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Carbon sequestration in soils – has the potential for climate change mitigation been over-stated?

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The term "carbon sequestration" is commonly used to describe any increase in soil organic carbon (SOC) content caused by a change in land management, with the implication that increased soil carbon (C) storage mitigates climate change. But this only true if the management practice causes additional net transfer of C from atmosphere to land. Limitations of C sequestration for climate change mitigation include: (1) the quantity of C stored in soil is finite; (2) the process is reversible; (3) even if SOC is increased there may be changes in the fluxes of other greenhouse gases especially nitrous oxide (N2O). Removing land from annual cropping and converting to forest, grassland or perennial crops will remove C from atmospheric CO_2 and genuinely contribute to climate change mitigation. However, indirect effects such as conversion of land elsewhere under native vegetation to agriculture could negate the benefit due to increased CO_2 emission. Re-vegetating degraded land, of limited value for food production, avoids this problem.

Adding organic materials such as crop residues or animal manure to soil, whilst increasing SOC, generally does not constitute an additional transfer of C from atmosphere to land – it depends on the alternative fate of the residue. Increases in SOC from reduced tillage now appear to be much smaller than previously claimed, at least in temperate regions, and in some situations increased nitrous oxide emission may outweigh any increase in stored C. The climate change benefit of increased SOC from enhanced crop growth (e.g. from the use of fertilizers) must be balanced against greenhouse gas emissions associated with manufacture and use of fertilizer.

For soils under long-term grassland there is less scope for increasing soil C stock than in arable soils because these already have a higher SOC content. A key issue with grasslands is to ensure good management practices that maintain the high SOC content. Any form of soil degradation, such as compaction or soil erosion caused by over-grazing, will lead to a loss of soil C. For any given environment it is necessary to define optimum conditions such as stocking rate and legume content in the sward to achieve maximum plant growth and retention of organic C in soil.

In general, any increase in SOC content, particularly in arable soils, will be beneficial for soil quality and functioning. So practices designed to increase SOC content can be regarded as "no regrets" actions – the result is likely to be beneficial for improved soil functioning and sustainability of the agricultural system, whether or not there is a benefit for climate change. However, there is a real danger that an over-emphasis on the benefits of soil C sequestration will detract from other measures that will often be more effective in combating climate change. These include governmental actions to minimise C losses from land having a large C stock (e.g. limiting deforestation and drainage of wetlands) and practices within agriculture for increasing the efficiency of use of nitrogen (from fertilizer or manure) in order to decrease the associated N2O emissions.