The need for evidence-based climate risk and adaptation assessments: Lessons learned from the AGRICA project

Lisa Murken[1]*, Julia Tomalka[1]*, David Abigaba[1], Antwi-Bosiako Amoah[2], Joseph Armathé Amougou[3], Muriel Anaba[3], Ponraj Arumugam[1,4], Eres Awori[5], Hye-Rin Léa Baek[1], Till Below[6], Matti Cartsburg[7], Abel Chemura[1,8], Carla Cronauer[1], Iulii Didovets[1], Adefires Worku Gizaw[9], Stephanie Gleixner[1], Nele Gloy[1], Enrico Grams[6], Lemlem Habtemariam[1], Anna Hampf[1], Ylva Hauf[1], Tim Heckmann[1,10], Boubacar Ibrahim[11], Lennart Jansen[1,10], Francis Jarawura[12], Timothée Kagonbé[13], Juliane Kaufmann[7], Priscilla Kephe[1], Lena Klockemann[6], Stefan Lange[1], Rahel Laudien[1], Stefan Liersch[1], Naima Lipka[1], Sophia Lüttringhaus[7], Sibylla Neer[6], Oblé Neya[11], Steffen Noleppa[7], Sebastian Ostberg[1], Jonas Pollig[6], Paula Romanovska[1], Felicitas Röhrig[14], Bernhard Schauberger[1,15], Roopam Shukla[1,16], Lina Staubach[7], Mesmin Tchindjang[17], Sabine Undorf[1], Regina Vetter[6], Sophie von Loeben[1], Christoph von Stechow[14], Katarina von Witzke[7], Chiara Sophia Weituschat[1], Michel Wortmann[1,18,19], Amsalu Woldie Yalew[1,20], Isabella Zouh[3], Christoph Gornott[1,10]

[1] Potsdam Institute for Climate Impact Research, Member of the Leibniz Association, Germany
[2] Environmental Protection Agency, Ghana
[3] Observatoire National sur les Changements Climatiques, Cameroon
[4] eLEAF, Netherlands
[5] National Agricultural Research Organisation, Uganda
[6] Deutsche Gesellschaft für Internationale Zusammenarbeit, Germany
[7] HFFA Research, Germany
[8] University of Twente, Netherlands
[9] Ethiopian Forestry Development, Ethiopia
[10] University of Kassel, Germany
[11] West African Science Service Centre on Climate Change and Adapted Land Use, Ghana
[12] SD Dombo University of Business and Integrated Development Studies, Ghana
[13] Ministry of Environment, Nature Protection and Sustainable Development, Cameroon
[14] German Federal Ministry for Economic Cooperation and Development, Germany
[15] University of Applied Sciences Weihenstephan-Triesdorf, Germany
[16] Indian Institute of Technology Roorkee, India
[17] University of Yaoundé I, Cameroon
[18] European Centre for Medium-Range Weather Forecasts, United Kingdom
[19] School of Geography and the Environment, University of Oxford, United Kingdom
[20] Centro Euro-Mediterraneo sui Cambiamenti Climatici, Italy
*shared first authorship

Corresponding author: Christoph Gornott (gornott@pik-potsdam.de)

Keywords: Agriculture, climate change, climate impacts, policy, scientific evidence, sub-Saharan Africa

Introduction

Climate change poses a threat to the agricultural sector, increasing the risk of crop failures, food insecurity and poverty. Given the need for an efficient allocation of scarce adaptation finance, scientific evidence can help to guide the prioritization of adaptation options. This article offers reflections on lessons learned from the AGRICA project, a collaboration between the Potsdam Institute for Climate Impact Research (PIK) and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ). Running from 2018 to 2024, AGRICA aimed to provide scientific evidence on climate risks, related impacts and suitable adaptation strategies for the agricultural sector in sub-Saharan Africa. Bringing together insights from science, development cooperation and policy, we argue for the need to produce and use rigorous scientific evidence for adaptation policy and planning, including for the formulation and implementation of ambitious National Adaptation Plans (NAPs) and Nationally Determined Contributions (NDCs). This is motivated by assessments such as from the IPCC (2022), which deems current NDC efforts in the agricultural sector insufficient for achieving the Paris Agreement. We discuss lessons learned with a focus on trade-offs between in-depth and standardized assessments, data availability and spatial resolution, modelling uncertainty and methodological pluralism to bridge the science-policy gap.

