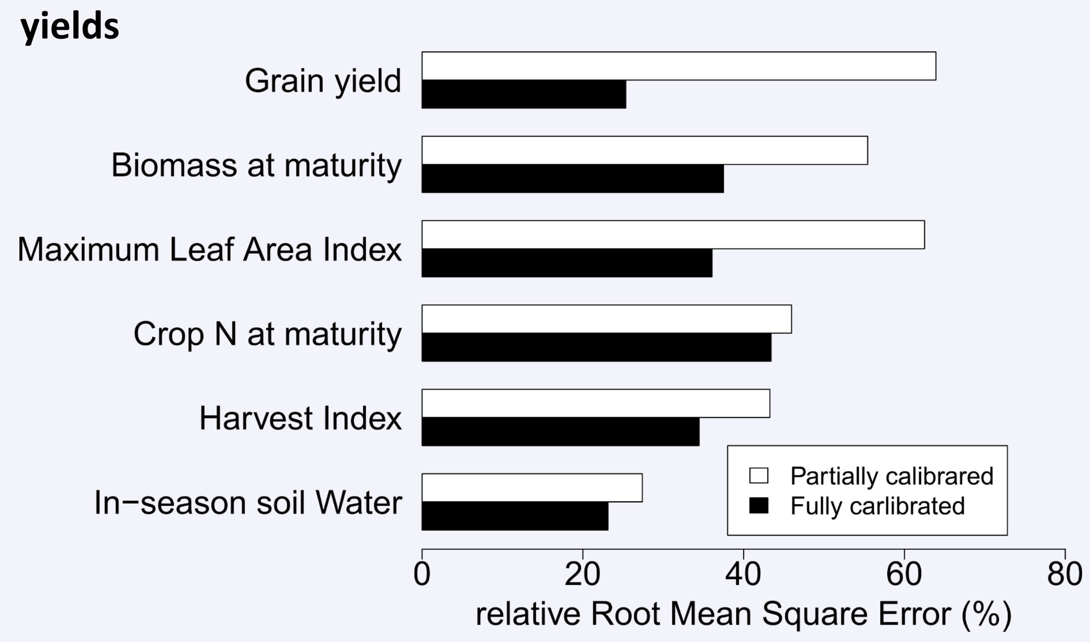

Fig. 2: Relative Root Mean Square Error (averages across models) of simulation – observation comparisons accross all five sites

- Simulated **grain yield varied widely** among models **with partial calibration** (coefficients of variation (CV) from 51% to 77% depending on site) **(Fig1.)**
- **Full calibration greatly reduced uncertainty** (CV 12-31% depending on site)
- Simulation **accuracy increased** with full calibration **for other maize growth variable (biomass, max. LAI)** but not for Crop N content at maturity and in-season soil water contents **(Fig. 2)**

