Celebrating 30 years of integrated climate impact research at the Potsdam Institute.

# Climate Change Impacts on Ethiopian Agriculture:

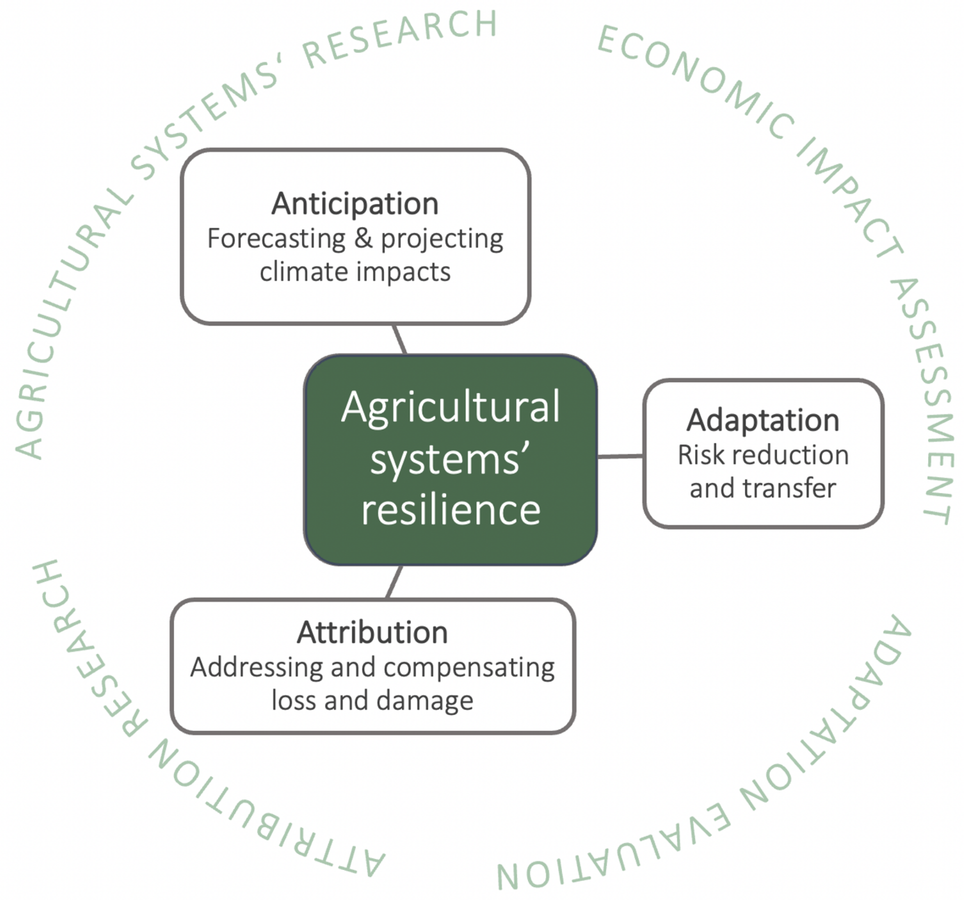
# Evidence from Crop Models

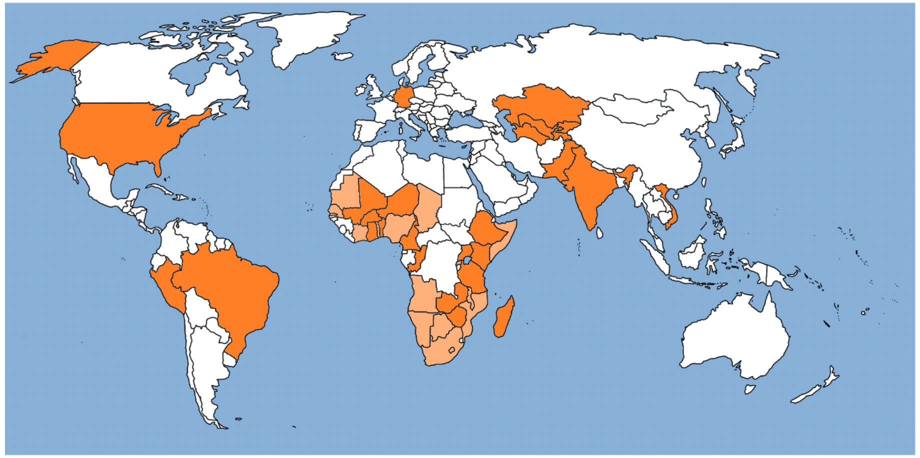
- Working Group Adapation in Agricultural Systems -

