Modelling P runoff losses from agricultural systems

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KEY MESSAGES

Fertiliser decision support systems are widely used for making phosphorus (P) fertiliser recommendations. However, the current decision support systems do not provide an environmental impact assessment of P runoff when making P fertiliser recommendations. This paper outlines the key components that need to be considered when developing fertiliser decision support systems to predict P runoff based on an extensive review of the latest literature.

AIMS

When land was first cleared in the southwest of Australia, the soils were P deficient. This deficiency has been corrected by the application of P fertilisers to the extent that most current P fertilisers are applied at maintenance rates or rate which balances out the amount of P removal in grain. The current P fertiliser practices have been achieved by conducting soil test measurements for P and the use of P fertiliser decision support systems for making P recommendations. In general, this approach has resulted in the efficient use of P fertiliser. However, in some coastal agricultural areas of the region, over-use of P fertiliser has resulted in eutrophication of estuarine waters. Minimal tillage with crop residue retention (conservation farming) has been widely adopted in Western Australia. This practice has the potential to reduce soil bound P loss (Particulate P) but can result in an increase in dissolved P loss due to the surface concentration of nutrients. As a result, agriculture is under increasing pressure to develop management practices to minimise P loss. Currently P decision support systems for grain cropping do not have routines for making predictions of P runoff into the environment.

The aim of this paper is to outline the key components that need to be considered when developing fertiliser decision support systems to predict P runoff based on an extensive review of the latest literature.

MODEL COMPONENTS

Calculation of P losses to the environment requires the use of three modelling components. First, water runoff is modelled to calculate runoff volume (Q_{surf}) and peak runoff rate (q_{peak}). Second, runoff volume and peak runoff rate are used in the modified universal soil loss equation to calculate sediment yield (SED). Third, runoff volume, peak runoff rate and sediment yield (SED) are used to calculate daily dissolved and particulate P runoff. Total annual P runoff is then calculated as the sum of dissolved P (DP) and particulate P (PP) runoff for each individual water runoff event.

Runoff volume

Runoff volume (Q_{surf}) is the daily total amount of rainfall minus infiltration, interception and evaporation. It is calculated using the United States of America Soil Conservation Service curve number method. Curve number is a function of the soil type, slope, surface cover (crop residues and vegetation), soil moisture content and cultural practices of the site. The curve number is a value between 1 and 100, with runoff potential increasing with increasing curve number.

Peak runoff

Peak runoff (q_{peak}), is predicted based on a modification to the rational formula. The rational formula method is based on the assumption that if a rainfall of intensity, I, begins at time t=0 and continues indefinitely, then the rate of runoff will increase until the time of concentration (t_{conc}) or when the entire sub-basin area is contributing to outlet flow. At this time, runoff is at its peak.

Sediment runoff

Sediment runoff is modelled using modified universal soil loss equation:

$$SED = 11.8(Q_{surf} q_{peak} area)^{0.56} K\ C\ P\ LS\ C_{frg}$$

where SED is the sediment yield on a given day (t), Q_{surf} is runoff volume (mm), q_{peak} is the peak runoff rate (m^3/s), area is the area of the study area (ha), K is the soil erodibility factor, C is the cover and management factor, P is the erosion control practices factor, L is the slope length factor and S is the slope steepness factor, and C_{frg} is the coarse fragment factor.

Phosphorus runoff

The transfer of soil P to runoff water is controlled by the physical and chemical processes such as dispersion, desorption, dissolution and diffusion. Phosphorus originating from the soil can be transported in runoff water either dissolved in solution (dissolved P, DP) or associated with eroded soil particles (particulate P, PP).

Dissolved P which includes inorganic (DP_i) and organic (DP_o) P in runoff is directly related to the quantity and reactivity of P near the soil surface according to the follow relationship.

$$DP = extraction\ coefficient \times available\ soil\ P \times Q_{surf}$$

Where DP is dissolved P loss in overland flow (kg P/ha), available soil P is the amount of Colwell extractable P and extraction coefficient is the fraction of soil test P that can be released to a given runoff volume. For Western Australian conditions, the impact of the different soil sampling depths needs to be assessed. Initial results for a range of soils of the Fitzgerald River basin showed that Colwell P was twice as high in the 0–2 cm depth as in the standard 0–10 cm sampling depth. Also the work showed that the DP_o fraction comprised a large proportion of the total DP in runoff and could contribute to leaching.

Particulate P which includes inorganic (PP_i) and organic (PP_o) P attached to soil and organic particles may be transported by surface runoff. The concentration of P per unit mass of eroded particles is related to the total P concentration of the soil. When compared to the soil, the concentration of total P in eroded soil particles is higher because the erosion process selects the more easily transported soil particles such as clay and low density organic particles. These particles have a higher sorption capacity for P than the bulk soil. The increased P concentration in eroded soil particles relative to the bulk soil is called the P enrichment ratio (PER). Once an appropriate P enrichment ratio is obtained, particulate P loss can be calculated as:

$$PP = TP \times SED \times PER \times Q_{surf}$$

where PP is particulate P loss in overland flow (kg/ha), TP is total soil P in a unit depth of surface soil, SED is sediment concentration (g sediment/L) in overland flow and PER is P enrichment ratio.

CONCLUSION

Modelling P runoff is a complex process but can be simplified to the use of three interacting components. These include a water runoff component, a soil erosion or sediment yield component and finally a P runoff component. Work is currently progressing, using a previously developed nutrient and lime calculator Soil Management Calculator (SMCAL), in developing and evaluating these modelling components for predicting P losses from grain cropping land in the southwest of Australia.

KEY WORDS

phosphorus, runoff

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