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Drought-triggered conifer stands decline and mortality in Siberia

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"Dark needle conifers" [DNC: Siberian pine (Pinus sibirica), fir (Abies sibirica), and spruce (Picea obovata)] decline and mortality was documented widespread Russia. Here we analyzed patterns (spatial and temporal) and causes of Siberian pine and fir decline and mortality in southern Siberian Mountains. Analysis was based on satellite (Landsat, MODIS), on-ground and dendrochronology data, climate variables and GIS technique. Climate variables studied included air temperature, precipitation, number of days with late frosts, relative air humidity, vapor pressure deficit, and drought index (SPEI, the Standardized Precipitation-Evapotranspiration index). Tree mortality began at elevations on shaped hilltops and steep south facing slopes, shifting with time to lower elevations with gentle slopes. Maximum mortality was within steep south (15°–25°) facing slopes and convex terrain elements, i.e. within terrain elements with a maximal water stress risk. Dendrochronology data showed that Siberian pine and fir mortality occurred after consecutive droughts during last decades. Tree ring widths were positively correlated with relative humidity and negatively with a drought index, vapor pressure deficit and occurrence of late frosts. The area of dead stands was correlated with increased drought. The uphill margin of mortality was limited by elevational precipitation gradients.

A significant impact of previous year growth conditions on the current ring width was found. That effect was attributed to drought-induced trees sensitization to bark beetles and fungy impact. Regeneration survived drought and showed a growth release while the upper canopy declined. Results obtained showed a primary role of water stress in Siberian pine and fir mortality with a secondary role of biotic impact.

At geographical scale fir and Siberian pine mortality were observed within southern parts of areal. Mortality began on the margins DNC-dominated stands within forest-steppe or conifer-broadleaf ecotones. Within closed DNC stands mortality was located within relief features with a highest water stress risk.

Meanwhile if model projections of increased aridity are correct DNC within the southern part of its areal will be replaced by drought-resistant species (e.g., Pinus silvestris and Larix sibirica). The observed Siberian pine and fir mortality is part of a broader phenomenon of DNC decline and mortality in European Russia, Belarus, Siberia, and the Russian Far East. Throughout Russia DNC mortality locations coincided with areas where drought index increase was observed.