Leibniz Association

# Working Group: Adaptation in Agricultural Systems

## - RD Climate Resilience -



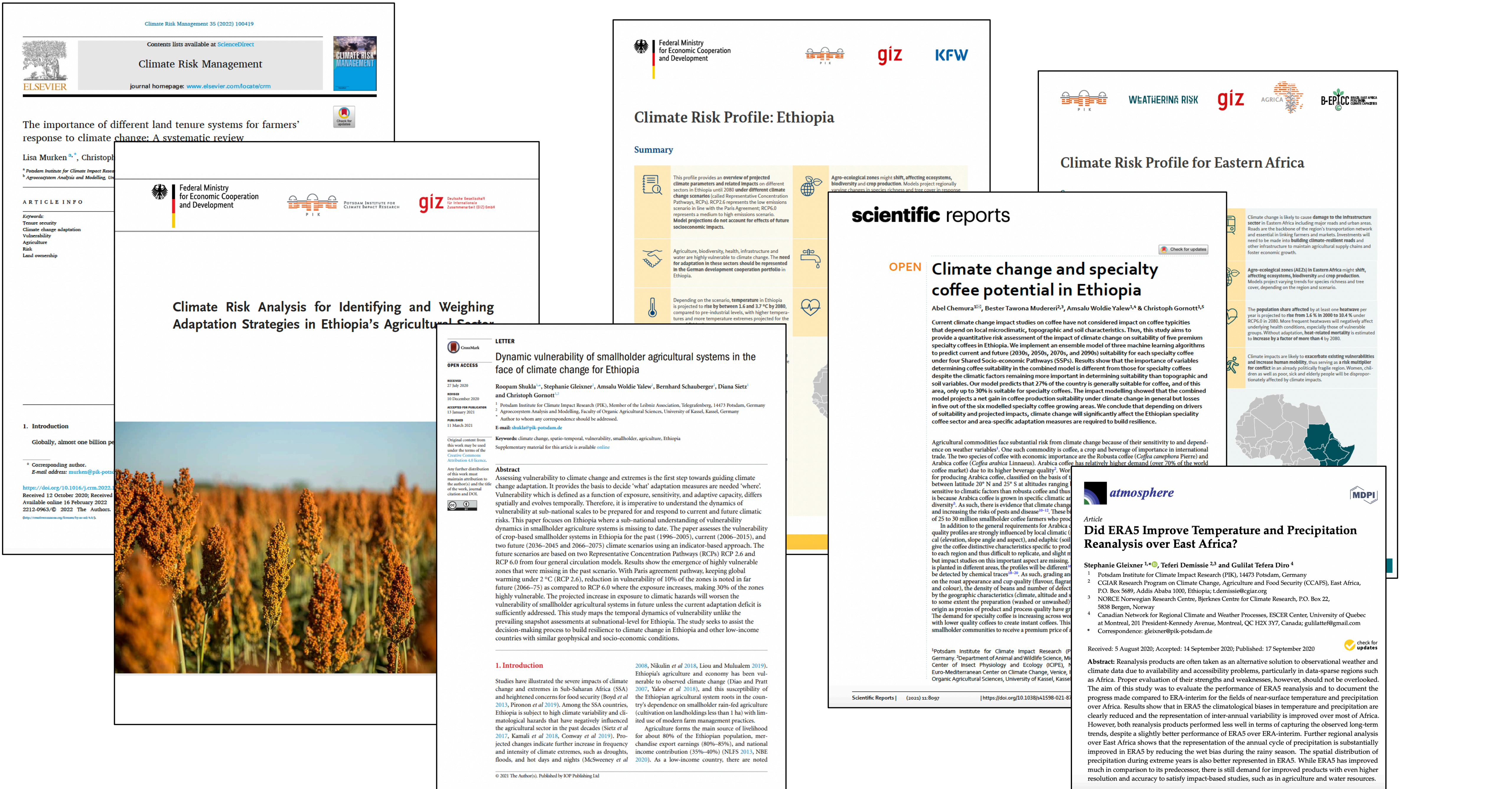



Project Countries

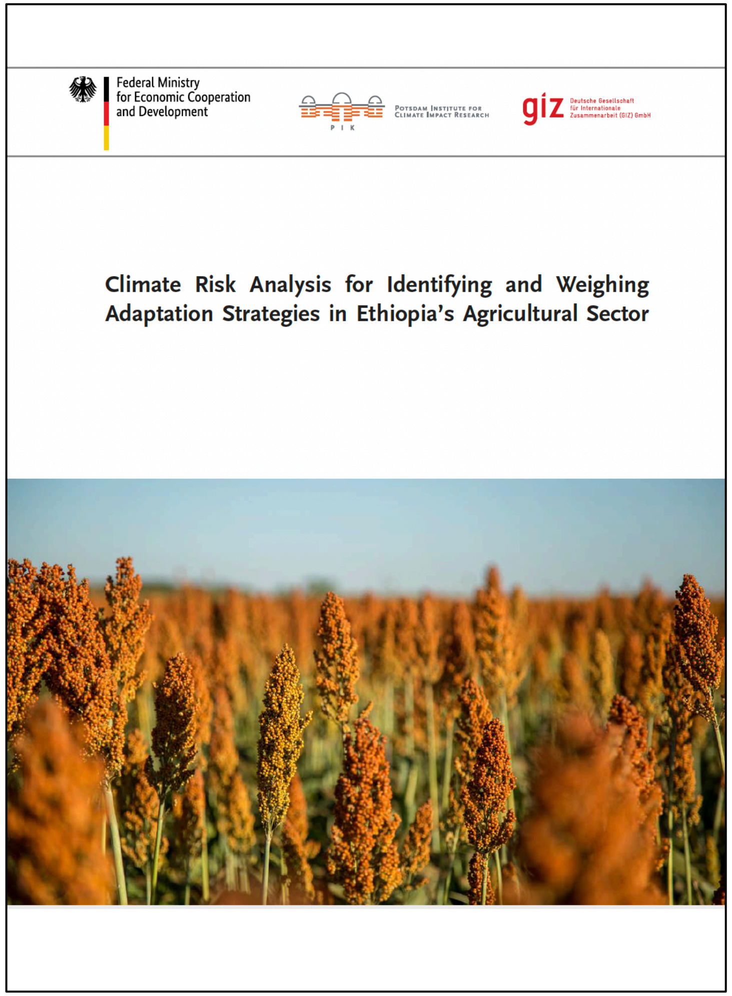
## Methods

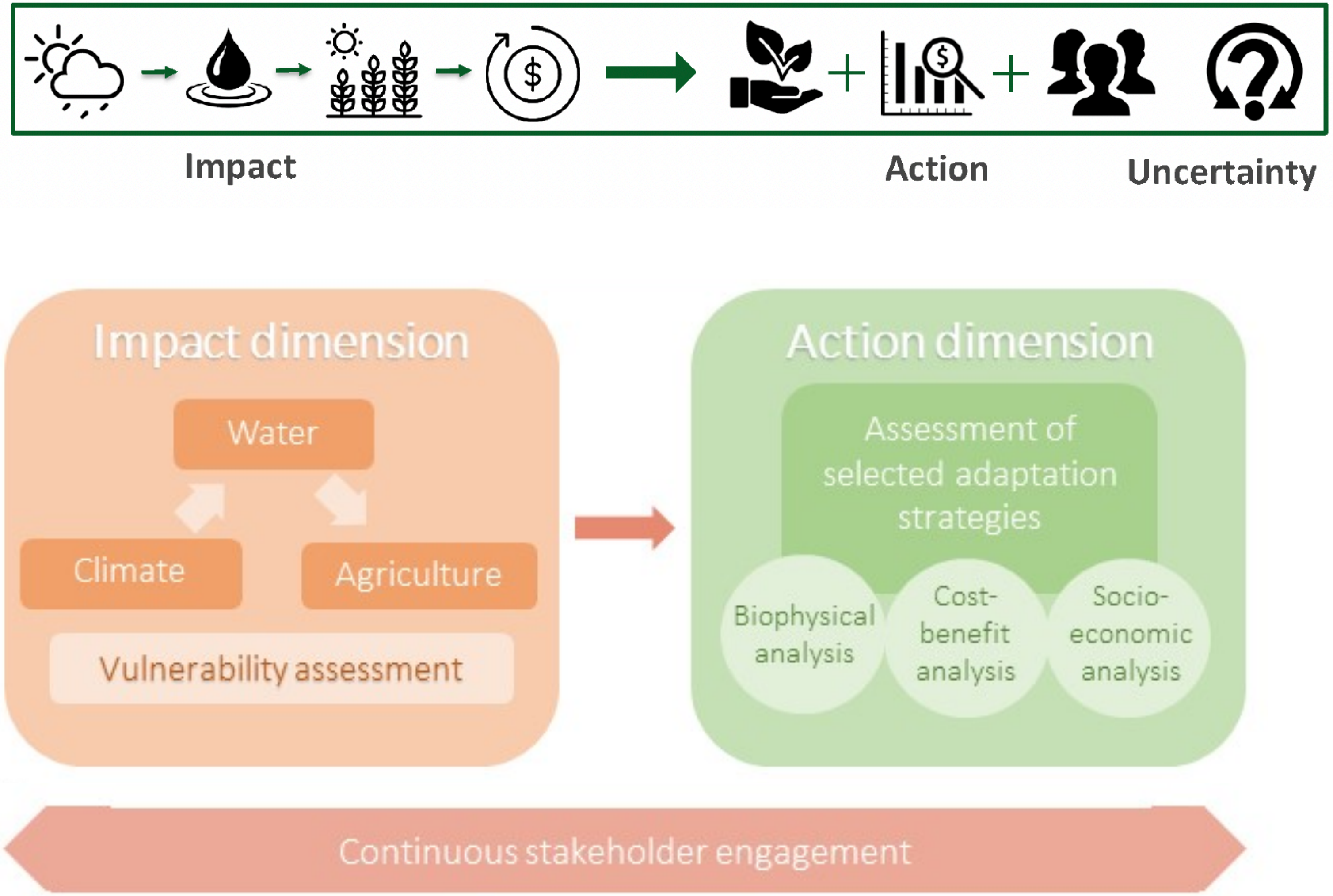
- **Semi-empirical/Statistical** models with process-based components, causal discovery algorithms and machine-learning
- **Process-based crop models** (e.g. SWIM, LPJmL, DSSAT, APSIM) to capture bio-physical relationships
