

Measurement of Evapotranspiration from Different Pasture Types Using the Rapid Chamber Method

M.K. McLeod¹, H.P. Cresswell², D.A. MacLeod¹, R.D. Faulkner³ and H. Daniel¹

¹ Division of Agronomy and Soil Science, University of New England, Armidale, NSW, 2350

² CSIRO Land and Water, Canberra, ACT, 2601

³ Division of Environmental Engineering, University of New England, Armidale, NSW, 2350

Abstract

A rapid chamber method (RCM) for evapotranspiration measurement was evaluated in the early stages of a wheat crop by comparison with the Bowen ratio method. Results from the two methods were in good agreement, particularly when slow fan speeds were used in the portable chamber. The rapid chamber method was then used to measure the evapotranspiration from degraded (mainly annual grasses), phalaris (*Phalaris aquatica*) dominant and phalaris-white clover (*Trifolium repens*) pastures. Evapotranspiration measurements obtained using the RCM compared well with those from a water balance method for the three pasture types over a six day period in July 1997. Daily evapotranspiration rates for the three pasture types were not different during this period as atmospheric demand limited evapotranspiration.

Key words: *Evapotranspiration, rapid chamber method, pasture.*

Maximising evapotranspiration (ET) in an agricultural system should be consistent with maximising plant production while minimising deep drainage. These are necessary objectives if the productivity of agricultural land is to be sustained. However, the prediction of evapotranspiration is difficult, and direct measurements such as with lysimetry or micro-meteorological techniques, are expensive. In addition, the micrometeorological methods are impractical to apply where different types of vegetation are present in small areas, as with plot or small paddock scale field experiments, because of error from advection.

Methods using small portable chambers can be used to determine evapotranspiration from different vegetation types within a small area (7, 8, 9). The principal of operation of the rapid chamber method (RCM) is that an increase of vapour density inside the portable chamber is determined while the chamber is over vegetation. Vapour density measurement continues for a period less than one minute. Measurement stops and the chamber is removed before evapotranspiration is reduced as plants respond to increased vapour or CO₂ concentration within the chamber. Small rotating fans are used to mix the air and water vapour within the chamber thus ensuring representative sampling by the single temperature and humidity sensors. The increase of vapour density within the chamber is proportional to the ET. Measurements are repeated at various times throughout the day, before the sequence of instantaneous rates are used to infer daily ET.

The objectives of this study were to: (a) evaluate the rapid chamber method by comparison with the Bowen ratio method in a wheat crop, and by comparison with a water balance technique under pasture, (b) quantify ET from three different pasture types, namely degraded pasture, phalaris dominant pasture and phalaris-white clover pasture, and (c) to determine if winter ET would be greater from phalaris-white clover pasture compared to degraded pasture containing mainly annual grass species.

