Divergent responses of ecosystem water-use efficiency to extreme droughts over Northern Eurasia

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Water, as one of the most basic environmental factors of terrestrial ecosystems, is of significant importance for the thermal acclimation and metabolism of terrestrial vegetation. Water availability is a major limitation to the distribution and productivity of terrestrial vegetation. At the ecosystem scale, water-use efficiency (WUE) is generally defined as the ratio of annual gross primary productivity (GPP) and annual evapotranspiration (ET). It indicates the coupling of the carbon and water gross fluxes exchanged between ecosystem and the atmosphere, and monitors the adaptability of an ecosystem to variable climate conditions. Previous researches have concluded a significant positive trend in WUE in most areas of terrestrial ecosystems over the globe, as a result of the increasing CO_2 concentration and climate change during the past several decades. At the same time, extreme climatic events, such as heat waves, drought etc., occurred across the globe. These changes have likely altered the ecological functioning of terrestrial ecosystems, as well as the structure of plant communities. Nevertheless, how terrestrial ecosystem WUE responds to extreme climatic events is still poorly understood.

In this study, we examine the impacts of extreme drought events on ecosystem WUE during 1948-2008, with a particular focus on distinguishing response of different biomes over Northern Eurasia. The responses of ecosystem WUE to extreme droughts differed among different regions. For northern high latitudes (north of 50˚N), hot days and increasing solar radiation were usually concurrent with droughts, which to some extent eliminate the limitations of low temperature and insufficient light on photosynthesis. In this case, vegetation productivity was potentially enhanced, with higher ecosystem WUE during drought years than during normal years. By contrast, for biomes in relatively arid climate conditions, extreme drought years tended to aggravate the water stress for vegetation growth. Consequently, in these regions, vegetation photosynthesis was largely suppressed with significantly lower ecosystem WUE observed. Our results, therefore, highlight that background climate is a crucial factor determining drought impacts on terrestrial carbon-water interactions. Further increases in baseline aridity could therefore exacerbate the impact of punctuated droughts on terrestrial ecosystems.

Keywords: water-use efficiency, droughts, terrestrial ecosystems

