Impacts and drivers of insect herbivory on element cycling in forests globally

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Abstract

The effects of insect herbivores on forest functioning are not well understood even though they can have important impacts on ecosystem processes by intercepting foliage before resorption and depositing nutrient-rich materials to the soil. In this thesis, I investigated the impact and drivers of insect folivores on carbon (C), nitrogen (N), phosphorus (P) and silica (Si) cycling in broadleaf forests, and how this varies with major climate variables. I first synthesized existing literature to identify gaps in knowledge and prioritize future research about the plant-silica-herbivore relationship, which has been overlooked despite recent growing interest in the importance of silica in terrestrial systems. In the field, I led the establishment of a network collecting leaf litter, fresh leaves, and soil from 74 plots in 40 broadleaf primary forests distributed across all continents (except Antarctica) using standardized methods to measure foliar production and background leaf-level herbivory rates. From these data, I calculated insect-mediated element fluxes from the canopy to the soil and compared them to other major sources of these nutrients. To learn how major climate variables may influence these fluxes locally and globally, a subset of plots was established along nine natural temperature and three precipitation gradients. Finally, I investigated how temperature can affect the movement of C and N in locally sourced leaf litter and three levels of insect frass + cadaver amendments decomposing along a highly constrained elevation gradient, to provide insights into the cascading effects of these deposits on decomposition processes.

I found substantial evidence for a wide variety of important interactions between plant Si and herbivory but highlight the need for more research particularly in non-graminoid-dominated vegetation outside of the temperate biome as well as on the potential effects of herbivory on Si cycling. The global mean for net insect-mediated N flux was approximately 25% of the global mean for atmospheric N deposition. The global mean for net insect-mediated P flux was 280% that of the global mean for atmospheric P deposition and 0.03% of the global mean for mineral weathered P. However, insect-mediated element fluxes represented a larger proportion of total N and P deposition in the tropical region than in temperate or boreal regions, which could have large implications for forests in P-limited areas such as the Tropics. Overall, insect folivores liberated greater amounts of studied elements from the canopy in warmer and drier sites than cooler and wetter sites globally, but trends at local scales did not always reflect global patterns. In addition, insect-mediated element fluxes were most affected by mean annual temperature (MAT) and mean annual precipitation (MAP) globally. Foliar production and leaf-level herbivory rate explained the most variability in insect-mediated element fluxes. In turn, foliar production and to a lesser extent leaf-level herbivory and foliar nutrient concentrations were largely driven by MAT. The litter decomposition study also demonstrated that increased MAT and insect inputs additively increased litter decomposition and N immobilization rates, with effects being stronger for litterbags amended with the highest, outbreak-level amount of insect inputs.

The findings from this thesis highlight that relatively small but chronic and labile forms of nutrients from herbivory by insects at low densities could affect long-term ecosystem C and nutrient cycling as much or more than episodic outbreak events. Climate change in broadleaf forests can have important but variable impacts on productivity and insect herbivory rates, with consequences for soil fertility and ecosystem processes, but the magnitude and direction of these impacts will depend on climate variable, foliar element and spatio-temporal scale.