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Topographical Controls on Hillslope-Scale Hydrology Drive Shrub Distributions on the Seward Peninsula, Alaska

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Shrubs are expanding across the Arctic tundra in response to warming, and topography and landscape hydrology are key controls of the spatial distribution of vegetation changes. Observations have shown that shrub expansion is located mainly on hillslopes, although the processes through which topography controls shrub expansion remain unclear. To examine hydrological controls on shrub distributions, we applied a coupled transect version of a mechanistic ecosystem model (*ecosys*) at the NGEE-Arctic Kougarok Alaska hillslope site, which is underlain by impermeable permafrost. Modeled distributions of the dominant plant functional types and aboveground biomass across the hillslope agreed very well (R^2 >0.85) with measurements in 2016. Modeled differences in soil water content across the slope during the growing season were driven by variations in total soil water holding capacity and lateral water flow. In the well-drained upper slope position of the hillslope, plant N-uptake was modeled to be low from microbial water stress (and thus lower N mineralization), resulting in smaller modeled plant biomass. Intermediate soil moisture in the middle slope position enhanced mineralization and plant N uptake, and thus plant biomass. The gentle slope and deeper soil in the lower slope position resulted in saturated soil conditions, reduced root and microbial O_2 uptake, and thus lower biomass. A simulation ignoring topography (i.e., a flat landscape with the same soil properties, plant and microbial traits, and climate forcing) over- or under-estimated (depending on hillslope position) vegetation productivity. Overall, the mean shrub NPP across the transect was underestimated by 34% in the flat landscape compared to the realistic interconnected grids across the slope gradient. Our results indicate that land models that do not account for hillslope- scale surface and sub-surface flows of water, nutrients, and energy may not accurately predict plant distribution changes in Arctic ecosystems.