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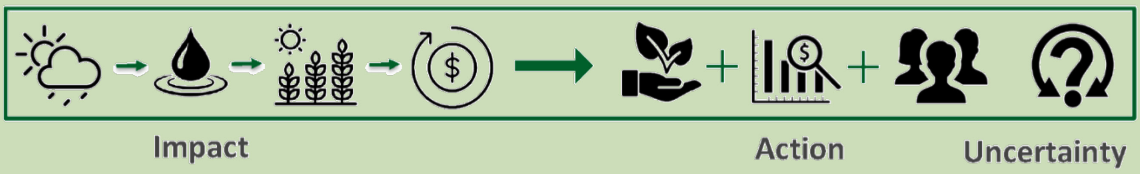
Climate risk analysis for identifying and weighing adaptation strategies in Ethiopia's agricultural sector

Executive summary

Study objective: While many countries recognise adaptation as an important component of their responses to climate change, little guidance on how to operationalise adaptation goals exists. As part of their international commitments, such as under the Paris Agreement, countries seek to develop and implement adaptation policies and investment plans, for instance as part of their Nationally Determined Contributions (NDCs) and National Adaptation Plans (NAPs). Oftentimes, only limited information on climate risks – upon which climate change adaptation decisions are based – is available. This constitutes the gap climate risk analyses seek to address, by providing evidence for substantiating political commitments and planning regarding adaptation. The climate risk analysis conducted for Ethiopia focuses on the evolving trends for temperature and precipitation, future water availability, the suitability of land for crop production and the spatial vulnerability of the agricultural sector. Based on this information, adaptation strategies are selected and analysed with regard to their feasibility, cost effectiveness and socio-economic aptitude for local conditions. The study results provide decision-makers in Ethiopia with costed adaptation scenarios, based on state-of-the-art climate risk modelling, as well as concrete recommendations for making agriculture more climate resilient. The findings can feed into national and sub-national adaptation planning processes, such as within Ethiopia's Climate Resilient Green Economy Strategy (CRGE), especially for agriculture and forestry, the Ethiopian NAP process, Ethiopia's NDC implementation and update, National Communications to UNFCCC and other relevant climate change policies. Furthermore, the climate risk study can also provide information and evidence for other planning and implementation levels, e.g. for extension officers working in Ethiopia's different zones or districts.



Study approach: The study models the impact chain from a changing climate to changing water availability and the resulting impacts in the agricultural sector, while taking into account the spatial differences of vulnerability to climate change in Ethiopia's regions and zones. The results then feed into an action dimension to assess different adaptation strategies with regard to their risk reduction potential, their cost-effectiveness and other socio-economic evaluation criteria, such as stakeholder interest and development co-benefits. The uncertainty attached to the results is critically discussed and recommendations targeting decision-makers are given. Throughout the study design and implementation, special attention was given to informing and consulting key stakeholders in Ethiopia to ensure that the study takes into consideration their interests and uses their local expertise, especially with regard to feasible adaptation strategies. This was undertaken through consultation workshops with the Ethiopian government (including the Environment, Forest and Climate Change Commission (EFCCC), Ministry of Agriculture (MoA), Ministry of Water, Irrigation, and Electricity (MoWie), Planning and Development Commission (PDC), Agricultural Transformation Agency (ATA) and the National Disaster Risk Management Commission (NDRMC)), an expert elicitation survey and qualitative interviews conducted with farmers, experts and other local key informants, such as from academia, civil society and the private sector. Other data used for the study includes observed weather and climate data, hydrological data from a variety of sources, information on crop yields and simulated past and future climate parameters from ISIMIP2b data (Inter-Sectoral Impact Model Intercomparison Project). The ISIMIP was created to offer a framework for the comparison of climate impact projections in different sectors, combining the power of a suite of impact models. It thus provides sound aggregate results on projected climate impacts (see Frieler et al. 2017 for further information)[1].