Trends and perspectives in analysing climate risks in the agricultural sector

Within the field of climate risk and adaptation assessments, a bulk of work focuses on biophysical impacts. Such studies model e.g. temperature and precipitation changes (Almazroui et al., 2020), and related impacts on water resources (Schewe et al., 2014) and agriculture (Müller et al., 2021). Among the existing body of climate risk literature, only few studies also consider adaptation. Recently, climate risk analyses have increasingly come to integrate socio-economic aspects, particularly when applying a vulnerability framework and analysing the susceptibility of systems or communities to climate-related hazards and their capacity to adapt. For example, the Climate Risk Sourcebook (Zebisch et al., 2023) provides a detailed guide for such assessments. With a focus on economic sustainability, the decision support tool Economics of Climate Adaptation (ECA) combines vulnerability assessments with economic impact studies to determine the best adaptation strategies (ECA, 2020). Examples of more standardized formats include the Climate Risk Country Profiles by the World Bank (2021) and the Climate-Smart Agriculture Country Profiles by CIAT (2021). While the former profiles focus on climatic changes and related impacts, the latter emphasize adaptation through different climate-smart practices. These series reflect the growing interest among different actors, including policymakers, international organizations and development agencies, in using climate risk assessments to shape national climate policies and plans.

Climate risk analyses and profiles in the AGRICA project

In many places, particularly in sub-Saharan Africa, there is a lack of data on climate impacts and suitable and economically viable adaptation strategies. Against this background, the Ghanaian Ministry of Food and Agriculture (MOFA) approached GIZ and PIK in 2018, highlighting the need for such data in the agricultural sector. Together, MOFA, GIZ, BMZ and PIK developed the concept for a scientific report that considers both climate impacts and adaptation. This stakeholder-driven effort played a key role in initiating AGRICA. As part of this project, PIK researchers developed in-depth climate risk analyses for Burkina Faso, Cameroon, Ethiopia, Ghana, Madagascar, Niger, Uganda and Zambia. Each analysis was developed in response to a strong interest by local political institutions, and in close collaboration with researchers and stakeholders from the partner countries. Stakeholders contributed to the studies by co-defining thematic priorities, sharing data, validating the results and jointly deriving policy recommendations from the findings. This stakeholder engagement process not only created a space for science-policy learning and knowledge co-production, it also facilitated the identification of challenges and needs faced by farmers, ensuring the relevance and applicability of the results and policy recommendations in a given context. The overall study approach puts an emphasis on biophysical modelling of climate impacts and adaptation strategies, while also integrating socio-economic factors, e.g. by conducting cost-benefit analyses of selected adaptation strategies or by considering aspects like the risk of maladaptation, the contribution to climate mitigation and other co-benefits, and the upscaling potential in a multi-criteria analysis (see Figure 1). This in-depth format is complemented by climate risk profiles, a standardized and brief format focusing on climate projections and related impacts in five sectors: agriculture, water, ecosystems, infrastructure and human health. Climate risk profiles have so far been developed for 15 countries and two regions in sub-Saharan Africa,[1] based on bias-adjusted climate data from the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP)[2] (Lange & Büchner, 2021).

