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Evaluating Climate Change Impacts and Adaptation Potential in Single and Double Cropping Systems using Crop Model Emulators

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Climate change poses significant challenges to global food security, particularly in regions relying on double cropping systems. Developing sustainable adaptation strategies for these systems is essential to mitigate climate-induced yield losses and ensure sustainable crop production under changing climate. However, the effectiveness of these strategies remains underexplored in many regions, especially in areas where double cropping systems are a cornerstone of agricultural productivity and food security. This study aims to establish a global framework for climate change adaptation in single and double cropping systems, focusing on optimizing management practices such as sowing dates and cultivar selection. As a first prototype, we assessed the impacts of climate change on rainfed soybean and maize in single and double cropping systems in Brazil.

Using an advanced crop model emulator, the CROp model Machine learning Emulator Suite (CROMES), we projected crop yields under two shared socioeconomic pathways (SSP126 and SSP585) for 2016–2100. Our results reveal that optimizing sowing dates and cultivar selection is crucial for adapting cropping systems to climate change. Double cropping soybean faces yield declines up to 40% under SSP585 but gains up to 10% under SSP126, with early-sown and early-maturing varieties suffering sharper losses (up to 75%). Double cropping maize grown in the second season shows greater resilience, with declines ranging down to only -20%, while single cropping maize again faces sharper losses, reaching down to -60%. Single cropping soybean can increase yields by up to 30% under SSP126 with later planting and longer maturity groups but declines up to -30% under SSP585.

These findings provide valuable insights for understanding the vulnerabilities and potential

adaptation strategies for single and double cropping systems in Brazil, setting the stage for broader global studies. Future work will extend this analysis to other key cereal-based double cropping systems in China, the United States, and Indonesia, contributing to a comprehensive global framework for transitioning to sustainable double cropping systems and securing food production under the pressures of climate change.