Impact of climate change on maize productivity and nitrogen cycling in the sub-humid tropics: a field case study under rainfall extremes in Zimbabwe

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Abstract: Changes in rainfall patterns and extreme wet and dry events are more frequent and will intensify globally because of global warming disrupting the water cycle (Rohde, 2023). This is particularly the case in Southern Africa with an increasing intensity and frequency of rainfall extremes. These events often lead to water stresses ranging from droughts to waterlogging, which may adversely impact the soil-crop processes (Kim et al., 2024) and reduce crop productivity and nutrient use efficiency. However, studies using rainfall manipulation experiments remain scarce. Most of such existing experiments have been conducted on natural ecosystems such as grasslands and woodlands in the northern temperate regions, with a clear gap on croplands in the tropics and poor focus on interactions with nutrient cycling (Beier et al., 2012).

To better understand the soil-crop nitrogen (N) dynamics under rainfall extremes, a field-scale rainfall manipulation experiment has been carried out in 2022-2023 and 2023-2024 cropping seasons in Harare, Zimbabwe (17°42'13.5"S 31°00'29.4"E) under sub-humid conditions. This is a part of a large 1.5 ha new long-term experiment established since November 2022 and registered within the Global Long-Term Agricultural Experiment Network (https://glten.org/experiments/368). Three main rainfall treatments replicated three times were established: reduced rainfall (-30%), normal rainfall and heavy rainfall (events of 100 mm/24h). The reduced rainfall treatment is achieved with an exclusion system above the maize canopy using transparent shelters covering about 30% of the plots surface. The heavy rainfall events are simulated with an irrigation system, and two events are applied per cropping season. Within these rainfall treatments, the study focused on four cropping systems treatments, resulting from the combination of two N

fertilization levels (0 and 80 kg N ha^{-1} yr^{-1}), with or without mulching (0 and 6 t DM ha^{-1} yr^{-1}). A bare soil treatment was also set up and monitored to study the soil functioning without crop. Key variables related to biomass production and N dynamics such as leaf area index, crop biomass and N uptake, yield, soil temperature, soil water and mineral N, mulch decomposition, and emissions of nitrous oxide (N_2O) were monitored from the first cropping season. An *in-situ* experiment using ^{15}N labelled fertilizer was conducted during the second cropping season to study the fate of fertilizer under the three rainfall treatments with and without mulch. Labelled N fertilizer was applied on microplots as basal application, first and second topdressing using non-cumulative split application approach with both soil and plant N and ^{15}N monitoring at different stages of plant growth.

The first-year results indicate that N dynamics in the soil were slightly affected by rainfall treatments and the presence of mulch. Total aboveground biomass and grain yield were negatively affected by reduced rainfall and absence of N fertilization. Mulch exhibited a buffering effect in topsoil layers, reducing soil temperature variations and maintaining moisture for a longer period during dry spells. The decomposition kinetics of the mulch were little affected by rainfall treatments but was quick, with 50% of initial dry mass decomposed in about 70 days. These results suggest a highly variable impact of rainfall extremes on biomass production, maize residue decomposition and N cycle depending on their timing, intensity and frequency of occurrence. Results from plant N uptake and from the ongoing analysis of the ^{15}N labelling experiment, along with the planned modelling work with the STICS soil-crop model should provide further clarification on the interaction between rainfall patterns and N cycle, as well as the short and long-term consequences on plant biomass production and recycling.

References

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