Catchment scale risk mapping
A flexible and adaptive approach to environmental diffuse pollution risk modelling using GIS

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The approach in context

- Complexity
  - Empirical and black box modelling
  - GIS-based risk modelling
  - Complex numerical models

Data requirements
The GIS risk modelling approach

Guidance tool → Appropriate scale

Easy to use → User friendly

Cost effective → Simple

Diffuse sediment risk
- Negligible risk
- Low risk
- Moderate risk
- High risk
- Cloud
The risk model approach

- Define risk equation based on approach
- Obtain required data (e.g. DEM, land use, rainfall etc.)
- Geoprocess data (using Open Source GIS software: QGIS, SAGA, WhiteboxGAT)
- Run risk model using geospatial data
- Generate risk outputs
- Create bespoke risk maps
- Outputs guide further work, e.g. detailed numerical Modelling, data collection, mitigation measures.

Calibration and validation (e.g. land use, measured data)
Identifying risk

- Risks are selected based on the specific investigation using expert judgement or values identified through previous research or the literature.
- Commonly a score-based system is used with relevant scores applied to land cover types based on their risk.

<table>
<thead>
<tr>
<th>Land use</th>
<th>Risk score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare land</td>
<td>10</td>
</tr>
<tr>
<td>Arable land</td>
<td>8</td>
</tr>
<tr>
<td>Pasture</td>
<td>4</td>
</tr>
<tr>
<td>Grassland</td>
<td>2</td>
</tr>
<tr>
<td>Woodland</td>
<td>1</td>
</tr>
<tr>
<td>Urban areas</td>
<td>1</td>
</tr>
</tbody>
</table>

- The risk score approach can be applied to any of the datasets used in a model, e.g. higher slope angles could be scored as higher risks.
Risk model datasets – example sediment risk model

\[(\text{Land cover}) + (\text{Rainfall}) + (\text{Slope angle}) + (\text{Soil erodibility}) \times (\text{Distance to channel})\]

= Risk map

Legend:
- Negligible risk
- Low risk
- Moderate risk
- High risk
- Cloud
Multidisciplinary approach

- Stakeholder engagement
- GIS
- Geomorphology
- Hydro-ecology
- Catchment dynamics
- Urban & rural land use
- Remote sensing
- Data processing & analysis
- Water quality
- Geology

Diffuse sediment risk
- Negligible risk
- Low risk
- Moderate risk
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Land use – remote sensing

• Commonly a key input to such risk models is land use.

• Some datasets, e.g. Land Cover and National Crop Maps. These are very detailed and can be used in the model where available and allowed. They are costly.

• CORINE is freely available but this is limited in resolution (~100m).

• Land cover data can be derived using Sentinel-2 and Landsat 8 satellite imagery.

• Resolutions vary between 10-20m for Sentinel 2 and 30m for Landsat 8.

• Can be made for any period when data is available (and cloud free).
Land use - methodology

- Land use was determined using simple Object Based Image Analysis in SAGA GIS and QGIS.

- Land use was classified using a combination of:
  - Differing band combinations
  - Open source aerial imagery
  - Topographical information
  - Feature information (field boundaries, furrows etc.)

- Validation based on extant imagery, mapping spectral response and field validation.
Land use: River Sow catchment

Land use
- Water
- Woodland
- Bare land
- Grassland
- Arable land
- Urban-Suburban
- Cloud

Spring 2016

Summer 2016

Autumn 2016

Winter 2016
River Sow: small catchment diffuse sediment pollution risk

- Risk model developed and run on the Sow catchment to investigate diffuse sediment risk.
- Catchment size is ~38 x 18km. Model grid cell size is 20m.
- Shows seasonal variation due to changing rainfall and land use.
Danjiangkou: (very!) large catchment nutrient pollution risk

- Agricultural nutrient pollution risk model developed and run on the Danjiangkou catchment, China. (the reservoir here is the key drinking water supply to Beijing).
- Catchment size is ~540 x 250km. Model grid cell size is 30m.
Examples of use – DOC risk and DOC flux - 1

Land use

DOC risk map

Acidification risk
Examples of use – DOC risk and DOC flux - 2

Peat climatic threshold

Calculations

Total DOC flux over Wales with climate change

Peat climatic threshold changes under different climate change scenarios

DOC flux per individual waterbody
Expanding the approach

- The flexibility of the method means it can be easily expanded or refined. For example:
  - **Calibration**: Field-based ground truthing of land use types if derived from satellite imagery or quantification of at-risk areas can be undertaken.
  - **Validation**: Using existing measured data, e.g. in-river suspended sediment concentration or DOC concentration, to validate results.
  - **Additional data**: New and/or higher resolution data can be substituted into the model and re-run as necessary.
  - **New processes**: New processes can be easily added to the model to improve the predictive ability, for example understanding impacts to groundwater.
  - **Semi-quantitative results**: The risk formula can be modified to allow the production of semi-quantitative results.
  - **Geostatistics**: Comparison between spatial variables used in the risk model and calculated risks can be investigated using geostatistics.
Thank you

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