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Climate change effects on vegetation in Northeastern Siberian tundra - How does shrub growth relate to local climate and what are potential effects of shrub expansion on permafrost thawing?

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The Siberian tundra is one of the key permafrost regions in the Arctic because of its large spatial extent and carbon-rich yedoma soils. Changes in permafrost thaw and concomitant carbon losses to the atmosphere can have large impacts on the global climate. Permafrost thaw is believed to strongly increase this century as a result of predicted increasing air temperature. At the same time, Arctic vegetation growth and composition is predicted to respond to future climate change. Deciduous shrubs are expected to benefit most from climate warming by increasing growth and expanding their range to higher latitudes. Evidence for recent increases in deciduous shrub cover in the Arctic region is limited thus far to small areas in Alaska.

We examined if deciduous shrubs at our research site in the Indigirka lowlands, Northeastern Siberia, show a growth response to the main climate variables, temperature and precipitation. We constructed tree-ring width chronologies for two key Arctic deciduous shrub species, Betula nana and Salix pulchra, dating back roughly 60 years. The ring widths records are compared to summer-warmth index and summer-precipitation data from the closest climate station, approximately 30 km from our site in order to detect the climate factor that mainly determines shrub growth.

On a larger scale, recent increases in Arctic productivity, measured as Arctic greenness (Normalized Difference Vegetation Index, NDVI), suggest that shrubs may have expanded during the 80ies and 90ies of the last century. Spectral reflectance data of varying vegetation composition measured at the tundra site were reduced to NDVI to link up with long-term NDVI data. We used a multiple regression analysis to estimate how variation in NDVI is explained by plant fractional cover of different plant functional types (graminoids, deciduous shrubs, evergreen shrubs, forbs, mosses and lichens). Deciduous shrub cover was the only significant explanatory parameter in the model after parameter deletion and explained most of the variation in NDVI, with NDVI increasing with deciduous shrub cover. We used a monthly 25-year long AVHRR satellite leaf area index (LAI) record to analyze how the vegetation in our research area responded to changes in summer warmth index and summer precipitation. Both climate variables were found to have a significant positive effect on LAI.

Finally, we present experimental evidence from a shrub removal experiment that shrub cover is negatively correlated with active layer thickness through shading of the soil surface and significantly reduces ground heat fluxes. These results show that an expansion of deciduous shrubs may stabilize permafrost at least on the short term, even under increasing air temperature.