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Catchment land use effects on fluxes and concentrations of organic and inorganic nitrogen in streams

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ABSTRACT

We present annual downstream fluxes and spatial variation in concentrations of dissolved inorganic nitrogen (NH_4^+ and NO_3^-) and dissolved organic nitrogen (DON) in two adjacent Scottish catchments with contrasting land use (agricultural grassland vs. semi-natural moorland). Inter- and intra-catchment variation in N species and the relation to spatial differences in agricultural land use were studied by determining catchment N input through agricultural activities at the field scale and atmospheric inputs at a 25 m grid resolution. The average agricultural N input of 52 kg N ha^{-1} yr^{-1} to the grassland catchment was more than 4 times higher than the input of 12 kg N ha^{-1} yr^{-1} to the moorland catchment, supplemented by 12.3 and 8.2 kg N ha^{-1} yr^{-1} through atmospheric deposition, respectively. The grassland catchment was associated with an annual downstream total dissolved nitrogen (TDN) flux of 14.4 kg N ha^{-1} yr^{-1}, which was 66% higher than the flux of 8.7 kg ha^{-1} yr^{-1} from the moorland catchment. This difference was largely due to the NO_3^- flux being one order of magnitude higher in the grassland catchment. Dissolved organic N fluxes were similar for the two catchments (7.0 kg ha^{-1} yr^{-1}) with DON contributing 49% to the TDN flux in the grassland compared with 81% in the moorland catchment. The results highlight the importance of diffuse agricultural N inputs to stream NO_3^- concentrations and the importance of quantifying all the major aquatic N species for developing a better understanding of N transformations and transport in the atmosphere-soil-water system.

1. Introduction

Human actions at the landscape scale impact the ecological state of stream ecosystems, particularly through land use change (Allan, 2004; Likens and Bormann, 1974). Over the last few centuries, land use change has taken place on a global scale increasing the area of different types of agricultural land (Goldewijk, 2001). One of the most significant changes in agricultural systems is the increase in nitrogen (N) inputs caused by application of mineral and organic fertiliser as well as organic manures associated with grazing livestock (Nieder and Benbi, 2010; Wade et al., 2005). However, significant uncertainties remain about the influence of land use on N export to the aquatic system at the catchment scale, due to the complexity of N dynamics in terrestrial systems (Alvarez-Cobelas et al., 2008).

In aquatic ecosystems, N enrichment at the catchment scale can have significant impact on water quality and is well known to be linked to eutrophication (e.g., Grizzetti et al., 2011). The main forms of reactive, i.e., biologically available, N dissolved in streamwater are ammonium (NH_4^+), nitrate (NO_3^-) and dissolved organic nitrogen (DON). However, most studies on catchment N export have focused on single N species, particularly on NO_3^- as this was understood to be the dominant form of N leaching from agricultural systems (Alvarez-Cobelas et al., 2008;

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Van Kessel et al., 2009). Generally, high soil organic matter content is considered to result in high concentrations and fluxes of streamwater dissolved organic carbon (DOC) and N compounds (e.g., Aitkenhead et al., 1999; Neff et al., 2003). A number of studies on the organic N fraction in streamwater have been conducted in forested systems associated with organic soils (e.g., Campbell et al., 2000; Perakis and Hedin, 2002). In recent years the importance of organic N as a significant form of streamwater N not only in semi-natural but also in agricultural areas has become apparent (e.g., Murphy et al., 2000; Scott et al., 2007), although the behavior and origin of DON in streamwater is not fully understood (Durand et al., 2011). Catchment studies therefore need to take into account all forms of streamwater N, including organic forms, to gain better understanding of controls on N export.

In this study, we investigated two Scottish catchments with contrasting land use, one dominated by grazed grassland, the other dominated by semi-natural moorland. Annual downstream fluxes of NH_4^+, NO_3^- and DON were established by sampling at the gauged catchment outlets at both fortnightly and hourly intervals; the latter during selected high flow events during 2008. A detailed landscape inventory provided data on spatial N input to the catchments by agricultural activities. The relationship between agricultural land use N input and spatial variability of concentrations within the catchments was studied by conducting

