E4S Brief

Towards digitalization for sustainable and resilient agriculture: Climate change impacts on agricultural suitability in Switzerland

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In a Nutshell

Climate change and its intensifying impacts pose significant challenges to food security and rainfed agricultural sustainability, both globally and in Switzerland. One pressing issue is how shifting climate patterns may affect cropland suitability, with profound implications for future agricultural food production and related planning and policy-making. This is particularly relevant in a country like Switzerland, as mountainous regions are more sensitive to the foreseen changes in climate. However, Switzerland currently lacks the comprehensive decision-support tools and the evidence base needed to sustain effective decisions in this area. This project aims to assess how climate change will alter crop suitability across Switzerland and how tools like digital data-driven technologies can inform and guide agricultural policies. The methodology involves two key steps: developing a data-driven mathematical model linking agricultural yield to climatic and soil factors; and assessing cropland suitability across Switzerland under current conditions and future climate change scenarios. The crop suitability model developed in this project allows the assessment of future spatially distributed shifts in suitability for the five major rainfed crops produced in Switzerland. The explicit identification of regions and crops most vulnerable to climate change thus offers actionable insights for better agricultural management and investment strategies.

What we do and why it matters

The project addresses a critical challenge of our time: supporting agricultural adaptation and ensuring food security under climate change. Untapping the potential of digital innovations - including the development of data-driven approaches for the identification of future crop suitability shifts - has the potential to contribute to the redesign of climate-resilient agricultural systems. With agriculture lying at the intersection of food security, environmental sustainability, and economic stability, our research questions align closely with E4S's mission to lead the transition toward a resilient economy by harnessing innovation. Specifically, the project lays the groundwork for developing cutting-edge digital modeling tools to improve evidence-based decision-making in the agricultural sector in an era of increasing data availability. Modeling outcomes provide actionable insights into the impacts of climate change on rainfed crop suitability in Switzerland, potentially relevant to policymakers designing effective and sustainable agricultural strategies, farmers and agribusinesses seeking adaptive solutions, and financial institutions managing economic risks. Additionally, they could inform consumers and society at large about the future of food production. By delivering science-based assessments that enable more informed management strategies and foster digital innovation, the project equips stakeholders with the knowledge and tools needed to navigate climate challenges effectively and contribute to the transition toward more resilient and sustainable agricultural planning.

How we do it and main findings

The focus of this project is the assessment of cropland suitability (CLS), defined as the potential of an environment to provide optimal soil and climate conditions for the growth and productivity of a specific crop. We evaluated the suitability of five major crops produced in Switzerland (wheat, barley, maize, rye, and grapes) under both current and future climatic conditions. To this end, we first developed a data-driven model, which mathematically links crop yield with soil factors (such as texture, organic carbon, pH) and climate factors (i.e, temperature, precipitation, solar radiation) - see **Fig. 1a**. While results presented in this brief focus on Switzerland, data to force the model were derived from global scale datasets, allowing our methodology to be applicable worldwide. The global model is applied to Switzerland using high-resolution maps of soil and climate factors, thus

enabling a detailed representation of Swiss CLS (**Fig. 1b**). Specifically, partial soil and climate suitability indices describing the impact of each soil and climate factor on CLS are combined to obtain an overall suitability index (SI, see **Fig. 1c-e**), ranging between 0 (not suitable) and 1 (highly suitable).

Taking the year 2000 as our reference baseline condition, we found that temperature and precipitation emerged as the most limiting factors for all five crops considered, with soil characteristics playing a relatively minor role. However, this impact varies depending on the specific crop and location, meaning that some regions are more vulnerable to climatic shifts and that future adaptation strategies should thus explicitly consider local climatic peculiarities. To further assess future changes in CLS, we considered temperature and rainfall projections according to the CH2018 climate change projections (corresponding to different global warming trajectories) and evaluated foreseen changes in end-of-century CLS. The results indicate that rising temperatures will greatly reduce CLS in many areas by 2090, particularly in the Swiss lowlands. For example, in the Central Plateau and Jura areas, temperature suitability for barley is projected to decline by up to 72% compared to the year 2000, leading to an overall suitability reduction of approximately 45%. While temperature emerged as the most influential driver of change, it will be interesting to further investigate the direct impact of rainfall temporal variations, with a specific focus on changes in the intensity and duration of rainfall events rather than focusing on annual total values only.

In conclusion, our findings provide a scientific basis for assessing the current state of cropland suitability and estimating its climate-driven shifts, supporting decision-making for sustainable agriculture. The insights presented here can assist policymakers, stakeholders, and researchers in developing adaptation strategies to ensure that agriculture remains resilient in the face of climate change.

