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Application of isotopic techniques to investigate the impact of insect herbivory on C and N cycling in a grassland system – a mesocosm study

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Ecosystem disturbances like insect pests induce time and space limited process heterogeneity that allow to quantify changes in biogeochemical reaction rates. Insect pests are known to impact element and organic matter (OM) cycling in ecosystems by defoliation and deposition of fecal material. To study the effects of such trophic interactions on OM and nutrient cycling in a grassland system under herbivore attack, a laboratory mesocosm experiment with grass (Dactylis glomerata) and grasshoppers (Chorthippus dorsatus) was conducted. In 12 mesocosms (50 cm in diameter, 100 cm in height) D. glomerata was sown in pasture topsoil (0-12 cm of a Calcaric Cambisol (Siltic), Hainich region, Germany) and left to grow for one year under constant climatic conditions (15°C) to establish a well-developed root system.

In 2015, the mesocosm was labeled over 5 days using 13CO_2-gas and 15N labeled feces (δ15N: 58‰ in order to trace the fate of C and N in above- and belowground plant organs (root, leave), insects, feces, soil, and soil solution. In three replicates, the following treatments were conducted: control, 13CO_2-labelling, 13CO_2-labelling+20 grasshoppers, and 13CO_2-labelling+20 grasshoppers +15N-labeled feces (+9.2 μg N*cm-2). During incubation, the mesocosms were irrigated (13 mm) and throughfall and soil solutions were sampled. After incubation, solutions, cold water extracts as well as microbial biomass (chloroform-fumigation) of two soil depths (0-4, 4-12 cm) were analyzed for DOC, δ13DOC, and dissolved N. Furthermore, TOC, δ13C, TN and δ15N values of all collected compartments were determined.

In general, 13CO_2-pulse labelling showed that after 5 days of incubation not only grasshopper feces but also leachates of feces were significantly enriched in 13C. Based on δ13C-values, herbivory induced a stronger 13C-enrichment in roots while shoots were less enriched. The input of 13DOC indicates a fast cycling of leaf-C via grasshopper and feces to the soil solution, soil microbes and grass roots. This was further confirmed by a 80 % mass loss and by a reduced N amount (-91%) of labeled feces. This may indicate a rapid release of N via leaching, and root-uptake (-0.82$\pm$0.28‰ compared to treatments without 15N (-1.54$\pm$0.12‰. 15N in grass leaves was not found to be enriched, however, significantly higher δ15N values were found in freshly excreted feces (0.62$\pm$0.4‰ compared to those of mesocosms without 15N addition (-0.14 $\pm$0.27‰. Hence, we hypothesize that part of the labeled N was also rapidly assimilated within plant and microbial biomass, taken up by grasshoppers, and returned via feces. The N amount in soil solution and cold water extracts did not increase due to herbivory supporting the assumption of a rapid plant uptake of released N. The low N concentrations of the mineral soil (0.14 %) and in soil solutions (1-2.3 mg L-1) point to very low N availability for the grass. We conclude that on the short-time scale in N-limited pasture systems heavy insect herbivory would not result in significant N leaching from the ecosystem.