- **Econometric methods** to analyze household survey data and randomized control trials

# Our Research on Ethiopia

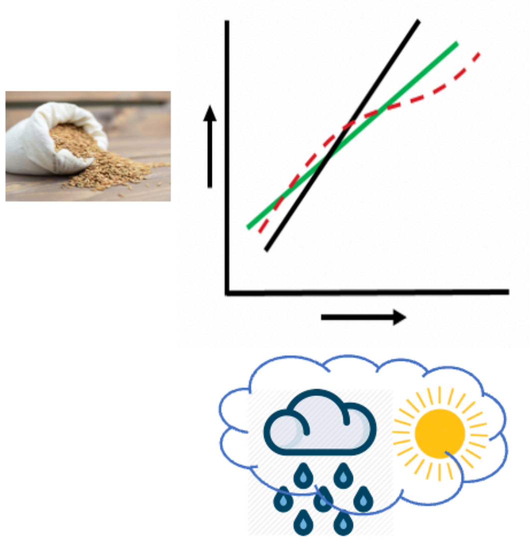


# AGRICA Climate Risk Report - Concept



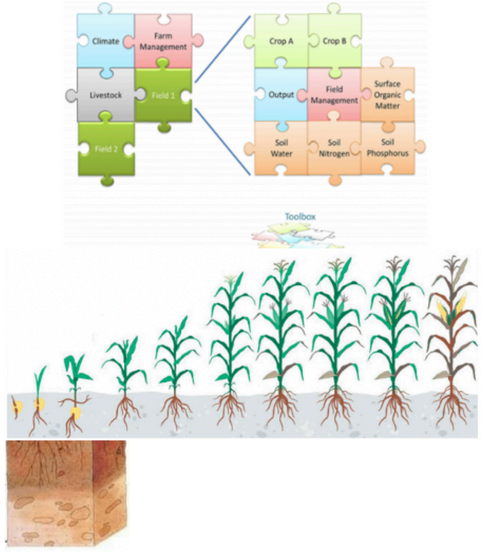



# AGRICA Climate Risk Report – Agricultural Impacts of Climate Change



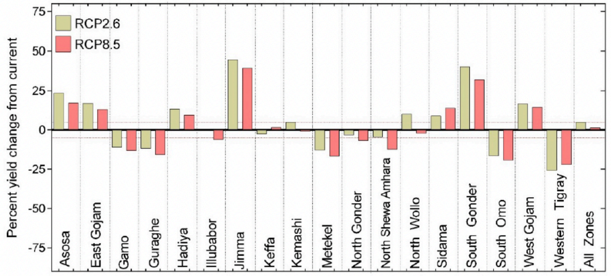
Statistical crop model AMPLIFY

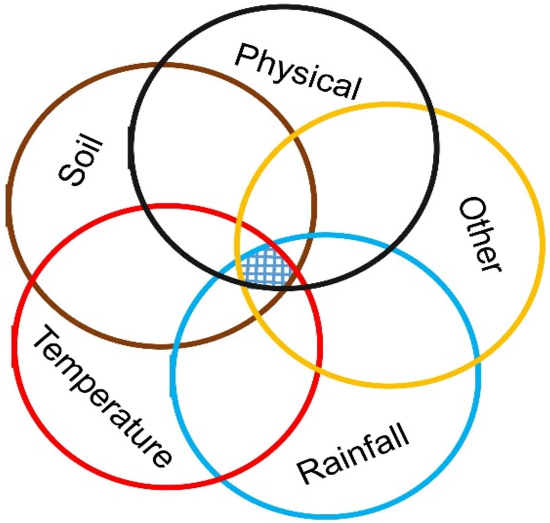
Weather explains 55-89% of year-to-year variability of nationally aggregated yield




