1) Problem/Research Objectives

Increasing energy demands and concerns about climate change and fossil fuel depletion has led to an interest in alternative energy systems. Bio-fuel demand may increase in the future. Bio-fuel can be produced from food grain or from non-grain plant biomass. There are potential problems associated with converting plants into bio-fuel. One potential problem is the competition between food demand and energy demand. Another potential problem is that use of plant residues of annual crops may lead to accelerated soil erosion and environmental risk. Compared to annual row crops, perennial vegetation, such as prairie, may have some desirable qualities for use as a bio-energy crop. However, a landscape conversion to perennial vegetation under a climate change background may significantly influence regional hydrology and nutrient dynamics. Thus, the main problem addressed in this project is to quantify field hydrology, including water balance and water use by evapotranspiration, ET, of annual row crops, corn and soybean, and a perennial mixed prairie.

Specific objectives of this research project are as follows:

- To measure and contrast dynamic soil water storage, drainage and evapotranspiration in reconstructed mixed prairie and no-till corn and soybean cropping systems.
- To understand the relation between field water balance components and off-site water quality impacts of alternative cropping systems and management strategies.
- To use field data to evaluate and improve a crop hydrological and water quality model, and then use the model to predict implications of land use conversion on water quality and quantity for a variety of selected cropping systems, soils, and climatic conditions.

2) Methodology

**Plant Canopy ET-Chamber Design and Construction:**

Portable, dynamic canopy chambers will be used to measure ET from the different cropping systems. The chambers avoid microclimate restrictions and are usable in small scale plots where eddy covariance and Bowen ratio methods are not suitable.

The portable, dynamic canopy chambers were constructed of aluminum frame covered with Mylar film to allow radiation to enter. Three different size chambers were constructed: small, medium and large, to fit over plants at different crop growing stages. The chamber sizes are shown in Table 1.
Table 1. Chamber Sizes

<table>
<thead>
<tr>
<th></th>
<th>Length (m)</th>
<th>Width (m)</th>
<th>Height (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>1.52</td>
<td>1.00</td>
<td>0.61</td>
</tr>
<tr>
<td>Medium</td>
<td>1.52</td>
<td>1.00</td>
<td>0.95</td>
</tr>
<tr>
<td>Large</td>
<td>1.52</td>
<td>1.00</td>
<td>1.56</td>
</tr>
</tbody>
</table>

The sensors installed in the chamber are LI-7500 gas analyzer. It is used to measure vapor concentration and carbon dioxide concentration varies with time. The device makes 20 measurements per second. Each measurement sequence lasted for one minute, so each time the chamber was used 1200 data points were collected to calculate the ET flux and the net carbon dioxide flux. This project focuses on the measured ET-fluxes.

Installed both inside and outside of the chamber are thermocouples which measure the air temperature, barometers which measure the air pressure, infrared thermometers which measure the plant temperature, and quantum sensors which measure the solar irradiance. These sensors are used to document that there are similar ambient conditions inside and outside of the chamber. A CR 3000 datalogger is connected to chamber sensors in order to record the data. Chamber are shown in Fig. 1.
Sampling Protocol:

The Comparison of Biofuel Systems (COBS) research site near Ames, Iowa was the field study site. It was established in 2008. There are 24 plots with 6 cropping systems. The research focus on corn in corn-soybean rotation, soybean in corn-soybean rotation and continuous prairie unfertilized system. Fig. 2 shows the COBS research site.

In order to determine the water storage, five TE sensors (FDR sensor, Decagon Devices Inc.) are installed at different depths 5 cm, 10 cm, 18 cm, 30 cm, and 50 cm in each plot. The sensors are used to monitor soil water content and soil temperature throughout the growing season. Drainage and rainfall data are collected and used to calculate plot water balances.

In 2013, chamber measurements of maximum and average ET fluxes were made on 16 selected sunny days. Diurnal ET flux measurements were made on 2 sunny days (DOY 168, DOY 241).

Data Analysis

The chambers were manually positioned over the crops for a minimum amount of time to collect accurate flux measurements (60 seconds). Then chambers were removed to minimize chamber effects on light, wind speed, and air/leaf temperature. The CR 3000 recorded the vapor concentration and carbon dioxide concentration with time. Theoretically, those concentrations should increase linearly, and ET can be determined from the slope of the line. We used an adaptive linear regression algorithm to calculate the slope of the linear trend and get the ET flux and carbon dioxide emission flux for each measurement period.
The chamber approach allows repeated measurements at multiple locations within the plot area, and the daily maximum and average ET flux can be determined. For diurnal measurements, a Fourier series is used to describe the trend of the diurnal evapotranspiration measurements.

