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Investigating the initial stages of soil formation in glacier forefields using the new biogeochemical model: SHIMMER

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Glaciers and ice sheets in Polar and alpine regions are retreating in response to recent climate warming, exposing terrestrial ecosystems that have been locked under the ice for thousands of years. Exposed soils exhibit successional characteristics that can be characterised using a chronosequence approach. Decades of empirical research in glacier forefields has shown that soils are quickly colonised by microbes which drive biogeochemical cycling of elements and affect soil properties including nutrient concentrations, carbon fluxes and soil stability (Bradley et al, 2014). The characterisation of these soils is important for our understanding of the cycling of organic matter under extreme environmental and nutrient limiting conditions, and their potential contribution to global biogeochemical cycles. This is particularly important as these new areas will become more geographically expansive with continued ice retreat.

SHIMMER (Soil biogeocHemIcal Model of Microbial Ecosystem Response) (Bradley et al, 2015) is a new mathematical model that simulates biogeochemical and microbial dynamics in glacier forefields. The model captures, explores and predicts the growth of different microbial groups (classified by function), and the associated cycling of carbon, nitrogen and phosphorus along a chronosequence. SHIMMER improves typical soil model formulations by including explicit representation of microbial dynamics, and those processes which are shown to be important for glacier forefields. For example, we categorise microbial groups by function to represent the diversity of soil microbial communities, and include the different metabolic needs and physiological pathways of microbial organisms commonly found in glacier forefields (e.g. microbes derived from underneath the glacier, typical soil bacteria, and microbes that can fix atmospheric nitrogen and assimilate soil nitrogen). Here, we present data from a study where we integrated modelling using SHIMMER with empirical observations from chronosequences from the forefield of Midtre Lovénbreen, Svalbard (78˚N), to investigate the first 120 years of soil development.

We carried out an in depth analysis of the model dynamics and determined the most sensitive parameters. We then used laboratory measurements to derive values for those parameters: bacterial growth rate, growth efficiency and temperature dependency. By applying the model to the High-Arctic forefield and integrating the measured parameter values, we could refine the model and easily predict the rapid accumulation of microbial biomass that was observed in our field data. Furthermore, we show that the bacterial production is dominated by autotrophy (rather than heterotrophy). Heterotrophic production in young soils (0-20 years) is supported by labile substrate, whereas carbon stocks in older soils (60-120 years) are more refractory. Nitrogen fixing organisms are responsible for the initial accumulation of available nitrates in the soil. However, microbial processes alone do not explain the build-up of organic matter observed in the field data record. Consequently, the model infers that allochthonous deposition of organic material may play a significant contributory role that could accelerate or facilitate further microbial growth.

SHIMMER provides a quantitative evaluation on the dynamics of glacier forefield systems that have previously largely been explored through qualitative interpretation of datasets.

References

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