Monitoring and modelling Phosphorus dynamics during runoff events over a transition from semi-arid grassland to shrubland

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During the last 150 years land degradation across the semi-arid grasslands of the south-western USA has been associated with an increase in runoff and erosion. Concurrent with this increase in runoff and erosion is a loss of phosphorus (P), which is a plant-essential nutrient. This paper investigates the runoff-driven redistribution and loss of dissolved and particulate-bound P that occurs during natural runoff events over a trajectory of degradation, from grassland to degraded shrubland, in central New Mexico. In the first part of our experiment, runoff-driven nutrient dynamics were monitored at four stages over a transition from grassland to shrubland, for naturally occurring rainfall events over 10 x 30 m bounded runoff plots. Results show that particulate-bound forms of P are responsible for the majority of P lost from the plots, due to erosion occurring during runoff events, whereas the dissolved component of P loss is negligible. Results indicate that for high-magnitude rainfall events, the output of P from the plots may greatly exceed the amount input to the plots, particularly over shrub-dominated plots where erosion rates are higher. Thus, the progressive degradation of semi-arid grassland ecosystems across the south-western USA and other semi-arid ecosystems worldwide has the potential to affect P cycling significantly through an increase in nutrient loss in runoff.

In order to model the observed P dynamics during runoff events (in particular particulate-bound nutrients), the Model for Assessing Hillslope to Landscape Erosion Runoff, And Nutrients (MAHLERAN) was then evaluated against runoff, erosion and P data from the four plots detailed above. A new module was developed to include a representation of particulate-bound nutrient dynamics. Understanding dynamics of both dissolved and particulate-bound nutrient dynamics during runoff events is imperative, because of their differing roles in terms of nutrient bioavailability and potential implications for plant dynamics.

Results of the model evaluation show that the runoff and erosion components of MAHLERAN perform reasonably well, as does the new particulate-bound nutrient sub-model, though not consistently. Performance of the particulate-bound nutrient model was better for the end-member (grass and shrub) plots, because of better parameterization data available for end-member vegetation types. Since the particulate-bound nutrient sub-model is by necessity strongly dependent on the simulated erosion rate, the performance of the particulate-bound nutrient model is dependent on the performance of the erosion component of MAHLERAN. The performance of the dissolved nutrient component of MAHLERAN was poor in this application, which indicates that the process representation for this semi-arid environment and the parameterization of the dissolved nutrient component were inadequate. However, given the low fluxes of dissolved P from this system, which appears to be dominated by P associated with particulates, such results do not detract from the ability of the model to simulate P dynamics of this semi-arid system.