Process-based crop model APSIM

Projected Changes in Maize Yield




Ensemble of ML Suitability Models

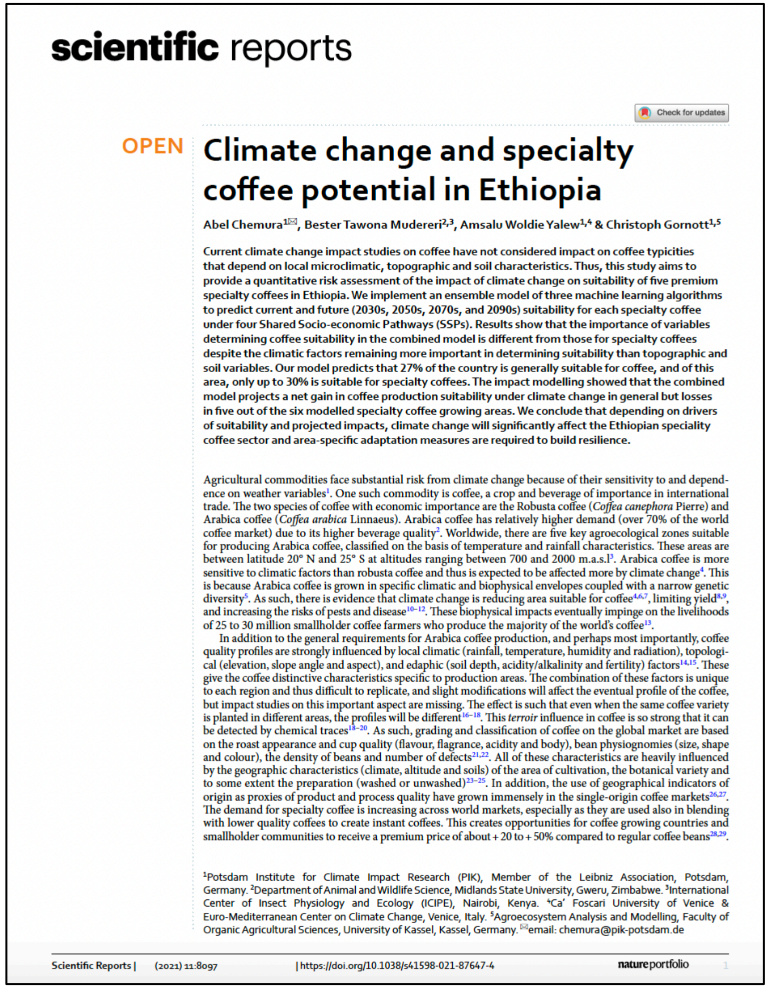
Decrease in suitability for Maize, Wheat and Teff. Increase in suitability for Sorghum.

# AGRICA Climate Risk Report – Assessment of Adaptation Strategies

| Adaptation strategy | Irrigation | Switching crops | Agroforestry | Fodder and feed improvement | Insurance |
|---|---|---|---|---|---|
| Risk response | Risk mitigation | Risk mitigation | Risk mitigation | Risk mitigation | Risk transfer |
| Risk mitigation potential | High | High | High[2] | High | No risk mitigation |
| Cost effectiveness | Medium | Medium | High | High | Risk transfer |
| Risk gradient | Risk-independent | Risk-specific | Risk-specific | Risk-independent | (Weather) risk specific |
| Upscaling potential | High | Medium | Medium-high | High | Medium |
| Development co-benefits | High | Medium | High | High | Medium |
| Potential maladaptive outcomes | High | Medium | Low | Medium | Medium |
| Stakeholder interest | High | High | High | High | Low |
| Institutional support requirements | Medium | Medium | Medium | Medium | High |

Focus on staple crops!

# Changes in Coffee Suitability



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## Climate change and specialty coffee potential in Ethiopia

Abel Chemura[1✉], Bester Tawona Mudereri[2,3], Amsalu Woldie Yalew[1,4] & Christoph Gornott[1,5]

**Current climate change impact studies on coffee have not considered impact on coffee typicities that depend on local microclimatic, topographic and soil characteristics. Thus, this study aims to provide a quantitative risk assessment of the impact of climate change on suitability of five premium specialty coffees in Ethiopia. We implement an ensemble model of three machine learning algorithms to predict current and future (2030s, 2050s, 2070s, and 2090s) suitability for each specialty coffee under four Shared Socio-economic Pathways (SSPs). Results show that the importance of variables determining coffee suitability in the combined model is different from those for specialty coffees despite the climatic factors remaining more important in determining suitability than topographic and soil variables. Our model predicts that 27% of the country is generally suitable for coffee, and of this area, only up to 30% is suitable for specialty coffees. The impact modelling showed that the combined model projects a net gain in coffee production suitability under climate change in general but losses in five out of the six modelled specialty coffee growing areas. We conclude that depending on drivers of suitability and projected impacts, climate change will significantly affect the Ethiopian speciality coffee sector and area-specific adaptation measures are required to build resilience.**

Agricultural commodities face substantial risk from climate change because of their sensitivity to and dependence on weather variables[1]. One such commodity is coffee, a crop and beverage of importance in international trade. The two species of coffee with economic importance are the Robusta coffee (*Coffea canephora* Pierre) and Arabica coffee (*Coffea arabica* Linnaeus). Arabica coffee has relatively higher demand (over 70% of the world coffee market) due to its higher beverage quality[2]. Worldwide, there are five key agroecological zones suitable for producing Arabica coffee, classified on the basis of temperature and rainfall characteristics. These areas are between latitude 20° N and 25° S at altitudes ranging between 700 and 2000 m.a.s.l[3]. Arabica coffee is more sensitive to climatic factors than robusta coffee and thus is expected to be affected more by climate change[4]. This is because Arabica coffee is grown in specific climatic and biophysical envelopes coupled with a narrow genetic diversity[5]. As such, there is evidence that climate change is reducing area suitable for coffee[4,6,7], limiting yield[8,9], and increasing the risks of pests and disease[10–12]. These biophysical impacts eventually impinge on the livelihoods of 25 to 30 million smallholder coffee farmers who produce the majority of the world's coffee[13].

In addition to the general requirements for Arabica coffee production, and perhaps most importantly, coffee quality profiles are strongly influenced by local climatic (rainfall, temperature, humidity and radiation), topological (elevation, slope angle and aspect), and edaphic (soil depth, acidity/alkalinity and fertility) factors[14,15]. These give the coffee distinctive characteristics specific to production areas. The combination of these factors is unique to each region and thus difficult to replicate, and slight modifications will affect the eventual profile of the coffee, but impact studies on this important aspect are missing. The effect is such that even when the same coffee variety is planted in different areas, the profiles will be different[16–18]. This *terroir* influence in coffee is so strong that it can be detected by chemical traces[18–20]. As such, grading and classification of coffee on the global market are based on the roast appearance and cup quality (flavour, flagrance, acidity and body), bean physiognomies (size, shape and colour), the density of beans and number of defects[21,22]. All of these characteristics are heavily influenced by the geographic characteristics (climate, altitude and soils) of the area of cultivation, the botanical variety and to some extent the preparation (washed or unwashed)[23–25]. In addition, the use of geographical indicators of origin as proxies of product and process quality have grown immensely in the single-origin coffee markets[26,27]. The demand for specialty coffee is increasing across world markets, especially as they are used also in blending with lower quality coffees to create instant coffees. This creates opportunities for coffee growing countries and smallholder communities to receive a premium price of about + 20 to + 50% compared to regular coffee beans[28,29].

