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协同作用通过增强细菌-真菌竞争削弱了草地土壤多功能性。论文标题：Warming and increased precipitation synergy undermines soil multifunctionality through enhanced bacterial – fungal competition in semi-arid grasslands

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Warming and increased precipitation synergy undermines soil multifunctionality through enhanced bacterial–fungal competition in semi-arid grasslands

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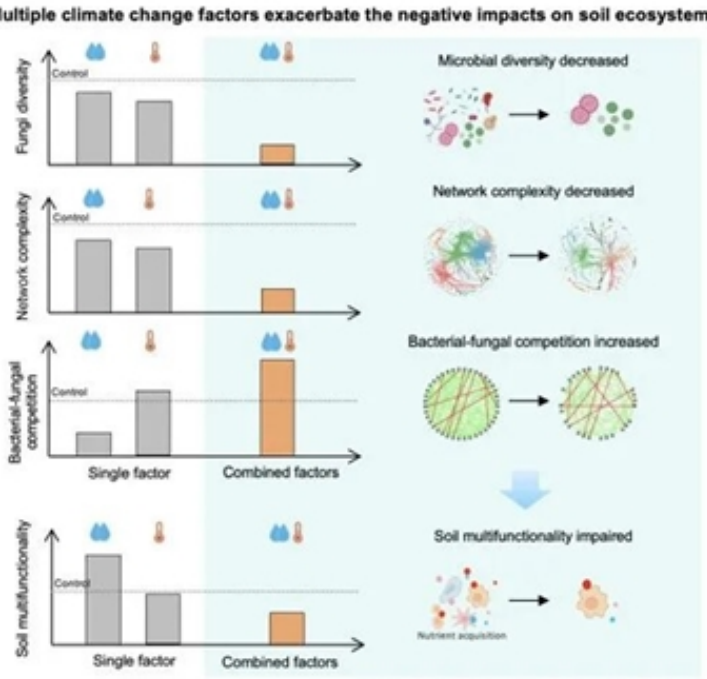
ABSTRACT

- Bacterial and fungal responded differently to warming and precipitation change.
- Warming amplifies the negative effects of precipitation on both bacteria and fungi.
- Warming and humidification intensify competition between bacteria and fungi.
- Enhanced bacteria and fungi competition impair soil multifunctionality.



Soil microbial communities play a crucial role in maintaining multiple soil functions in terrestrial ecosystems. However, evidence linking soil microbial communities to soil multifunctionality under warming and precipitation changes remains limited. In this study, we conducted a three-year climate change experiment in a semi-arid grassland to explore the effects of warming (using open top chambers) and precipitation change (increased or decreased by 40%), as well as their interactive effects on soil microbial communities and multifunctionality. Our results indicated that the impacts of climate change became more pronounced in the third year compared to the first year after the experimental treatments were initiated. In addition, warming amplified the negative effects on soil microbial diversity, interactions, and multifunctionality under increased precipitation. Notably, the combination of warming and increased precipitation negatively impaired soil multifunctionality by intensifying competition between bacteria and fungi. Our results show that the structure of soil microbial communities, network complexity, and multifunctionality were more sensitive under the concurrence of warming and increased precipitation in semi-arid grasslands, due to their long-term adaptive mechanisms to dry environments. Therefore, it is essential to incorporate the interactions among soil microbes into future predictions of soil multifunctionality under complex climate

本研究依托在黄土高原草地生态系统开展的一项为期三年的气候变化模拟实验，探究了增温（使用开顶箱）和降水变化（增加或减少40%）及其交互作用对土壤微生物群落和多功能性的影响。研究结果表明，与气候变化处理第一年相比，其影响在第三年变得更加显著；在增水条件下，增温加剧了其对土壤微生物多样性、互作关系以及多功能性的负面影响，增温与增水的交互作用通过提高细菌与真菌之间的竞争作用削弱了土壤多功能性。由于半干旱地区草地生态系统对气候环境的长期适应性，其土壤微生物群落结构、网络复杂性和多功能性在增温与增水同时发生时更为

敏感。

土壤微生物群落在维持陆地生态系统的多种土壤功能中起着至关重要的作用。然而，关于增温和降水变化交互影响下土壤微生物群落与土壤多功能性之间关系的证据仍然有限。

为了加强我们关于半干旱草地土壤微生物群落及其与土壤多功能性关系在响应多重气候变化的理解，我们在黄土高原地区进行了增温和降水变化的交互控制实验，具体包括增温（开顶箱）、降水减少（40%）和降水增加（40%）的单独和交互处理。研究结果表明：半干旱草地生态系统中土壤微生物群落对增温和降水增加的交互作用更为敏感。细菌和真菌对增温和降水变化的响应有所不同，在增温背景下，增水提高了细菌多样性，但真菌多样性则出现了下降。增温和增水的交互作用不仅改变了微生物多样性，还降低了其相互作用和网络连接性，最终削弱了微生物群落的稳定性和气候韧性。此外，增温增水通过增强细菌与真菌间竞争作用削弱了土壤多功能性。

总体而言，我们的研究突显了未来气候变化下将土壤微生物相互作用纳入土壤多功能性预测的重要性，在研究气候变化影响时也应考虑土壤微生物对其环境条件的适应性。黄土高原暖湿化可能对草地土壤多功能性产生强烈影响。

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专题征稿

城市土壤生态与同一健康

Call for papers: Urban Soil Ecology and One Health

Urban landscapes are complex incubators for emerging public health threats, including the persistence and spread of zoonotic pathogens that jeopardize the integrated health of humans, animals, plants, and environments—a nexus addressed by the One Health framework. Within these ecosystems, soil biodiversity is a keystone component that underpins critical ecosystem functions, yet it persists as one of the least understood elements of urban ecosystems.

Aligned with the World Soil Day 2025 theme, "Healthy soils for healthy cities," this special issue calls for research to address this knowledge gap. We seek submissions that illuminate the distribution patterns and functional contributions of urban soil biota, particularly under pressures from human activity and climate change. We are also interested in studies exploring how harnessing urban soil biodiversity can lead to nature-based solutions for mitigating biodiversity loss, adapting to climate change, and reducing the urban burden of disease. We particularly encourage studies proposing frameworks for embedding soil biodiversity into urban governance and policy to directly enhance One Health outcomes.

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