1 Frieler, K., Lange, S., Piontek et al. (2017). Assessing the impacts of 1.5°C global warming – simulation protocol of the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP2b), Geosci. Model Dev., 10, 4321–4345, https://doi.org/10.5194/gmd-10-4321-2017.

Key findings

The first table highlights key results from the impact part of the climate risk analysis, regarding projected climate change impacts on Ethiopia's agricultural sector.

Impact dimension	
Climate	• **Mean annual temperature** is projected to increase by 1.6°C until 2030, by 1.9°C until 2050 and 1.8°C by 2090 under the low-emissions scenario (RCP2.6), and from 1.8°C by 2030, 2.6°C by 2050 and 4.6°C by 2090 under the high-emissions scenario (RCP8.5), compared to pre-industrial levels. • Projected **precipitation changes** are highly uncertain and vary spatially, but climate simulation models agree on a precipitation increase during the second half of the century under RCP8.5. • The number of **very hot days and tropical nights** per year is projected to increase, especially under RCP8.5 and by the end of the century. • **Extreme precipitation events** are also projected to increase, under both scenarios and for all future periods.
Water	• For the **Blue Nile basin**, which covers large parts of Amhara, Benishangul-Gumuz and Oromia region, the multi-model median of average annual discharge projections increases in all future periods (P1: 2021-2040, P2: 2041-2060 and P3: 2080-2099) under both climate scenarios, with the projected increase ranging from 10% to 45%. • For the **Awash River basin**, which covers parts of Oromia, Amhara, Afar and Somali region, the changes of the multi-model median of average annual river discharge show an increase of up to 32% under RCP8.5 until the end of the century. • The multi-model mean shows an **increase of monthly river discharge** in all periods for the majority of months under both climate scenarios. The changes under RCP8.5 towards the end of the century are higher compared to the other periods and RCP2.6. • The highest changes are projected in May-June and October under both climate scenarios and can reach up to 51%. This could be an indicator of **prolongation of the wet period**, which could lead to more water available for irrigation in the region. • An increase of the river discharge in the Blue Nile basin means a **higher water availability for agriculture** in all three future periods under both RCPs. An increase of potential evapotranspiration towards the end of the century can lead to higher water demand for irrigation.
Agriculture	• Climate has a **substantial impact on crop production** in Ethiopia. On national average, climate explains 55-89% of the year-to-year yield variability. • The results show that there will be a **net maize yield increase** of 5% under RCP2.6 and 1% under RCP8.5 in Ethiopia, by 2050. However, six zones are projected to experience **maize yield losses** under climate change, depending on the emissions scenario: Western Tigray (decrease between 22 to 26%), South Omo (decrease between 16 to 19%), North Shewa (Amhara) (decrease between 4 to 12%), Metekel (decrease between 13 to 17%), Guraghe (decrease between 12 to 16%) and Gamo-Gofa (decrease between 11 to 13%). • Crop suitability modelling results show that the suitability of areas to produce maize, teff, sorghum and wheat in Ethiopia is variable across the different agro-ecological zones and will change with future climate change. • At national level, a net loss in **maize** suitability of 5% under RCP2.6 and 7% under RCP8.5 is projected, although some areas will see increased suitability and others will experience lower suitability. For **teff**, a net loss suitability in Ethiopia of 4% under RCP2.6 and 7 % under RCP8.5 is projected. A net increase in the areas suitable for **sorghum** of 5% under RCP2.6 and by 2% under RCP8.5 at national level by 2050 is projected. Finally for **wheat**, the suitability will decrease by 9% under RCP2.6 and by 12% under RCP8.5 at national level, representing the largest losses in suitability for the four crops. • Regarding maize yield changes, the **economic impacts** will be higher in zones in the Oromia and Southern Nations, Nationalities and Peoples' (SNNP) regions, compared to zones in Tigray and Amhara. Out of four sample zones analysed, Gamo-Gofa and Illubabor observe the biggest impacts, 6.8 and 6.4 million USD respectively under the RCP8.5 scenario by 2050.

