Tropentag 2022
September 14-16, 2022

Conference on International Research on Food Security, Natural Resource Management and Rural Development
organised by the Czech University of Life Sciences, Prague, Czech Republic

Crop diversification under climate change: A comparative assessment in Ghana, Burkina Faso, Ethiopia and Niger

Abel Chemura[a*], Lisa Murken[a], Nele Gloy[a], Paula Aschenbrenner[a], Sophie von Loeben[a], Christoph Gornott[a,b]

[a]Potsdam Institute for Climate Impact Research (PIK), Member of the Leibniz Association, Potsdam, Germany
[b]Agroecosystem Analysis and Modelling, Faculty of Organic Agricultural Sciences, University of Kassel, Kassel, Germany.

Abstract

Diversified farming systems maintain functional biodiversity at multiple spatial and temporal scales in order to be productive, resilient and efficient. However, the potential for transforming to or maintaining diversified agricultural systems depends on the ability of the selected crops to be sustained under the climate of the specific areas they are grown. Climate change can affect the ability of one or more crops to grow within specific niches and thereby reducing their potential to be part of a crop diversification strategy. In this study, we assessed the agro-climatic suitability of four major food crops in Ghana (maize, sorghum, cassava and peanut), Ethiopia (maize, sorghum, teff and wheat), Burkina Faso (maize, sorghum, cowpea and peanut) and Niger (maize, sorghum, cowpea and peanut) under current and projected climatic conditions using the EcoCrop crop suitability model. We find that suitability for four crops will decrease in Burkina, Ghana and Niger, while it will increase only in Ethiopia with the magnitude dependent on the climatic scenario. Positive changes in suitability are also projected for three crops in Ghana (up to 26.3%) and for Ethiopia (up to 7.7%), while in Burkina Faso area suitable for three crops will decrease (up to -36.8%) and remain relatively unchanged in Niger (~1%). Instead, areas that are suitable for only one crop will increase in Burkina Faso, Ghana and Niger, while it will decrease only in Ethiopia. We therefore conclude that the potential for higher crop diversification will be negatively impacted by climate change. The impacts will vary within and across countries and thus, will influence planning for scaling up diversification as an agroecological measure.

Keywords: multiple cropping, crop suitability, food crops, climate impacts, farming systems

* Corresponding author email: chemura@pik-potsdam.de

Introduction

Crop diversification is an agroecological practice of cultivating more than one crop of the same or of different species in a given area in the form of rotations and/or inter- and/or alley cropping. Diversified farming systems maintain functional biodiversity at multiple spatial and temporal scales in order to be productive, resilient and efficient. Crop diversification is one of the most ecologically feasible, cost effective, and rational ways of reducing uncertainties in agriculture (Pellegrini & Tasciotti, 2014). This is because studies have showed that food availability at household scale increases with crop diversity (Waha et al., 2018) and that diversification has highest potential for national yield stabilisation (Renard & Tilman, 2019). Crop switching and diversification have been presented among key climate change adaptation strategies (Beyer et al., 2022; Rising & Devineni, 2020). However, the potential for transforming or maintaining diversified agricultural systems depends on the ability of the of the 'new' or added crops to complete their cycle with reasonable production outcomes in the targeted areas which is referred to as their suitability (Sloat et al., 2020). Diversifying cropping systems is a ttransformational adaptation strategy required for areas where climate change impacts are projected to be severe that stabilising yields under a changing climate is not feasible (Rippke et al., 2016).

Despite the potential for diversification to contribute to agricultural resilience especially for smallholder farmers, few studies have focused on design of diverse agricultural systems and on assessing diversification potential under climate change. There are therefore no explicit indications of which crop combinations work where and with what individual or combined production outcomes under climate change, while impact studies on agriculture have mostly focused on individual select crops and assessment of adaptation measures also mostly on these individual crops. With the understanding that climate change could affect the ability of one or more crops to grow within specific niches and thereby reducing their potential to be part of a crop diversification strategy, the goal of this study was to assess crop diversification potential and how it varies between and within some countries under current and projected climatic conditions in Africa. It is hoped that such information will provide benchmarks on which progress or changes towards multiple cropping/crop diversification between different times and locations can be measured, and identify areas for targeting diversification. The working definition of multiple cropping in the context of this study is where farmers allocate different fields to different crops in the same growing season (not intercropping).

