Journal of Hydrology 373 (2009) 426–435

Contents lists available at ScienceDirect

Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol

Energy balance and water use in a subtropical karst woodland on the Edwards Plateau, Texas

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ARTICLE INFO

Article history:
Received 20 May 2008
Received in revised form 1 May 2009
Accepted 4 May 2009

This manuscript was handled by P. Baveye, Editor-in-Chief, with the assistance of Michel Bakalowicz, Associate Editor

Keywords:
Aquifer recharge
Evapotranspiration
Energy balance
Ecohydrology
Karst
Deep roots

SUMMARY

Woody encroachment into karst grasslands and savannas is presumed to reduce water availability and aquifer recharge, in part, because deep roots extract large quantities of water from perennial sources within the fractured bedrock underlying shallow soils. If true, energy balance partitioning and transpiration in woody ecosystems should be decoupled to an extent from rainfall, and sensitivity of the energy balance and evapotranspiration (ET) to rainfall and water deficits should be dampened. We evaluated responses of energy and water vapor fluxes to rainfall and water deficits in a live oak (*Quercus virginiana*)-Ashe juniper (*Juniperus ashei*) woodland on the karst Edwards Plateau, TX, USA, over a 2-year period using eddy covariance measurements of the turbulent fluxes. Total ET during the two years was 1416 mm, 92% of total rainfall. We observed large and rapid reductions in λE and increases in H during drying cycles, and high correlation between ET and soil water content in the upper 20 cm of the root zone. In most cases, ET declined at the same time as soil water content, indicating that the woodland relied heavily on water from recent rainfall events, rather than antecedent water. We found no evidence that deep roots were extracting significant amounts of water from a perennially stable supply of water. Excavations at the woodland site revealed a rock layer at 20 cm below the soil surface, with a dense root mat above the rock and penetration of relatively few roots into the rock through cracks and fissures. Thus, the most likely sources of water for trees were soil water and a limited supply of water stored in near-surface fractured rock layers.

Introduction

Woody plant encroachment into arid and semi-arid grasslands and savannas is occurring worldwide (Archer et al., 2001; Van Auken, 2000), with potentially significant consequences for hydrology and biogeochemical cycling (Houghton et al., 1999; Baldocchi et al., 2004; Engel et al., 2005). The hydrologic impact of woody encroachment is particularly worrisome in karst landscapes because karst aquifers provide 25% of freshwater supplies for human consumption worldwide and 40% in the US (White et al., 1995). Karsts are landscapes formed from dissolution of soluble rocks, mainly limestone and dolomite. They generally have well-developed underground drainage systems, and strong interactions between surface and groundwater flow (Bonacci et al., 2009).

There is a wide-spread perception that woody encroachment, especially in karst landscapes, has significant negative effects on water yield (e.g. Tennesen, 2008). However, reality may be more complicated. A conceptual model by Huxman et al. (2005) laid out criteria for impacts of woody encroachment on water yield. According to this framework, a reduction in streamflow is predicted in semi-arid uplands only if there is potential for rapid subsurface flow. Even though this condition may be characteristic of karst, it is by no means ubiquitous (Wilcox et al., 2005; Schwinning, 2008). For example, in the stepped landform of the Edwards Plateau largely unbroken rock layers close to the surface all but prevent downward fracture flow and deep root formation (Wilcox et al., 2007).

To date, perceptions of woodland ecohydrology on the Edwards Plateau have been shaped by studies conducted in the fault zone of the Balcones Escarpment. In this narrow zone along the eastern edge of the Edwards Plateau, roots of Ashe juniper (*Juniperus ashei* Buckholtz) and live oak (*Quercus virginiana* Miller) were observed in caves to depths of 9 m and 22 m, respectively, tapping into perched water tables (Jackson et al., 1999). Because these deep roots of juniper and oak have larger xylem conduit diameters and hydraulic conductances than shallow roots, they can contribute disproportionally more to water use if they encounter significant sources of water at depth (McElrone et al., 2004). Indeed, Jackson et al. (2000) found that water from depths greater than

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doi:10.1016/j.jhydrol.2009.05.007