Soil management calculator for predicting phosphorus losses under cropping systems in Western Australia

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Key Messages

- Large summer fallow rainfall events and wet growing seasons can result in water run-off in the wheat belt of Western Australia.
- A model has been developed to assess the impact of these events on phosphorus (P) run-off losses. The phosphorus-loss routines have been included in the previously-developed nutrient and lime model, soil management calculator (SMCAL).
- The model illustrates how water run-off and resulting phosphorus run-off can be managed by retaining wheat stubble and banding phosphorus fertiliser.

Background and Aims

Agriculture in many parts of the world is coming under increasing pressure to develop management practices that will minimise phosphorus (P) loss to the environment. Water and phosphorus run-off have been monitored in a catchment studied near Jacup (Jerramungup) in the south-coast region of Western Australia (Wong, 2011 pers. comm.). The amount of phosphorus run-off was significant and resulted in phosphorus concentrations in stream water greater than the ANZECC trigger values for water quality.

A strategy to reduce phosphorus loss is to improve phosphorus fertiliser recommendations with the use of models, such as NUlogic by CSBP, used in WA. However, this model does not contain routines that allow for prediction of water and phosphorus run-off.

Work has recently been undertaken to include these routines in the nutrient and lime model, soil management calculator (SMCAL). These routines were derived from models developed in the United States (Neitsch *et al*., 2005; Vadas *et al*., 2008, 2009).

This paper applies the developed water and phosphorus run-off routines to make an assessment of the amount of water and phosphorus run-off from a shallow sandy duplex located on a 1% slope within the Jacup catchment.

Method

Model

The approach used to model water and phosphorus run-off has been described by Anderson *et al*., (2010). This modelling approach has been included in the previously-developed nutrient and lime model, SMCAL. In brief, the water run-off routines come from the soil water assessment tool (SWAT) used widely throughout the world (Neitsch *et al*., 2005) while, the phosphorus run-off model comes from Vadas *et al*., (2008, 2009). The phosphorus run-off model relies on empirical relationships developed and has been observed to reliably predict fertiliser phosphorus run-off in the US using only a few input parameters.

Soil phosphorus in run-off is divided into dissolved or labile phosphorus and particulate phosphorus based on fraction size. Dissolved phosphorus is associated with fractions < 0.45 µm, whereas particulate phosphorus is associated with fractions > 0.45 µm.

This phosphorus run-off model was adopted because it addresses the following key issues:

- The behaviour of recently-applied phosphorus (fertiliser or manures) or recycled phosphorus (crop residues) has been noted to be different than the phosphorus already incorporated within the soil pools.
- Recently-applied fertiliser can dominate phosphorus run-off with the soil phosphorus having a relatively minor role.
- No-till crop systems have less particulate soil phosphorus loss, but greater dissolved or labile phosphorus loss derived from surface applications of manure and fertiliser compared with conventional tillage systems.

A schematic depiction of the model is shown in Figure 1. In general it separates the applied phosphorus (fertiliser, manure crop residues) and soil phosphorus into different pools, which can have varying impacts on the amount of phosphorus run-off.

The soil type used in the study was a shallow sandy duplex with a curve number of 88. This curve number defines the relationship between rainfall and run-off. It is an empirical relationship developed in the US. Slope of the study sites was set to 1%. The impact of soil phosphorus was assessed by varying the models' input soil test values. Rainfall data was obtained from the meteorological site located at Jerramungup. Rainfall for the January 2006 rainfall event was adjusted to the values reported by (Wong, 2011 pers. comm.).

