Climatic and Environmental Controls on Recent Arctic Tundra Shrubification

Zelalem Mekonnen,[1*] William Riley,[1] Logan Berner,[2] Nicholas Bouskill,[1] Margaret Torn,[1] Go Iwahana,[3] Amy Breen,[3] Isla Myers-Smith,[4] Mariana García Criado,[4] Yanlan Liu,[1] Eugénie Euskirchen,[3] Scott Goetz,[2] Michelle Mack,[5] Robert Grant,[6] Verity Salmon,[7] Colleen Iversen,[7] Sébastien Biraud,[1] and Mark Lara[8]

[1]Lawrence Berkeley National Laboratory, Berkeley, CA;
[2]Northern Arizona University, Flagstaff, AZ;
[3]University of Alaska Fairbanks, Fairbanks;
[4]University of Edinburgh, Edinburgh, United Kingdom;
[5]Northern Arizona University, Flagstaff, AZ;
[6]University of Alberta, Edmonton, Canada;
[7]Oak Ridge National Laboratory, Oak Ridge, TN;
[8]University of Illinois, Urbana, IL

Contact: (zemekonnen@lbl.gov)
BER Program: ESS
Project: NGEE Arctic
Project Website: https://ngee-arctic.ornl.gov

Vegetation composition shifts, and in particular, shrub expansion across the Arctic tundra are some of the most important and widely observed responses of high-latitude ecosystems to rapid climate warming. These changes in vegetation potentially alter ecosystem carbon balances by affecting a complex set of soil–plant–atmosphere interactions. We synthesized the literature and found that shrub expansion is affected by several interacting factors including climate warming, accelerated nutrient cycling, changing disturbance regimes, and local variation in topography and hydrology. Under warmer conditions, tall deciduous shrubs can be more competitive than other plant functional types in tundra ecosystems because of their taller maximum canopy heights and often dense canopy structure. We also examined the role topography plays in determining shrub expansion by applying a coupled transect version of a mechanistic ecosystem model (*ecosys*) in a tundra hillslope site across the Kougarok watershed, Alaska. We found that intermediate soil water content in the mid-slope position enhanced mineralization and plant N uptake, thereby increasing shrub biomass. A simulation that removed topographical interconnectivity between grid cells resulted in (1) a 28% underestimate of mean shrub biomass and (2) over or underestimated shrub productivity at the various hillslope positions. Our results indicate that land models need to account for differences in plant traits that control competition and hillslope-scale coupled surface and subsurface hydrology to accurately predict current shrub distributions and future trajectories in Arctic ecosystems.