The management of a marginal acid Organic soil to decrease phosphorus losses and meet an ecological target

Bernard Simmonds

Supervisors
Prof. Rich McDowell (AgResearch)
Prof. Leo Condron (Lincoln University)
Phosphorus limitation

Waituna Lagoon and Awarua Wetland

McDowell, Larned and Houlbrooke 2009
Waituna Wetlands Scientific Reserve and lagoon

- Internationally significant (Ramsar) wetland and lagoon

- Approx. 80% of 210 km² catchment is dairy with high P losses (mean = 2 kg P/ha/yr, but up to 65 kg P ha/yr noted)

- Need 50% less P losses in catchment to improve ecology of lagoon.
Primary questions

1. Does the rate of P loss change with time since development?

2. How much and by what pathway is P being lost (surface v subsurface)?

3. What suitable strategies are available to decrease loss especially in the high-P loss Organic soil?

4. Will this result in the 50% decrease required?
Rate of P loss with time since development?

- Survey of land and soil history and management from 80 sites used to construct mass balance of inputs and outputs:
  - Years since development
  - Soil fertiliser/lime inputs and frequency

- Soil from each site analysed for “indicators of P loss” such as water extractable P (WEP for runoff) and explanatory drivers (e.g. texture).
Rate of P loss with time since development?

WEP highest for more recently developed soils (with low P retention)

Mass balance estimated mean losses of 38 and 21 kg P ha\(^{-1}\) yr\(^{-1}\) for Organic and Podzol soils

Indicated Organic soils, recently developed out of scrub at most risk of P loss
By what pathway is the P being lost?

Wet and dry Organic soil placed in runoff boxes, rainfall applied and surface runoff and subsurface flow collected.

Most important pathway determined by quantifying forms and fractions of P in runoff.
By what pathway is the P being lost?

Dry, hydrophobic = infiltration-excess, soil erosion

Wet, anaerobic = Fe-P release

Most P subsurface and as filterable reactive P (highly bioavailable)
Summary of initial trials

• First 10 years since development = highest P losses

• Subsurface transport = most important pathway for P losses

Optimise early-stage soil management activities that can influence subsurface P losses

• Soil liming
• Fertiliser use
• Pasture species
Strategies to decrease P loss: Liming

- In mineral-rich soils, raising pH affects metal-P solubility and also increases mineralisation rates increasing P concentrations in solution.

- **HYP:** The quantity and bioavailability of P lost from Organic soil increases with pH and would be exacerbated when P fertiliser was also applied.

- Replicate pots of different P rates, limed to pH 4.5, 5.5 and 6.5 (from pH 4)
FRP loss increased with P rate at all pH levels.

Cumulative FRP was 45% and 73% lower at pH 5.5 and 6.5 compared to pH 4.5.

Fractionation data suggested Ca-P formation with increasing pH.

**Recommendation:** quickly get to pH 5.5-6.5 (little short-term mineralization, pH optimal for pasture growth).
Strategies to decrease P loss: Fertiliser solubility

- **HYP**: Fertiliser P losses in runoff are lower from 1% water-soluble reactive phosphate rock (RPR) than 97% water-soluble superphosphate (super). But solubility of RPR, and P loss in subsurface flow, is enhanced by low soil pH.

- Replicate pots of pH 4.5, 5.5 and 6.5 received 0, 50, 100 or 200 kg P/ha of either super or RPR.
At pH 4.5 and 5.5, FRP losses similar for RPR and Super
No difference between ryegrass yields
At pH 6.5 FRP losses 55% lower from RPR than Super
Mean ryegrass yield 7% higher in Super than RPR

**Recommendation:** Apply RPR (not Super) and maintain pH at or > 5.5
Strategies to decrease P loss: Pasture design

- **HYP:** *Lotus corniculatus* tolerant of low pH, soil P, and wet soils. When grown in these conditions *Lotus* sp. produces comparable yield but loses less P loss than white clover and ryegrass.

- Replicate pots, limed to pH 4.5, 5.5 and 6.5, receiving 0, 50, 100 or 200 kg Super/ha/yr and sown in *Lotus* sp., ryegrass or white clover.
Once established, no yield differences between species across pH regimes.

Mean FRP losses least at high pH due to Ca-P fixation.

At pH 4.5, plant P uptake similar. Ryegrass uptake greater at pH 5.5 and 6.5 resulting in lower P loss

**Recommendation:** Sow ryegrass dominant sward, maintain pH at or above 5.5.
Can a target designed to decrease P losses by 50% be achieved?

- **Liming**: Compared to pH 4.5, liming decreased FRP loss by 45% and 73% at pH 5.5 and 6.5, respectively.

- **Low solubility fertilizer**: Compared to super, RPR decreased FRP loss by 55% at pH 6.5.

- **Alternative pastures**: P losses from ryegrass were 29% and 46% lower than clover and Lotus at pH 6.5.

**YES**

- **Recommendation**: In high P loss soils recently developed from scrub, sow ryegrass dominant pasture, lime to pH 5.5 or above and fertilise at a low rate (for low Olsen P) with RPR (or similar).