Relationship between evapotranspiration and pan evaporation in cold-climate subsurface-flow constructed wetlands ·SHORT COMMUNICATION·

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INTRODUCTION

Data from two wetland treatment systems in the Midwestern United States provide insight concerning the relationship between wetland evapotranspiration (ET) and pan evaporation (EP) in insulated, horizontal subsurface-flow constructed wetlands. An energy balance was performed on each system using the terminology provided in Treatment Wetlands (Kadlec and Knight, 1996) to determine energy gains and losses. The evapotranspiration component of the energy balance ($\lambda\rho ET$) proved to be the largest source of energy loss from each wetland system (Wallace and Nivala, 2005; Nivala, 2005). The data presented reiterates the significance of ET in subsurface-flow constructed wetlands, and supports/expands on the correlation between ET and pan evaporation provided by Bavor et al. (1998).

SITE DESCRIPTION

The first wetland (Jackson Meadow) is located in Marine on St. Croix, Minnesota, USA (Lat 45.1˚N, elevation 256 m) and was designed to treat domestic waste from a cluster of 32 homes, with a design flow of 21 m^3/d. The area of the treatment cell is 650 m^2, and consists of a 45-cm-thick gravel bed insulated with a 15-cm layer of peat mulch. The system is equipped with an internal aeration system (Wallace, 2001). An energy balance was performed on the Jackson Meadow system for the time between July 2000 and April 2002.

The second wetland (Jones County) is located at the Jones County Sanitary Landfill near Anamosa, Iowa, USA (Lat 41.5˚N, elevation 250 m) and was designed as a pilot-scale treatment system for landfill leachate. The design flow of the system is approximately 0.4 m^3/d, and the area of the treatment cell is 93 m^2. This wetland system also consists of a gravel layer (30 cm deep) overlain by a layer of well-degraded compost (15 cm thick), and is equipped with an internal aeration system (Wallace, 2001). An energy balance was performed on the Jones County wetland system for the time between August 2001 and January 2003.

RESULTS

Pan evaporation (EP) data was obtained from nearby climatological stations in St. Paul, Minnesota for the Jackson Meadow wetland (Climatology Working Group of Minnesota, 2005). EP data for the Jones County wetland was obtained from the National Oceanic and Atmospheric Administration (NOAA) website(National Oceanic & Atmospheric Administration, 2005). In Minnesota and Iowa, EP data is reported as monthly averages for May through September, and as 10-day averages for the last (first) days of April (October). EP data is not recorded between October 11 and April 20 due to sub-freezing weather conditions. Wetland ET rates are compared against wetland EP rates for the two systems in Figure 1 and Figure 2.

Figure 1. Evapotranspiration vs. Pan Evaporation for the Jackson Meadow Wetland, Marine on St. Croix, Minnesota (Lat 45.1˚N).

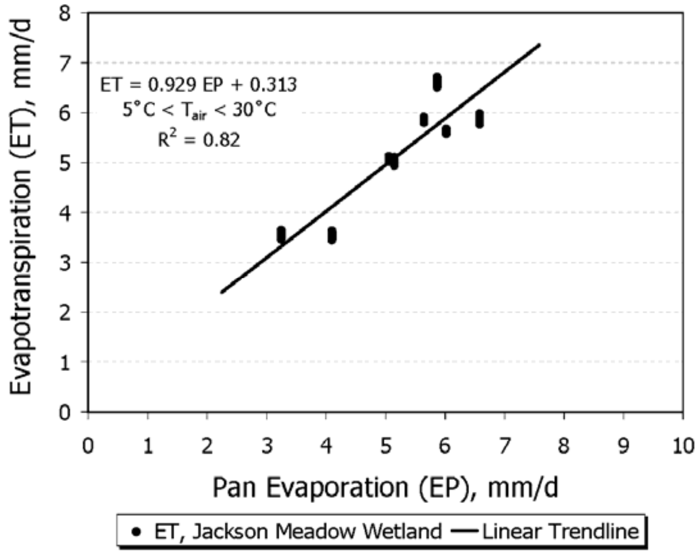
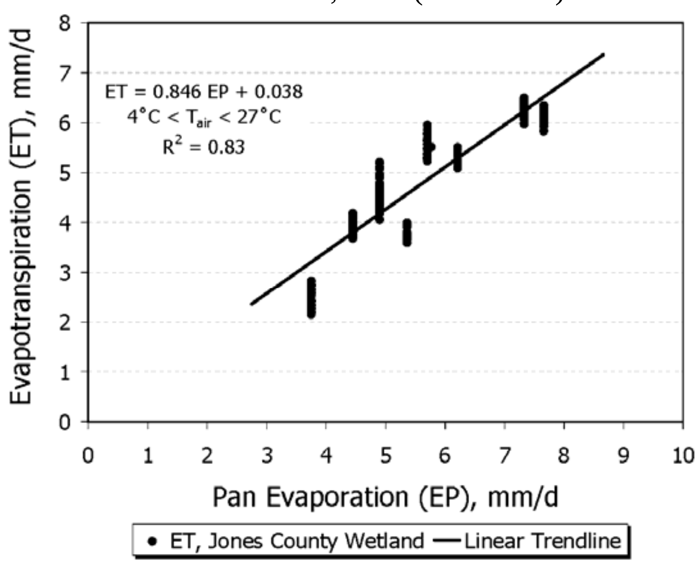


Figure 2. Evapotranspiration vs. Pan Evaporation for the Jones County Wetland, near Anamosa, Iowa (Lat 41.5˚N).



Where: *EP* is Pan Evaporation, mm/d; and T_{air} is the average daily air temperature as measured at the site, ˚C.

DISCUSSION AND CONCLUSIONS

The correlations between ET and EP for these two wetland systems are in general agreement with previous estimates by Bavor *et al*. (1988) and King et al. (1997). Bavor *et al*. proposed two equations for horizontal subsurface-flow wetlands; one for cattail/gravel and another for bulrush/gravel. King suggested that ET in subsurface flow wetlands be approximated as 80% of pan evaporation. The Bavor *et al*. equations are presented here in comparison to those obtained for the Jackson Meadow and Jones County wetland systems:

Cattail/gravel SSF (Bavor *et al*. 1988)
$ET = 1.128\ EP + 0.072$ mm/d
$R^2 = 0.72$
$12^\circ C < T_{air} < 25^\circ C$

Bulrush/gravel SSF (Bavor *et al*. 1988)
$ET = 0.948\ EP - 0.0027$ mm/d
$R^2 = 0.93$
$12^\circ C < T_{air} < 25^\circ C$

Jackson Meadow
$ET = 0.929\ EP + 0.313$ mm/d
$R^2 = 0.82$
$5^\circ C < T_{air} < 30^\circ C$

Jones County
$ET = 0.846\ EP + 0.038$ mm/d
$R^2 = 0.83$
$4^\circ C < T_{air} < 27^\circ C$

Results from the Jackson Meadow and Jones County wetland systems demonstrate that evapotranspiration can be approximated by pan evaporation during periods of the year when the temperature is above freezing. These data sets demonstrate that pan evaporation data can be applied over a wider temperature range ($5^\circ C < T_{air} < 30^\circ C$) than the earlier work of Bavor et al. ($12^\circ C < T_{air} < 25^\circ C$).

The aeration systems used at the wetland sites may serve to increase ET losses during the winter due to the low relative humidity of the air, but does not appear to significantly affect evapotranspiration rates during warmer months (April – October).

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