Quantifying Plant Water Use on Rangelands Through Soil Water Modeling

Xuejun Dong, Bob Patton, Anne Nyren and Paul Nyren
NDSU –Central Grasslands Research Extension Center, Streeter, ND 58483

To quantify the amount of water used by plants, which is proportional to biomass production, we need an understanding of the factors in the soil-plant-atmosphere system that control plant transpiration. In particular, we need a detailed accounting of soil water dynamics, upon which an understanding of many other ecosystem processes, such as photosynthesis and carbon sequestration, is hinged.

In our study of native grasslands at CGREC, we incorporated our field measurements of soil water content, soil hydrologic parameters and leaf area index into a computer model of soil water flow. The model "Austere-layered" by Warrick (2003) was modified and extended to simulate the water budget of a 10–foot deep soil column over 111 days from May 14 to September 1, 2009. Plant growth was assumed to start on April 15 and reach a maximum on July 15. The soil water content measured on the first day (May 14) was interpolated and used as the initial water profile. The space step of the model is one-inch of soil depth and the time step is 100 seconds. The model considers rainfall infiltration and redistribution, plant root water extraction, deep drainage and soil surface evaporation. Equations for soil water flow were borrowed from literature on drainage and irrigation engineering and have been extensively tested on various soils. However, two parameters describing maximum rooting depth and root distribution were estimated using soil moisture data measured at CGREC, as well as based on literature data.

Two field sites were tested: one had been subjected to long-term moderate grazing and the other heavy grazing for 17 years before they were fenced to exclude grazing in 2006 for a soil respiration and carbon sequestration study. The fenced sites were clipped manually one to two times a year to simulate moderate and heavy grazing, respectively (Figure 1). The reason for using few but heavy clippings is to better estimate the amount of forage removed by the clipping. We can see the marked exponential leaf area growth in the moderate site in June (Figure 1).

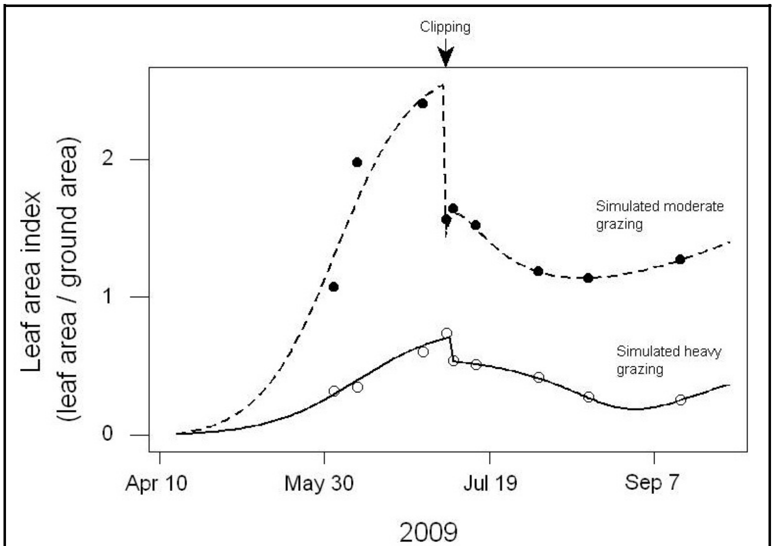


Figure 1. Seasonal dynamics of leaf area index on simulated moderately and heavily grazed sites at CGREC in 2009.

From simulated evaporation and transpiration (Figure 2), we see that, during the first week of simulation when leaf area index was low, evaporation was dominant over transpiration on both sites. After that, the trend was sustained only on the heavy site but reversed on the moderate site. The heavy clipping in early July promoted a rapid increase in evaporation from both sites. The most rapid root growth of ½ in. per day was predicted during the rapid leaf area growth period (data not shown). The maximum rooting depths for the moderate and heavy sites were determined as 4.8 ft. and 2.7 ft., respectively (Figure 3). The model gives a strong exponential root distribution on the moderate site, but gives a more or less uniform distribution on the heavy site. On the moderate site, the growing drying front in the upper 2 ft. of the soil profile limited root water extraction, but plants were able to reach deeper to compensate (Figure 3). On the heavy site, although root water extraction was only slightly limited by drought, the majority of the solar energy was lost through evaporation due to a much lower leaf area index.

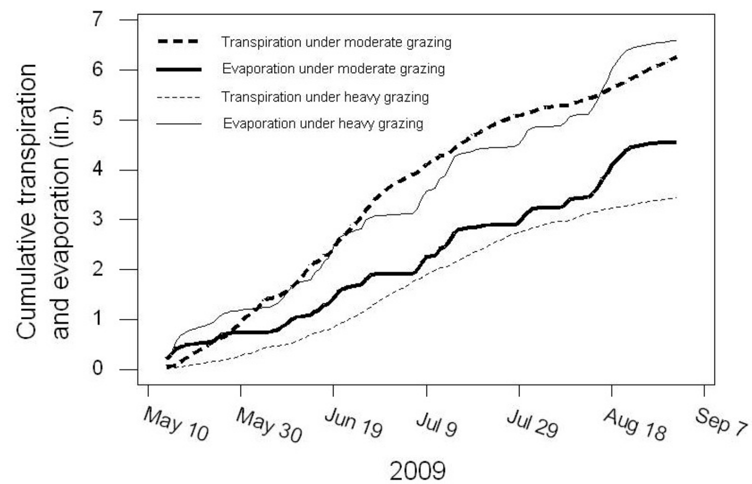


Figure 2. Cumulative transpiration and soil evaporation on simulated moderately and heavily grazed sites at CGREC in 2009.

