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Water footprints of cellulosic bioenergy crops: Implications for production on marginal lands

M.Z. Hussain[1,2], S.K. Hamilton[1,2,3*], A.K. Bhardwaj[1,2,4], B. Basso[1,5], M. Abraha[2,6], and G.P. Robertson[1,2,7]

Introduction

Soil water availability is a limiting factor for crop evapotranspiration (ET) and photosynthesis. Limited water availability can reduce crop productivity, even in relatively humid climates.

Perennial crops will become increasingly important biofuel feedstocks, and will often be grown on marginal lands with lower water availability.

We need information on how these crops compare in ET and water use efficiency (WUE) for biofuel production compared to traditional row crops, and particularly corn (maize).

Recent studies have assumed substantially higher water use by perennial grass cropping systems than by corn in the humid temperate climate of the Midwest US (e.g., Le et al. 2011 PNAS).

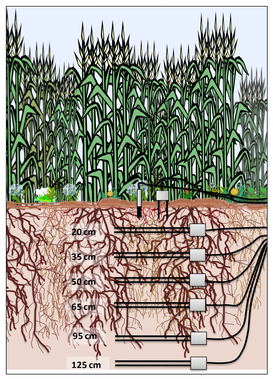
Objectives and methods

Our objective was to compare ET and WUE for biomass and biofuel production in five perennial cropping systems—**switchgrass, *Miscanthus*, a native grass mixture, a native prairie, and hybrid poplar**—as well as **corn (maize),** all rain-fed cropping systems on well-drained loam soils.

We monitored temporal changes in root-zone soil moisture in these cropping systems over four years at the Great Lakes Bioenergy Research Center's (GLBRC) sustainability research site in southwestern Michigan, U.S.A.

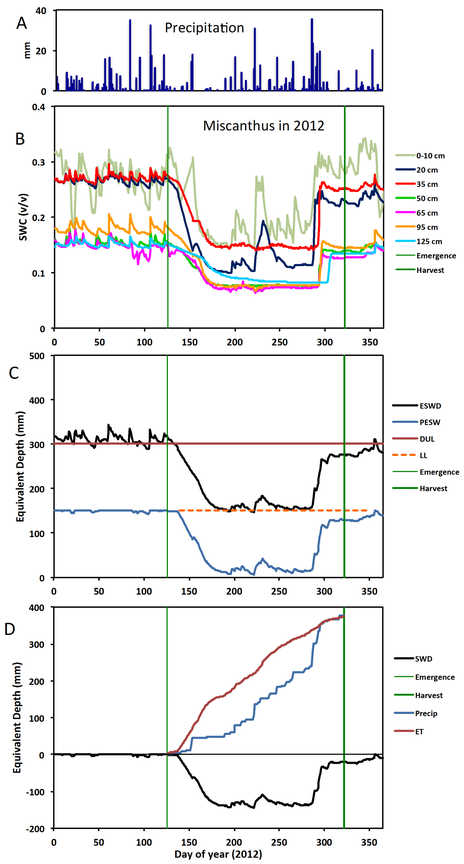
- Time domain reflectometry (TDR) probes monitored soil water content at multiple depths (**Figure 1**)
- The seasonal drawdown of soil water provided an indication of crop water use
- The SALUS crop model estimated ET when soils remained wet by coincident rainfall

FIG. 1



Results

FIG. 2



An example of soil water data and calculations is in **Figure 2** above, where ESWD = equivalent soil water depth; PESW = plant-extractable soil water; DUL = drained upper limit; LL = lower limit of PESW; SWD = soil water deficit.

Full results are shown in **Figure 3**. Three of the four years had normal rainfall, but 2012 had a severe summer drought (Fig. 3A; blue shows growing-season rainfall and gray shows total).

Water use by the perennial systems was not greatly different from corn. Corn grain and stover are indicated by gold and green, respectively. Crops used from ~half to nearly all of the available water (**Figure 4**).

Water use efficiency for biomass and for ethanol production was variable, dictated mostly by variation in biomass and harvest yield.