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SPIEGEL Wissenschaft

Äthiopien

## Klimawandel bedroht Anbau hochwertiger Kaffeesorten

Sie schmecken blumig, fruchtig oder würzig statt bitter. In Äthiopien wachsen einige besonders exquisite Kaffeebohnen, doch klimatische Veränderungen könnten die Anbauflächen reduzieren.

14.04.2021, 17.47 Uhr

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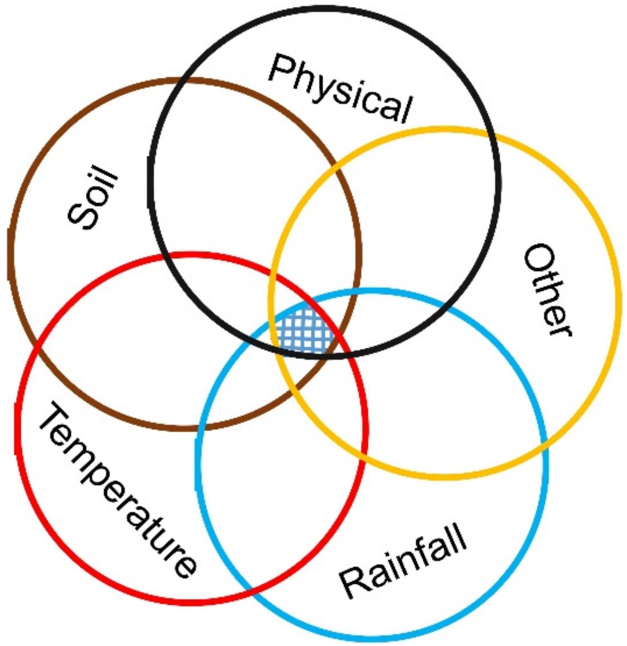
Wissen | Kaffee für eine heiße Welt: Wilde Sorte soll Klimawandel trotzen

## Kaffee für eine heiße Welt Wilde Sorte soll Klimawandel trotzen

In Äthiopien bedroht die globale Erwärmung den Kaffeeanbau mit herkömmlichen Sorten. Doch es gibt Ideen für Gegenmaßnahmen – und eine robuste Art als Alternative.