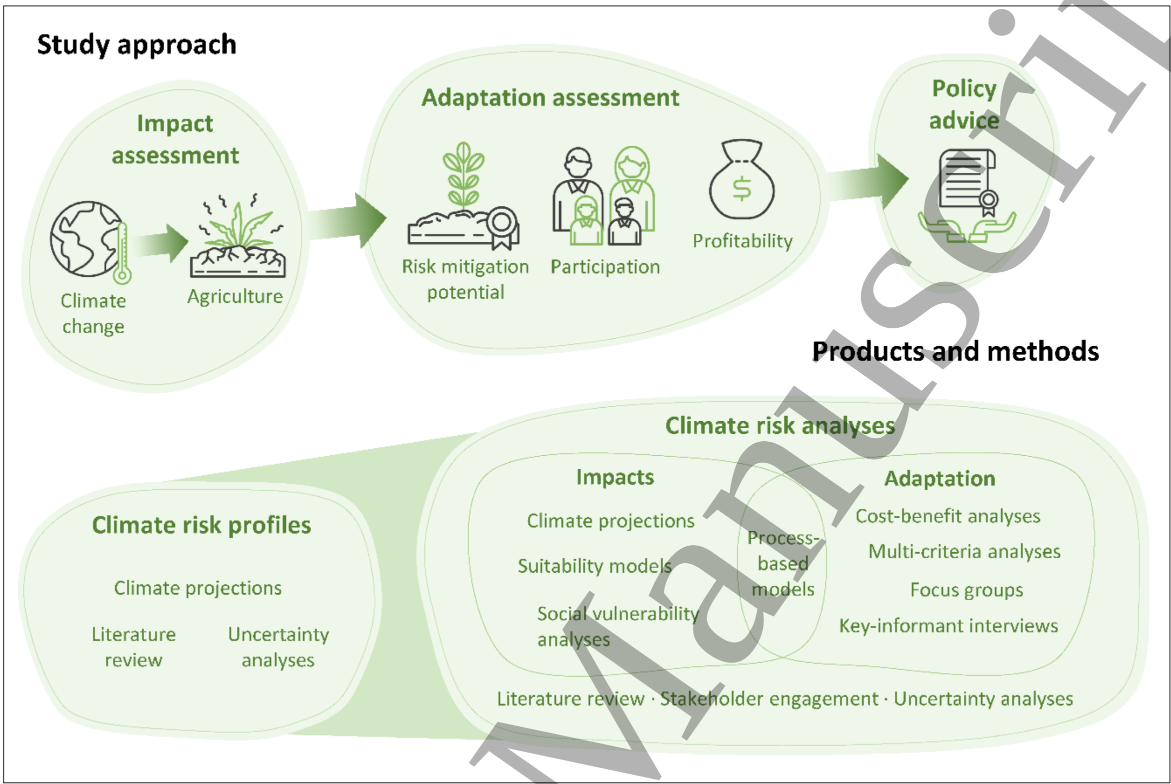

Figure 1: Overview of the study approach, products and methods in the AGRICA project.

To support the use of the generated insights, AGRICA placed a strong emphasis on communicating the findings to different audiences, such as policymakers and farmers. In addition to peer-reviewed articles, dissemination activities included policy briefs, presentations at international climate policy conferences, infographics, short films, university lectures, student scholarships and dissemination in local languages to thousands of smallholder farmers in remote areas via the NGO *Farm Radio International*. Overall, AGRICA succeeded in feeding scientific evidence on climate risks and adaptation into various NAPs, NDC investment plans, and climate-related national strategies, among others. For example, the results of the climate risk analysis for Cameroon were taken up in a regional adaptation plan, while in Ghana, the study results informed the Adaptation Communication to the UNFCCC (Government of Ghana, 2021). The Ethiopian government used the climate risk analysis to mainstream climate change into a national strategy on sustainable land management. In Madagascar, AGRICA analyses were included in a funding proposal to the Green Climate Fund (GCF). The climate risk profiles were also used in different ways, including as briefing material for ministers, the UN and by a Dutch investment firm to inform climate-proof investments.

[1] See an overview of all climate risk analyses and profiles: https://www.pik-potsdam.de/en/institute/departments/climate-resilience/projects/project-pages/agrica
[2] See more information on ISIMIP: www.isimip.org

Lessons learned from the AGRICA project

AGRICA has produced significant scientific evidence on climate impacts and adaptation strategies in the agricultural sector in sub-Saharan Africa. In the following, we reflect on the application of these results in climate policy and implementation processes.

Trade-off between in-depth and standardized assessments

To address trade-offs between comprehensive, in-depth climate risk assessments and concise, standardized assessments, we developed two products: Climate risk analyses and climate risk profiles (see Figure 1). *Climate risk analyses* were tailored to stakeholder preferences, focusing on the selection of crops (e.g. staple crops like maize or cash crops like coffee) and adaptation strategies (e.g. agroforestry or improved seeds). This stakeholder engagement process created trust and ownership, and increased the relevance of the analysis and the likelihood of stakeholders adopting its recommendations. Although this process was perceived as useful by a wide spectrum of stakeholders, it was also time and resource-intensive. Furthermore, precisely because of its in-depth approach, the climate risk analyses were selective as they focused on some crops and adaptation strategies, while excluding others. Although this selection was based on local stakeholder interest, it was at times misinterpreted as an objective prioritization. Yet, other crops or adaptation strategies could have also been considered, with similar or even higher levels of efficiency.