FIG. 3

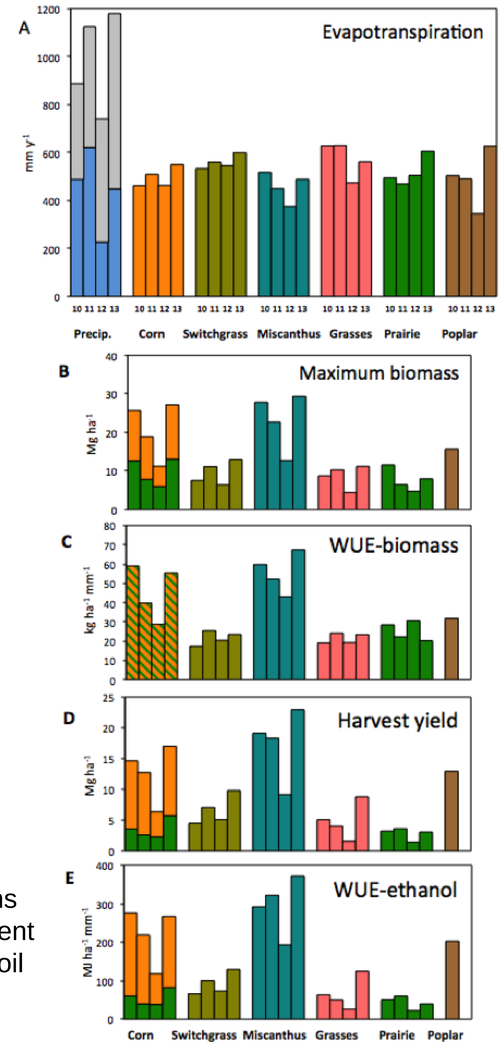
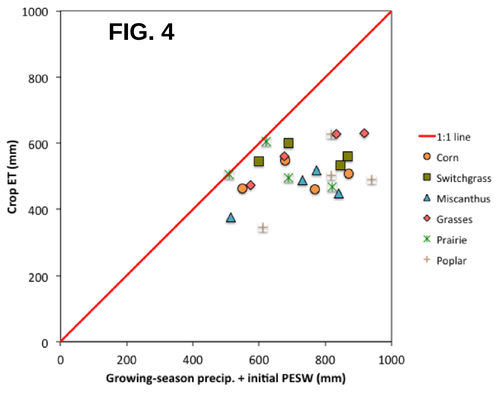


FIG. 4



Discussion

Water use

These observations of water use over years of highly variable growing-season rainfall suggest relatively consistent water use except in 2012, the severe drought year.

These findings contrast with the watershed water balance (Hamilton poster 807), which suggests that vegetation ET (mixture of cropland and unmanaged) scales proportionately with total precipitation across years.

Water use efficiency

Miscanthus had the highest WUE for biomass and ethanol production, followed by corn, whereas the native grass and prairie systems had relatively low WUEs; poplar was intermediate.

Maximum biomass and harvest efficiency largely determined differences in WUE, rather than water use.

Conclusions

The primary conclusion of this study—that **perennial biofuel crops do not use more water than corn** across years of either abundant or very limited water availability—contrasts with earlier modeling studies and implies that rain-fed perennial biomass crops will not greatly alter landscape water balances.

Author affiliations:

[1] W.K. Kellogg Biological Station, Michigan State University, Hickory Corners, MI 49060
[2] Great Lakes Bioenergy Research Center, Michigan State University, East Lansing, MI 48824
[3] Department of Zoology, Michigan State University, East Lansing, MI 48824
[4] Current address: Central Soil Salinity Research Institute, Indian Council of Agricultural Research, Karnal, Haryana 132001 India
[5] Department of Geological Sciences, Michigan State University, East Lansing, MI 48824
[6] Department of Geography, Michigan State University, East Lansing, MI 48824
[7] Department of Plant, Soil, and Microbial Sciences, Michigan State University, East Lansing, MI 48824

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