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Crop rotation boosts yields and soil quality

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Crop rotation has been shown to synergistically improve barley yields and soil quality on the Tibetan Plateau, where challenging climatic conditions, limited crop choices and low baseline soil fertility threaten agricultural sustainability.

Agriculture stands as the backbone of global food security, yet conventional farming practices often come at the cost of soil degradation and stagnating crop yields. Crop rotation — a longstanding practice — offers a sustainable solution by enhancing biodiversity within cropping systems. This, in turn, supports essential ecosystem services such as pest and disease control, carbon sequestration and soil fertility, while minimizing reliance on external inputs. The incorporation of legumes in rotational sequences is widely recognized as a key strategy for achieving synergistic increases in crop yields and ecosystem service functions[1]. Crop diversification without legumes can also achieve potential yield advantages in regions where legumes are not agronomically or economically feasible. Despite the potential, the benefits of crop rotation are underexplored on the Tibetan Plateau, where agriculture faces challenges such as harsh climate, limited crop options and low soil fertility.

Now, writing in *Nature Food*, Wu and colleagues[2] present a compelling examination of the effect of crop rotation on barley yields and soil quality on the Tibetan Plateau. The research compares various cropping patterns, including short-term (≤5 years), mid-term (5–10 years) and long-term (>10 years) continuous cropping, with rotations involving wheat or rapeseed. Remarkably, the study found a 17% increase in barley yield within Tibetan barley–wheat rotation and an impressive 21% increase within Tibetan barley–rapeseed rotation compared with long-term continuous cropping. Additionally, crop rotation considerably improved soil quality, a critical factor for long-term agricultural sustainability. The unique aspect of the study lies in its utilization of 39 long-term field trials, spanning different durations, to substantiate the synergistic enhancement in both barley yields and soil quality through crop rotation, particularly on the Tibetan Plateau. These findings align with global efforts to promote regenerative agriculture, highlighting the transformative potential of crop rotation in improving yields and soil health over time. They resonate with a growing body of literature advocating for agricultural diversification to enhance sustainability[3].

Soil quality is a multifaceted concept that encompasses physical, chemical and biological properties essential for plant growth. The research reveals that rotating barley with wheat or rapeseed not only boosts yield but also improves soil quality, primarily by increasing soil microbial biomass and decreasing pH, which are key factors in overcoming the challenges of continuous cropping. A previous study also demonstrated that inclusion of legumes in rotation sequences can fix atmospheric nitrogen, reducing the need for synthetic fertilizers and increasing the fertility of the soil for subsequent crops[4]. Crop rotation improves soil quality by diversifying root structures, accessing various nutrient pools and aerating the soil. It also contributes to the buildup of organic matter, which is crucial for maintaining soil structure and water-holding capacity. Consequently, the enhancement of soil nutrient dynamics due to diverse root exudates, and the promotion of soil microbial diversity and activity, collectively contribute to the observed improvements in soil quality and barley yield.

The long-term benefits of crop rotation are particularly noteworthy in the face of increasing challenges posed by climate change, when the need for adaptable and resilient farming systems is more urgent than ever[5]. The capacity of crop rotation to enhance soil health, boost yields and reduce dependency on chemical inputs positions it as a crucial tool for transforming agricultural systems. Ongoing research and the widespread adoption of crop rotation are essential for developing resilient and sustainable food systems that can withstand environmental stresses while maintaining productivity. Although this study only confirms the long-term benefits of crop rotation for barley cultivation on the Tibetan Plateau, it also serves as an inspiration and catalyst for recognizing the long-term value of crop rotation benefits worldwide. The study's implications are particularly relevant for policymakers and agricultural practitioners focusing on sustainable land management strategies that prioritize ecosystem services and long-term productivity over short-term yield gains.

Despite the benefits, the implementation of crop rotation faces challenges, including economic pressures to maximize short-term yields and a lack of knowledge about effective rotation strategies. Introducing new crops like wheat and rapeseed in areas traditionally dedicated to barley may lead to short-term economic setbacks due to incompatibilities with agricultural machinery, insufficient field management knowledge and marketing difficulties. Opportunities to overcome these challenges include government incentives for sustainable practices, educational programmes that promote the understanding of crop rotation, and research on tailored systems for specific regions and crop demands[1]. Future research should assess the economic viability of crop rotations under different conditions and identify market opportunities for various crops. Supportive policies,

including subsidies and farmer training, will be crucial for successful implementation. Collaboration among researchers, policymakers and farmers is key to scaling up these practices for sustainable agriculture[6].

Furthermore, data limitations continue to constrain our understanding of rotation effects on the socio-economy, environment and potential trade-offs in crop production. Additional research is needed to evaluate how crop rotation influences ecosystem services, such as nutrient cycling, pollutant retention, soil fertility and water regulation. Quantifying the spatial and temporal variability in rotation effects on ecosystem services, yield and economy dynamics on a global scale will provide a more comprehensive perspective on the long-term benefits of crop rotation. Beyond the case study on Tibetan barley, the effects of crop rotation for specific crops worldwide require further exploration, particularly on a larger scale, to determine whether crop rotation can achieve the synergistic goals of increasing crop yields, soil quality, economic benefits and enhancement of ecosystem services. Achieving an effective crop rotation system through the rational configuration of crops can lead to a win–win situation for both yield and environmental effects, thereby supporting the sustainable development of agriculture[7].

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Competing interests

The authors declare no competing interests.