Increasing root carbon inputs to agricultural soils by optimized genotype selection

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The removal of carbon (C) from the atmosphere by binding C in soils can play an important role for mitigating climate change. The political pressure to reduce greenhouse gas emissions in agriculture is rising and promotes cropping systems with steady yields, but higher soil C sequestration. To enhance soil organic C stocks, higher organic C inputs to agricultural soils are necessary. Optimized genotype selection and breeding towards increased root biomass may enhance root C inputs and may therefore be a promising, easy-to-implement management option for C sequestration. The potential to increase root C inputs without compromising yield is only shown in few studies. We compiled 14 studies with experimental data in this review in order to estimate the potential of genotype selection to enhance root biomass without compromising yield. We created a database including root biomass, shoot biomass and yield of field grown winter wheat, spring wheat, silage maize, winter rapeseed and sunflower. The minority of genotypes showed a potential to increase root biomass without compromising yield compared to the average. Those who did, showed a mean of 12 % yield increase and a mean of 19 % root biomass increase compared to the average. This indicates that genotype selection may have a stronger effect on below than above ground biomass increase. Averaged over those genotypes that showed a potential to enhance root biomass, a mean root C increase of 0.11 Mg C ha^{-1} a^{-1} would be possible without yield reduction. Yield was significantly correlated to root biomass and crop type. The increased root biomass may stabilise yields as a climate adaption option under changing climatic conditions with increasing drought events during vegetation periods. The root: shoot ratios varied not only between, but also within crops. Overall, we could show that genotype selection can be a win-win option by increasing soil C while maintaining or even enhancing yield.

Keywords: root carbon inputs, carbon sequestration, climate change mitigation

Linking root biomass and traits with soil C and nutrients stocks and microbial activity down to 100 cm depth in a young Mediterranean agroforestry system

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In the subsoils, roots represent a major source of organic matter. Moreover, the C inputs from rhizodeposition, root turnover (mostly perennial species) and root mortality at harvest (annual crops) have a long residence time in soil due to slow decomposition rates. However, deeper understanding of the root impact on soil C stocks and nutrient dynamics is still required, especially in deep horizons of mixed species agroecosystems.

This study aims to assess the heterogeneity of the root distribution and the root traits in two main components of an alley-cropping system, i.e. the crop and the understory vegetation strip (UVS) located under the tree rows; and to relate the root variables to soil physical, chemical and microbiological properties according to the distance from the tree and to soil depth.

The experimental alley-cropping site "DIAMS" (Mauguio, France) was planted in 2017 with *Robinia pseudoacacia* (294 trees ha^{-1}). In May 2020, we assessed the fine root biomass density, distribution, functional traits, chemical composition and some soil physical, chemical and microbiological properties in 3 soil layers (0-20, 20-50 and 50-100cm), 3 locations (the UVS under the tree rows, the wheat (Crop-1m) at 1 to 2m perpendicular to the tree line (under tree shade) and the crop (Crop-4m) at 3.4 to 4.5m from the tree (no tree shade)) and in 3 independent replicated plots.

The crop roots at 0-20 cm of depth had a biomass reduced by 3-fold near the UVS compared to far from it. UVS and crops showed similar root traits response to depth with a decrease of specific root length and stele diameter associated with an increase of root C:P ratio. The estimated annual root C inputs represented less than 0.6% of the organic C stocks and was less important under the UVS than the crop, at depth, due to C input pathways (turnover vs. mortality, respectively). Between 0 and 50 cm of depth, the soil C stocks increased with root C stocks, whereas below 50cm the relationship was negative, suggesting that root effect on soil-C might shift in subsoil. At all depths, the root stoichiometry had a tight link with extracellular enzyme N activities. According to ecoenzymatic stoichiometry, subsoil seemed more nutrient limited.

Altogether, our results suggested that increasing root biomass up to 50 cm (in our case) can foster soil C storage. In contrast, in deeper soil layers, an increase in root inputs, having high C:N ratios, could induce microbial N limitations and consequently restraint soil C storage.

Keywords: *Robinia pseudoacacia*, soil C sequestration, alley-cropping, root traits, soil enzymatic activity

Cover Crops Affecting Pool Specific SOC Sequestration in European Cropland – A Meta-Analysis

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Abstract

The "4 per mille" initiative proposes that by increasing the global soil organic carbon (SOC) stocks by 0.4 % per year, the global anthropogenic greenhouse gas (GHG) emissions could be offset. Especially croplands are often low in SOC and by enhancing SOC levels in these soils, GHG emission can be partly compensated. This can be achieved by adopting SOC enhancing land management practices, such as the cultivation of cover crops (CC). Up to now, no quantitative analysis of cover crop effects on SOC pool level has been done for Europe.

