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Carbon stocks increase in grassland soils after deep soil flipping in New Zealand

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Sequestration of soil organic carbon (SOC) can offset global carbon dioxide emissions but deep soil modifications are rarely considered in this context. Deep soil flipping (full inversion to 1-3 m) is practiced on New Zealand's South Island West Coast to improve drainage on highly podzolized sandy grassland soils. By flipping, SOC rich topsoils are buried in the subsoil and subsoils with low SOC content are brought to the surface to form new topsoils. In this study, we quantified changes in SOC stocks and stability by developing a chronosequence (3-20 years) of flipped topsoils (0-30 cm) which were sampled in 2005/07 and re-sampled in 2017. Additionally, subsoil samples (30-150 cm) were collected (2017) to evaluate changes in stocks of SOC previously buried by flipping. Density fractionation was applied on recent and buried topsoils along the chronosequence to assess changes in SOC stability. Flipping caused a significant increase of SOC stocks by 69 $\pm$ 15 % (179 $\pm$ 40 Mg SOC ha^{-1}) over 20 years in 0-150 cm depth. The top 0-30 cm accumulated 3.6 Mg SOC ha^{-1} year^{-1}. Despite significant SOC accumulation, the SOC stocks in the upper 15 cm of new topsoils were 36 $\pm$ 5 % lower than the original topsoils, suggesting an ongoing SOC accumulation after 20 years. Flipped subsoil C stocks (30-150 cm) were 160 $\pm$ 14 Mg ha^{-1} higher than un-flipped subsoils and showed no significant change with time since flipping. Furthermore, the flipped subsoils contained up to 32 % labile SOC, which was similar to labile SOC contents found in the topsoils. Consequently, buried SOC was preserved due to burial. This study confirms that deep flipping of poorly drained soils under continuous grassland management can markedly slow the decomposition of buried SOC and allow the accumulation of new topsoil C, resulting in substantial sequestration of SOC over the whole soil profile.