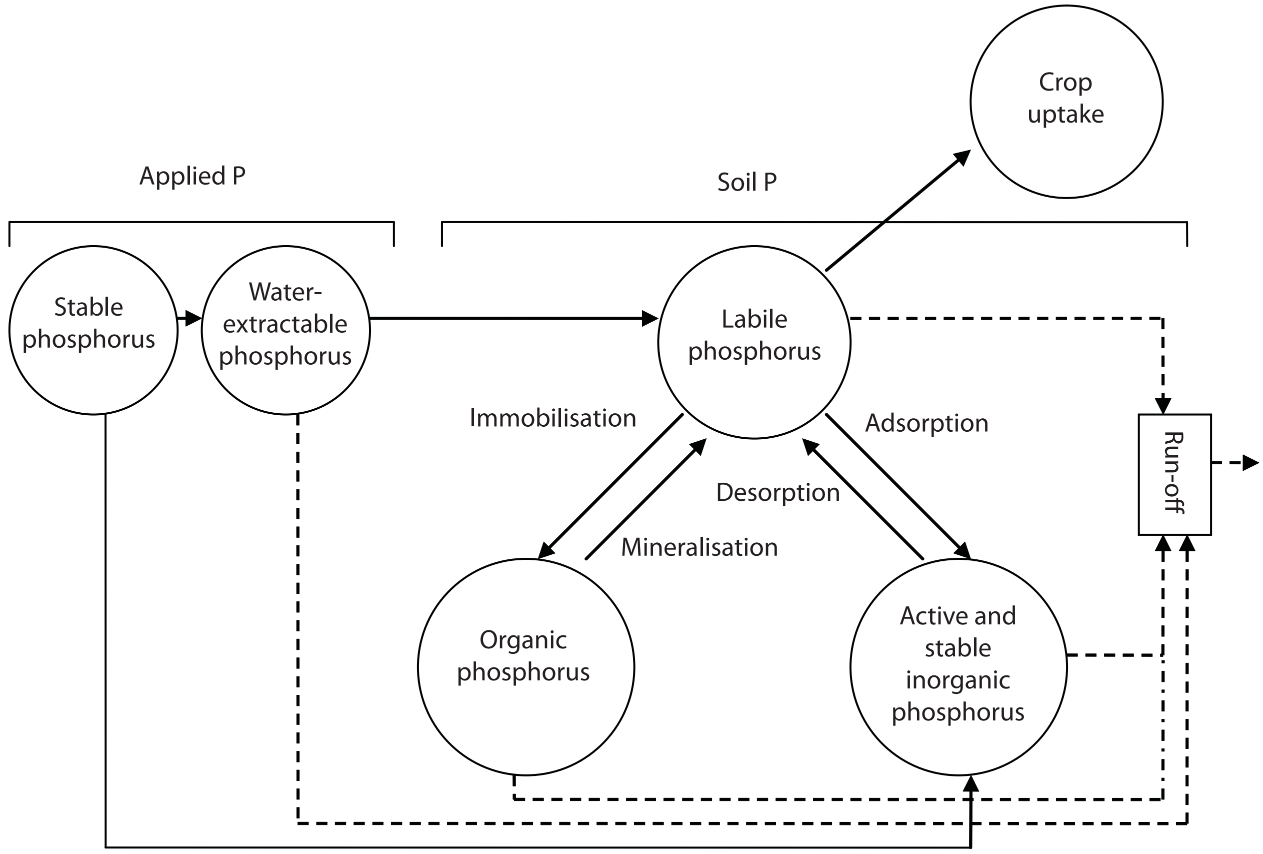

Figure 1. Schematic depiction of applied phosphorus (fertiliser, manure crop residues) and soil phosphorus pools, and pathway of phosphorus transformation between pools.

Experimental site

The study area is an ~1000 km^2 catchment mostly under crop and pasture located near Jacup (Jerramungup) in the south-coast region of WA (Wong, 2011 pers. comm.). Phosphorus concentrations were continuously monitored during a three-year period (2005–2007) at five stream locations across the catchment. Phosphorus concentrations were consistently above 10 µg P/L (Australian and New Zealand Environment Conservation Council [ANZECC] trigger values for management response for upland rivers) throughout the monitoring period, illustrating the importance of being able to predict the amount of phosphorus run-off from these soils.

Results

The south-west region of Australia has a Mediterranean-type climate. Cropping mainly occurs in the zone that receives < 450 mm of annual rainfall and as a result there tends to be little water run-off on average. The exceptions occur when growing season rainfall (GSR) is greater than average, or when there is a large summer fallow rainfall event. The model developed can be used to assess the impact of these rainfall patterns on water and phosphorus run-off. This was done for the relatively wet growing season that occurred at Jacup during 2005 and the large summer fallow rainfall event (89 mm) that occurred at Jacup during January 2006 resulting in large amounts of water run-off.

Growing season rainfall events

Growing season rainfall greater than average can result in phosphorus run-off, as occurred at Jerramungup during 2005. These rainfall events are illustrated in Figure 2. During 2005 there were no significant summer fallow rainfall events. However, the remainder of the year was characterised by a relatively wet growing season, annual rainfall of 582 mm and GSR (April-October) of 475 mm.

