

12 years of irrigation in a drought stressed pine forest speeds up carbon cycling and alters the soil biome but has negligible effects on soil organic matter storage

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Inneralpine valleys are experiencing repeated summer droughts, which have caused a die-back of pine forests since the 1990s. Drought limits the metabolic activity and hence C cycling in the plant and soil system. The net effects of drought on soil organic matter (SOM) storage is, however, ambiguous as drought affects both C inputs and outputs. Moreover, in the long-term, water limitation is also altering above- and belowground diversity due to species-dependent resistance and adaptation to drought. In our study, we explored how ten years of irrigation of a water-limited pine forest in the central European Alps altered above- and belowground diversity and C cycling in the plant and soil systems.

The decadal long irrigation during summer time strongly increased ecosystem productivity with litter fall and fine root biomass being increased by +50 and +40%, respectively. At the same time, soil CO₂ efflux was stimulated by 60%, indicating that the removal of water limitation enhanced both the inputs and outputs of C into soils. The accelerated C cycling was also mirrored by compositional shifts in the soil microbiome. 454-pyrosequencing of ribosomal marker genes indicated that irrigation promoted bacteria and fungi with more copiotrophic life style strategies, that are typical for nutrient-rich conditions associated with a higher decomposition. Determination of SOM pools revealed a C loss in the organic layer under irrigation (-900 gC m⁻²) but a C gain in the mineral soil (+970 gC m⁻²), resulting in a negligible net effect. The likely mechanisms for the altered vertical SOM distribution might be (1) an accelerated mineralization of litter in conjunction with higher C inputs from the rhizosphere and/or (2) an increased incorporation of litter in the mineral soil as suggested by a litter bag experiment showing a stimulated activity of the macrofauna with a 5-fold increase of the earthworm density. In summary, our long-term irrigation experiment revealed that the removal of water limitation during summer in a drought-prone pine forest strongly altered C fluxes and the belowground community composition. However, the net effect on SOM stocks was negligible due to a balancing out of C in- and outputs.