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Quantifying carbon loss by water erosion across a semi-arid grass to shrub transition

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Terrestrial storage of soil organic carbon (SOC) far outweighs the storage of carbon in vegetation. However, current understanding of the rates of carbon loss from soils is limited and at best, is also highly uncertain. Houghton et al., (1999) estimate that total annual loss of carbon from soils due to land-use change in the period 1980-1989 was as high as 1.7 ± 0.8 Gt yr-1, whereas Lal (2004) suggests that the global loss of soil organic carbon due to soil cultivation is 78 ± 12 Gt, with soil-erosion processes accounting for 26± 9 Gt over the period 1850 to 1998. This amounts to 0.2 Gt of carbon lost per year due to soil erosion, but notably with an error of 35% in either direction. Thus, it is clear that the potential for carbon loss by water erosion from soils may be great; however, significant uncertainty is currently associated with estimates of erosion-driven soil-carbon losses.

This paper reports on a monitoring experiment in the semi-arid landscapes of the US southwest, which are subject to high intensity, monsoon rainfall régimes, and high rates of overland flow and erosion. It builds on previous work to explore the relationships between overland flow, erosion and carbon loss across a grass to shrub ecotone. We quantify spatial variability of SOC across the ecotone, to illustrate the uncertainty surrounding point-based or spatially averaged estimates of SOC. In addition, we illustrate how SOC loss can vary along a continuum of vegetation change from grass to shrub-dominated landscapes, demonstrating the implications of vegetation change and land degradation on carbon loss by soil erosion.

Characterisation of SOC stores shows that more SOC is stored in soils beneath shrubs than grasses and that soils beneath both vegetation types store more SOC than bare soils. Whilst there are differences in the area-weighted SOC storage across the grass to shrub transition, these differences are non-linear. Total SOC stored beneath the grasses varied significantly across the transition, increasing as the grass cover became more sparse. Data suggest that surviving grasses in the landscape, are able to retain more SOC than their counterparts in ‘pristine’ grasslands. Similar results are seen for shrubs, where progressively more SOC is found in storage beneath canopies, as the shrubs become more established in the landscape.

Finally, redistribution of SOC due to water erosion is quantified. Results illustrate that greater losses of soil and carbon will occur as the ecosystem degrades and shrubs become established, with a concomitant increase in bare soil in the landscape. Landscapes that are covered by shrub species are therefore not only more susceptible to erosion, but will also lose more carbon per unit of soil loss than grasslands. In combination, the transition of ecosystem structure, or pattern of resources and its function, particularly the redistribution of those resources by overland flow will lead to significant increases in the loss of soil organic carbon from the system.