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Severe drought greatly reduces sap flux and recovery ability of mature Mongolian Scots pines (Pinus sylvestris var. mongolica) in a semi-arid sandy environment

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Trees in water-limited ecosystems are often face to the significant challenges of drought due to the low level as well as high seasonal variation of precipitation. However, the knowledge on how and to what extent the trees adapt to the fragile environment is limited, particularly in semi-arid sandy area. In this study, sap flux densities (Js) of mature Mongolian Scots pine (Pinus sylvestris var. mongolica, MSP) trees planted in sandy land were measured successively in a 4-year period with a high difference in annual rainfall between years, and up-scaled to daily transpiration at plot-level (Ts). The results clearly showed the great fluctuation of Ts varied synchronously with dry-wet cycles of soil moisture induced by the erratic rainfall pattern, and the continuous decline in non-, mild-, moderate-, and severe drought during the study period. As a result, the ratio of sap flux to reference evapotranspiration (Ts / ET0) in sunny days showed a negative linear relationship with the severity of drought in upper soil layer (0 - 1 m) ($P < 0.01$). the monthly mean Ts / ET0 over the period also declined with the progressive reducing of groundwater table (gw) ($P < 0.01$). The decrease of Ts induced by erratic drought during the growing season got recovery by the coming rainfall, however, this recovery ability failed even after the severe and long-term drought removed. We concluded that the upper soil layer (0 - 1 m) contributed the most water use of MSP during a growing season. The severity and duration of drought from this layer induced greatly reduction of Ts. Nevertheless, groundwater table determined whether the total recovery of sap flux while soil drought removed can be reached. The results provided practical information for optimizing MSP's management to prevent the developing of degradation, e.g. by reducing irrigated farmland area greatly to prevent groundwater from exploiting unsustainably to cope with climate change in this ecologically fragile zone.