Background and project objectives

Drylands, which include arid, semi-arid and dry-subhumid ecosystems, cover about 41% of the Earth's land surface and support over two billion people, many at subsistence level. Although primary production in these systems is co-limited by water and nitrogen (N), significant ecosystem N losses occur due to the discontinuous and temporally asynchronous N supply and demand by plants and microbes. These N losses have been indicated to reinforce the negative feedback loop between plant biomass, water and sediment transfers, and associated nutrient fluxes further exacerbating plant N limitation and soil fertility in dryland ecosystems. The desertification paradigm designates a crucial role for biotic communities to reduce the accumulation of soil nitrates in order to avoid N loss during heavy rainfall periods, but the tangible impact of plant communities on belowground ecosystem processes remains largely elusive in complex real-world ecosystems. A better understanding of the mechanistic linkages between plant community structures and ecosystem processes is critical to support policy-makers involved in the design of land planning and management strategies.

In the PlaBioF project ("Linking living plant traits to soil biogeochemical functions in ecosystem patches under different land use regimes using an isotope-based assessment"), the overall research objective of the PlaBioF project is to determine the influence of living plants on N cycling processes at the landscape-scale. Two different research studies using novel methodological approaches were undertaken. The innovative nature of this project lies in the combination of state-of-the-art methods and concepts in plant ecology and biogeochemistry that complement each other in a multi- and interdisciplinary framework. This is achieved by integrating expertise of two research institutions that share a common research interest in global change ecology, but each have a different conceptual and methodological background in the complementary scientific subdisciplines of plant ecology (outgoing host, Multidisciplinary Institute of Plant Biology - IMBIV, UNC-CONICET, Argentina,) and biogeochemistry (return host Isotope Bioscience Laboratory – ISOFYS, Ghent University, Belgium). The proposal contains a 2-year training period to learn and apply the use of plant trait approaches at one of the worldwide leading institutes in trait-based ecology. The acquired skills and knowledge will be disseminated through several mentoring and tutoring mechanisms at the return host institution.

Work performed

In a first study, natural abundance patterns of stable N isotopes were applied to assess patterns of preferential uptake of N forms and its relationship to plant root traits. Natural abundance N signatures of NO_3^-, NH_4^+, DON and whole plants from a semi-arid model forest were analyzed to provide robust estimates of plant N source partitioning and relative N cycling rates under in-situ conditions. Bayesian isotope mixing models were applied to assess the relative contribution of the different N forms to plant N uptake, and were related to architectural and symbiotic root traits measured on excavated plant roots.

In a second study, root-permeable cores filled with a common soil were installed at 192 assessment spots in a regional landscape under similar climate, including primary forest, secondary forest, mixed shrublands and degraded shrublands as land use types. These cores were installed under representative vegetated patches and open spaces between the vegetation. We then re-visited the in-growth cores 13 months after their instalment, after which in-situ gross N cycling measurements were performed with minimal rhizosphere disturbance, and subsamples for root trait determinations, phospho-lipid fatty acid (PLFA) measurements and dissolved organic carbon (DOC) analyses were taken.

Results obtained

The results of the first study indicated a tight link between soil C and N cycling in semi-arid ecosystems. We reject the hypothesis that dissolved organic N (DON) is a significant plant N source, and suggest that the microbial communities outcompete plants for organic N sources due to the reduced C-bioavailability in the soil. Rather, high microbial recycling of dissolved organic matter confines plant N uptake to inorganic N forms. Herbaceous plants assimilated greater relative amounts of NH_4^+ compared to woody plants, findings that are potentially related to differences in root architectural traits between both growth forms. Still, all plants dominantly rely on NO_3^- that is made dominantly available through the fixation of atmospheric N_2 and soil organic N decomposition, followed by autotrophic nitrification.

In the second work, a shift towards greater proportions of plant root traits indicative for resource-conservative strategies in the ecosystem types subjected to higher management intensities was observed. Concomitantly, greater microbial and fungal abundances were found in the less disturbed ecosystem types. The shift in rhizosphere characteristics caused a slowdown of mineral N turnover in the sites subject to higher management intensities. Plant-soil feedbacks will therefore reinforce the plant N-limitation, and enable the persistence and expansion of resource-conservative species across the extensive land management gradient. Gross mineral N retention rates generally corresponded to gross mineral N production, but a break in the cycle was observed when resource-conservative plant communities and biocrusts co-occur within the landscape. At this tipping point, significantly higher mineral N production than mineral N retention was observed for the interspaces, while vegetation communities showed a low capacity to intercept and assimilate N exports from the system.

Impact and use

The production and retention of bio-available N is clearly a plant species-specific feedback process. In the rhizosphere of plant colonizing the more degraded ecosystems, reduced N production through N mineralization, coupled with continued mineral N losses will ultimately reinforce plant N limitation and cause shifts in plant community composition towards species that are either capable of N fixation or are tolerant of low N availability. Without the right plants in the system, initial ecosystem N losses will not be captured by the biotic community, and reinforce ecosystem N loss, soil fertility decreases and the expansion of specific plant species over others. These observations have implications for plant species selection in ecosystem conservation and restoration management, as plant-soil interactions clearly affect ecosystem resilience. The mechanistic insights of soil N cycling may also enable a better understanding of climate change impacts that are predicted to impact upon soil C allocation belowground and linkages of biogeochemical cycles. Therefore, this knowledge fills a critical gap in our understanding of plant functional biodiversity impacts upon soil biogeochemistry in dryland ecosystems and enables the improved design of effective and sustainable land management practices in dryland ecosystems. Low to intermediate land management intensities are therefore imperative to avoid the crossing of ecosystem tipping points that leads to abrupt changes in dryland N and vegetation dynamics, and threatens the provision of major ecosystem services of local rural livelihoods.

Photographs

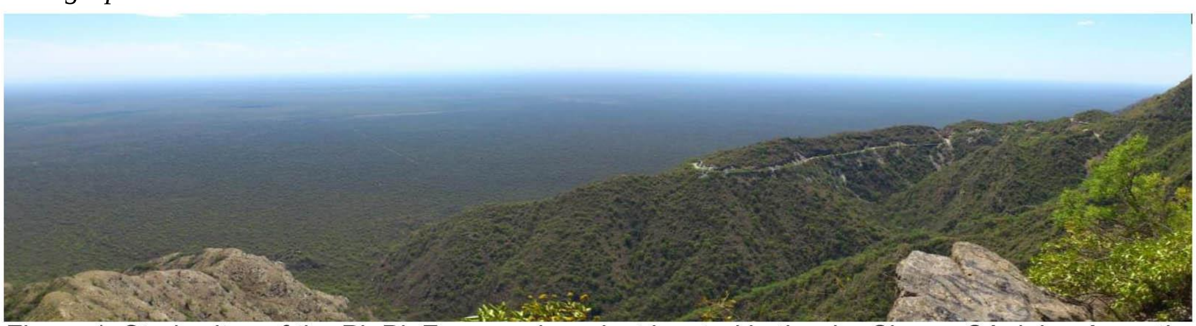

Figure 1. Study sites of the PlaBioF research project located in the dry Chaco, Córdoba, Argentina.

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