# Climate Change Impacts in on speciality coffee

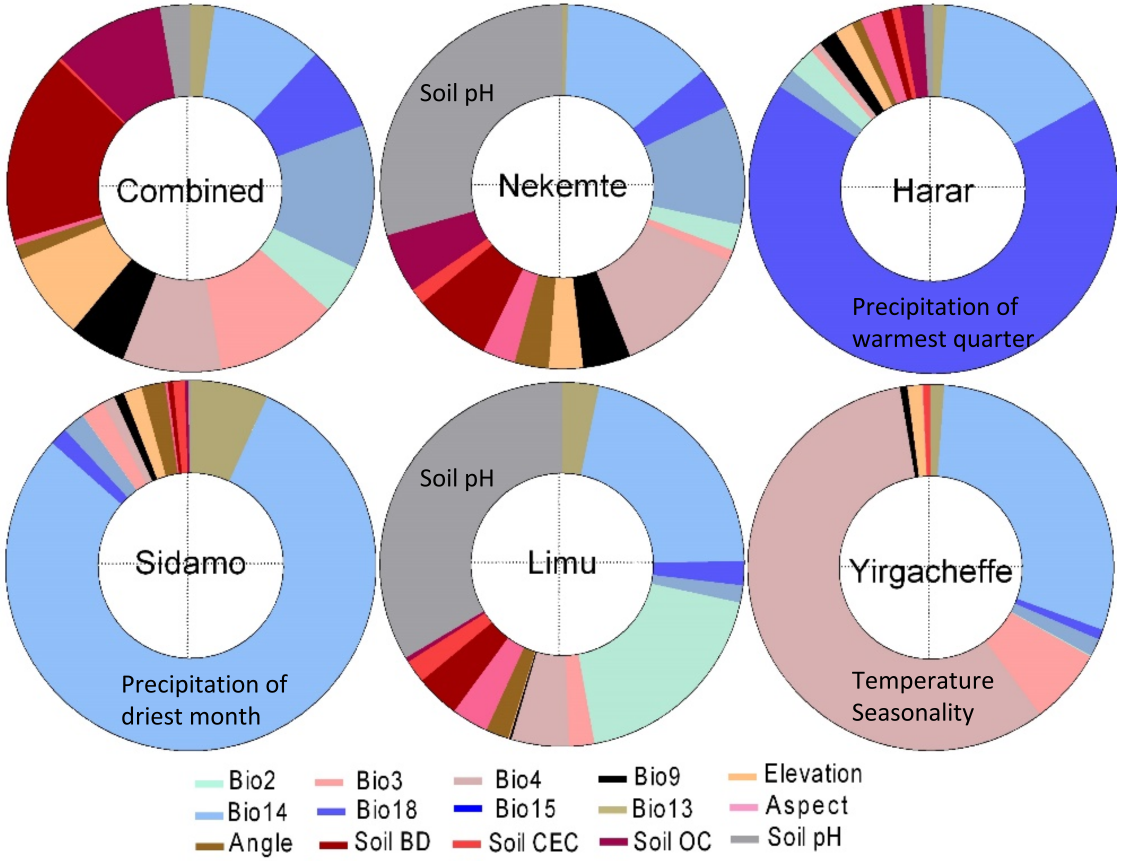

Approach:
Suitability Model




**Focus on Yirgacheffe, Sidamo, Harar/Mocca, Nekemte and Limu**

# Influences on Coffee Suitability

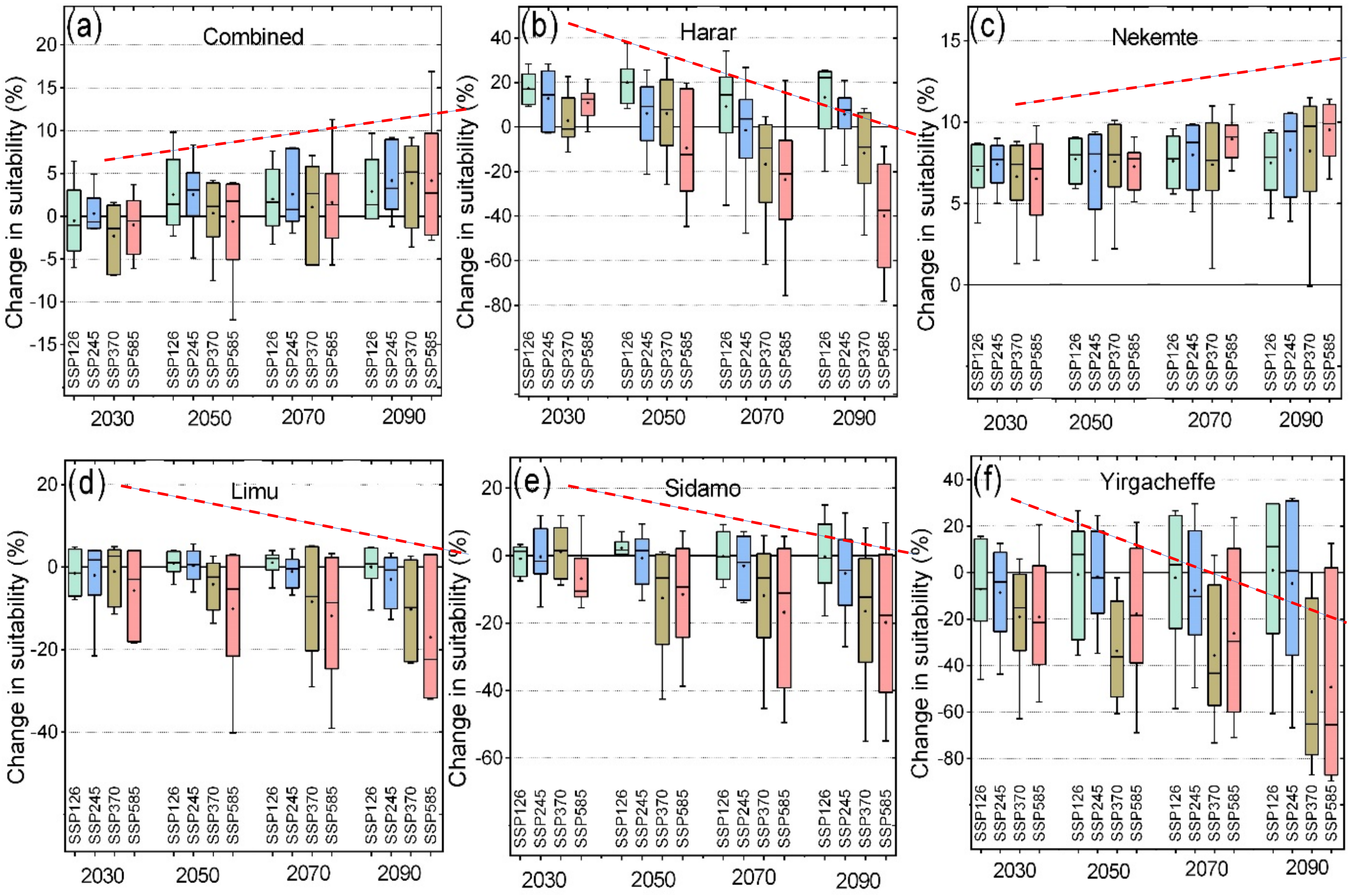
- What environmental and biophysical conditions are necessary for coffee in general and specialty coffee in particular?




No single dominant variable for suitability of coffee but for specialty coffees.

# Future Changes in Coffee Suitability

- What environmental and biophysical conditions are necessary for coffee in general and specialty coffee in particular?
- How would future changes of these conditions change impact speciality coffee?



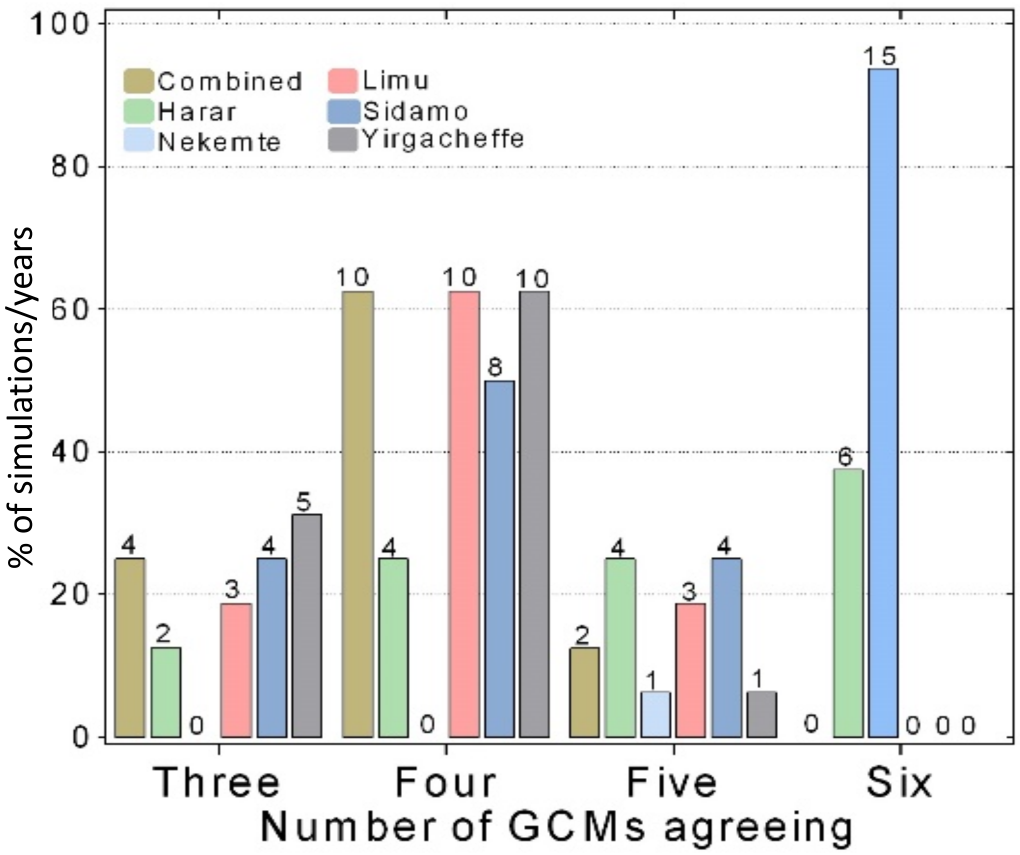
# Deciding Resilience Pathways

- What environmental and biophysical conditions are necessary for coffee in general and specialty coffee in particular?
- How would future changes of these conditions change impact speciality coffee?
- How can these impacts be mitigated with adaptation?

