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Management of hotspots for sustainable crop production: hotter, deeper, or simply more?

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Hotspots in agricultural soils, which include rhizosphere, detritusphere and drilosphere, are characterized by strongly different dynamics than those of natural ecosystems. This involves hotspot properties such as element cycling intensity, microbial activation, lifetime or spatial extension. Evidence from studies around the globe suggests that key hotspot characteristics intensify or increase under strongly limiting cropping conditions e.g. low-input agriculture: i) nutrient mining is more intensive around roots in infertile soils, ii) root exudates decompose more slowly under water limitation, and iii) the rhizo-hyphosphere forms a more spatially extended hyphal network under P deficiency. These examples suggest that smart management of hotspots might be a sustainable strategy to overcome soil limitations, not only for crop production on marginal soils but also as a strategy to save resources for future agriculture.

Here, we will present a set of studies applying management strategies, which actively modify hotspot intensity, lifetime or spatial extension with the aim to manipulate biogeochemical cycles of the respective agroecosystem. Most traditional, tillage enlarges the topsoil detritusphere or moves it to lower soil depths. Rather novel but increasingly studied approaches seek to modify rhizosphere properties: applying genotypes with i) specific root traits such as an optimized root morphology (e.g. modified root hairs or deeper fine root system) or ii) modified root exudate compositions and resulting rhizosphere microbiomes. Such approaches need to be applied site- and agroecosystem-specifically to optimize resource utilization. Moreover, as agroecosystems are under long-term controls, hotspot management strategies are not limited to one growing season but can stretch over years of cultivation. The generation of specific biopores – the root channels -

created by e.g. tap-rooted or deep-rooting cover crops is a management practise inducing a rhizosphere-detritusphere-rhizosphere transition over time. 'Re-activated' hotspots feature unique biogeochemical conditions for young roots as well as microbial communities. Such 'highways to subsoil' foster rhizosphere establishment in subsoils, where i) hotspots remain moist and thus active under drought and ii) where gradients from hotspots to bulk soils are for magnitudes higher compared to topsoils. All these aspects present a unique, however largely unexploited potential for future agriculture, yet.

By a novel set of methodological approaches and their combinations, comprising multi-isotope applications, in-situ imaging techniques, biomarkers and microbial activity measures with high spatial resolution, we will provide new insights into the potential of hotspot management in agroecosystems. We will discuss implications for crop production under resource limitation up to the potential for a sustainable development of future agricultural production systems especially in the face of projected climate change.