Development of a sub-field scale phosphorus critical source area index which utilises LiDAR DEMs and GIS

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Introduction

- Diffuse phosphorus (P) losses from agricultural land must be controlled to reduce eutrophication and water quality degradation
- Critical Source Areas (CSAs) are areas at highest risk and need to be accurately identified to cost-effectively target mitigation measures and best management practices
- Existing CSA indices (termed P Indices in the US) have limitations:
  - they are spreadsheet-based
  - they only identify CSAs at the field scale
  - watercourse proximity is used as a proxy of runoff propensity and P transport risk, which does not account for topographic or microtopographic controls
  - erosion risk does not account for flow accumulation or sub-field scale topography
  - mobilisation potential and hydrological connectivity are poorly defined
- These limitations could be addressed using improved conceptual models (Fig. 1), high resolution LiDAR Digital Elevation Models (DEMs) and GIS

Methodology

- A new GIS-based CSA Index was developed, integrating source, mobilisation and transport factors (Table 1) collected in four contrasting Irish agricultural catchments (Fig. 2) within the Teagasc Agricultural Catchments Programme (7.5-12 km²)
- The optimal DEM resolution for modelling the Topographic Wetness Index (TWI) in these catchments was identified as 1-2 m in a previous study (Fig. 3).
- The 2 m LiDAR DEM was therefore selected to model HSAs
- An HSA Index was developed by integrating TWI and soil drainage datasets and reducing risk scores in upslope drainage areas which flowed into topographic sinks such as depressions and hedgerow banks (Fig. 4)
- CSA factors were rasterised in ArcGIS. Values were categorised and assigned relative risk scores ranking P loss potential
- A CSA Index (Fig. 5) was then created by totally risk scores for dissolved and particulate P losses using a component formulation. Grid cells within the highest risk scores were identified as CSAs

Table 1. CSA Index factors and advantages over existing tools

<table>
<thead>
<tr>
<th>Feature</th>
<th>P Index</th>
<th>CSA Index</th>
<th>HSA Index</th>
<th>HAA Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>Soil P concentrations</td>
<td>Soil type and soil P pools</td>
<td>Soil type and soil P pools</td>
<td>Soil type and soil P pools</td>
</tr>
<tr>
<td>Mobilisation</td>
<td>% degree of P adsorption of soil and water solutions</td>
<td>% degree of P adsorption of soil and water solutions</td>
<td>% degree of P adsorption of soil and water solutions</td>
<td>% degree of P adsorption of soil and water solutions</td>
</tr>
<tr>
<td>Transport</td>
<td>Soil drainage class</td>
<td>Soil drainage class</td>
<td>Soil drainage class</td>
<td>Soil drainage class</td>
</tr>
<tr>
<td>Delivery</td>
<td>Flow sinks</td>
<td>Flow sinks</td>
<td>Flow sinks</td>
<td>Flow sinks</td>
</tr>
<tr>
<td>Impact</td>
<td>Erosion risk</td>
<td>Erosion risk</td>
<td>Erosion risk</td>
<td>Erosion risk</td>
</tr>
</tbody>
</table>

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Results (Preliminary)

- Flow sinks
- TWI
- Soil drainage class
- HAA Index
- HSA Index

Discussion and Conclusion

- If CSAs are to be accurately identified in catchments dominated by microtopography, 1-2 m LiDAR DEMs are required to model HSAs
- Results show that the new CSA Index identifies CSAs at the sub-field scale and captures the influence of microtopography
- Breakthrough points and delivery points along CSA pathways, where P is transported between fields or delivered to the drainage network, are easily identifiable, allowing the targeting of sub-field scale mitigation measures to reduce P losses at the most cost-effective locations
- The approach provides more scientifically robust estimates of P loss risk compared to conventional spreadsheet-based CSA Indices, by accounting for P mobilisation potential and microtopographic controls
- The methodology can also be applied to identify CSAs of other diffuse nutrients and pollutants
- Calibration and validation of the CSA Index will be undertaken using measured P loss data

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