Plant root material makes a substantial contribution to the soil organic carbon (C) pool, but this contribution is disproportionate below 20 cm, where 30% of root mass and 50% of soil organic C is found. Root carbon inputs changed drastically when native perennial plant systems were shifted to cultivated annual plant systems. We used the reconstruction of a native prairie and a continuous maize field to examine both the relationship between root carbon and soil carbon and the fundamental rooting system differences between the vegetation under which the soils developed versus the vegetation under which the soils continue to change. In all treatments we found that root C:N ratios increased with depth, which may help explain why an unexpectedly large proportion of soil organic C is found below 20 cm. Measured root C:N ratios and turnover times along with modelled root turnover dynamics showed that in moving from prairie to maize, a large, structural-tissue dominated root C pool with slow turnover, concentrated at shallow depths was replaced by a small, non-structural-tissue dominated root C pool with fast turnover evenly distributed in the soil profile. These differences in rooting systems suggest that while prairie roots contribute more C to the soil than maize at shallow depths, maize may contribute more C to the soil than prairies at deeper depths.

Please provide a 500-character non-technical summary (without discipline-specific jargon) of your paper that may be used to promote your work to a broader audience. The summary must be in paragraph form without lists. It should highlight your main conclusions and results, and what the implications are. If possible, please also summarize briefly why you did the research and how you did it.

The sustained productivity of a soil is dependent upon preserving and increasing the amount of soil organic matter, mostly made of carbon, contained in the soil. Half of the world’s soil organic carbon, but only 30% of the world’s root mass is found below 20 cm. Temperature and oxygen availability decreases and moisture generally increases deeper in the soil, all of which slow down decomposition. However, these factors have been able to only partially explain why there is so much soil organic carbon at deeper depths relative to the root material that is placed there. We found that the composition of root material also changes with depth. Roots that are deeper in the soil are made up of more carbon and less nitrogen when compared to roots at shallower depths, making the deep material more difficult for microorganisms to decompose. This means that root material at deeper depths is more likely to follow a decomposition pathway where some carbon is lost as carbon dioxide, but the remaining organic matter is relatively immobile. Meanwhile, roots at shallower depths are easier for microorganisms to decompose relative to deep roots, resulting in more microbially processed and mobile carbon compounds that are transported deeper into the soil. Thus, root composition differences with depth contribute to the disproportionate relationship of soil organic carbon and root mass.

Root carbon inputs at all depths changed drastically when native perennial plant systems were shifted to cultivated annual plant systems. We used the reconstruction of a native prairie and a continuous maize field to examine both the relationship between root carbon and soil carbon and the fundamental rooting system differences between the vegetation under which the soils developed versus the vegetation under which the soils continue to change. Measured root carbon:nitrogen ratios and turnover times along with modelled root turnover dynamics showed that in moving from prairie to maize, a large, structural-tissue dominated root carbon pool with slow turnover, concentrated at shallow depths was replaced by a small, non-structural-tissue dominated root carbon pool with fast turnover evenly distributed in the soil profile. These differences in rooting systems suggest that while prairie roots contribute more carbon to the soil than maize at shallow depths, maize may contribute more carbon to the soil than prairies at deeper depths.

Elucidating the mechanisms determining soil C retention and addition is important as we strive to design systems that maintain and build soils that are productive and resilient. The role of roots and root composition, as well as the importance of soil organic C below 20 cm should be carefully considered in such designs. This work shows that we should question intuitive assumptions, such as environmental controls on decomposition with depth and the consequences of replacement of a large root pool with a small root pool.

Roots deeper in the soil are made up of more carbon and less nitrogen when compared to roots at shallower depths. Comparison of prairie and maize rooting systems showed that in moving from prairie to maize, a large, structural-tissue dominated root carbon pool with slow turnover, concentrated at shallow depths was replaced by a small, non-structural-tissue dominated root carbon pool with fast turnover evenly distributed in the soil profile.