Vulnerability	• Overall, most of the zones in the **very high vulnerability** class are located in the regions of Dire Dawa, Gambela, Somali, Oromia and SNNP. • **Highest exposure** was found in the Afar, Somali, Tigray and Benishangul-Gumuz regions. • The Gambela region was observed to be **most sensitive** to changes in climate parameters, followed by zones in the Dire Dawa region. • Zones with the lowest scores of **adaptive capacity** were found in the Dire Dawa, Amhara, and Harari region.

In the table listed below, main results of the action part of the full climate risk study are summarised. **Five different adaptation strategies** were assessed: irrigation, improved crop management, agroforestry, improved fodder and feed as well as crop insurance.

Action dimension	
Irrigation	• Stakeholder consultations, interviews, the expert survey conducted and document analysis made clear that **irrigation is a key adaptation priority** in Ethiopia. • Irrigation can help smallholder farmers to compensate for the negative impacts of erratic and insufficient rainfall and significantly stabilize agricultural production. It has **high potential** to reduce climate risks to crop production and increase resilience. • Currently, irrigation is not wide-spread yet in Ethiopia (estimates range between 2 to 3% of agricultural land, with water coming from Ethiopia's ample surface water resources), with considerable potential to upscale its usage. • Irrigation requires a **considerable investment** and only becomes profitable after some years, depending on the type of irrigation system and the farm location. Institutional support is usually required and care has to be taken to avoid **potential maladaptive outcomes** from irrigation.
Improved crop management	• Improved crop management, such as using improved seeds, applying fertiliser and shifting the planting dates, has **high transformative potential** for increasing yields. • **Increasing soil organic carbon** in Ethiopia by 20% has positive effects on crop suitability for all crops (increasing suitability between 2 to 6%, depending on scenario and crop), especially for maize and wheat. Enhancing organic carbon produces the greatest suitability increases under RCP8.5 for maize, teff and sorghum (approx. 5% suitability increase) and also has positive mitigation effects. • However, **shifting the growing season** forward by four weeks will result in detrimental effects on suitability of the four crops (wheat, teff, maize and sorghum), with suitability losses of up to 10% projected, and can thus not be recommended as an adaptation strategy. • Depending on the type of strategy employed, **cost-effectiveness is medium to high**. Some strategies, such as shifting cropping patterns according to projected future suitability, only become profitable after a considerable time period, e.g. shifting from maize to sorghum production.
Agroforestry	• Agroforestry has the **potential to stabilise** maize yields in zones which are projected to experience yield losses under climate change. 10% or 20% shade levels can reduce the losses projected (between 4 to 26% in some zones), but would negatively affect yields in zones which are projected to benefit from climate change. • **Those results are rather conservative**, as they do not take into account the potential yield increases and other benefits of enhanced soil organic carbon due to agroforestry strategies, for instance. • The economic analysis showed that adapting maize production with agroforestry is very beneficial in comparison to the inaction scenario. Over time, it has a **highly positive return on investment**, with a benefit-cost ratio (BCR) of 5.1 and an internal rate of return (IRR) of 42.7%.

Improved fodder and feed	• To improve fodder and feed, a number of adaptation strategies have proven successful in Ethiopia, for example: Improved and high-yielding forage varieties, intercropping grasses and cereals with legumes, cultivation of irrigated fodder banks, natural pasture improvement through removing of invasive weeds, temporal zero-grazing and cut-and-carry feeding regimes on degraded pastures to restore and increase carrying capacity. Such strategies **can boost livestock production**, resilience and farmer income. • A cost-benefit analysis of **irrigated Napier grass** as a particularly promising adaptation strategy showed that it is **highly cost-effective**. Importantly, the farmer's investment in Napier grass will pay off after three years when the break-even point between net costs and net benefits is reached.
Crop insurance	• Index insurance schemes for crops and livestock have been developed and tested in several pilot schemes in Ethiopia, but are not widely implemented yet. • Crop insurance can be considered an **important adaptation strategy**, because it can address risk, which cannot be mitigated in an economically sensible way with physical adaptation measures and acts as **a safety net for farmers** in times of extreme weather events. However, premium costs may not be affordable for farmers, requiring financial support to farmers in order to increase uptake.