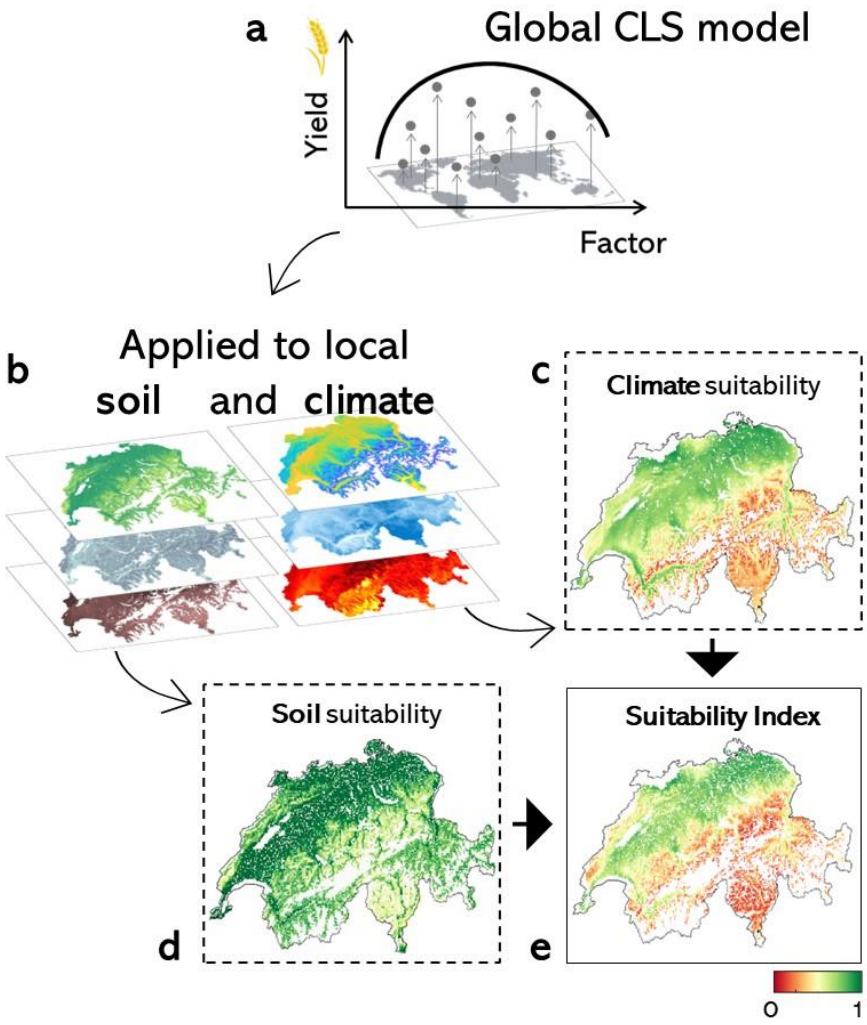

Figure 1: Graphical abstract of the cropland suitability (CLS) model. (**a**) Global data-driven CLS model. (**b**) CLS model applied to Switzerland. (**c**) Climate suitability resulting from temperature, precipitation and solar radiation. (**d**) Soil suitability resulting from soil texture (sand-to-clay ratio), soil organic carbon, and pH. (**e**) Overall suitability index, computed as a combination of climate and soil suitabilities ($SI = SI_{climate} \cdot SI_{soil}$).

Call for action

The impacts of climate change on agriculture are accelerating, threatening food security and environmental sustainability worldwide. While it is largely recognized that agricultural policy instruments can benefit from digital technologies and climate-informed scientific evidence, the adoption and development of digital technologies in agriculture is still in its infancy, particularly for policy-making purposes. Our project provides a science-based foundation for understanding how crop suitability will evolve in Switzerland in light of projected future climates, offering key insights for adaptation strategies to ensure a resilient agricultural future. By leveraging digital innovations and data-driven modeling, we empower stakeholders with quantitative information needed to make informed decisions that may enhance agricultural sustainability and resilience.

We call for policymakers to integrate climate-informed and science-based evidence to inform agricultural planning and policy, fostering sustainable land use and supporting farmers in their adaptation efforts. We advise agricultural institutions and companies to incorporate climate risk assessments into investment strategies, ensuring the adaptation to modern challenges while remaining sustainable. We invite researchers and technology developers to collaborate in advancing digital solutions and reimaging agricultural practices. Last but not least, we engage consumers and society in the conversation on sustainable food systems, promoting awareness, responsible choices, and proactive exchanges.

Building climate resilience in agriculture requires joint efforts and science-driven approaches. This project is a first step toward achieving this goal, offering a blueprint for the estimation of expected climate-driven shifts in cropland suitability. The time to act to ensure a resilient agricultural future is now: through collaboration and innovation, we can shape a more sustainable and secure food future.

"Adapting agriculture to climate change is crucial to ensure food security for a growing population. In an era of increasing data availability, untapping the potential of data-driven digital technologies to assess climate-driven shifts in crop suitability can inform a fundamental redesign of agricultural systems."

- Sara Bonetti, Assistant Professor, EPFL

Learn more

- 27 April – 2 May 2025, Climate change impacts on Swiss cropland suitability, Abstract of the poster for the EGU 2025 conference (European Geosciences Union General Assembly) - Vienna, Austria, https://meetingorganizer.copernicus.org/EGU25/EGU25-16347.html

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