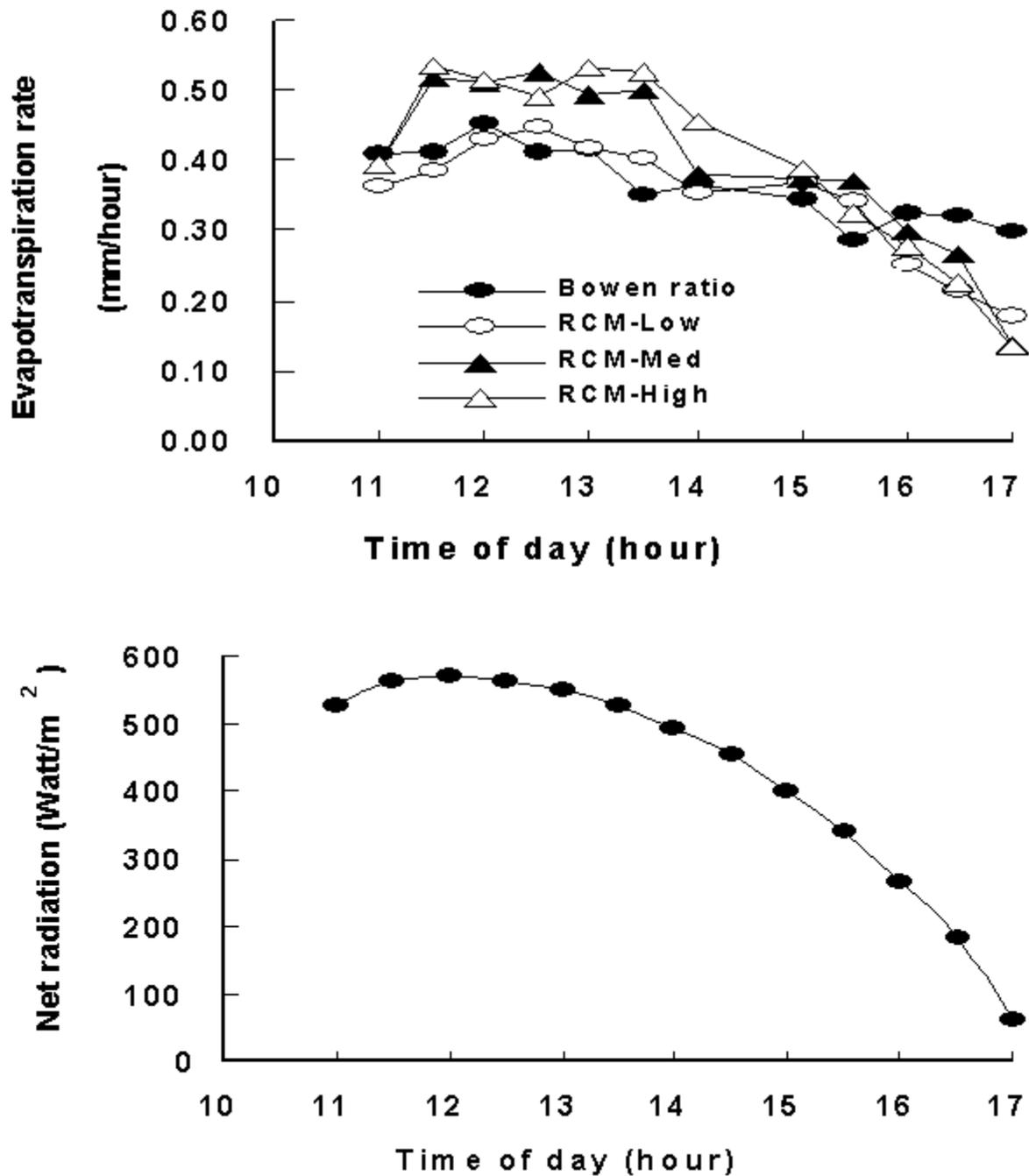


Figure 1

Results and discussion

Comparison with the energy balance method (Bowen ratio)

The comparison of evapotranspiration measured by the RCM with the Bowen ratio (BR) method (2, 6) was conducted in the centre of a field of actively growing winter wheat at Moree, in northern New South Wales, on 19 and 20 August, 1997. The wheat crop was planted on June 5, 1997, and was about 20 cm high at the time of ET measurement. The basic construction and the calibration of the ET chamber

followed Stannard (9) although single additional humidity and temperature probes were installed outside the chamber, and the hemispherical chamber used was 0.67 m in diameter. The fans used to mix air and water vapour within the dome were operated at three different speeds (resulted in air velocities of 2.7, 4.9, and 10.8 km/hr) to examine the effect on ET determination. A correction (preliminary value only) was used to account for error in ET determination from water condensing on the inside of the chamber.

Both the Bowen ratio and the RCM produced a similar pattern of daily evapotranspiration (Fig. 1a), being broadly consistent with the daily pattern of net radiation (Fig. 1b). Discrepancies between the hourly evapotranspiration rates predicted by the two methods occurred after 15:30 in the afternoon. It is suspected that the Bowen ratio method slightly overestimates the ET values, when the temperature is declining toward the end of the day. Also, where the two faster fan speeds are used with the RCM, ET rates are greater than those indicated by the Bowen Ratio method at around midday from 11:30 to 14:00. It is likely that at greater fan speeds, humid air trapped near the soil surface is disturbed by the fans and introduced into the atmosphere above the plants. This water vapour would then be erroneously considered as ET. The divergence between the RCM and the BR coincides with the period of maximum radiation for the day. During this period the difference between humidity in the boundary layer and in the atmosphere above is likely to be greater than early or late in the day when boundary layer humidity will tend to equilibrate with that in the atmosphere above. Thus, error from boundary layer disturbance with large fan speeds is likely to be larger around the middle of the day as the data suggest. Note that data from the RCM are collected over a period of seconds over a small area (0.35 m^2) and then aggregated, ie. there is interpolation between measurement points. The Bowen ratio method differs in that ET is determined at 10 minute time intervals before being averaged over a 30 minute period. The ET determination from the BR method is a measurement over a much larger area compared to the rapid chamber method.

Statistical analysis with a t-test showed that the hourly ET rates measured 12 times using BR and the RCM with three different fan speeds were not significantly different. Also, the cumulative daily ET obtained using BR and RCM with the three fan speeds over a two day period were not significantly different. However, the lowest fan speed is preferable because it produces ET values closest to those determined by the BR method. The risk of introducing humid air trapped by vegetation in a boundary layer is lessened at low fan speeds. Low fan speeds have also been observed as giving the most uniform mixing of air inside the chamber (1, 5). Ideally, fan speed should produce air velocities within the chamber that generate sufficient mixing of air and vapour for sensor measurements to be representative, but without disturbing the naturally occurring boundary layer present at the time of measurement.

Evapotranspiration from three pasture types

Measurement of pasture evapotranspiration was conducted at Big Ridge 2 research station, Chiswick, New South Wales. The dominant soil type in the area is Manganic Eutrophic Brown Chromosols (4). Mean annual rainfall is 795 mm. Mean minimum and maximum air temperature during winter is 0°C and 12.7°C , respectively, while in summer, it is 12.7°C and 32.0°C (3). The site contains degraded pasture (dominated by annual grasses), phalaris dominant pasture, and phalaris-white clover pasture. At the time of sampling, the green biomass on the three treatments was similar, and frosts were frequent.