Selected results of the analysis

After summarising the most important findings from the climate risk analysis, some results are now presented more in detail, to illustrate the tables above. The order is chronologically as followed in the full climate risk analysis and in the two tables above, moving from examples regarding climate change impacts to Ethiopia's agricultural sector to assessments of concrete adaptation strategies.

Increasing heat extremes

A particularly notable result from the climate impact analysis regards projections on future heat extremes in Ethiopia. ISIMIP models project an increase in temperature for Ethiopia under both scenarios (RCP2.6 and RCP8.5) and in all periods (2030, 2050, 2090) with very high confidence. Very hot days (maximum temperature above 35°C) and tropical nights (minimum temperature above 25°C) are projected to increase under all scenarios and periods, both in frequency and severity (see Figure 1), with pastoralist areas being the most affected.

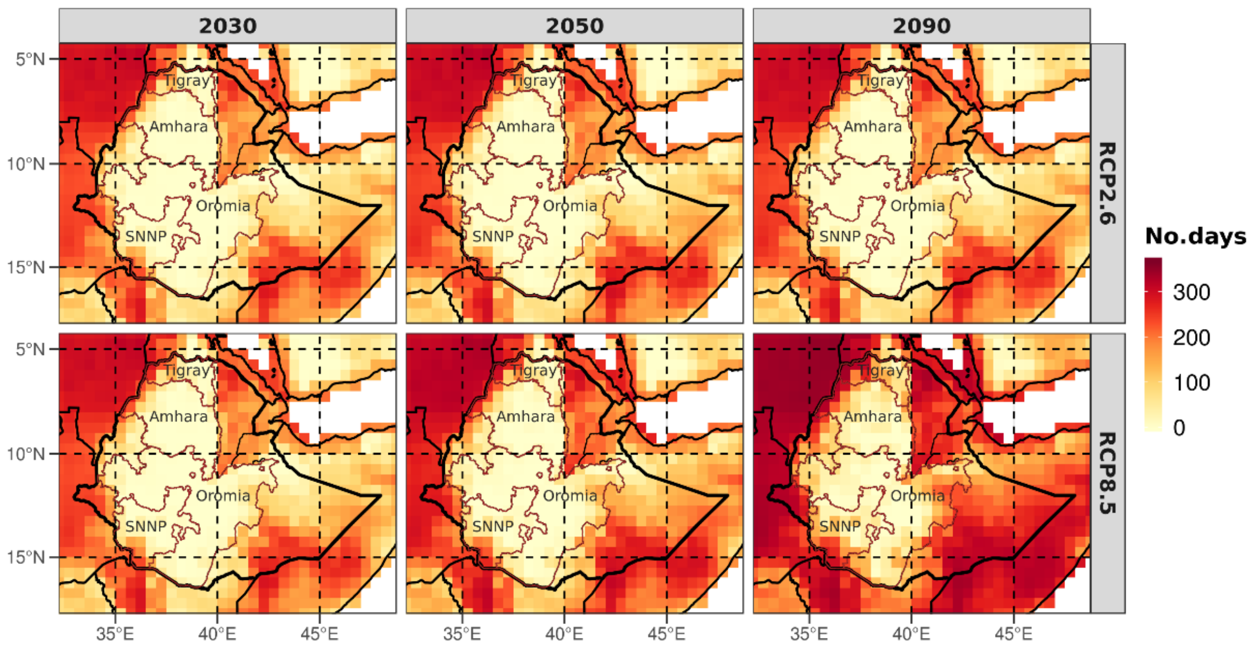


Figure 1: Average number of very hot days (temperature above 35°C) per year in 2030, 2050 and 2090 under scenario RCP2.6 and RCP8.5. Results are averages over three ISIMIP climate simulation models.