2) Model sensitivity to climate change

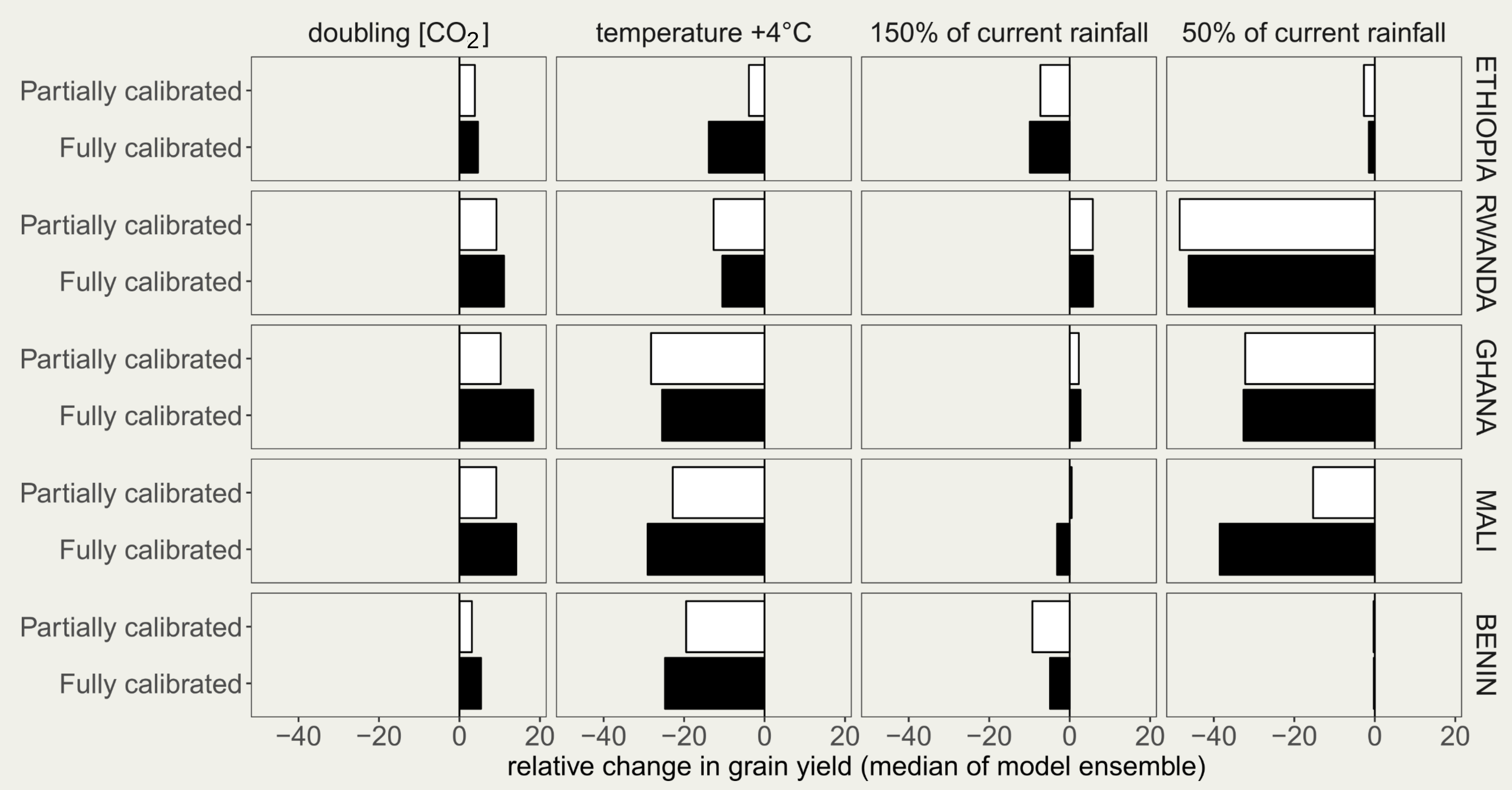

Fig 3: Relative change in simulated maize yield (median of model ensemble) with climate change