Material and Methods

The EcoCrop (Ramirez-Villegas et al., 2013), a crop suitability model was used for assessing climate change impacts on crop diversification potential in four countries. Crop suitability is a measure of the ability of climatic and other biophysical characteristics of an area to sustain a crop production cycle to meet current or expected targets (Chemura et al., 2020). The EcoCrop model was used for producing spatially explicit suitability simulations for the crops by using parameterized thresholds to determine bioclimatic suitability which is a score of the ability of a crop to complete its production cycle in a given climatic and biophysical space (Figure 1). This approach has been widely used in climate change impact studies including in the IPCC AR6 (Pörtner et al., 2022). Four major staple crops in each of the four countries of Burkina Faso (maize, sorghum, millet and peanut), Ethiopia (maize, sorghum, teff and wheat), Ghana (maize, sorghum, cassava and peanut) and Niger (maize, sorghum, millet and peanut) were used as selected by stakeholders through workshops.

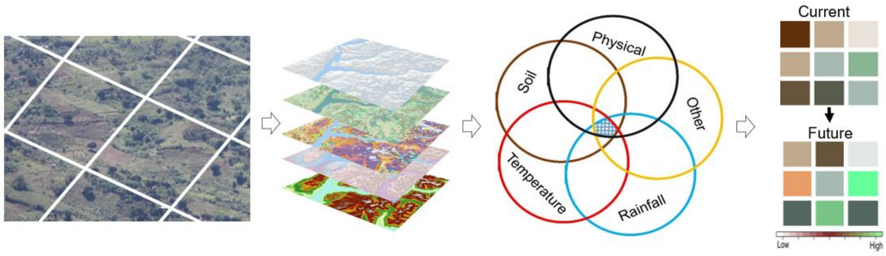

Figure 1: Schematic representation of a crop suitability model used for climate change impact assessment for multiple crops in Ghana, Burkina Faso, Niger and Ethiopia.

The EcoCrop model was calibrated first by using observational data from W5E5 data (Lange et al., 2021) with model results compared with FAOSTAT cropped area for each crop and known databases which show where the crop is grown in each country. Climate change assessment was done by replacing the observational data with projections from the ISIMIP3b for three scenarios linearly combined with three representative concentration pathways (SSP1:RCP2.6, SSP3:RCP7.0, SSP5:RCP8.5) for 10 GCMs for the mid-century (average of 2035-2064 data). The suitabilities of the crops were then combined to determine the number of crops that are suitable for each grid under current and future conditions, with climate impact being the difference between these after Chemura et al. (2020).

Results and Discussion

Diversification potential under current climate

At country scale, Ghana has the most potential for diversification under current climatic conditions with 69.7% 0f the country able to support four crops, with the least proportion being Ethiopia (0.8%, Figure 2). In Burkina Faso, 41% of the country is suitable for producing at least 3 crops while 3.7% of Niger can produce at least one of the four crops under current conditions. The spatial distribution of the suitabilities under current climate conditions for each country are shown in Figure 3.

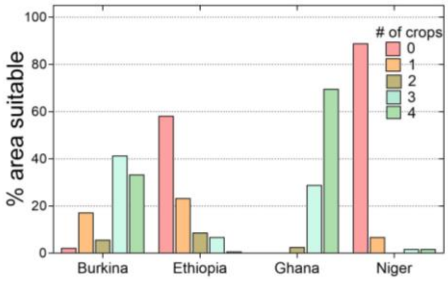

Figure 2: Percentage area in each country currently suitable for the multiple crops.

