Work Package 1:
Refinement of Critical Loads

Task 1:
Update and Refinement of Critical Loads

B Reynolds

Centre for Ecology & Hydrology, Bangor
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1 Summary
Uncertainty in the values used to parameterise the steady-state models used to calculate critical loads of nutrient nitrogen and acidity for UK woodland habitats have been evaluated and compared with European estimates. The results show wide ranges in uncertainty resulting from methodological differences across Europe and scaling factors. There is a need for coordinated effort to agree upon uncertainty ranges for critical load input data so that a consistent approach is employed across Europe.

The sodium dominance index (NaDI) model for predicting catchment mineral weathering rates has been evaluated using data from applications of the MAGIC model in five acid sensitive regions of the UK. Overall, the NaDI model did not perform as well as a regression model based on the simple concept of the sum of the excess base cation concentrations in the water. In practical terms, the NaDI model is simpler to apply, only requiring the measurement of three base cations in a stream water sample whereas an additional measurement of chloride ion is required to calculate excess base cation concentrations.

2 Policy relevance
This task provides technical input to the UK National Focal Centre (UKNFC) in support of their mapping activities and provision of data to the Co-ordination Centre for Effects. The work takes the form of contributing to assessment and development of critical load models, provision and review of data and assessment of uncertainties.

3 Project update
Two pieces of work have been undertaken within this task over the last year. The first was to contribute to an examination of the uncertainties in the data used to calculate steady-state acidity and nutrient nitrogen critical loads for woodland habitats in the UK. The models use data from a wide range of sources and the accuracy of the critical loads are influenced by the accuracy of the input data sets. The work was led by the UKNFC (Liz Heywood and Jane Hall) and aimed to quantify the uncertainties in the data used and to make comparison with values calculated by other European countries. The work has been accepted for publication in the journal ‘Environmental Science and Policy’ (Heywood et al., in press).

The second piece of work made a regionalised assessment of the sodium dominance index proposed by White et al. (1999) as a technique for estimating catchment mineral weathering rates. Mineral weathering is one of the fundamental processes determining soil and freshwater susceptibility to acidification. Unfortunately, weathering rates are extremely difficult to measure and a modelling approach is often required. This may vary in sophistication from simple, semi-quantitative map based assessments to steady state and dynamic, processed based models. White et al. (1999) have proposed that in areas with a strong maritime influence, such as the UK, the sodium dominance index (NaDI), the ratio of the concentration of Na\(^+\) to ΣNa\(^+\) + Ca\(^{2+}\) + Mg\(^{2+}\) in a stream water sample will provide a quantitative index of the catchment weathering rate upstream of the measurement point. The model was originally tested by the authors in a number of Scottish catchments with a wide range of bedrock geology using weathering rates calculated by the MAGIC model to calibrate
the NaDI. Here, data from 293 sites in five acid sensitive regions of the UK have been used to further evaluate the performance of the model. The outputs were presented as a poster (Reynolds et al., 2005) at the recent Acid Rain 2005 conference in Prague.

4 Collaboration with Dynamic Modelling and Freshwater Umbrella

The work on the sodium dominance index was in collaboration with Dr Chris Evans and used data from MAGIC model runs (Evans et al., 2001) funded previously by Defra under the ‘Dynamic Modelling of Acidification Processes (EPG 1/3/133) and the ‘Acidification of Freshwaters: The Role of Nitrogen and Prospects for Recovery’ project (EPG 1/3/117).

5 Key findings

The work on uncertainty revealed a wide range in the estimates of uncertainty in model parameters and in the methods used to derive them. Possible reasons for these differences were the range of methods used to estimate uncertainty, the scale at which the uncertainty was assessed and underlying methodological differences used to estimate parameter values. Greater transparency in the way the uncertainties are derived is necessary for improving communication between scientists and decision makers. Specific recommendations arising from the work are that parameter uncertainty should be defined exactly in terms of range, distribution and where appropriate scale and ecosystem type. There is a need for coordinated effort to agree upon uncertainty ranges for critical load input data so that a consistent approach is used across Europe.

In the regional assessment of the NaDI model, the data set for each region was split randomly into two halves. One half was used to construct simple linear regression models of a) MAGIC weathering rate vs. NaDI and b) MAGIC weathering rate vs. \( \Sigma xsBC \); the sum of \( xsNa^+ + xsCa^{2+} + xsMg^{2+} \). The second half of each data set was used to test the predictive capabilities of the regression models.

Table 1 shows the \( r^2 \) values for the model calibrations and for the relationships between the weathering rates predicted by the regression models and MAGIC weathering rates. The model using \( \Sigma xsBC \) invariably gave higher \( r^2 \) values for both calibration and testing. For three regions, the means of the residuals (regression model prediction minus MAGIC weathering rate) were lower for the \( \Sigma xsBC \) compared to the NaDI model. The opposite was true for the Cairngorms and Wales. For all regions, the standard deviation of the residuals was higher for the NaDI model, implying greater variability in the predictions. For the NaDI model, residuals were negatively correlated with MAGIC weathering rates for all regions except the Cairngorms. For the \( \Sigma xsBC \) model, the residuals were randomly distributed for the Cairngorms and Galloway, positively correlated with MAGIC weathering rate for the Lake District and negatively correlated for the Pennines and Wales.
1) Values of $r^2$ for the calibration and testing of the NaDI and $\Sigma$xSBBC regression models

<table>
<thead>
<tr>
<th>Region</th>
<th>Model calibrations</th>
<th>Model testing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of sites</td>
<td>NaDI ($r^2$)</td>
</tr>
<tr>
<td>Cairngorms</td>
<td>19</td>
<td>0.684</td>
</tr>
<tr>
<td>Galloway</td>
<td>28</td>
<td>0.694</td>
</tr>
<tr>
<td>Lake District</td>
<td>25</td>
<td>0.754</td>
</tr>
<tr>
<td>Pennines</td>
<td>27</td>
<td>0.861</td>
</tr>
<tr>
<td>Wales</td>
<td>48</td>
<td>0.705</td>
</tr>
</tbody>
</table>

Overall, the NaDI model did not perform as well as the regression model based on the simple concept of $\Sigma$xSBBC concentrations. In practical terms, the NaDI model is simpler to apply, only requiring the measurement of three base cations in a stream water sample whereas an additional measurement of chloride ion is required to calculate excess base cation concentrations.

6 References


