Geophysical Research Abstracts
Vol. 21, EGU2019-4283, 2019
EGU General Assembly 2019

Biogeomorphic feedbacks between paraglacial adjustment and vegetation succession in Mueller glacier foreland, New Zealand

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Feedbacks between geomorphic and vegetation dynamics create spatial patterns of vegetation, soils and landforms in biogeomorphic ecosystems and determine their structure and functioning. In glacier forelands, it was shown that these biogeomorphic feedbacks link paraglacial adjustment and vegetation succession and control landscape development and stability over space and time (Eichel et al. 2016, 2018). However, the role of biogeomorphic feedbacks also depends on the environmental setting of the biogeomorphic ecosystem, e.g. on its geomorphic disturbance regime and the occurrence of ecosystem engineer species. In glacier forelands, previous research has primarily focussed on the European Alps and different environmental settings have not been comprehensively investigated yet.

Here, we explore the coupling between paraglacial adjustment and vegetation succession in the Southern Alps, New Zealand. In comparison to previously investigated glacier forelands in the European Alps, the selected foreland of Mueller Glacier is characterized by an extraordinarily high geomorphic activity due to high amounts of precipitation (∼4000 mm yr-1) and frequent storm events, a mostly continuous glacier wastage since the Little Ice Age maximum (1730/1735) and a mostly endemic flora. Our objectives are to (i) analyse linkages between paraglacial adjustment and vegetation succession in space and time, (ii) identify potential ecosystem engineer species, and (iii) determine the extent of biogeomorphic feedbacks and their role for landscape development and stability. To assess biogeomorphic feedbacks in space and time, we conducted a vegetation and environmental plot survey (55 plots) and created geomorphic and vegetation maps from field mapping, a UAV survey and deep learning algorithms (convolutional neural networks). Finally, we linked geomorphic and ecologic properties to the glacial chronology (Winkler, 2018).

Analyses of plot data, geomorphic and vegetation maps show that (i) paraglacial adjustment and vegetation succession are mostly independent from terrain age but depend on material properties and are interlinked in a biogeomorphic succession. (ii) Once geomorphic activity decreases, stable patches are created by the prostate/low growing shrub species Muehlenbeckia axillaris and Coriaria spp., which are therefore potential ecosystem engineer species that promote slope stabilization and facilitate further vegetation succession. (iii) Biogeomorphic feedbacks mostly occur on a local (patch) scale, large areas of the foreland are either dominated by unvegetated highly active slopes or dense late-successional vegetation. Yet, our results indicate that vegetation colonization and ecosystem engineering are important controls for landscape stabilization, which can take substantially longer than in the European Alps. In conclusion, our study shows that similar biogeomorphic feedbacks link paraglacial adjustment and vegetation succession in the European and the Southern Alps, but feedback strength and extent depend on environmental setting.

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