Diversification potential under climate change

The spatial distribution of crop suitabilities under climate change are shown in Figure 3. From these results, indications are that under climate change the suitability for four crops will decrease in Burkina, Ghana and Niger, while it will increase only in Ethiopia with the magnitude dependent on the climatic scenario (Figure 3 and 4a). In Burkina climate change will shift many areas currently suitable for the four crops to produce only three or two crops in central parts of the country but with a northward shift in improved crop suitability, particularly under SSP3:RCP7.0 and SSP5:RCP8.5 scenarios. In Ethiopia, the areas suitable for producing the four crops in the north will be lost under all scenarios while it increases in the south-central regions, and in Amhara and part of Oromiya regions, many areas will be able to produce only one crop instead of two or three that are possible under current conditions. In Ghana, the results indicate that the northern parts that are currently not suitable for cassava will have an increased suitability for the crop in the future, while in the south areas suitable for two crops will increase, down from four and three. In Burkina, the current potential for producing 4 crops in the south will be lost by 2050 (Figure 3).

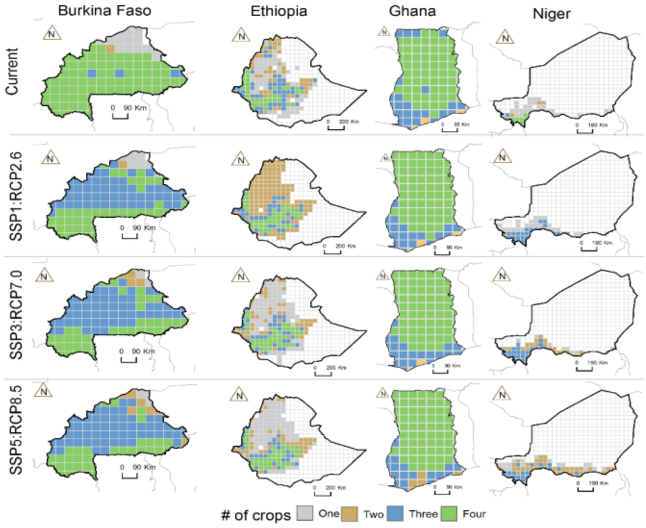

Figure 3: Maps showing the current distribution of potential for multiple cropping in Burkina Faso, Ethiopia, Ghana and Niger as columns and under current, and 2050 climate change represented by SSP1:RCP2.6, SSP3:RCP7.0 and SSP5:RCP8.5 scenarios.

In terms of area, positive changes in suitability are projected for three crops in Ghana (up to 26.3%) and for Ethiopia (up to 7.7%), while in Burkina Faso area suitable for three crops will decrease (up to -36.8%) and remain relatively unchanged in Niger (~1%). In Burkina Faso and Ghana, the extend of loss for suitability of four crops increases with severity scenario and, interestingly, the projected increases in suitability for four crops in Ethiopia also increase with severity of the scenario (Figure 4a). Instead, areas that are suitable for only two crops will increase in Burkina Faso, Ghana and Niger (Figure 4c). Under the most severe scenario (SSP5:RCP8.5), a 56% increase in areas suitable for only one crop is projected in in Burkina Faso (Figure 4d). The overall result is the impacts of climate change on potential for crop diversification depend on country (while varying within country) and scenario, with projected losses in crop diversification potential in Burkina Faso, Ghana and Niger and some increases in Ethiopia.

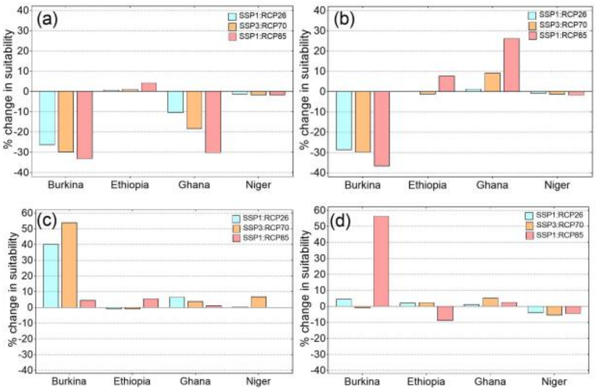

Figure 4: Percentage change in area suitable for (a) four (b) three (c) two and (d) one in each country by 2050 under SSP1:RCP2.6, SSP3:RCP7.0 and SSP5:RCP8.5 scenarios.

