Using earth observation for constraining uncertainty in sediment loss predictions

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Abstract Current Earth Observation (EO) satellites have limited ability to discriminate variables necessary for predicting the impact of nutrient loss on water quality. This project investigates whether new hyperspectral EO sensors provide enhanced accuracy and more detailed spatial context to aid the characterization of crop type and fractional ground cover. These are key input parameters in models of field and catchment scale nitrogen, phosphorus and sediment loss to streams. Such contemporary information, when coupled with supporting (e.g. digital elevation model) data, will help identify vulnerable areas and provide a framework for developing pollution risk assessment tools based on the spatial co-location of risk factors (slope, erodible soils, crop type).

Key words Earth observation; modelling; runoff; sediment

INTRODUCTION

Application of sediment loss models such as EUROSEM require detailed crop-specific information such as fractional ground cover in order to constrain uncertainty in model predictions (Quinton, 1997). Such contemporary data within and between fields cannot be obtained at the catchment scale except through the use of Earth Observation (EO) satellite derived products. Hyperspectral data (126 bands: 437–2485 nm) has been acquired at a 4 m spatial resolution for a farm catchment in Herefordshire, England. By applying novel spectral unmixing techniques, hyperspectral imaging is providing data on crop type, fractional ground cover and the presence of trash or stubble. The generated EO imagery is being fully validated using cropping management and measurements of within-field variability in fractional ground cover.

METHODS

As hyperspectral imagery provides estimates of fractional ground cover, a parameter that is explicitly represented in the EUROSEM model, the sensitivity of estimates of erosion flux and hence phosphorus loss from fields can be assessed. Here, the effect of mildew on crop establishment was assessed in terms of sediment loss predictions.
The EUROSEM model (Morgan et al., 1998) was parameterized for a field cultivated with winter wheat at ADAS Rosemaund, a 250 ha mixed farm in Herefordshire, England, forming a discrete surface water catchment where measurements indicate that suspended sediment moves readily in runoff. A 6 ha silty clay loam field of length 300 m, a 10% slope and 200 m width was used. Manning’s $n$, cultivation and subsequent cumulative raindrop impact together define surface roughness in the model. Fractional ground cover was varied using a leaf area index (LAI) of between 3 (healthy) and 1 (severe mildew).

RESULTS

A synthetic 20 mm, 150 min duration rainfall event was applied in EUROSEM using a normally distributed intensity. Such events are typical of heavy rainfall in this region. Results in Fig. 1 show a simulated runoff and erosion event occurring under winter wheat with LAI of 2. Table 1 shows that differences in the relationship between runoff volume and the sediment mass are not straightforward. Results suggest variations in LAI (e.g. due to mildew) may result in large differences in predicted sediment mobilization (and hence phosphorus loss), although predicted runoff appears less strongly influenced.

![Fig. 1 Simulated runoff and sediment response (20 mm rain in 150 min).](image)

<table>
<thead>
<tr>
<th>Input LAI</th>
<th>Runoff (m$^3$ ha$^{-1}$)</th>
<th>Runoff/effective rainfall ratio</th>
<th>Sediment loss (kg ha$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthy crop</td>
<td>3</td>
<td>92.0</td>
<td>483</td>
</tr>
<tr>
<td>Light mildew</td>
<td>2</td>
<td>91.4</td>
<td>770</td>
</tr>
<tr>
<td>Severe mildew</td>
<td>1</td>
<td>102.5</td>
<td>803</td>
</tr>
</tbody>
</table>
Time-series predictions of sediment loss from EUROSEM (Fig. 1, Table 1) increase by as much as 66% relative to those from a healthy crop with a LAI of 3. Such preliminary analyses indicate the considerable sensitivity of such models to the value of parameters related to fractional ground cover. Predictions of phosphorus loss to freshwaters often comprise a sediment loss model and a P loss model applied in series. This approach carries the significant risk of compound predictive uncertainty arising from the propagation of errors through successive model components. However, it has been demonstrated that additional information on fractional ground cover, such as can be provided by EO techniques, can constrain the uncertainty in predictions of models applied at the catchment scale.

Agricultural census data is accurate and may be used to drive nutrient models at the catchment scale, but it is not contemporary and is contextually imprecise in terms of the location of vulnerable fields at risk of significant nutrient loss (e.g. potatoes). Therefore, validation of hyperspectral data at the field scale should allow the provision of reliable contemporary data at larger spatial scales where contextual information from census sources is often limited.

Acknowledgement The support of BNSC LINK to facilitate this work is gratefully acknowledged.

REFERENCES