By conducting a meta-analysis, WP2-MIXROOT-C aims to quantitatively assess the CC effects on SOC pools throughout soil depths (0-100 cm) in European cropland soils. The pools chosen for this analysis are the microbial biomass carbon (MBC), the particulate organic matter (POM) and the mineral associated organic matter (MAOM) pool, as well as total SOC. Experimental studies conducted on a global level will be acknowledged as primary data input for the analysis, as long as the Köppen-Geiger climatic zone of the site is also present in Europe. This will allow us to incorporate more data whilst ensuring relevance for the European climate. Alongside, we will study the effects of moderators such as pedo-climatic factors (soil pH, soil texture class, percentage of clay, silt and sand, climatic zone, rainfall and temperature), other agricultural management practices (e.g., tillage, residue management, fertilization etc.) and CC characteristics and their management (species mixes vs. monoculture and legume vs. non-legume crops, shoot-to-root ratio, C/N ratio, frost resistance, seeding rate, sowing and harvesting time, termination method and time).

The meta-analysis will be conducted according to the quality criteria-set for meta-analyses in agriculture and soil sciences, which was previously developed by our group in WP7-EJP SOIL. This set will ensure that all key elements, necessary in producing a meta-analysis, will be present in our study. The overall effect sizes will provide the scientific community with valuable information about the state of knowledge on SOC pool specific sequestration rates influenced by CC and corresponding quantitative data. These results will offer guidance for future research and assist decision making processes regarding climate friendly management of agricultural soils.

Keywords: effect size; catch crop; MAOM; microbial carbon; POM; synthesis

C accumulation in the roots and sequestration in the soils of different types and agro-ecosystems in Lithuania

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Previous studies in Lithuania show that different agro-ecosystems such as forests, grasslands, and croplands provide different Soil organic carbon (SOC) stocks in the different soil types. SOC stocks at Lithuanian national level were estimated in 754 permanent observation plots (Armolaitis et al., 2021). The SOC stocks were obtained for eight WRB Reference Soil Groups. The mean SOC concentrations in the 0–10 and 10–30 cm topsoil of most soil groups, especially fertile forest soils (Cambisols, Luvisols +Retisols) were higher for forest land and grasslands, and lower for croplands. The averaged SOC stock in topsoil varied from 56 t ha^{-1} (Arenosols) to 118 t ha^{-1} (Cambisols) in mineral forest soils and was 150 t ha^{-1} (Histosols) in organic forest soils. The total averaged SOC stock in mineral topsoil of forest land, grassland, and cropland was 80, 74, and 72 t ha^{-1}, respectively.

The important role of this SOC sequestration could be assigned to the roots of plants. However, root derived C sequestration in Lithuania is investigated less, than total SOC stocks in the soil. Lithuanian and foreign researchers state that after the insertion of the plant biomass, the roots decomposed more slowly than their aboveground parts. In Lithuania, different grassland systems were investigated for biomass output and C accumulation in the roots. According to our investigations, the composition of grasslands significantly affects the biomass of roots in the soil. Results showed that the most productive mixture was red clover with fescue, which accumulated 8763 DM kg ha^{-1}. The carbon accumulated in the roots of grassland species mixtures differed from 3299 to 4388 kg C ha^{-1}. The highest C amount was found in the roots of red clover and fescue mixture - 4388 kg C ha^{-1}, while for monoculture red clover it was – 3563 kg C ha^{-1} and for fescue – 3299 kg C ha^{-1}. Meanwhile, C accumulated in the shoots varied from 2914 to 5134 kg C ha^{-1} and mostly were taken from the system for livestock. The same tendency was observed for P and K in the roots of different mixtures. The highest lignin quantity was observed for red clover, which successfully could be used in the mixtures to prolong root decomposition and C stabilization in the soil.

All these data give important reasons to think that carbon sequestration in the roots could be elevated by using different land-uses, mixtures and management practices and more investigations needed in Lithuanian and all Europe scales. Therefore, within EJP Soil, MIXROOT-C and MaxRoot-C will provide important lacking information about SOC sequestration.

Keywords: SOC, root carbon, grasslands, forest, cropland

Potential of cover crops to sequester soil organic carbon in German croplands

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Cover crops have been suggested to maintain or even increase soil organic carbon (SOC) stocks in croplands which can contribute to soil fertility and climate change mitigation. The potential of cover crops to increase SOC stocks critically depends on how many additional cover crops can be integrated into existing crop rotations. Detailed management data are needed to quantify the SOC sequestration potential of cover crops. These are now available from the first German Agricultural Soil Inventory.

We simulated the SOC sequestration potential of cover crops using an SOC model ensemble consisting of RothC and C-TOOL. We developed a new carbon input estimation method for cover crops taking the effect of climate and sowing date on the development of the biomass into account.

We found that only one third of the cultivation windows are currently used for cultivating cover crops. Thus, the cultivation area could be tripled with additional 2 Mio ha each year which would increase total carbon input by 12% to 4.13 Mg C ha^{-1} a^{-1}. Within 50 years, this would result in 35 Tg more SOC in the topsoil of German croplands corresponding to on average 0.06 Mg C ha^{-1} a^{-1} and 2.5 Tg CO_2 equivalents per year. Our simulations predicted a negative SOC trend with business-as-usual management which cannot be stopped by maximizing cover crop cultivation. However, including cover crops remains a crucial strategy for managed cropland soils to maintain soil fertility and mitigate climate change.

Keywords: climate change mitigation, carbon modelling, carbon input estimation