Conclusions and Outlook

The aim of this study was to provide quantitative and spatial information on which crop diversification, an important agroecological strategy, can be scaled under climate change in Burkina Faso, Ethiopia, Ghana and Niger in the face of climate change. We conclude that climate change will not only to change the geography of individual crop suitability but also affect the potential for farmers to diversify through adding other crops as potential additional crops become unsuitable in some areas. The impact of climate change on the number of crops possible vary within and across countries with Ghana and Ethiopia have higher diversification potential even under climate change compared to Burkina and Niger. The overall potential for higher number of crops decreases with climate change, meaning that while crop diversification can hedge against climate change impacts, its possibility will also be limited by changing conditions. The projected changes in suitability for multiple crops are however less than those for individual crops, indicating that crop diversification is resilient as at least two or three of the four crops will remain possible in many agricultural areas in each country under climate change, emphasising that crop selection is important for diversification to be successful. Future studies should consider adaptation planning for diversified systems by selecting adaptation strategies that work for more than one crop.

References

Beyer, R. M., Hua, F., Martin, P. A., Manica, A., & Rademacher, T. (2022). Relocating croplands could drastically reduce the environmental impacts of global food production. *Communications Earth & Environment*, *3*(1), 1-11.

Chemura, A., Schauberger, B., & Gornott, C. (2020). Impacts of climate change on agro-climatic suitability of major food crops in Ghana. *PloS one*, *15*(6), e0229881.

Lange, S., Menz, C., Gleixner, S., Cucchi, M., Weedon, G. P., Amici, A., Bellouin, N., Schmied, H. M., Hersbach, H., & Buontempo, C. (2021). WFDE5 over land merged with ERA5 over the ocean (W5E5 v2. 0).

Pellegrini, L., & Tasciotti, L. (2014). Crop diversification, dietary diversity and agricultural income: empirical evidence from eight developing countries. *Canadian Journal of Development Studies/Revue canadienne d'études du développement*, *35*(2), 211-227.

Pörtner, H.-O., Roberts, D. C., Adams, H., Adler, C., Aldunce, P., Ali, E., Begum, R. A., Betts, R., Kerr, R. B., & Biesbroek, R. (2022). Climate change 2022: Impacts, adaptation and vulnerability. *IPCC Sixth Assessment Report*.

Renard, D., & Tilman, D. (2019). National food production stabilized by crop diversity. *Nature*, *571*(7764), 257-260.

Rippke, U., Ramirez-Villegas, J., Jarvis, A., Vermeulen, S. J., Parker, L., Mer, F., Diekkrüger, B., Challinor, A. J., & Howden, M. (2016). Timescales of transformational climate change adaptation in sub-Saharan African agriculture. *Nature Climate Change*, *6*(6), 605-609.

Rising, J., & Devineni, N. (2020). Crop switching reduces agricultural losses from climate change in the United States by half under RCP 8.5. *Nature communications*, *11*(1), 1-7.

Sloat, L. L., Davis, S. J., Gerber, J. S., Moore, F. C., Ray, D. K., West, P. C., & Mueller, N. D. (2020). Climate adaptation by crop migration. *Nature communications*, *11*(1), 1-9.

Waha, K., Van Wijk, M. T., Fritz, S., See, L., Thornton, P. K., Wichern, J., & Herrero, M. (2018). Agricultural diversification as an important strategy for achieving food security in Africa. *Global change biology*, *24*(8), 3390-3400.