

Soil organic matter build-up during soil formation in glacier forelands around the world

Khedim N., Cécillon L., Poulenard J., Barré P., Baudin F., Marta S., Gielly L., Ambrosini R., Rabatel A., Dentant C., Cauvy S., Anthelme F., Tielidze L., Messenger E., Choler P., Ficetola F.



Since the last glacial maximum, soil formation due to the continued ice retreat has been a strong sink of carbon accumulating as soil organic matter (SOM). With global warming, the surface area of deglaciated forefields will strongly increase in the near future, leading to the emergence of new terrestrial ecosystems in many regions of the world. The fate of SOM accumulation in recently deglaciated environments remains largely unknown, either regarding the drivers of its carbon or nitrogen sequestration rates, or the biogeochemical stability of newly sequestered carbon.

This study aimed at identifying general patterns in SOM build-up during the initial stage of soil formation and ecosystem development (up to 500 years) in different glacier forefields around the world. Specifically, we tested two hypotheses (i) the net accumulation rate of SOM depends on climatic drivers, (ii) SOM accumulation on glacier forelands is accompanied by an overall decrease in its carbon stability. For this purpose, we measured total soil organic matter concentration (C and N), its stable isotopic composition (^{13}C , ^{15}N), and its distribution in carbon pools of different thermal stability using Rock-Eval[®] thermal analysis as indicators of its biogeochemical stability. We worked on ten soil chronosequences on glacier forefields (four Andeans, one Canadian Rockies, one Greenland, two Alps, one Caucasus, one Himalaya). We then tested the effect of soil age (time since barren soil exposure) and climatic variables (mean temperature of warmest quarter and precipitation of warmest quarter) on the build-up of SOM (total concentration, isotopic signature and distribution in carbon pools).

We found that the soil organic carbon accumulation was faster on glacier foreland experiencing warmer climates during summer. We also noted significant allochthonous carbon and nitrogen input, reflecting the presence of ancient carbon in the early stage of soil formation and nitrogen atmospheric deposition of anthropogenic origin in some glacier forelands, particularly in the northern hemisphere. The build-up of soil carbon pools also showed consistent trends across the soil chronosequences of the ten glacier forelands. During the first decades of soil formation, the very low SOM quantities were dominated by a very stable carbon pool with a small but significant labile carbon pool. This may highlight the presence of organic matter derived from ancient carbon on the different forefield glaciers, decomposed by an active

living trophic network of soil microorganisms. The overall stability of SOM then slowly decreased with time at all sites, reflecting the soil carbon input from plants and indicating that labile carbon contributes more than stable carbon to SOM sequestration during the initial stage of soil formation.

Figure: Generic trends in the biogeochemical signatures of soil organic matter (SOM) during its accumulation in recently deglaciated (up to 500 years) topsoils. (* not statistically correlated with soil age, ** not statistically correlated with SOC concentration, POC 1: small and highly thermolabile pyrolysable organic carbon pool characterized by Rock-Eval® thermal analysis using a Rock-Eval® 6 Turbo device (Vinci Technologies) corresponding to the carbon evacuated as CH, CO or CO₂ during a three minutes isotherm at 200°C during the pyrolysis phase, POC 2: intermediate pyrolysable organic carbon pool corresponding to the carbon evacuated as CH, CO or CO₂ during the temperature ramp of the pyrolysis phase between 200 and 650°C, ROC: organic carbon resistant to pyrolysis corresponding to the carbon evacuated during the oxidation phase, CH POC 1: proportion of carbon released as volatile hydrocarbon effluents (CH) for POC 1, CH POC 2 : proportion of carbon released as volatile hydrocarbon effluents for POC 2).