Weather data were collected at the COBS site weather station. The Priestley-Taylor Equation used the weather station measurements to calculate potential evaporation at the site.

Plot water balance for each cropping system was calculated with the measured soil water contents, drainage, and rainfall. Rainfall was the input, water content change was change in storage, and the outputs were drainage and ET. Using plot measurements, ET was calculated as the residual. The water balance ET measurements were compared with the chamber ET measurements, and the measured ET values were compared with the potential ET calculations.

3) Principal Findings and Significance

ET-Chamber Measured Flux

Figure 3 provides one example of the ET-chamber measured water vapor concentrations with time. Indeed, the chamber provided data with a strong linear trend, and it was easy to calculate ET fluxes.

![Fig. 3 ET-chamber measured water vapor concentrations with time.](image)

ET-Chamber Measured Diurnal Fluxes in the Cropping Systems

Comparison of the diurnal ET fluxes among the three cropping systems showed that corn exhibited larger ET fluxes than soybean and prairie, and prairie had larger ET fluxes than soybean. The diurnal ET-curves in Fig. 4 contain flat tops, which may be...
due to dry soil conditions. The dry soil conditions in 2013 limited actual ET in the cropping systems.

Fig. 4 Chamber measured diurnal ET fluxes in the cropping systems.

Seasonal Chamber ET, Water Balance ET, and Potential ET

Comparison of seasonal ET fluxes (chamber method and water balance method) with potential ET (Priestley-Taylor Equation) showed that for the 2013 dry growing season, the potential ET was larger than the actual ET due to limitations in the available soil water.

The water balance ET values were generally less than the chamber ET values, because soil water was measured only to a depth of 50 cm and plant roots may have extracted water from deeper soil (Fig. 5). Thus, the chamber ET data very reasonably compared with the water balance ET values.
Fig. 5 The upper figure shows a comparison between potential evaporation and chamber ET, and the lower figure shows a comparison between water balance ET and chamber ET.

Soil Water Contents Decreased During the Growing Season

Figure 6 presents the precipitation and soil water content data during the 2013 growing season for the prairie and soybean plots. The decreasing trend of soil water content through entire season was due to the dry weather with relatively low
precipitation. Soil water content of the prairie field shows rapid decrease in the early season. The prairie matured earlier than corn and soybean. Prairie began to use soil water earlier than corn and soybean. Later in the growing season soil was relatively dry in the prairie while soil was wetter in corn and soybean. With low precipitation in 2013, the soil water contents exerted control on ET of the cropping systems. Early in the season the prairie had largest ET, while later in the season, due to larger water contents, soybean ET exceeded prairie ET.

Fig. 6 Precipitation and Soil Water Content Data during the Growing Season

**Significance**

During the 2013 growing season, the evapotranspiration flux was measured on 18 different days, including 2 diurnal ET flux measurements. Chamber-ET values were compared with water balance values and potential evaporation. Based on the comparisons, it is clear that the portable canopy chamber provided reasonable estimates of ET flux for the different cropping systems. Thus, we have developed a new method for quantifying plot-scale ET fluxes of annual and perennial cropping systems.

4) **Summary and Conclusions**

ET from different cropping systems was quantified with the chamber measurements. Early in the growing season, ET fluxes in prairie were larger than in soybean. Late in the growing season, ET fluxes in soybean were larger than in prairie. Although measurements in only one cropping season do not provide conclusive information on
the long-term impacts of crop water use and regional hydrology, the results do help us understand the timing of crop water use in a dry year. Because of early growth and a long growth period, the prairie uses water early and causes the soil to dry out quickly which limits late growth opportunities. One preliminary conclusion is that soil water is needed for a longer period of time to meet the demands of prairie as compared to corn and soybean. This is important information to consider for rain-fed agricultural areas.

5) Listing of publications that have resulted from this research

Two posters of this research were presented. The posters had abstracts as well.


6) Student support provided by this research

Graduate Students -- Devinder Sidhu and Zhuangji Wang were supported by Agronomy Department Endowment funds, and Chenyi Luo was supported in part on these project funds.

Undergraduate Student -- Jackson Griffith was supported by these project funds.

7) Achievements and awards for this research

None

8) Any additional funding this research has received

The research project was partially supported with USDA funds and Pioneer funds, and the required matching funds for the project were provided by Iowa State University Department of Agronomy Endowment.