The development of *climate risk profiles* did not involve stakeholder input and hence was more time-efficient. However, due to the standardized format, the climate risk profiles would at times include information that was less relevant to a country. For example, the climate risk profile for Zambia includes two indicators related to humid heatwaves, although this type of heatwave is not frequent in Zambia. This example illustrates how standardized assessments can come at the expense of relevance for a country or region. Nonetheless, many stakeholders valued the concise and standardized overview, which allowed for an easy comparison across countries.

Data availability and spatial resolution

Lack and low quality of data are key impediments to adaptation planning in many sub-Saharan African countries and beyond (Theokritoff & D'haen, 2022). Under the AGRICA project, comprehensive datasets were collected or created, ranging from projected crop yield changes to adaptation behaviour of local farmers. At the same time, input data was needed for many analytical steps, which was often difficult to obtain. For example, the crop yield and suitability models used in AGRICA require observed yield, soil and management data for model calibration. A recurring challenge was limited availability of this data, or incomplete or low-quality datasets, stemming e.g. from a reluctance to share available data, underfunded data collection entities or lack of digitization (Kephe et al., 2021).

The spatial resolution of input data for climate impact models posed another challenge, as it is often too coarse to offer farm-level advice. Therefore, some stakeholders expressed the need for higher-resolution data to provide more specific information, e.g. at the level of smaller administrative units or landscapes like river basins. Localized information can provide a more accurate understanding of climate impacts and help to tailor adaptation strategies to specific contexts, which is often mandated by local policies and plans.

An example from the climate risk analysis for Ethiopia illustrates this: Using the process-based crop model APSIM, we analysed the potential of agroforestry to mitigate climate impacts on maize yields. As can be seen in Figure 2, only some administrative zones in Ethiopia are projected to experience maize yield decreases due to climate change, whereas, overall, climate change is likely to have a positive effect on maize yields. What does this mean for the implementation of agroforestry as an adaptation strategy? As trees provide shading and cooling, among other benefits, this adaptation strategy will only be highly beneficial where maize yield losses are expected, but might lead to yield reductions where climate change is projected to increase yields.

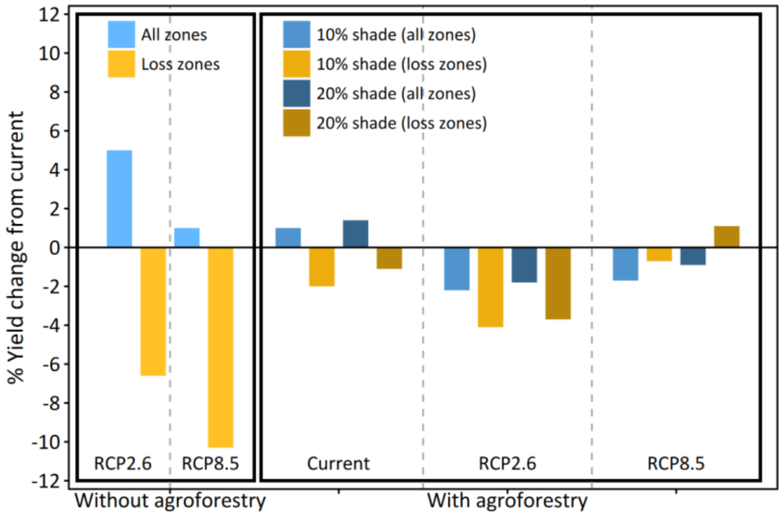

Figure 2: Projected effects of agroforestry shading on maize yield changes in Ethiopia.

Modelling uncertainty

Model-based analyses entail uncertainties, arising from factors such as uncertainties in climate change scenarios or model discrepancies (IPCC, 2021). We tried to minimize these uncertainties by using climate model ensembles and by carefully evaluating the performance of crop models before applying them on a larger spatial scale. Nonetheless, uncertainty in model results remains and may have been exacerbated by the use of model results in further model-based analyses, creating a cascading effect of uncertainty (Vetter et al., 2017). Generally and as also found in other climate impact analyses, projected changes in air temperature and related changes, such as sea level rise or heat-related mortality, are more certain than projections of precipitation changes and related changes like flooding (IPCC, 2021) (see Figure 3).

