Enhancing cropping systems resillience to climate variability in Africa through grain legume intergration: A meta-analysis

AUTHORS

Adam Muhammad Adam
Eric Koomson
Carsten Marohn
Frank Rasche
Folkard Asch
Georg Cadisch

Hans-Ruthenberg-Institute, University of Hohenheim

I. INTRODUCTION

Enhancing cropping systems resilience to climate variability and extreme events is crucial step to ensure food security and livelihoods improvement in Africa due to limited adaptation capacity and dependence on rainfed agriculture. According to the Intergovernmental Panel on Climate Change synthesis reports, climate variability and extreme weather events have been observed in many parts of Africa negatively impacting the food security of millions in the continent (IPCC, 2023).

In response to these challenges, crop diversification through intercropping is considered as eco-friendly, affordable, more sustainable, and a short-term approach to minimize the impacts of climate change on African food systems. Several intercropping systems have been reported in literature across different parts of Africa. Yet, it remains unclear which of the system is more resillient to climate variability and extreme events. Additionally, knowledge on how species composition shape intercropping systems resilience to climate variability is generally lacking. Therefore, we conducted a meta-analysis to gather existing knowledge and quantitatively assess the role of species combination,for shaping intercropping systems resilience to climate variability in Africa.

II. METHODS AND RESULTS

Methods

Data Compilation and processing

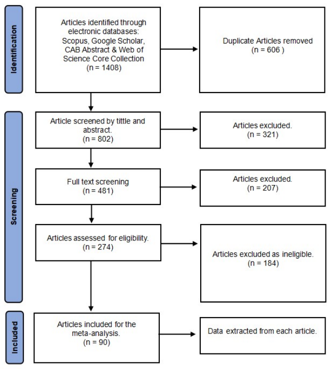

Fig 1. Methodological approach for data collection

Climate Anomaly Index

Standardized precipitation evapotranspiration index (SPEI) was used as an indicator for climate anomaly in each growing seasons as described by Vicente-Serrano et al. (2010) below:

$$SPEI_i = Pi - ET_o \qquad (1)$$

where Pi is the precipitation and ET_o is the potential evapotranspiration. Precipitation and Temperature data in each study were obtained from gridded CHIPRS and NASA power datasets, respectively.

Response Variables

The **mean effect size** (response ratio) was calculated according to the equation 2 (Hedges et al.,1999).

$$RR = \ln\left(\frac{X_t}{X_C}\right) = \ln X_t - \ln X_C \qquad (2)$$

where RR is the natural log response ratio of the individual studies; X_t and X_C are the mean yield of the intercrops and monoculture systems, respectivly.

Complementarity was calculated using the following equation described by Loreau and Hector, (2001):

$$CE = \Delta Y - NCOV(\Delta RY, M) \qquad (3)$$

Compitition/Facilitation among the species was assessed following equation described by Diaz-Sierra et al. (2017):

$$NInt_c = 2\frac{\Delta P}{P_{sum} + |\Delta P|} \qquad (4)$$

The values of $NInt_c$ is -1 for competitive exclusion, and +1 for obligate facilitation.

Results

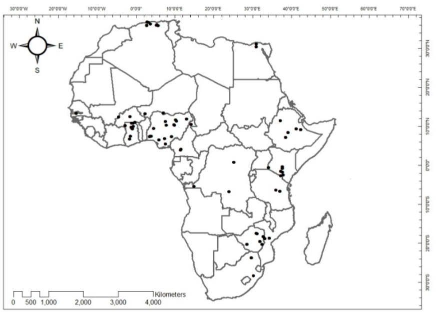

Fig 2 Spatial distribution of intercropping experiments included in the meta-analysis.

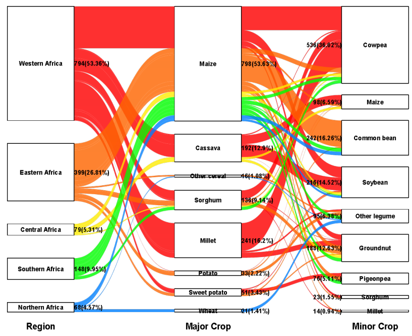

Fig 3: Intercropping systems diversity over different regions of Africa.

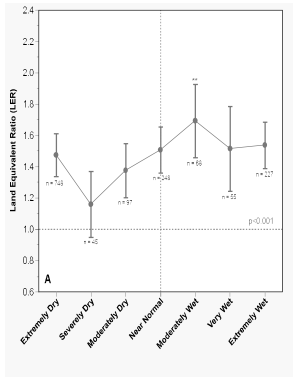

Fig 4: Effects of climate variability on intercropping systems productivity across various diversification options in Africa. n indicates the sample size of the observation.

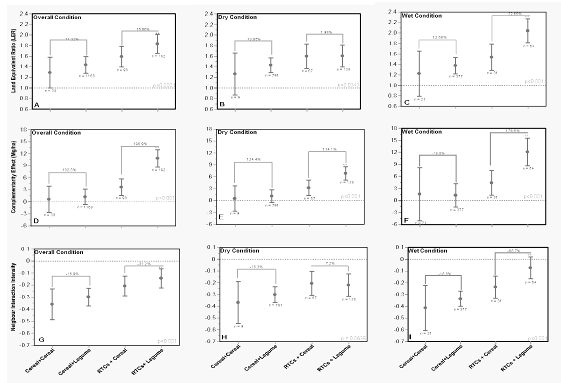

Fig 5: Response of various intercropping systems to climate variability in terms of systems productivity and resource utilization. The value of neighbor interaction intensity is interpreted like correlation coefficient as -1 for competitive exclusion, and +1 for obligate facilitation.

III. CONCLUSION

Our results revealed that grain legume integration enhances systems resilience to climate variability by at least 11% in comparison to non-legume systems. Importantly, the positive legume effect is more pronounced under root and tuber (RTCs) cropping systems. Hence, promoting legume integration in root and tuber crops systems could be a highly promising agroecological pathway to climate resilient cropping systems in Africa.

References

Díaz-Sierra, R., Verwijmeren, M., Rietkerk, M., de Dios, V.R., Baudena, M., 2017. A new family of standardized and symmetric indices for measuring the intensity and importance of plant neighbour effects. Methods in Ecology and Evolution 8, 580–591. https://doi.org/10.1111/2041-210X.12706

Hedges, L.V., Gurevitch, J., Curtis, P.S., 1999. The meta-analysis of response ratios in experimental ecology. Ecology 80, 1150–1156.

IPCC, 2023. A Report of the Intergovernmental Panel on Climate Change. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

Loreau, M., Hector, A., 2001. Partitioning selection and complementarity in biodiversity experiments. Nature 412, 72–76.

Contact

Adam Muhammad Adam
Agronomy in the Tropics and Substropics
Hans-Ruthenberg-Institute
University of Hohenheim
Stuttgart, Germany
am.adam@uni-hohenheim.de

Partners

Funded by the European Union