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Decoupling the deep: crop rotations, fertilization and soil physico-chemical properties down the profile

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Crop fertilization provides vital plant nutrients (e.g. NPK) to ensure yield security but is also associated with negative environmental impacts. In particular, inorganic, mineral nitrogen (Nmin) fertilization leads to emissions during its energy intensive production as well as Nmin leaching to receiving waters. Incorporating legumes into crop rotations can provide organic N to the soil and subsequent crops, reducing the need for mineral N fertilizer and its negative environmental impacts. An added bonus is the potential to enhance soil organic carbon stocks, thereby reducing atmospheric CO_2 concentrations.
In this study we assessed the effects of legumes in rotation and fertilization regimes on the depth distribution - down to 1 m - of total soil nitrogen (Ntot), soil organic carbon (SOC) as well as isotopic composition (δ13C, δ15N), electrical conductivity and bulk density as well as agricultural yields at a long-term field experiment in Gießen, Germany.
Fertilization had significant but small impacts on the soil chemical environment, most particularly the salt content of the soil, with PK fertilization increasing electrical conductivity throughout the soil profile. Similarly, fertilization resulted in a small reduction of soil pH throughout the soil profile. N fertilization, in particular, significantly increased yields, whereas PK fertilizer had only marginal yield effects, indicating that these systems are N limited. This N limitation was confirmed by significant yield benefits with leguminous crops in rotation, even in combination with mineral N fertilizer.
The soil was physically and chemically influenced by the choice of crop rotation. Adding clover as a green mulch crop once every 4 years resulted in an enrichment of total N and SOC at the surface compared with fava beans and maize, but only in combination with PK fertilization. In contrast, fava beans and to a lesser extent maize in rotation lowered bulk densities in the subsoil compared with clover. This resulted in a reduction of N density at depth, which was not mirrored in C densities, indicating that fava beans decouple C and N cycles in the deep soil profile. We then tested whether these effects are a result of plant (i.e. enhanced rooting depth associated with lowered subsoil bulk density) or microbial (i.e. N-cycling and denitrification processes) activities, by investigating the isotopic signatures of C and N down the profile.
Our results indicate that the selection of crop rotation influences soil C and N cycling and depth distribution. Although mineral N fertilizer has significant benefits for yield, the choice of crop rotation has a greater influence on soil C and N cycling and specifically the addition of leguminous plants into rotation can provide additional yield benefits and stability. Incorporating legumes into crop rotations affects soil physical and chemical properties and decouples C and N cycles in the deep soil profile, indicating different nutrient and water cycling processes in the deep soil profile.