A novel technique to measure the total evaporation and its components during sprinkler irrigation

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Summary

Using the Eddy Covariance-sap flow method, significantly higher values of ET and reduced values of sap flow were measured during sprinkler irrigation over a mature cotton crop. The major components of total evaporation are canopy evaporation during irrigation and residual canopy interception. The measurements show that canopy evaporation is the dominant component of the total ET during sprinkler irrigation followed by canopy interception, while soil evaporation is negligible when the canopy is closed.

Introduction

Sprinkler irrigation is becoming a preferred method as the water available for irrigation around the world becomes increasingly scarce, especially in arid and semi arid regions. However, little is known about its performance in terms of water use efficiency under field conditions (Smith *et al.* 2002). The phenomenon of evaporation during sprinkler irrigation including its relationships to other soil-plant-atmospheric processes has not yet been completely understood (De Wrachien and Lorenzini 2006), although it is important for optimal design of irrigation and appropriate irrigation scheduling. Recently this was predicted by Thompson *et al.* (1997), but the results were not verified due to the lack of an appropriate field measurement technique. Recent advancement of the eddy covariance (ECV) technique suggests that the dynamics of evaporation and transpiration during sprinkler irrigation can be explained reasonably using ECV and sap flow measurements. Therefore, the aim of the study is to quantify the dynamics of evaporation and sap flow during sprinkler irrigation using ECV-Sap flow method on the basis of energy balance equation.

Methods and Materials

The study was conducted at the Agricultural Experimental Station situated at the University of Southern Queensland, Toowoomba, Australia. A cotton crop was irrigated using a small movable sprinkler irrigation system with low angle and low pressure impact sprinklers. The ECV system was installed in the middle of the irrigated circle of 50 m diameter. The irrigations were applied for 3 hours in the middle of the day.

The latent heat flux λE, and hence ET, was deduced by measurement of all major terms of energy balance over the irrigated cotton crop. The Bowen Ratio (β) was used to calculate λE described as:

$$\lambda E = \frac{R_n - G}{1 + \beta}$$

where R_n is the net radiation, H is the sensible heat flux, G is the soil heat flux and β is the Bowen Ratio defined as $\beta = H / \lambda E$.

The sensible heat flux (H) and latent heat flux were measured using ECV technique while net radiation (R_n) and soil heat flux (G) were measured by a four component net radiometer and soil heat flux plates, respectively. The temperature and relative humidity at the experimental site were measured using temperature and relative humidity probes placed at the outside of the irrigated plot. The measurements were made every 0.1 sec and the 5 min averages were recorded in the same data logger. The sap flow was measured using sap flow system which consisted of six dynagauge sap flow sensors and a data logger. The sensors were installed on six randomly-selected plants within the irrigated area.

Results & Discussion

Figure 1 presents an example of the results from one irrigation. It shows that the values of ET during irrigation increased significantly due to the evaporation from the wet canopy and droplet evaporation during flight as the direct effect of irrigation. At the same time, a significant reduction in transpiration occurs, reflected in the measurements of sap flow, because the evaporative energy was fully consumed to evaporate the intercepted water on the canopy. A similar trend was predicted by Thompson *et al.* (1993).

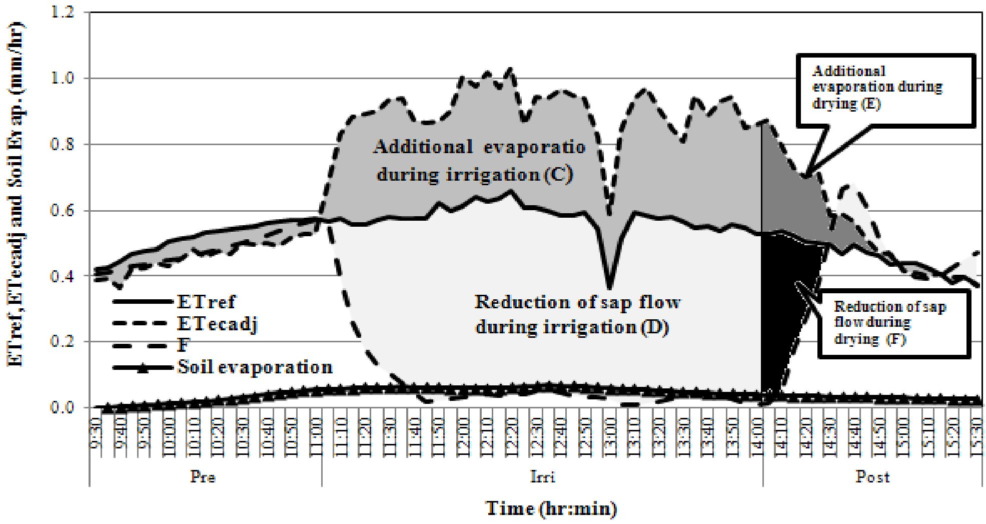

Figure 1: Components of total ET measured by ECV-sap flow method during sprinkler irrigation

From the figure it is seen that total volume of canopy evaporation during and immediately following irrigation is the summation of:

- additional evaporation during irrigation (*C*) which includes canopy evaporation from the wet canopy and droplet evaporation during flight,
- reduction of transpiration during irrigation in terms of sap flow (*D*) which would have occurred without irrigation,
- canopy interception which includes the additional evaporation during drying of the canopy (*E*) and reduction of transpiration in terms of sap flow during drying (*F*).
- soil evaporation which under the closed (mature) canopy condition is negligible.

The figure shows that canopy evaporation during and after irrigation is the dominant component in evaporation from sprinkler irrigation.

References

De Wrachien, D., and Lorenzini, G. (2006). Modelling spray flow and waste in sprinkler irrigation practice: An overview. *Actual Tasks on Agricultural Engineering, Proceedings, 34*, 227-250.

Smith, R.J., Baillie, C.P., and Gordon, G. (2002). Performance of travelling gun irrigation machines, *Conference Proceedings, Australian Society of Sugar Cane Technologists,* 24, 235-240.

Thompson, A., Gilley, J., and Norman, J. (1993). A sprinkler water droplet evaporation and plant canopy model: II. Model application. *Transactions of the ASAE, 36*(3), 743-750.

Thompson, A.L., Martin, D.L., Norman, J.M., Tolk, J.A., Howell, T.A., Gilley, J.R., et al. (1997). Testing of a water loss distribution model for moving sprinkler systems. *Transactions of the Asae, 40*(1), 81-88.