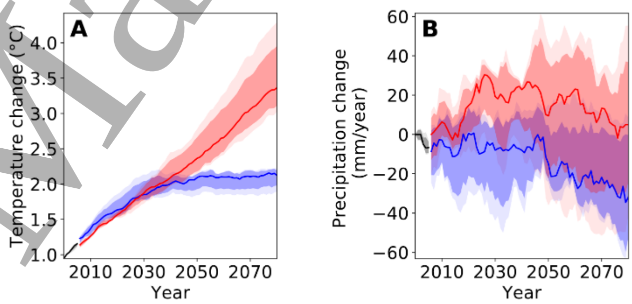

Figure 3: Projections of air temperature (A) and annual mean precipitation (B) for Zambia for RCP2.6 (blue) and RCP6.0 (red). The shaded areas illustrate uncertainty through model disagreement: The more models disagree, the higher the uncertainty and the larger the shaded area.

What does this mean for recipients of climate risk analyses and profiles? Some of the stakeholders AGRICA worked with perceived high uncertainty in modelling results as irritating and wondered how to make decisions based on a diversity of possible and, in some instances, co-existing outcomes. Although this is a fair question, it can be argued that it is exactly this diversity that offers insights into various possible futures, highlighting the need for a broad portfolio of adaptation strategies. For example, addressing future precipitation trends, which often show both excess water and drought as two co-existing outcomes, will require adaptation strategies like agroforestry that can buffer both phenomena and investments into strengthening the resilience of entire agroecosystems in a transformative way. It is therefore important to carefully and transparently communicate uncertainties to enable policymakers to take informed decisions, while incentivizing investments in uncertain fields of action.

Methodological pluralism to bridge the science-policy gap

Through exchanges with policymakers, development actors and farmer groups, amongst others, we learned that requirements for scientific evidence vary across stakeholder groups. Consequently, a combination of methods and approaches is required, in particular that of model-based approaches with empirical assessments, which offers three advantages:

First, through an integration of methods it is possible to provide comprehensive information that considers the complexity of agricultural and food systems, even if imperfectly. To this end, we followed a multi-criteria approach, considering not only aspects like improvements in yields or the profitability of an adaptation strategy, but also, for example, potential maladaptive outcomes. However, to truly account for the complexity and the context-specificity of adaptation decisions, a closer integration of model-based approaches with empirical assessments should remain a continuous scientific pursuit. For example, randomized controlled trials can offer quantifiable data on adaptation effectiveness, which can be combined with biophysical impact models for more nuanced results.

Second, different stakeholders require different types of evidence. While stakeholders like policymakers, development agencies and private sector representatives were interested in model-based analyses, stakeholders working closer to the ground (e.g. farmers) were sceptical of advice solely derived from such analyses and tended to adhere to established farming practices. They wanted to see actual proof (e.g. increased yields) of the effectiveness of the proposed adaptation strategies on their own farms or on demonstration plots. A combination of model-based and empirical assessments can satisfy the requirements of different groups and increase the overall robustness of scientific results.

Third, a combined approach allows for the study of different time horizons. The analyses in AGRICA cover different timeframes, including the years 2030, 2050, 2080 and 2090. While a long-term perspective is needed to analyse climatic trends and the suitability of adaptation strategies, it often stands in conflict with short-term policy goals and short-term economic prospects of farmers. Projections for the year 2090 may feel too irrelevant or uncertain to be trusted, although they are needed in particular to detect potential maladaptive outcomes in the long term. Empirical assessments of current conditions can also help to contextualise model-based results and ground them in present-day realities.

The case for evidence-based adaptation planning

Climate risk and adaptation assessments can guide the allocation and prioritization of scarce adaptation finance, while helping to bridge the gap between scientific evidence and adaptation policy, planning and implementation. In the AGRICA project, we developed a unique approach for such assessments, with the following lessons learned: i) Trade-offs between different levels of depth and breadth need to be carefully considered, depending on the target audience, and communicated effectively to ensure that thematic priorities remain comprehensible and that methodological shortcomings are easily understood; ii) Lack and low quality of data require advancements in data collection and storage efforts, data sharing arrangements and complexity research; iii) Modelling uncertainty needs to be communicated transparently and towards different audiences to ensure trust and usability of modelling results; iv) A combination of model-based and empirical assessments can effectively inform different stakeholders and decisions across various spatial and temporal scales.

