EGU24-18553, updated on 27 Oct 2024
https://doi.org/10.5194/egusphere-egu24-18553
EGU General Assembly 2024

Adapting Italian Agriculture to Climate Change: A MONICA Model Analysis of Chickpea and Lentil Phenology Shifts

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The impact of climate change on agricultural systems is profound, prompting the need for adaptive crop management strategies. In this context, our study leverages the MONICA crop model, which has been finely tuned and validated using data from Italian chickpea and lentil field trials, to predict how these crops will respond to future climatic changes across Italy. Central to our research are two pivotal questions: firstly, the expected changes in chickpea and lentil phenology under future climate scenarios in Italy; and secondly, the strategies Italian farmers can employ to adjust to these phenological shifts, thereby optimizing the production of these legumes in potentially shifting cultivation areas.

The MONICA model, specifically tailored for chickpea and lentil, incorporates comprehensive field trial data to accurately simulate these crops. Applied across the Italian peninsula in a 1 km^2 gridded format, the model provides an extensive analysis of how different climate conditions will affect crop phenology.

Our research is structured around three different 30-year simulation periods: a historical baseline (1994-2023), an intermediate future (2024-2053), and a distant future (2054-2083), each under two distinct IPCC emission scenarios (SSP1-2.6 and SSP2-4.5). This approach facilitates a thorough investigation into the influence of climate change on the growth and development of chickpea and lentil, with a special focus on the timing of flowering and maturity to deduce phenological changes.

Preliminary results reveal notable shifts in phenology, with significant implications for the timing of flowering and maturity, thereby affecting overall crop cycles. Subsequently, the study delves into adaptive strategies by assessing various factors, including yield, yield quality, yield stability, economic impact, water use efficiency, and soil fertility, with an emphasis on nitrogen levels.

The study evaluates four distinct crop rotation strategies:

- *Benchmark*: A conventional Italian 4-year rotation comprising legume, wheat, maize, and barley.
- *Autumn Shift*: The *Benchmark* rotation, but with chickpea and lentil sown in autumn.
- *Sustainable*: Replacing maize in the *Benchmark* rotation with a cover crop (clover), resulting in a legume, wheat, clover, and barley sequence.
- *Sustainable Autumn Shift*: The *Sustainable* rotation with autumn sowing for chickpea and lentil.

These strategies are scrutinized under the different climate scenarios to assess their effectiveness in adapting to the anticipated phenological changes. Early findings indicate that altering sowing dates and modifying crop rotations can markedly affect yield, yield stability, and the overall sustainability of agriculture. Specifically, crops sown in autumn, especially within the sustainable rotations, demonstrate potential in adapting to the expected shifts in phenology, poten- tially yielding more stable crops and environmental advantages.

Our research aims to furnish Italian farmers with practical insights, assisting them in adapting sowing dates and management practices to uphold sustainable legume production amidst climatic shifts. Beyond its immediate application, this research offers a framework that could be applied to other regions and crops, thereby enhancing our understanding of agricultural adaptation to climate change.