Dynamics of Evapotranspiration over Biofuel Crops

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Introduction

In an attempt to ease the demand for petroleum and combat climate change, globally and nationally, there is an increased interest in biofuel production (Fargione et al., 2008). Usually undisturbed lands or lands previously on conventional agriculture are used for such purposes. Previous studies have mainly focused on carbon exchange and sequestration with little attention given to the water and heat fluxes due to such land conversion. However, water and heat exchange between plant canopies and the atmosphere are closely related to carbon fluxes and are as equally important. This study in general examined the water fluxes across seven large-scale sites in Midwest US following land-use conversion – with more emphasis on:

- ❑ the magnitude and seasonal dynamics of evapotranspiration (ET) over biofuel crops?
- ❑ the influence of previous and present cultivation on evapotranspiration?

Eddy covariance (EC) method

Mean vertical gradients of fluxes are almost entirely the result of turbulent mixing and can be defined in terms of turbulent (or eddy) components of velocities and of the properties being transferred (Kaimal and Finnigan, 1994). The mean flux (F) across any plane is directly proportional to the covariance between the wind component normal to that plane and the entity in question (Swinbank, 1951; Kaimal and Finnigan, 1994).

$$F \qquad \overline{} \qquad (1)$$

where ρ_a is the mean density of air, C_p the specific heat capacity of air, w the vertical wind speed, S the scalar entity of interest (e.g., CO_2, water vapor, heat, or any trace gas), the primes denote fluctuation from the mean over a certain sampling period of time and the overbars represent component means. The EC (Fig. 1) method is regarded as a standard for a direct means of measuring mean vertical turbulent fluxes above extensive surfaces using fast response sensors for measurement of w and S, and their fluctuations (Swinbank, 1951). In this study water vapor and heat exchanges between plant surfaces and the atmosphere were used to determine latent (evapotranspiration) and sensible heat flux densities.

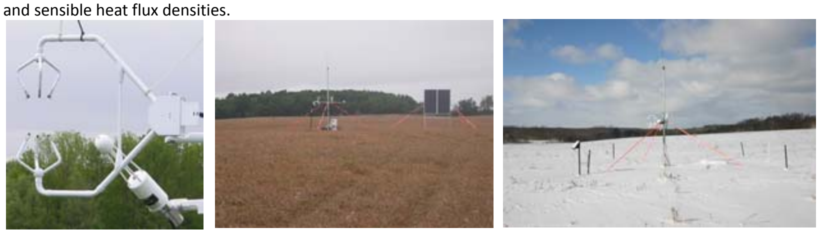

Fig 1. The Eddy covariance instruments at GLBRC scale-up plot fields

Experimental sites

EC towers and ancillary sensors were deployed over seven large-scale sites in south-western Michigan at W.K. Kellogg Biological Station (85º24'W, 42º24'N) to examine the magnitude and dynamics of carbon, water and heat fluxes. One site was kept undisturbed as a reference , whereas the previous and present land-use of the other sites are shown in Table 1.

Table 1. Previous and present land-use history of the study sites.

Site ID	Area (ha)	20 years prior to 2008	2009	2010 to present
7	9.1	Native Prairie - (Conservation Reserve Program – CRP)	Native Prairie	Native Prairie
1	17.9		No till soybean	Switch grass
2	13.1			Prairie
3	19.5			Corn
4	11.2	Corn-Soybean rotation (Conventional Agriculture – AG)	No till soybean	Corn
5	14.1			Prairie
6	23.0			Switch grass

Results

❑The diurnal ET or latent heat flux (LE) pattern followed net radiation (R_{net}) Fig 3 (a) and (b). The seasonal pattern (Fig 4) is distinct as well with low ET in winter when R_{net} is low; increasing in spring with the onset of rain, increase in radiation load and emerging plants with its peak in summer; gradually decreasing with decrease in radiation load, rainfall and senescence of plants, going back to its lowest in winter.