| | | | | | Potential of Adaptation Measures | | | |
|---|---|---|---|---|---|---|---|---|
| | Model Performance | Climate Change Impacts | Model Agreement | Top Change Contributors | Intensification | Agroforestry | Soil Fertility Management | Irrigation |
| Combined | ●●● | ● | ●● | Bio14, Bio15, Bio3, Soil BD, Soil OC | - | - | - | - |
| Harar | ●● | ●● | ●●● | Bio 18 | ●● | - | - | ●● |
| Nekemte | ●●● | ● | ●●● | Bio14, Bio4, Soil pH | - | - | - | - |
| Limu | ●●● | ●● | ●● | Bio14, Bio2, Soil pH | ●● | ●●● | ●● | ●●● |
| Sidamo | ●●● | ●● | ●● | Bio14 | ● | ● | - | ●●● |
| Yirgacheffe | ●●● | ●●● | ● | Bio4 | ●●● | ●●● | ● | ●●● |

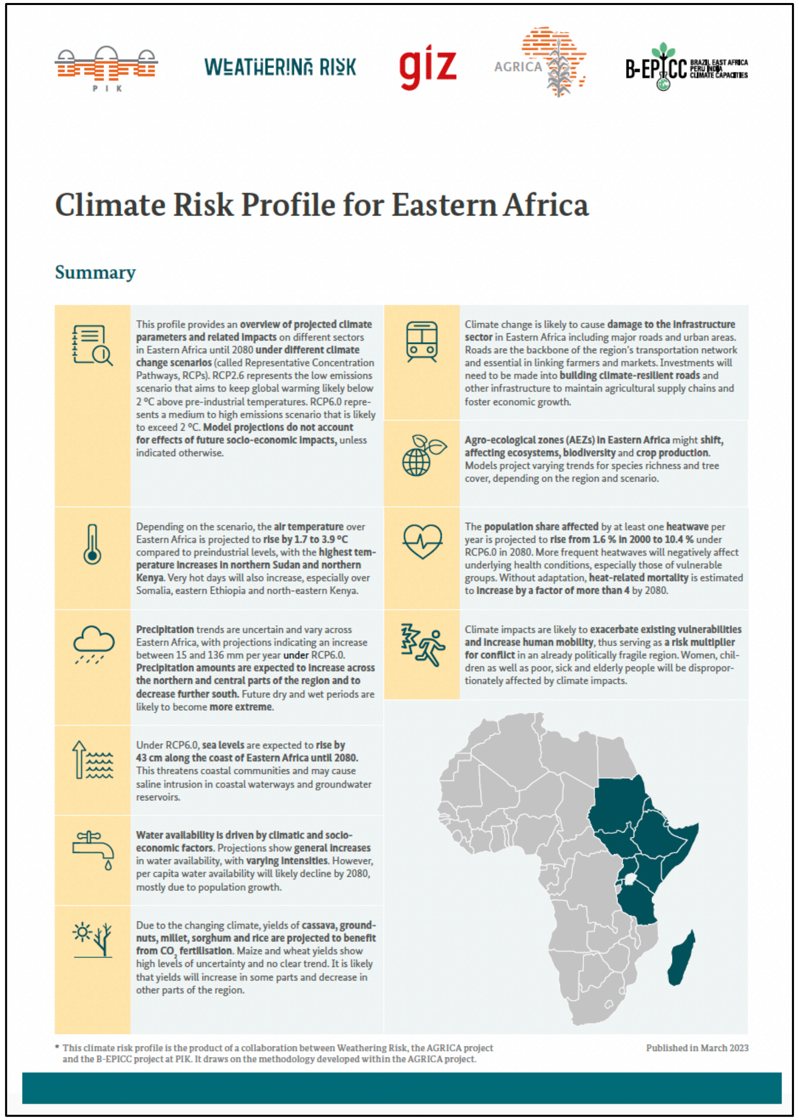
● low ●● medium ●●● high

# B-EPICC era:
# Continuing coffee research with focus on model agreement




- This study was based on six GCMs, how do results with other GCMs compare?
- How robust are results across emission pathways and time?
- Are results based on global warming levels more robust and informative?

# B-EPICC era:
# Climate Risk Profile for East Africa



Climate Risk Profile for Eastern Africa

Summary

This profile provides an **overview of projected climate parameters and related impacts** on different sectors in Eastern Africa until 2080 **under different climate change scenarios** (called Representative Concentration Pathways, RCPs). RCP2.6 represents the low emissions scenario that aims to keep global warming likely below 2 °C above pre-industrial temperatures. RCP6.0 represents a medium to high emissions scenario that is likely to exceed 2 °C. **Model projections do not account for effects of future socio-economic impacts,** unless indicated otherwise.

Depending on the scenario, the **air temperature** over Eastern Africa is projected to **rise by 1.7 to 3.9 °C** compared to preindustrial levels, with the **highest temperature increases in northern Sudan and northern Kenya**. Very hot days will also increase, especially over Somalia, eastern Ethiopia and north-eastern Kenya.

**Precipitation** trends are uncertain and vary across Eastern Africa, with projections indicating an increase between 15 and 136 mm per year under RCP6.0. **Precipitation amounts are expected to increase across the northern and central parts of the region and to decrease further south.** Future dry and wet periods are likely to become **more extreme**.

Under RCP6.0, **sea levels** are expected to **rise by 43 cm along the coast of Eastern Africa until 2080.** This threatens coastal communities and may cause saline intrusion in coastal waterways and groundwater reservoirs.

**Water availability is driven by climatic and socio-economic factors**. Projections show **general increases** in water availability, with **varying intensities**. However, per capita water availability will likely decline by 2080, mostly due to population growth.

Due to the changing climate, yields of **cassava, groundnuts, millet, sorghum and rice are projected to benefit from $CO_2$ fertilisation**. Maize and wheat yields show high levels of uncertainty and no clear trend. It is likely that yields will increase in some parts and decrease in other parts of the region.