Climate impacts on crop production

Besides weather influence on crop yields and projected yield losses under climate change, the suitability of an area to produce a certain crop is also affected. We have thus used suitability models to characterise the current suitability for maize, sorghum, teff and wheat in Ethiopia and to understand the crop suitability changes under different climatic scenarios. The results in Figure 2 show that maize, teff and wheat will see net suitability decreases in Ethiopia under both emissions scenarios, only sorghum will experience gains in suitability. The expected losses in net suitability are higher for the high emissions scenario, as compared to the low emissions scenario.

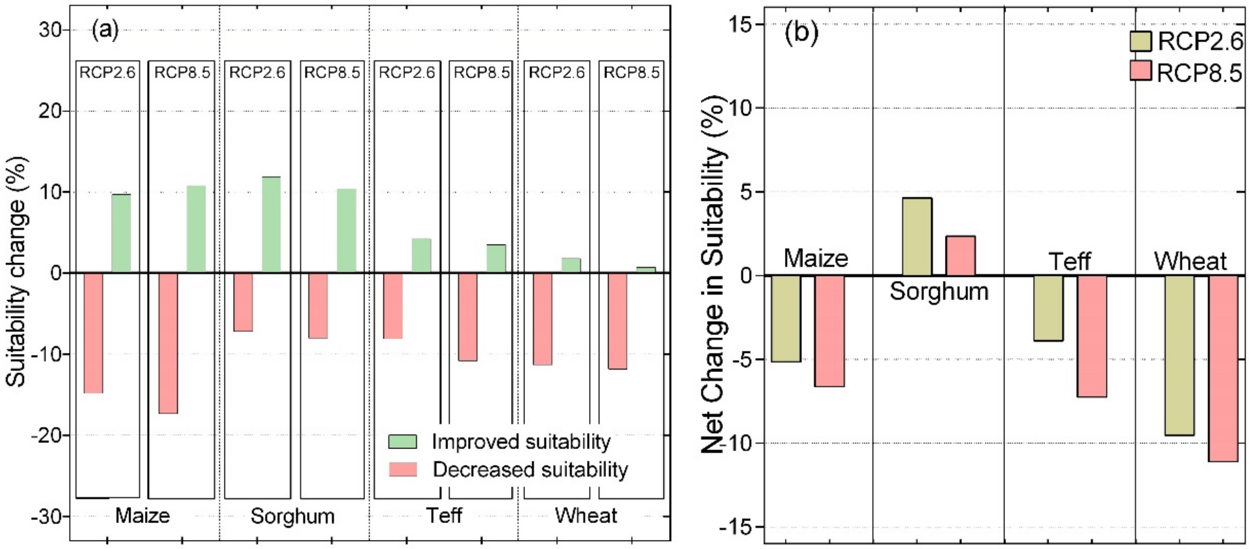


Figure 2: Total (a) and net (b) impact of climate change on suitability of maize, teff, sorghum and wheat in Ethiopia under RCP2.6 and RCP8.5.

Spatial vulnerability

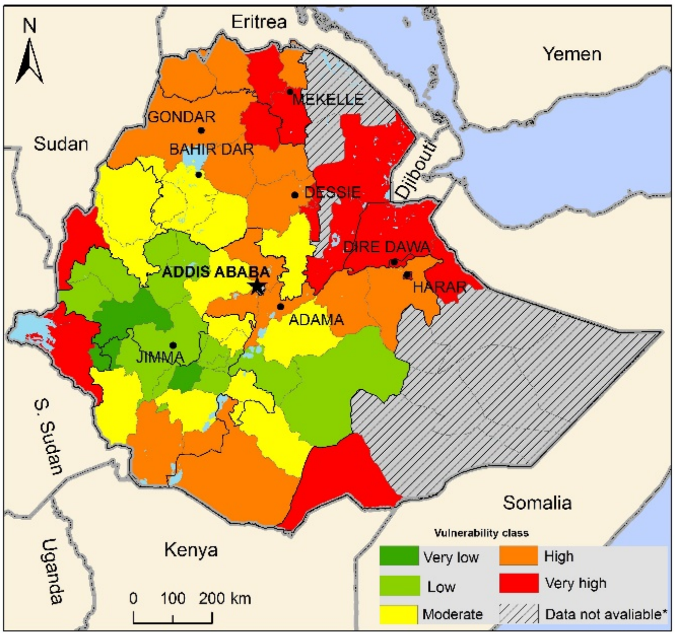


Figure 3: Vulnerability to climate change for different zones of Ethiopia.