❑ET decreased after herbicide application in 2009, following death of the plants that were contributing to ET. ET also responded to other management practices such as planting and harvest, however such activities coincide with natural weather variations that drive ET.

❑In 2009, the daily maximum ET ranged between 5.10 and 5.74 mm across sites. The ET from 2010 was greater than in 2009 while the annual precipitation amount was similar in both cases (Fig 4). 2011, the wettest year of the three, showed the highest ET.

❑The CRP sites had lower annual ET, for example in 2009 (423 to 486 mm) compared to the AG sites (around 522 mm). Also in 2010 and 2011, the CRP sites had roughly lower annual ET than the AG sites when similar crops were considered. Soil water content (data not shown) was also consistently lower in the CRP sites than in the AG sites. The reference site had mixed ET ranking; among the highest in 2009 and 2011 but lowest in 2010.

❑ET varied among plant types: the soybean in 2009 had consistently lower ET throughout compared to the other biofuel crops in 2010. The annual precipitation amount was similar in 2009 and 2010. In general, corn exhibited the highest ET, followed by switch grass and prairie within a single growing season. However, the length of the growing season for these crops are different.

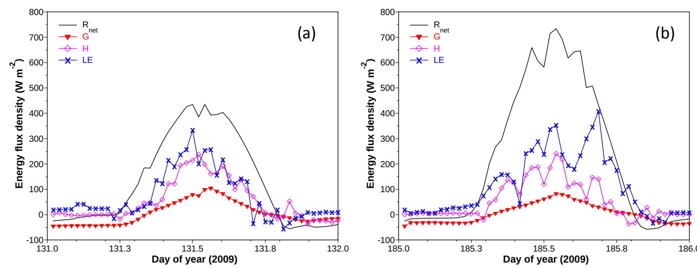

Fig 3. Typical half-hourly diurnal energy fluxes in (a) spring and (b) summer over biofuel crops. Rnet is net radiation, G, H and LE represent soil, sensible and latent heat flux densities, respectively.

Conclusions

❑ Daily and seasonal ET is driven by availability of precipitation, solar radiation load and presence of foliage area.

❑ET changes in response to management practices.

❑ET is affected by previous and current land-use activities.

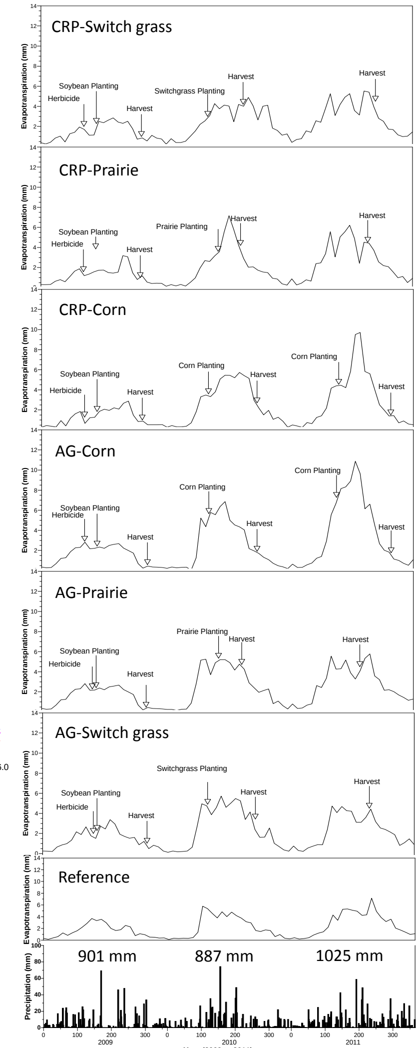

Fig 4. Dynamics of average biweekly evapotranspiration over the study sites from 2009 to 2011 along with daily (vertical bars) and annual (figures above bars) precipitation. Arrows and annotations indicate management practices.

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