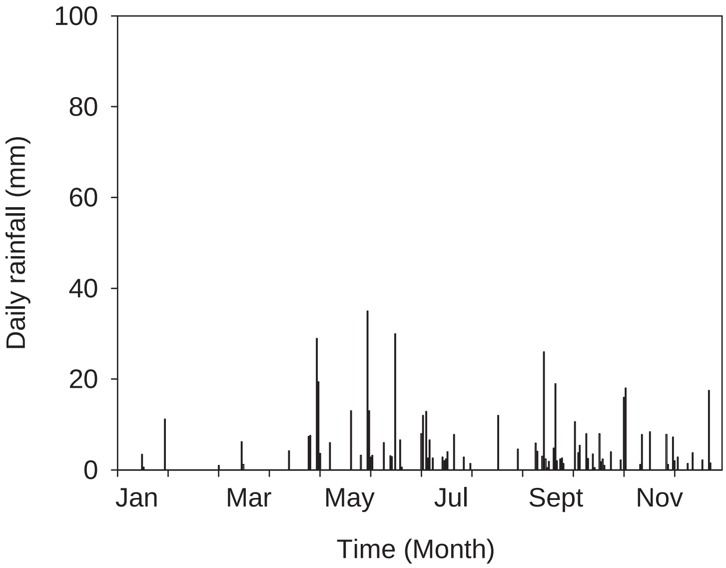

Figure 2. Daily rainfall (mm) events that resulted in an annual rainfall of 582 mm measured at Jerramungup during 2005.

Under this rainfall pattern the model predicted the following amounts of phosphorus run-off. In the presence of soil cover (2.1 t wheat straw/ha) only 1 mm of water run-off was predicted and no phosphorus run-off (graph not presented). In the absence of soil cover predicted water run-off was 16 mm with predicted phosphorus run-off increasing with level of soil phosphorus (see Figure 3). The increase in phosphorus run-off occurred from both the particulate and labile soil phosphorus pools. For the level of soil phosphorus at which most growers operate, Colwell P between 20 and 40 mg/kg, total phosphorus run-off was in the order of 0.06 to 0.10 kg/ha of phosphorus.

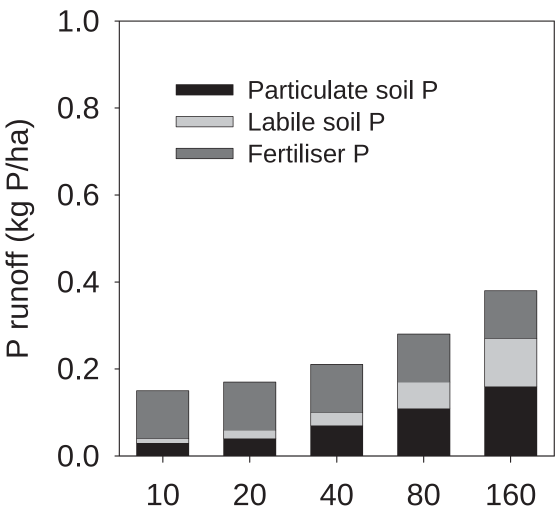

Figure 3. Growing season phosphorus run-off (kg/ha) predicted by SMCAL at various levels of Colwell P (mg/kg soil) when there was no soil surface cover. Predictions were based on a shallow sandy duplex with a curve number of 88 and slope of 1%.

Phosphorus fertiliser (5–15 kg/ha of phosphorus) is applied when crops are sown during May to June. When 10 kg/ha was top-dressed on May 13, SMCAL predicted that 0.11 kg/ha of phosphorus would be loss in the run-off (see Figure 3). At the level of soil phosphorus maintained by most growers (20 mg/kg), the applied fertiliser phosphorus accounts for 65 % of total phosphorus run-off. Thus the model predictions illustrate the relatively large impact fertiliser phosphorus input has on phosphorus run-off when phosphorus is applied to the soil surface. In contrast, when 10 kg/ha of phosphorus was banded on May 13, no fertiliser phosphorus run-off was predicted.