To gain insights into factors shaping future vulnerability in Ethiopia, we assessed the vulnerability of different zones in Ethiopia to observed climate change at zone-level. Based on the definition of vulnerability as a function of exposure, sensitivity and adaptive capacity, an index-based approach was used, including both bio-physical and socio-economic dimensions. Figure 3 shows the spatial distribution of vulnerability based on the final vulnerability score. Most of the zones with the highest values that are represented in the very high vulnerability class are located in the regions of Dire Dawa, Gambela, Somali, Oromia and SNNP. It can be seen that the highly vulnerable areas are located along the periphery of the country. Generally, the regions with low vulnerability correspond to urban areas and areas with higher agricultural potential, which are less affected by changes in climate.

Adaptation example: Agroforestry

The five adaptation strategies assessed within the climate risk analysis were analysed using different methods and data. The core of the assessment formed a biophysical analysis using climate impact models. Those results were taken up in cost-benefit analyses, to evaluate the economic potential of the selected adaptation strategies. Below we show how this was done for agroforestry, where agroforestry interventions were first implemented and assessed using the crop model APSIM, with the results then feeding into a micro-level cost-benefit analysis.

Biophysical adaptation assessment

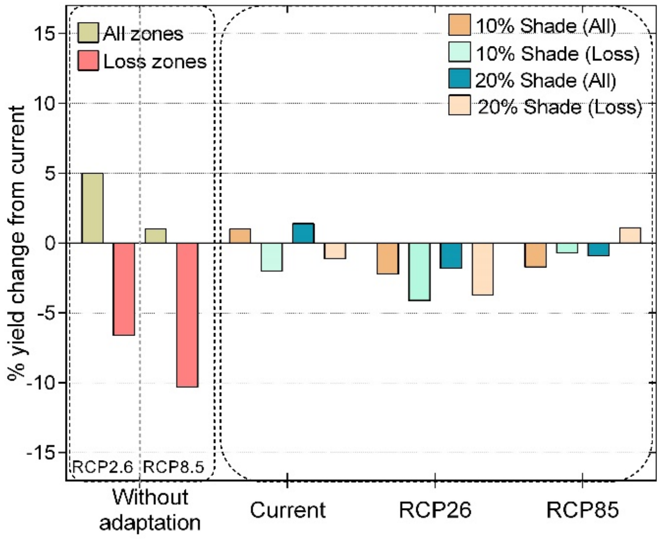


Figure 4: Effect of agroforestry shading on maize yield changes in Ethiopia.

The effect of agroforestry on maize production in Ethiopia was simulated with APSIM. Within APSIM, it is possible to perform virtual experiments to predict and understand options, with enough confidence to guide the development of agricultural policies. The most important of the tree-crop interactions under agroforestry is shade and its impact on crop growth and yield. Shade improves soil fertility, influences moisture availability and regulates the crop microclimate. The results indicate that the shading effect works best in zones which are projected to experience warming, but it may have detrimental effects in zones that are less affected and experience no yield losses under climate change.

Economic adaptation assessment

In this cost-benefit analysis, the effect of agroforestry in a maize farming system was analysed, with a farmer introducing shade-providing mango trees into its farm. The results presented in Figure 5 show that adapting maize production with agroforestry is highly beneficial in comparison to the no-adaptation-scenario. Over time, it has a very positive return on investment, when assuming constant climatic conditions and also under future climate change impacts. Further, agroforestry practices offer scope for many development co-benefits, such as improving soil fertility, protecting against soil erosion and sequestrating carbon.

