Water Balance Controls on Vegetation Productivity Across the Climatic Gradients of the Central United States

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Abstract. In the subtropics and midlatitudes, water is the most important abiotic control on terrestrial plant productivity. In this paper, the soil-water balance and plant water use are examined over a domain encompassing the central United States using a statistical-dynamical ecohydrology model (SDEM). The seasonality in the model and its incorporation of a two-component canopy model allow for application and testing of the hypothesis that vegetation density, in the form of peak green leaf area index (LAI), is maximized, within upper and lower bounds, such that, in an average season, soil moisture in the latter half of the growing season just reaches the point at which water stress is experienced. Another key feature of the SDEM is that it partitions evapotranspiration into transpiration, evaporation from canopy interception, and evaporation from the soil surface. That partitioning is significant for the soil-water balance because the dynamics of the three processes are very different. The partitioning and the model-maximized LAI are validated based on observations in the literature, as well as through the calculation of water-use efficiencies with modeled transpiration and large-scale estimates of vegetation productivity. Modeled-maximized LAI are seen to be at least as accurate as the unaltered satellite-based observations on which they are based. Surprising little dependence on climate and vegetation type is found for the percentage of total evapotranspiration that is soil evaporation, with most of the variation across the study region attributable to soil texture and the resultant differences in vegetation density. The implication is that the higher (lower) soil moisture content in wet (dry) climates is more-or-less offset by the greater (lesser) vegetation density. Finally, analysis of the sensitivity of maximized LAI to soil texture shows that the model is able to reproduce the so-called “inverse texture effect”, which consists of the observation that natural vegetation in dry climates tends to be most productive in sandy soils despite their low water holding capacity.