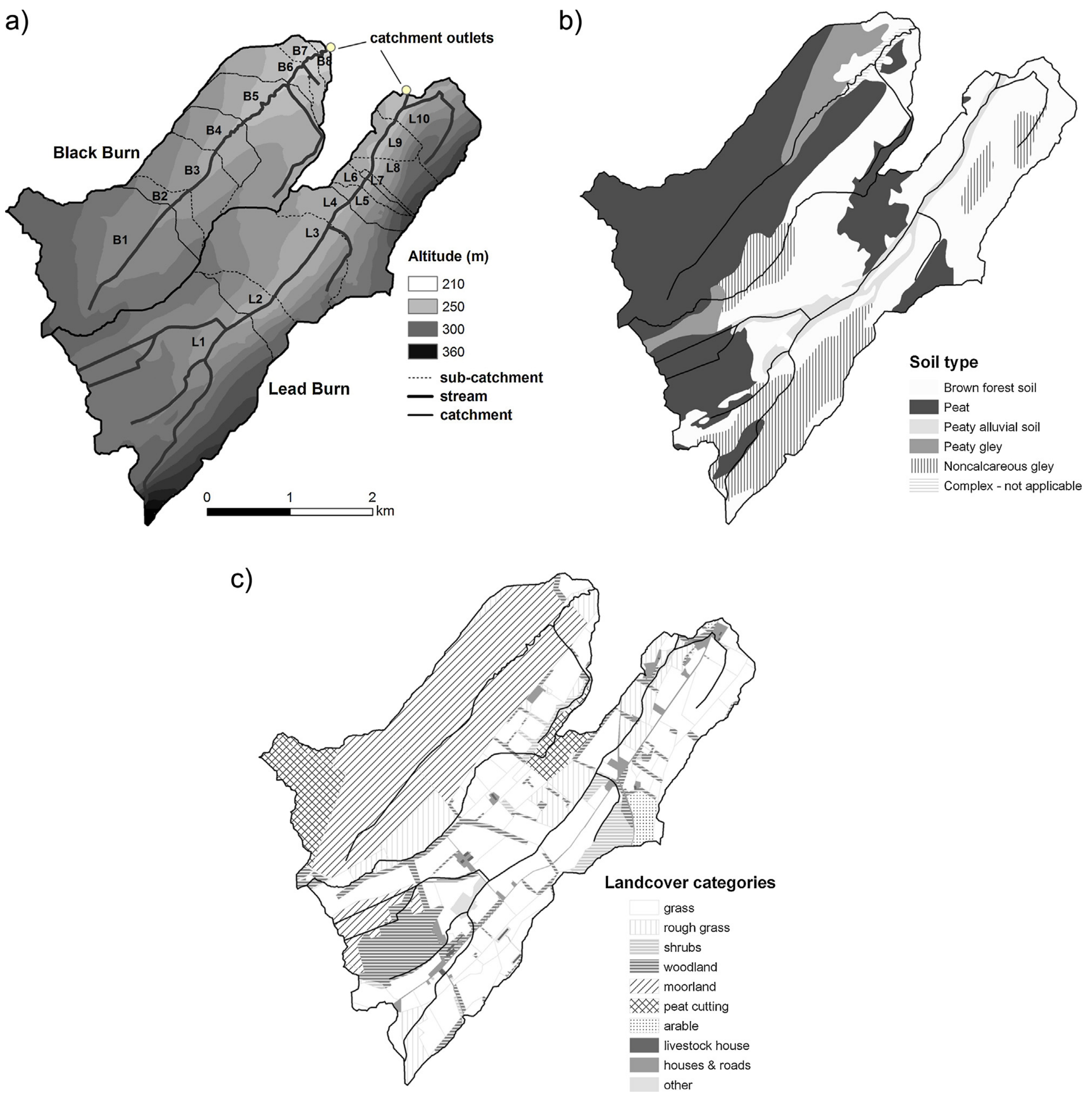

Fig. 1. Maps of (a) topography, (b) soil and (c) land cover of the Black Burn and the Lead Burn catchment. Streamwater samplings and discharge measurements were carried out at the catchment outlets. Not all tributaries of the main streams are shown. ©Digital terrain data from Intermap Technologies Inc. 2010 were used in the derivation of catchment boundaries shown, together with other information. ©Soil types are based on the Scottish Soil Survey, The James Hutton Institute 2011 (license MI/2008/296). The equivalent FAO names are: brown forest soil = cambisol, peat = histosol, peaty alluvial soil = humic fluvisol, peaty gley = humic gleysol, noncalcareous gley = gleysol (FAO/UNESCO, 1974).