Climate change is likely to cause **damage to the infrastructure sector** in Eastern Africa including major roads and urban areas. Roads are the backbone of the region's transportation network and essential in linking farmers and markets. Investments will need to be made into **building climate-resilient roads** and other infrastructure to maintain agricultural supply chains and foster economic growth.

**Agro-ecological zones (AEZs) in Eastern Africa** might **shift, affecting ecosystems, biodiversity** and **crop production**. Models project varying trends for species richness and tree cover, depending on the region and scenario.

The **population share affected** by at least one **heatwave** per year is projected to **rise from 1.6 % in 2000 to 10.4 %** under RCP6.0 in 2080. More frequent heatwaves will negatively affect underlying health conditions, especially those of vulnerable groups. Without adaptation, **heat-related mortality** is estimated to **increase by a factor of more than 4** by 2080.

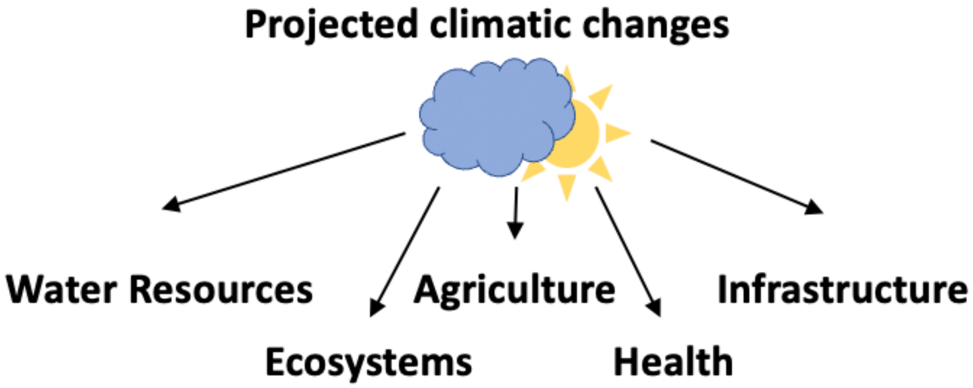
Climate impacts are likely to **exacerbate existing vulnerabilities and increase human mobility**, thus serving as **a risk multiplier for conflict** in an already politically fragile region. Women, children as well as poor, sick and elderly people will be disproportionately affected by climate impacts.

* This climate risk profile is the product of a collaboration between Weathering Risk, the AGRICA project and the B-EPICC project at PIK. It draws on the methodology developed within the AGRICA project.

Published in March 2023

Brief for NDC and NAP implementation and climate risk-informed decision making:

- **Comprehensive**: Projected changes for climate and its impacts in five related sectors under two GHG emission scenarios
- **Coherent**: Climate and climate impact projections based on ISIMIP data
- **Concise**: 12 page document

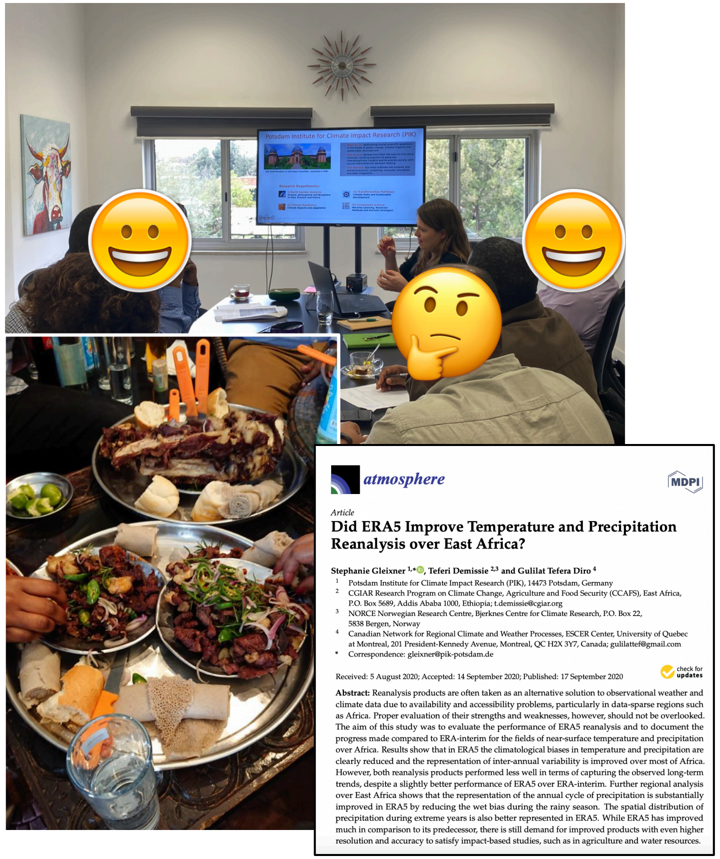


# B-EPICC era:
# Impact of Soil pH on crop suitability

Presentation on Friday morning by Tamirat Jimma

# B-EPICC era:
# Collaboration between PIK and ILRI

Research Stay 2020



atmosphere MDPI

*Article*

**Did ERA5 Improve Temperature and Precipitation Reanalysis over East Africa?**

**Stephanie Gleixner [1,*], Teferi Demissie [2,3] and Gulilat Tefera Diro [4]**

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**Abstract:** Reanalysis products are often taken as an alternative solution to observational weather and climate data due to availability and accessibility problems, particularly in data-sparse regions such as Africa. Proper evaluation of their strengths and weaknesses, however, should not be overlooked. The aim of this study was to evaluate the performance of ERA5 reanalysis and to document the progress made compared to ERA-interim for the fields of near-surface temperature and precipitation over Africa. Results show that in ERA5 the climatological biases in temperature and precipitation are clearly reduced and the representation of inter-annual variability is improved over most of Africa. However, both reanalysis products performed less well in terms of capturing the observed long-term trends, despite a slightly better performance of ERA5 over ERA-interim. Further regional analysis over East Africa shows that the representation of the annual cycle of precipitation is substantially improved in ERA5 by reducing the wet bias during the rainy season. The spatial distribution of precipitation during extreme years is also better represented in ERA5. While ERA5 has improved much in comparison to its predecessor, there is still demand for improved products with even higher resolution and accuracy to satisfy impact-based studies, such as in agriculture and water resources.

Research Stay 2022

Research Stay 2023

Celebrating 30 years of integrated climate impact research at the Potsdam Institute.

# Thank you!

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