SOIL HYDROLOGICAL AND HYDROCHEMICAL RESPONSES IN THE ALLT A' MHARCAIDH CATCHMENT, SCOTLAND

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INTRODUCTION

- Given that mountain ecosystems are amongst the first to respond to environmental pressures; this study provides important base-line information to assess how changes in climate, hydrological pathways and nitrogen (N) deposition may influence nitrogen leaching within an upland oroarctic environment (the Allt a'Mharcaidh catchment in the Western Cairngorms, Scotland).
- Here we present a unique study that integrates detailed catchment information with an application of the dynamic hydrochemical model, MAGIC (Model of Acidification of Ground water In Catchments).

A) RESEARCH CATCHMENT AND APPROACH

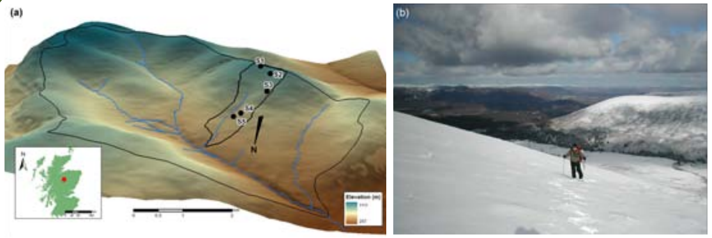


Figure 1: a) Map showing the location of the Allt a' Mharcaidh catchment and research sites b) Photograph of the hill slope.

A sequence of 5 sites, spanning a gradient of 550m and a range of soil/vegetation types, was chosen to represent larger-scale hydrochemical responses in the Allt a' Mharcaidh catchment. Soil lysimeters, Delta-T Theta probes (to measure soil moisture content) and temperature sensors were installed within soil organic and mineral horizons in 2004. In addition, the hydrochemistry of deposition, the spring and stream are monitored.

B) HYDROLOGY OF THE SOIL

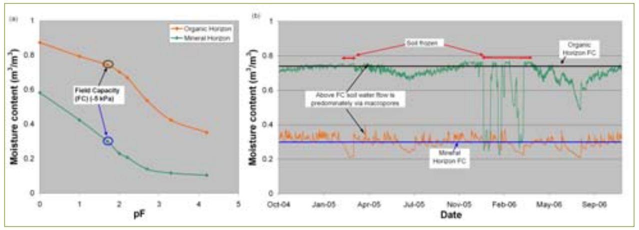


Figure 2: a) Soil moisture retention curve and b) Time series of soil moisture content from October 2004 to October 2006

Data from theta probes installed next to each soil lysimeter indicates when soil water flow is via macropores and contributing to soil solution chemistry (Figure 4). This information will be linked to temperature data to identify how drying/wetting and freeze/thaw cycles influence nitrogen dynamics in oroarctic environments and will be used to enhance the preliminary model applications shown in Figure 5.

C) SOIL CARBON AND NITROGEN STOCKS

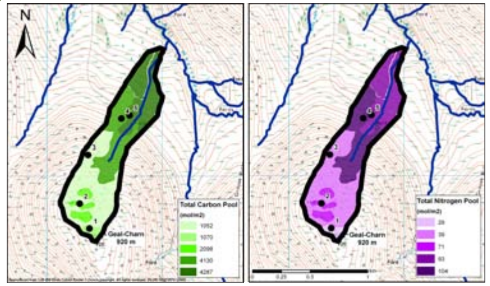
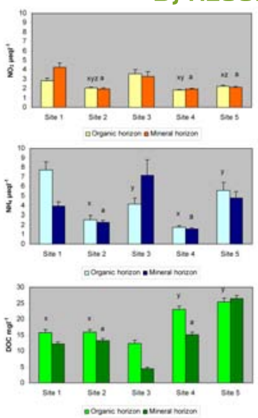


Figure 3: Maps showing the spatial variability of carbon and nitrogen pools at a sub-catchment scale

Topographic features and drainage characteristics influence the spatial variability of soil and vegetation communities that are key to the development of soil carbon and nitrogen pools. We will use this information within a modelling framework to simulate nutrient concentrations and link sites by hydrological pathways.

D) RESULTS: SOIL WATER NUTRIENT CONCENTRATIONS



Nitrate (NO_3)

- The least soil water NO_3 concentrations are observed at sites with the greatest carbon pools (Sites 2, 4, and 5).
- No statistically significant difference is observed between NO_3 concentrations in the organic or mineral horizons.

Ammonium (NH_4)

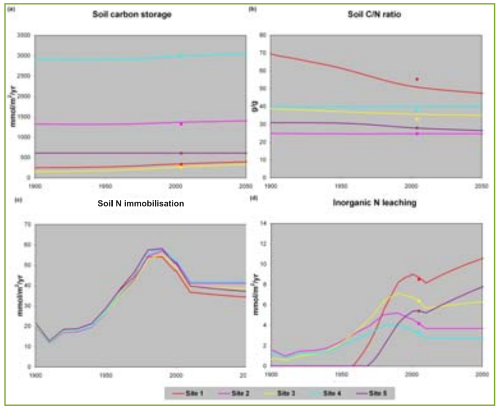
- Ammonium is the dominant inorganic N fraction at sites 1,3 and 5.
- Large differences in NH_4 concentrations are observed between the organic and mineral horizons, but the trend is not consistent.

Dissolved Organic Carbon (DOC)

- Generally DOC concentrations are higher in the organic horizon.
- DOC concentrations are closely related to the labile carbon pool.

Figure 4: Soil water NO_3, NH_4 and DOC concentrations. Means sharing the same letter are not significantly different (CL =95%); error bars represent the standard error of the mean (n=100).

E) RESULTS: DYNAMIC MODELLING



MAGIC simulations (calibrated to 2005 data) reflect the highly heterogeneous nature of mountain environments in terms of nitrogen deposition, soil C stocks, and the effect of these on the timing and magnitude of soil N leaching (Fig. 5). The model simulates significant N-induced increases in C stocks at sites 1 (45%) and 3 (64%) from 1900 to 2050 (Fig. 5a). Sites with smaller C pools are more responsive to changes in N deposition, and soil C/N ratios decline more rapidly at these sites (Fig. 5b). Sites 2, 3 and 4 have above-zero modelled soil water N concentrations in 1900, but appear less responsive to change due to greater N immobilisation capacity (Fig.5c) so future soil water N concentrations at these sites are forecast to remain stable.

Figure 5: MAGIC simulations from 1900-2050, Allt a' Mharcaidh sub-catchment

CONCLUSIONS AND FUTURE DIRECTION: The Allt a' Mharcaidh transect study demonstrates how in mountain environments, small-scale heterogeneity in altitude, slope position, local topography and exposure all influence soil development and vegetation communities, such that the five sites studied vary in their susceptibility to nitrogen saturation. The accurate prediction of N deposition impacts on sensitive montane ecosystems may therefore ultimately require a finer-scale approach (in terms of spatial scale) than can currently be achieved by national scale assessments.

In the future, nutrient dynamics in the vertical (soil profile) and lateral dimension will be modelled by coupling output from MAGIC with terrain analysis within a GIS, and utilising soil moisture data.

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