Summer fallow rainfall events

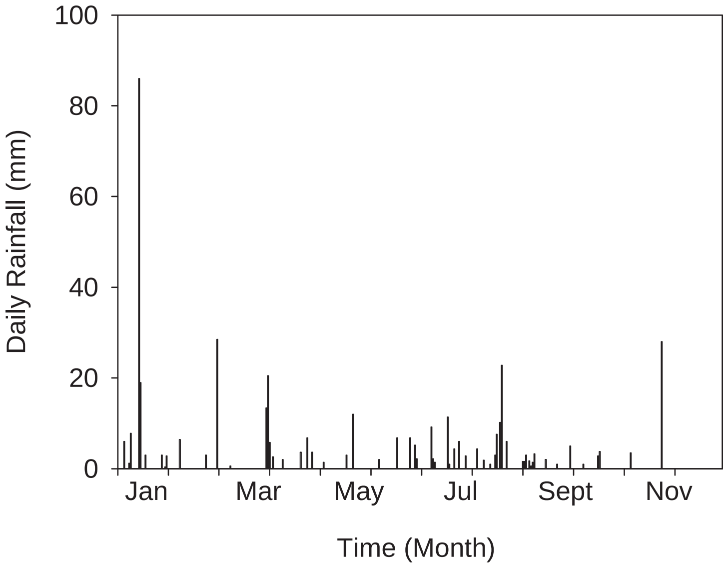

Figure 4. Daily rainfall (mm) events that resulted in an annual rainfall of 435 mm measured at Jerramungup during 2006.

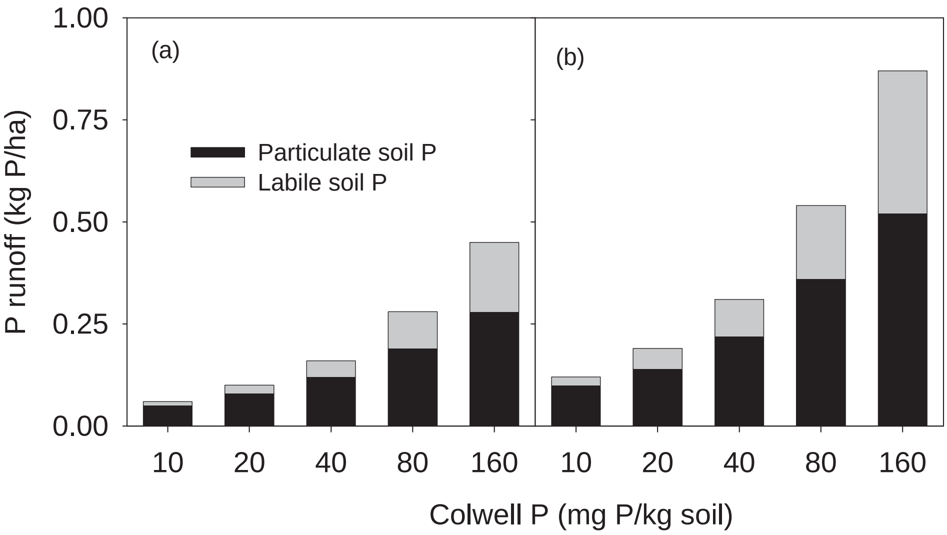

Figure 5. Summer fallow phosphorus run-off (kg/ha of phosphorus) predicted by SMCAL when soil surface cover was set at (a) 2.1 t wheat straw/ha and (b) 0.0 t wheat straw/ha for various levels of Colwell P (mg/kg soil). Predictions were based on a shallow sandy duplex with a curve number of 88 and slope of 1%.

A large summer fallow rainfall event (89 mm over two days) occurred at Jerramungup during January 2006 (see Figure 4). This rainfall event resulted in large volume of water run-off. The remainder of the year was characterised by a relatively-dry growing season (191 mm), giving an annual rainfall of 435 mm.

Management of soil cover by retaining crop residues is an important practice to prevent water run-off (see Figure 5). When the soil surface was covered with 2.1 t of cereal straw/ha the model predicted 26 mm of run-off. In the absence of this soil cover the model predicted 50 mm of water run-off. In the presence or absence of soil cover, phosphorus run-off increased with increasing levels of Colwell soil P. The increase in phosphorus loss occurred for both the particulate and the labile phosphorus pools. For a typical level of soil Colwell P (20–40 mg/ha), total phosphorus run-off was predicted to be in the range 0.10 to 0.32 kg/ha of phosphorus.

Discussion

A model that takes into account both water and phosphorus run-off can be used to predict the impact of stubble management and phosphorus fertiliser rate and placement method on phosphorus run-off. Predictions by the model in relation to a catchment study near Jerramungup suggests that water and phosphorus run-off can be managed by retaining cereal straw and the banding phosphorus fertilisers. The routines used in the model were derived from models developed in the US. Hence, experimental validation, by carrying out run-off experiments, of these routines in agricultural regions in WA is required before they are adopted in fertiliser recommendation models used in WA.

Key Words

Phosphorus, run-off

Acknowledgments

The studies were funded by the Grains Research and Development Corporation (GRDC), Department of Agriculture and Food Western Australia (DAFWA) and Murdoch University.

Project No.: UMU 00030

Paper reviewed by: Dr Mike Wong

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