Estimating the impact of climate change on cowpea production in Sudan Savanna using field cultivation data

In the semi-arid region of West Africa known as the Sudan Savanna, cowpea — a drought-resistant legume crop — is widely cultivated. Despite its importance as a protein source in the region, the yield per unit area is extremely low, and there are concerns about the increasing impact of extreme weather events such as heavy rainfall and drought due to climate change in the future. Addressing climate change, including predicting future production variability and identifying its causes, is urgently needed.

Yield prediction models can estimate crop yields by inputting meteorological conditions such as rainfall and temperature, as well as information about soil fertility and water characteristics. However, existing models targeting cowpea are specialized in predicting yields in optimal environments with minimal environmental stress, making it difficult for them to be applied to the harsh environments in Africa. To reveal the impact of climate change on cowpea production, this study aims to improve the accuracy of yield prediction models by utilizing field cultivation data in the Sudan Savanna accumulated in previous studies.

We created a yield prediction model using data from the cultivation of 20 cowpea varieties (n=1380) over four years with varying rainfall conditions in two representative soil types, Lixisols and Plinthosols, in the region. This allowed us to estimate yields in a wide range of environments, including dry and wet conditions (Fig. 1). Based on the latest global climate change predictions (Coupled Model Intercomparison Project Phase 6, CMIP6), it is forecasted that in West Africa, over the next 30 years, rainfall during the cowpea cultivation period (July to October) as well as the number of days with heavy rainfall exceeding 30 mm will increase (Fig. 2 top). The estimated yield model revealed that with increased rainfall and more days of heavy rainfall, cowpea yields in Lixisols will significantly decrease (Fig. 2 bottom). Furthermore, it is predicted that although cowpea yield reductions during drought periods will be mitigated compared to the present, drought-induced yield reductions will continue to be most severe in Plinthosols (Fig. 3).

Lixisols are relatively fertile and have high yields, making them significant areas for crop production. However, it is anticipated that excessive soil moisture stress will worsen due to increased rainfall, necessitating measures such as introducing tolerant varieties. In Plinthosols, drought-induced yield reductions are relatively greater than the reduction caused by excessive soil moisture, highlighting the need to control drought impact in the future.

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Lixisols (1 month after sowing, 2016)

Plinthosols (Harvesting time, 2017)

Fig. 1. Cultivation of cowpea in two dominant soil types in the Sudan Savanna

Twenty local varieties were cultivated for four years (2016-2019) in two dominant soil types in Sudan Savanna, namely Lixisols and Plinthosols. Lixisols (left) are prone to waterlogging shortly after rainfall, while Plinthosols (right) are susceptible to drought due to intermittent rainfall cessation.

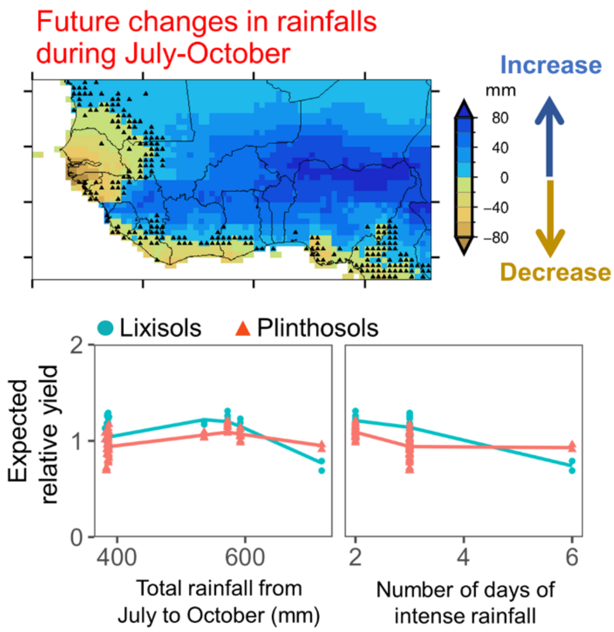

Fig. 2. Predictions of rainfall changes in West Africa and cowpea yield responses

(Top): Future predictions (2020-2049) compared to the present (1990-2019) regarding total rainfall during the cowpea growth period (mid-July to mid-October). Analysis results from CMIP6 simulations. Black dots indicate locations where the changes are statistically significant at the 5% level. (Bottom): Predicted relative yield in response to increased rainfall and number of heavy rainfall days (30 mm or more per day). The line represents local polynomial regression.

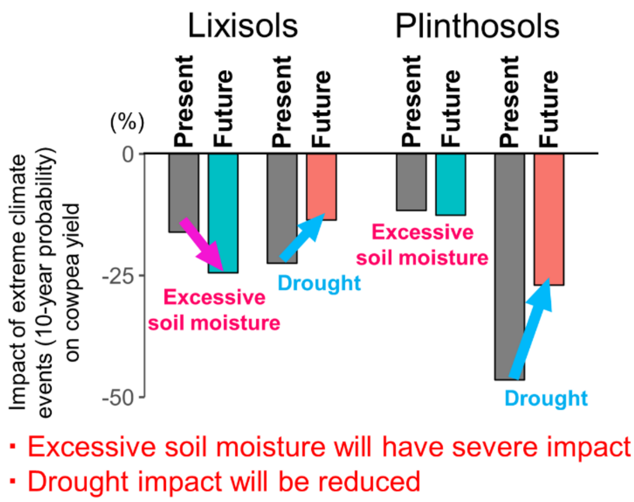

Fig. 3. Impact of extreme weather events on cowpea yields in different soil types

Comparison of cowpea yield reduction rates in Lixisols and Plinthosols during excessive soil moisture stress and drought stress, comparing the present (1990-2019) and future (2020-2049).

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