Impact of Legacy Soil Phosphorus on P Loss in Runoff from a Grazed Grassland Hillslope

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Despite the implementation of EU regulations controlling the use of fertilisers in agriculture, legacy soil P remains a significant threat to water quality across Europe.

Significant time lag between the implementation of measures and the decline in soil P to levels compatible with good water quality.

Although the positive relationship between soil P accumulation and losses to water has been elucidated, fewer studies have evaluated this relationship under a scenario of declining soil P, where direct losses could be quantified.

**Aim:**
To examine P loss from grassland plots with low to high soil P indices following cessation of P application.

**Objectives:**
Examine trends in P loss from runoff and drainage from all plots 2005-2012.

Relationship between Olsen soil P and losses via runoff (overland flow) and drainage pathways.

Examine relationships to hydrological drivers – rainfall, soil moisture deficit.
CENIT Grassland experimental site (Est. 1987), AFBI Research Farm, Hillsborough, Co. Down.

- Perennial Ryegrass, grazed Apr-Oct
- Hydrologically partitioned 0.2 ha (14 x 43 m) plots
- Drainage and Runoff flow collected at base of slope - separate v-notch weirs monitored continuously over a range of 0.01-7.0 L s⁻¹ (±4%)
- Drumlin till overlying Silurian metasediments
- HOST class 24 – slowly permeable mineral soil, gleyed within 40cm, impermeable bedrock (~54% NI land cover).
Management history

- 1989-2000 - uniform P application across plots
- 2000-2004 - 0, 10, 20, 40 & 80 kg P/ha/yr in 6 equal applications March-September
- From October 2004 – 2012 All P applications ceased

During P amendment (2000 –2005)  
- Annual TP loss was highly variable (0.19 - 1.55 kg P ha$^{-1}$ yr$^{-1}$ zero P fertilizer; 0.35 to 2.94 kg P ha$^{-1}$ 80 kg P ha$^{-1}$ fertiliser).
- Plots receiving highest P fertiliser applications lost most.
- Difficult to identify a clear Olsen- P concentration at which P losses increased.
- Plot receiving 0P did not decline.

From 2005 onward – Olsen P in decline across all plots
Soil Olsen P distribution across plots

Lower concentrations at middle and bottom of plot may be attributed to greater mobilisation from areas with highest CSA risk

Runoff examined on an event basis (SRP and TP).
Event Q consistent across plots – indicates hydrological behaviour relatively similar across plots.

Daily Runoff Volumes

PO > P80 after 12 years with no P application

Runoff Event FWMC SRP (mg/L)

PO > P80 after 12 years with no P application

EQS High (0.025 mg/L)

EQS Good (0.035 mg/L)
Linear mixed effects modelling

- Fixed Effects – Event rainfall, antecedent SMD, Time, Month
- Random intercepts – significant (P<0.05) but intercept not related to Plot
- Random slopes (by Plot) – no improvement in the model – Soil Olsen P not significant
- Key variable: antecedent SMD

(1) logFWMC ~ Time

(2) logFWMC ~ Time + anteSMD + Rain + Month
Antecedent SMD
Modelled using daily meteorological data (BADC) for Hillsborough (SMD model of Schulte et al 2005)
Runoff events preceded by a period of high (>6mm) SMD – drier soils - tend to lose more P
Attributed to soil aggregate breakdown during drying, slaking and dispersion as soils re-wet and cell lysis during drying and rewetting cycle releasing P

Climatic effects – duration of inter-event (IE) periods seems to have increased in last decade.
Drainage losses examined on a weekly basis
Inconsistencies: Flows differ among plots. Efficiency of the sub-surface drainage to intercept infiltrating water – affecting dilution?
Flow variation among plots evident – dilution effects (P40 lowest flows). Seasonality – concentrations highest in summer (less dilution)

<table>
<thead>
<tr>
<th>EQS Exceedances</th>
<th>P0</th>
<th>P10</th>
<th>P20</th>
<th>P40</th>
<th>P80</th>
</tr>
</thead>
<tbody>
<tr>
<td>% &gt; 0.025</td>
<td>19.9</td>
<td>34.2</td>
<td>42.5</td>
<td>90.2</td>
<td>18.6</td>
</tr>
<tr>
<td>% &gt; 0.035</td>
<td>13.3</td>
<td>21.8</td>
<td>35.4</td>
<td>80.1</td>
<td>11.5</td>
</tr>
</tbody>
</table>
Conclusions:

- Under conditions of P decline soil Olsen P concentration does not significantly influence either drainage or runoff losses.

- May have implications where Olsen P is used as an indicator of probable WQ improvement following mitigation measures – on soils similar to these.

- Adding land management differences is likely to further complicate trend detection.

- Runoff event FWMCs appear to have declined slightly during 2005-12.