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Quantifying the pedo-ecohydrological structure and function of degraded, grassland ecosystems

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Grassland ecosystems cover significant areas of the terrestrial land mass, across a range of geoclimates, from arctic tundra, through temperate and semi-arid landscapes. In very few locations, such grasslands may be termed ‘pristine’ in that they remain undamaged by human activities and resilient to changing climates. In far more cases, grasslands are being degraded, often irreversibly so, with significant implications for a number of ecosystem services related to water resources, soil quality, nutrient cycles, and therefore both global food and water security. This paper draws upon empirical research that has been undertaken over the last decade to characterise a range of different grasslands in terms of soil properties, vegetation structure and geomorphology and to understand how these structures or patterns might interact or control how the grassland ecosystems function. Particular emphasis is placed upon quantifying fluxes of water, within and from grasslands, but also fluxes of sediment, via the processes of soil erosion and finally fluxes of the macronutrients Nitrogen, Phosphorus and Carbon from the landscape to surface waters.

Data are presented from semi-arid grasslands, which are subject to severe encroachment by woody species, temperate upland grasslands that have been ‘improved’ via drainage to support grazing, temperate lowland grasslands, that are unimproved (Culm or Rhôs pastures) and finally intensively managed grasslands in temperate regions, that have been significantly modified via land management practices to improve productivity. It is hypothesised that, once degraded, the structure and function of these very diverse grassland ecosystems follows the same negative trajectory, resulting in depleted soil depths, nutrient storage capacities and therefore reduced plant growth and long-term carbon sequestration. Results demonstrate that similar, but highly complex and non-linear responses to perturbation of the ecosystem are observed, regardless of the environmental setting or wider climatic conditions that the grasslands experience. Furthermore, it is demonstrated that the relatively stable ecosystem state that has prevailed in the ‘pristine’ grasslands studied, is in fact very fragile and may be easily altered, either by anthropogenic forcing, due to land management or by ‘semi-natural’ processes, related to climate change or changes in the incidence of wildfires (for example). Once structurally altered, it is also shown that positive feedbacks will occur to accelerate the loss of critical resources (topsoil and nutrients) from the ecosystem, in particular in drylands, resulting in widespread land degradation that cannot be reversed. In the temperate grasslands studied, it is shown that anthropogenic intervention may halt or even to some degree reverse the degradation of the soil-vegetation-water continuum. However, such ‘landscape restoration’ approaches are costly and require long-term management commitment if they are to succeed.

Finally, analysis of water, sediment and nutrient fluxes from this range of grasslands also demonstrates how critical ecosystem services that grasslands can provide; including soil water storage to buffer downstream flooding, soil carbon storage and enhanced biodiversity are reduced, often to the point where restoration of the original (pristine) landscape function is impossible. To conclude, discussion is made of how we can learn across grass landscapes globally, to ensure that those ecosystems that might be restored to build resilient landscapes under future climates are well understood and that future efforts to manage grasslands for increased food production do not degrade these critical ecosystems further.