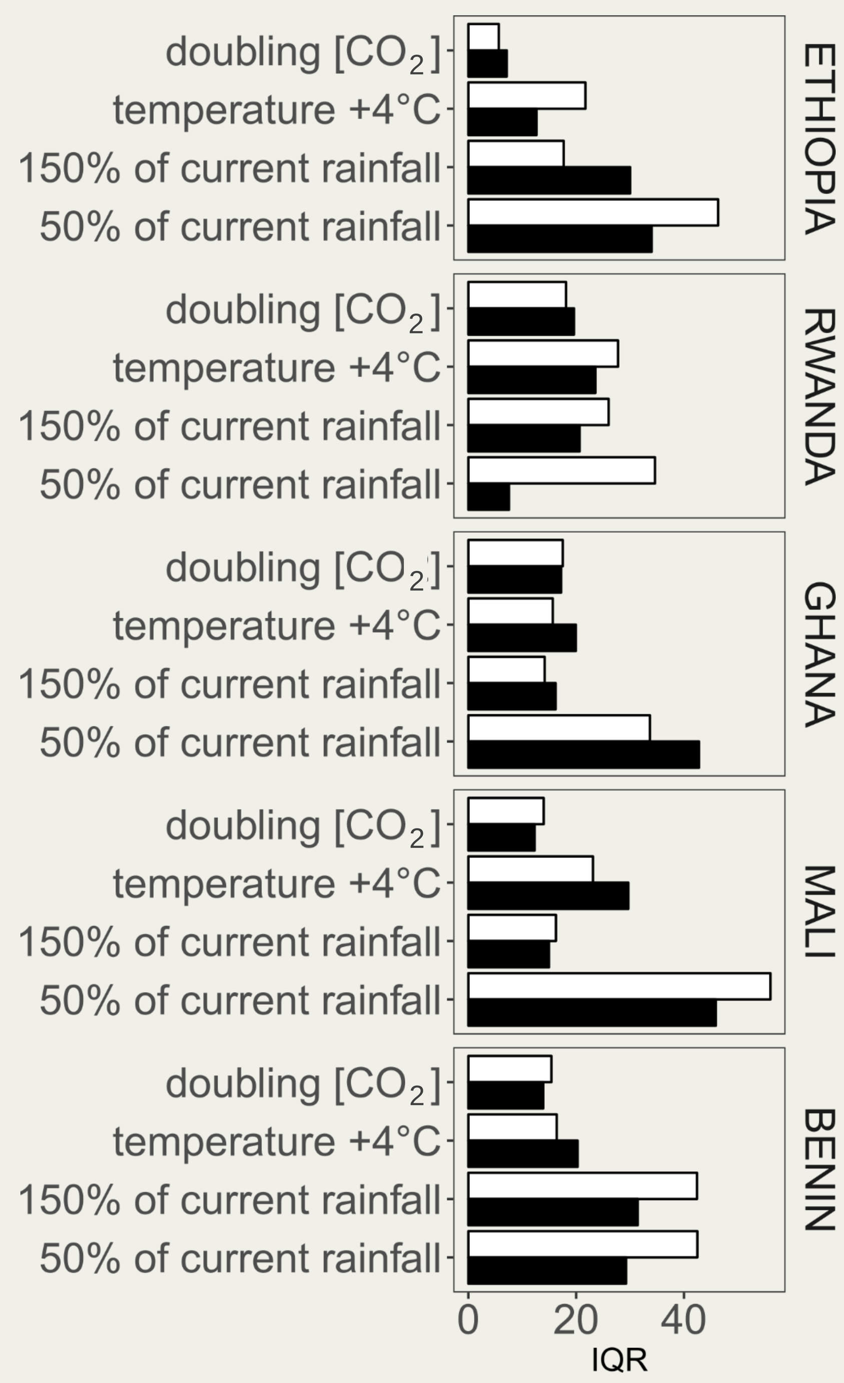

Fig 4: Uncertainty in model response (*i.e.* Inter Quartile Range (IQR) of ensemble relative change in simulated maize yield)

- Ensemble median yield (with 80 kg N/ha) **(Fig 3.)**
  - **increased slightly** with doubling [CO_2]
  - **decreased** with **+4°C** (more strongly in warm sites)
  - Decreased or increased (depending on site) at **150% of current rainfall**
  - **Decreased** (except in Benin) at **50% of current rainfall**
- Full calibration did not alter significantly ensemble median sensitivity to [CO_2], temperature and rainfall changes compared with partial calibration (**Fig 3.**)
- Model response uncertainty was highest with 50% of current rainfall at all sites (**Fig. 4**).
- Uncertainty in model response to change in rainfall did not decrease substantially with full calibration (**Fig 4.**) except in Rwanda for 50% of current rainfall

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4 Conclusion

- Although model simulations of water – and nutrient-limited yield in low input conditions greatly improved after full calibration, models response to changes in climate factors, especially rainfall, remained highly uncertain.
- This questions our ability to derive robust recommendations for decision-making using modelling on adaptation to climate change in sub-Saharan Africa
- Further analysis will address the impact of model structure and calibration procedure on response to changes in temperature and rainfall