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Planetary limits to soil degradation

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Soils are essential to life on Earth but are rapidly degrading worldwide due to unsustainable human activities. We argue that soil degradation constitutes a key Earth system process that should be added as 10th **Earth system process to the planetary boundaries framework.**

Soil degradation shares all key traits with the nine Earth system processes already present in the planetary boundaries framework. It is caused by human activity, has the potential to cause unacceptable environmental change, shows tipping point behavior when forced beyond a critical level, is relevant on both local and global scales, and is strongly interrelated with the other Earth system processes.

Healthy soils have a level of resilience against disturbances but once forced beyond a critical level, they are at risk of entering into a downward spiral of degradation fuelled by strong positive feedback loops. Well-documented examples include the local feedback between loss of soil structure and soil biota and the large-scale feedback loop between soil erosion and climate change. The final degraded state of the soil is unable to sustain human life on earth. The fall of past civilizations has been related to their inability to protect the soil. At present, ~33% of the global soils are moderately to severely degraded as a direct result of human activities such as unsustainable agricultural practices, urban expansion, and industrialization. Estimates show that by 2050, 90% of our soils will be degraded, the majority of our ecosystems will be compromised and the entire human population will be affected.

Soils are essential to life on Earth through the provision of soil functions and ecosystem services such as biomass production (including ~95% of the food we eat), climate regulation, water storage and purification, habitat provision, and nutrient cycling. They play a key role in achieving many of the Sustainable Development Goals (SDGs) including SDG 15: life on land, SDG2: zero hunger, and SDG6: clean water and sanitation. Soil degradation leads to critical disruptions to *biosphere integrity*, *biogeochemical flows*, *climate change*, and *land-system change*, all processes that have already crossed their planetary boundaries. Hence, in order to improve the planetary boundaries framework and clearly signal the need to protect the soil, we call for soil degradation to be considered the 10th Earth system process in the planetary boundaries framework.