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Impacts of early vegetation on biogeochemical cycles

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Lycophytes (club mosses) represent a distinct lineage of vascular plants with a long history including numerous extant and extinct species. They enriched the soil carbon pool through newly developed root-like structures and promoted soil microbial activity by providing organic matter. They enhanced soil carbon dioxide (CO_2) via root respiration and also modified soil hydrology. These effects had the potential to promote the dissolution of silicate minerals, thus intensifying silicate weathering. The weathering of silicate rocks is considered one of the most significant geo-chemical regulators of atmospheric CO_2 on a long (hundreds of thousands to millions of years) timescale. The motivation for this study is to achieve an increased understanding of the realized impacts of lycophytes on silicate weathering and past climate. To this end, it is necessary to quantify physiological characteristics, spatial distribution, the carbon balance, and hydrological impacts of early lycophytes. These properties, however, cannot be easily derived from proxies. Hence, as a first step, a process-based model is developed here to estimate net carbon uptake by these organisms at the local scale, considering key features such as root distribution, stomatal regulation of water loss, and root respiration.
The model features ranges of key physiological traits of lycophytes to predict the emerging characteristics of the lycophyte community under any given climate by implicitly simulating the process of selection. In this way, also extinct plant communities can be represented.
In addition to physiological properties, the model also simulates weathering rates using a simple limit-based approach and estimates the biotic enhancement of weathering by lycophytes. We run the Lycophyte model, called LYCOm, at seven sites encompassing various climate zones under today's climatic conditions. LYCOm is able to simulate realistic properties of lycophyte communities at the respective locations and estimates an average NPP ranging from 245 g carbon m^{-2} $year^{-1}$ in Costa Rica to 126 g carbon m^{-2} $year^{-1}$ in Estonia. Our limit-based weathering model predicts a chemical weathering rate ranging from 0.026 to 0.31 mm rock a^{-1} , thereby highlighting the potential importance of lycophytes at the local scale for enhancing chemical weathering. Our modeling study establishes a basis for assessing biotic enhancement of weathering by lycophytes at the global scale and also for the geological past.