We hope that these lessons learned can guide future efforts in the field of climate risk and adaptation assessments, informing policy processes and interventions on the ground, and raising ambitions for a transformation of agricultural and food systems towards greater climate resilience.

References

Almazroui, M., Saeed, F., Saeed, S., Nazrul Islam, M., Ismail, M., Klutse, N. A. B., & Siddiqui, M. H. (2020). Projected Change in Temperature and Precipitation Over Africa from CMIP6. *Earth Systems and Environment*, *4*(3), 455–475. https://doi.org/10.1007/s41748-020-00161-x

CIAT, ICRISAT, & BFS/USAID. (2021). *Climate-Smart Agriculture in Mali* (CSA Country Profiles for Africa Series). International Center for Tropical Agriculture (CIAT); Bureau for Food Security, United States Agency for International Development (BFS/USAID).

ECA. (2020). *Economics of Climate Adaptation: Bringing Pieces together for Climate Action*. Economics of Climate Change. https://eca-network.org/

Government of Ghana. (2021). *Ghana's Adaptation Communication to the United Nations Framework Convention on Climate Change*. Environmental Protection Agency.

IPCC. (2021). *Climate Change 2021 – The Physical Science Basis: Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (1st ed.). Cambridge University Press. https://doi.org/10.1017/9781009157896

IPCC. (2022). *Climate Change 2022: Mitigation of Climate Change—Cross-Sectoral Perspectives. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)*. Cambridge University Press.

Kephe, P. N., Ayisi, K. K., & Petja, B. M. (2021). Challenges and opportunities in crop simulation modelling under seasonal and projected climate change scenarios for crop production in South Africa. *Agriculture & Food Security*, *10*(1), 10. https://doi.org/10.1186/s40066-020-00283-5

Lange, S., & Büchner, M. (2021). *ISIMIP3b bias-adjusted atmospheric climate input data (v1.1)* [dataset]. https://doi.org/10.48364/ISIMIP.842396.1

Müller, C., Franke, J., Jägermeyr, J., Ruane, A. C., Elliott, J., Moyer, E., Heinke, J., Falloon, P. D., Folberth, C., Francois, L., Hank, T., Izaurralde, R. C., Jacquemin, I., Liu, W., Olin, S., Pugh, T. A. M., Williams, K., & Zabel, F. (2021). Exploring uncertainties in global crop yield projections in a large ensemble of crop models and CMIP5 and CMIP6 climate scenarios. *Environmental Research Letters*, *16*(3), 034040. https://doi.org/10.1088/1748-9326/abd8fc

Schewe, J., Heinke, J., Gerten, D., Haddeland, I., Arnell, N. W., Clark, D. B., Dankers, R., Eisner, S., Fekete, B. M., Colón-González, F. J., Gosling, S. N., Kim, H., Liu, X., Masaki, Y., Portmann, F. T., Satoh, Y., Stacke, T., Tang, Q., Wada, Y., … Kabat, P. (2014). Multimodel assessment of water scarcity under climate change. *Proceedings of the National Academy of Sciences*, *111*(9), 3245–3250. https://doi.org/10.1073/pnas.1222460110

Theokritoff, E., & D'haen, S. A. L. (2022). How is science making its way into national climate change adaptation policy? Insights from Burkina Faso. *Climate and Development*, *14*(9), 857–865. https://doi.org/10.1080/17565529.2021.2018985

Vetter, T., Reinhardt, J., Flörke, M., van Griensven, A., Hattermann, F., Huang, S., Koch, H., Pechlivanidis, I. G., Plötner, S., Seidou, O., Su, B., Vervoort, R. W., & Krysanova, V. (2017). Evaluation of sources of uncertainty in projected hydrological changes under climate change in 12 large-scale river basins. *Climatic Change*. https://doi.org/10.1007/s10584-016-1794-y

World Bank. (2021). *Climate Risk Profile: Kenya*. The World Bank Group.

Zebisch, M., Renner, K., Pittore, M., Fritsch, U., Fruchter, S. R., Kienberger, S., Schinko, T., Sparkes, E., Hagenlocher, M., Schneiderbauer, S., & Delves, J. L. (2023). *Climate Risk Sourcebook*. GIZ.