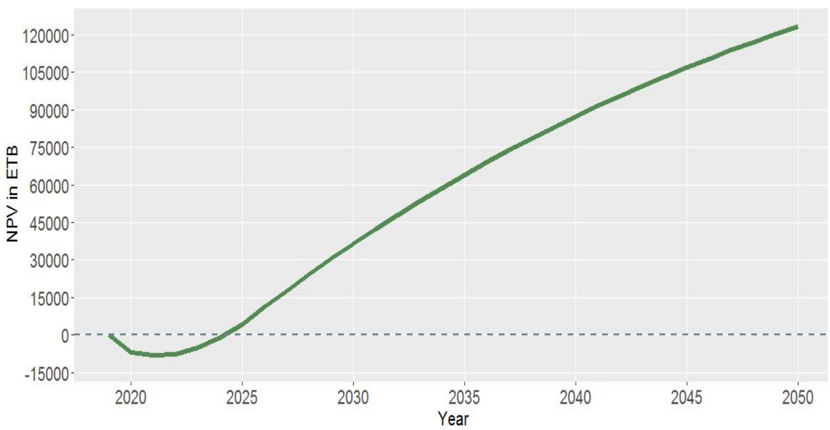


Figure 5: Development of the net present value from 2020 to 2050 when switching from maize monoculture to maize production within an agroforestry system under future climate change impacts (in ETB).

Internal rate of return: 42.65%
Net present value (NPV): 123,273ETB (= 4,057USD)
Benefit cost-ratio: 5.10

Multi-criteria assessment of selected adaptation strategies

The table below gives an indicative assessment of the five adaptation strategies according to nine criteria (e.g. institutional, economic, biophysical and socio-economic indicators). The colours can be read as follows: green = positive performance, yellow = medium performance, red = negative performance, blue = neutral/ no judgement implied. The category "risk response" refers to the fact that some adaptation strategies mitigate specific risks and thus can only be cost-effective, if impacts actually occur. In case of no impact, the investment (or a part of it) will be lost. The table also highlights the different performance of adaptation strategies across criteria, meaning that the individual assessment of a strategy can differ according to stakeholders' priorities. For more detailed information and the full assessment, please refer to the entire climate risk study.

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

Conclusion

The climate risk analysis for Ethiopia's agricultural sector provides a mixed account of the country's future exposure and vulnerability to climate change. Overall, Ethiopia's agricultural sector may benefit from increasing yields under climate change, while the areas where staple crops can be grown may shrink. Climate change impacts for the agricultural sector are thus ambiguous in Ethiopia and need to be carefully considered for agricultural policy and planning. Uncertainty from precipitation projections is high and other results regarding future precipitation levels would substantially influence the agricultural outlook. Yet, CO_2 fertilisation effects and technological improvements over time are not considered in this analysis. If taken into account, models might project future yield increases, even when considering uncertainty in precipitation projections. However, the results show high regional variation, indicating a need for adapting the parts of Ethiopia that are particularly affected by climate change. Based on these impact findings and in consideration of the local context, suitable adaptation strategies can be selected. The five adaptation strategies analysed in this study show high potential as outlined above and contribute, in most of the cases, to other development goals independent from the change of climatic conditions. Many other adaptation strategies can also be suitable and effective, with a combination of strategies appearing as most promising for a climate resilient transformation of Ethiopia's agricultural sector.

2 The risk mitigation potential is high up until a threshold of shade and only in specific environments, where yields are projected to decline under climate change. Careful targeting of agroforestry interventions is thus crucial.

This summary is based on a study prepared by the Potsdam Institute for Climate Impact Research (PIK) for the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ), in cooperation with the Ethiopian government. The report aims to contribute to Ethiopia's NDC implementation and to the objectives of the NDC Partnership.

In contribution to:

NDC PARTNERSHIP
ACCELERATING CLIMATE AND DEVELOPMENT ACTION