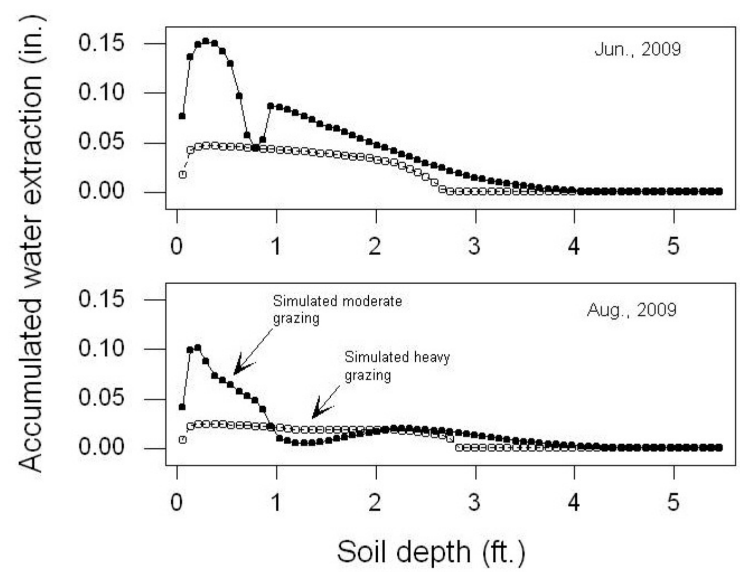
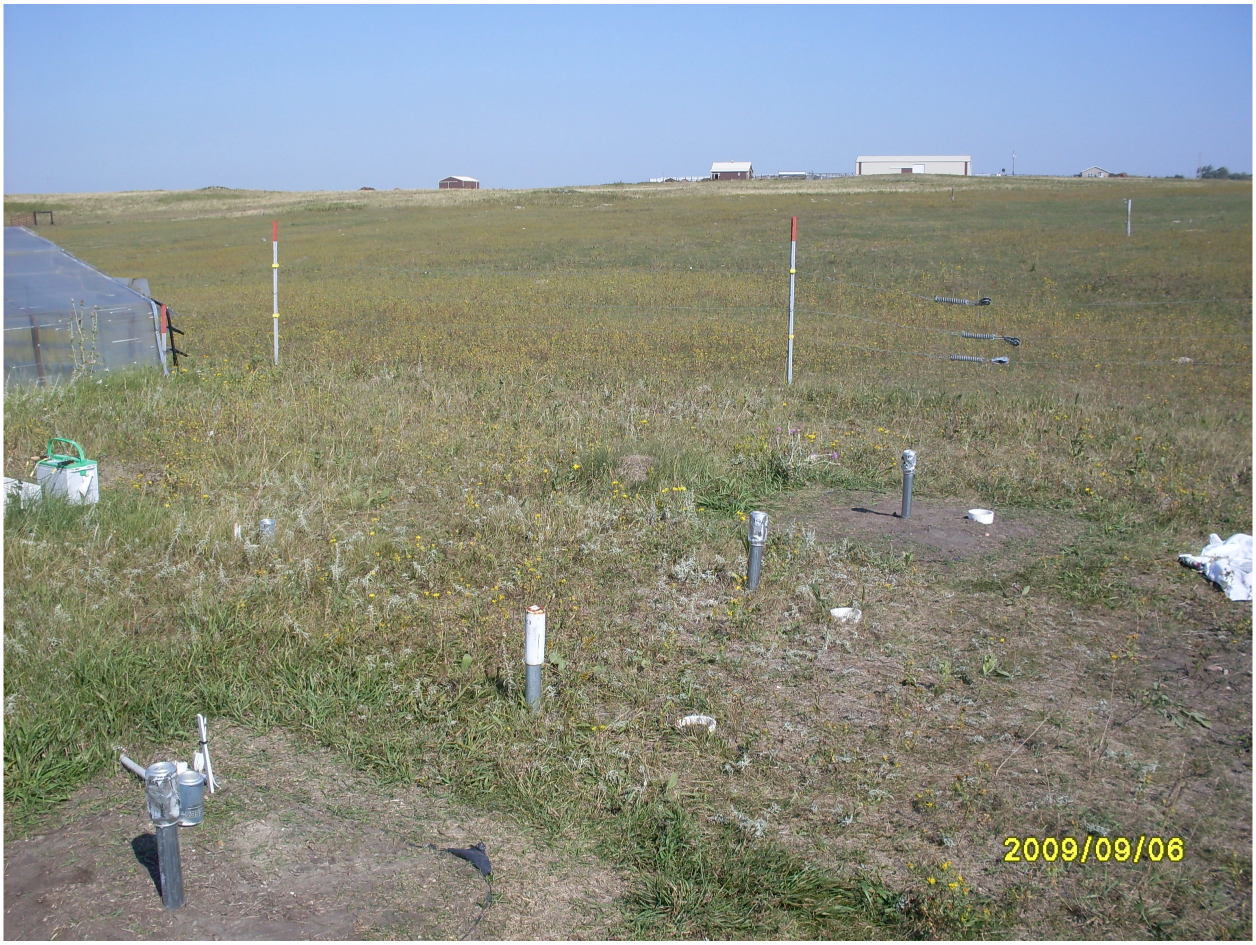


Figure 3. Accumulated water extraction by plant roots from each inch of soil of sites at CGREC during June and August of 2009.

This research shows that if we make good use of the most recent developments of soil water modeling (especially concerning dynamic root growth and non-uniform root distribution), we can predict soil water dynamics quite accurately based on limited field data, which is very common in reality. In grazing management, it is a challenging task to control the levels of use so as to keep a balanced "interplay" between maximizing forage production and conserving soil water. Computer modeling provides an opportunity for us to visualize these complex interactions.



Study site on a heavily grazed pasture.