DROUGHT EFFECTS ON MULTI-SCALE WATER USE AND ECOSYSTEM CARBON EXCHANGE IN A DESERT ECOSYSTEM

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学 位 論 文 要 旨

Abstract of Doctoral Thesis

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論文題目：マルチスケールでの砂漠生態系における水利用及び生態系炭素交換に対する干ばつの影響

Title of Thesis：Drought effects on multi-scale water use and ecosystem carbon exchange in a desert ecosystem

論文要旨：

Abstract：

Drought is an important factor markedly influencing biotic and abiotic processes and then have considerable effects on ecosystem key material and energy processes, such as water and carbon cycles over a wide region on the earth terrestrial surface. In arid and semi-arid lands, drought effects on ecosystem are more obvious even decisive. In the current study, drought effects on crucial water and carbon processes of typical desert ecosystem are examined at various scales based mainly on four-year field measurement via sap flow and gas exchange flux techniques. The studied ecosystem is dominated by a desert shrub, *Haloxylon ammodendron* and locates on the southern edge of Gurbantünggüt desert in Northwest China and Central Asia.

Transpiration per leaf area and stomatal conductance for water vapor at leaf, branch and whole plant scales and their response to air drought (atmosphere vapor pressure deficit, VPD) and other climate factors are compared in chapter 2. Daytime average transpiration and stomatal conductance at leaf scale were higher than that at branch and whole plant scales. High level of transpiration at leaf and branch scales appeared proximately at midday time while that of whole plant scale appeared at morning time, inducing reduced transpiration in 79% of daytime. Transpiration at the three scales showed similar response to photosynthesis photon flux density (PPFD), increasing with enhanced PPFD at low light condition and nearly saturating under high-level PPFD. Similarly, transpiration at three scales linearly increased with increasing VPD. Under high VPD, however, leaf- and branch-scale transpiration nearly saturated while that of whole plant-scale declined with increasing VPD. For stomatal conductance, its sensitivity to VPD (m/G_{sref}) decreased continually from 0.52 at whole plant scale to 0.35 at leaf scale. This showed that whole-plant average stomata was more sensitive to air drought and had more conservative water use strategy protecting whole plant water

homeostasis compared with that at leaf and branch scales. The different magnitude of transpiration, stomatal conductance and their response to air drought could be only explained by canopy patchiness, which could reduce whole plant water loss and allow partial assimilation by part of the canopy under drought, which was considered as one of the key mechanisms to balance water loss and carbon acquisition at whole plant scale.

Canopy-scale transpiration and stomatal conductance for water vapor and their response to air drought (VPD) and soil drought (volumetric soil water content, SWC) are examined in chapter 3 during the second half of growing season, when annual prolonged drought occurs. When SWC was less than 3%, canopy transpiration linearly increased with increasing PPFD and VPD in each year and the sensitivity of canopy transpiration to VPD (defined as the slope of linear regression between them, K) increased linearly with increasing SWC. At the same time, stomatal sensitivity to VPD (m/G_{sref}) decreased linearly from 0.52 to 0.35 with increasing annual average SWC, inducing a transfer from a more anisohydric to a more isohydric stomatal behavior with increasing soil drought. When SWC decreased less than 3%, canopy transpiration had no response to SWC, while the sensitivity to VPD of canopy transpiration and canopy stomatal conductance were higher and lower than that in the driest year when SWC larger than 3%, respectively. This results pointed out that 3% was the soil drought threshold for normal survival of *H. ammodendron*, below which this plant lost the ability in stomatal regulation on water loss and suffered the high risk of mortality. The flexibility of stomatal behavior to soil drought was one key strategy facilitating the survival of *H. ammodendron* in such an extreme dry environment and making a balance between maximizing carbon production when soil moisture was attractable and keeping hydraulic security when soil moisture was more limited.

Chapter 4 introduces the soil drought effects on key processes of water and carbon cycles at ecosystem scale in the studied desert ecosystem. At last, whether ecosystem evaporative fraction (EF) can be used as a proxy of drought to trance soil drought effects on ecosystem assimilation and respiration in desert ecosystem is also tested. Both ecosystem GPP and R_{eco} showed positive linear correlation with SWC, however, the sensitivity of GPP to SWC was 3.8 times higher than that of R_{eco} during the entire growing season. As a result, ecosystem carbon sequestration capacity decreased under soil drought. At intra-annual scale, significant correlation between GPP and SWC was found only in spring while that between R_{eco} and SWC was found in all growing seasons and the sensitivity increased continually from spring to autumn. Ecosystem water use efficiency of gross carbon uptake (WUE) showed a weak correlation with SWC. Similarly, EF also had weak correlation with SWC and explained only 2% and 5% of variation of GPP and R_{eco}, respectively. Hence, EF was not a good proxy of soil drought and failed to trance the response of GPP and R_{eco} to soil drought, indicating energy partitioning was not tightly coupled with ecosystem carbon exchanges in this desert ecosystem.