Measurement of ET was conducted with the rapid chamber at either hourly or 30 minute intervals from sunrise to sunset. Results were collected over a six day period from 15/7/97 to 20/7/97. Profile water content to 1.20 m depth was measured at daily intervals using a locally calibrated neutron moisture meter (NMM) and time domain reflectometry (TDR). This enabled comparison of ET measured with the RCM with that determined from change in profile water storage. No rainfall was recorded during the six day measurement period, and no significant rainfall had been recorded in the previous two months. Analysis of soil water content and tensiometer measurements indicated that drainage beyond the depth of water content measurement was not expected to occur during the six day period of ET comparison.

Table 1. Cumulative pasture evapotranspiration calculated using the measured profile water storage and the rapid chamber method from 15/7/97 to 20/7/97.

Pasture type and Replicate No.	Cum. water loss measured by NMM and TDR (mm)	Cum. ET measured by the RCM (mm)
Degraded 1	5.64	6.19
Degraded 2	6.65	6.05
Phalaris 1	6.75	5.19
Phalaris 2	3.63	5.78
Phal. W.clover 1	6.10	5.48
Phal. W.clover 2	6.63	5.79

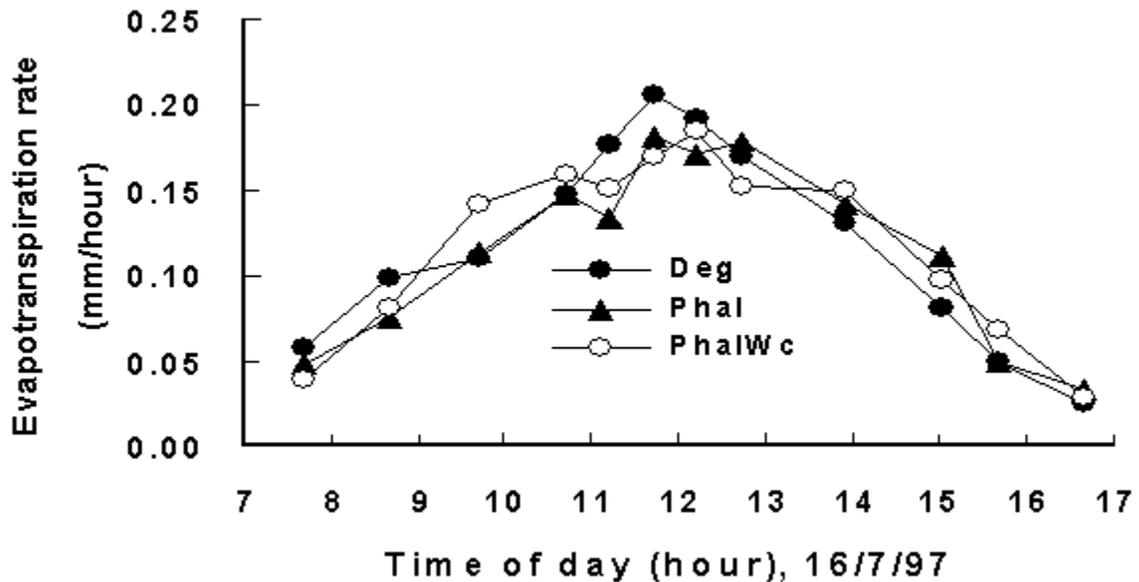


Figure 2

Comparison with soil profile water loss

Comparison between cumulative ET calculated from changes in profile water storage and ET as determined by the chamber method is presented in Table 1. In most cases, a reasonable agreement is obtained between measured water loss and measured evapotranspiration, except for phalaris pasture, replicate number 2 (bold), (Table 1). In this replicate, the ET inferred from the water loss calculation seems inconsistent with the other replicate and substantially different to the other treatments. It is suspected the neutron moisture meter or TDR measurement error could be contributing. ET measurement error as a percentage is likely to be greater when determining small ET rates as we are doing here. Analysis of variance showed that cumulative water loss measured with the NMM and TDR are not significantly different from the cumulative ET measured with the RCM ($P=0.79$).

Pasture evapotranspiration

The daily pattern of pasture evapotranspiration rate follows the pattern of solar radiation. ET is smallest at the beginning and at the end of the day and reaches the maximum rates at around midday (Fig. 2). A greater evapotranspiration rate in the morning compared to that in the late afternoon is probably due to

some evaporation of dew, and absorption of heat by the soil. Measured cumulative water loss and ET were not significantly different between the three pasture types (Table 1; $P=0.51$) for this six day winter period. In July, at Armidale, ET is more likely to be limited by atmospheric demand rather than by the ability of the soil to supply water to the plant roots. ET is also likely to be less responsive to leaf area as evaporation from bare soil might be at rates similar to plant transpiration. While winter ET data will be useful for comparing annual water balance in the pasture treatments, differences are only likely to be observed where transpiration in one or more of the treatments falls below atmospheric demand.

Conclusions

The rapid chamber method has the advantage of being a direct measurement of ET, and while tedious to use, it is more economical than other methods and practical on the plot scale. The rapid chamber method is reliant on the internal fans operating at an appropriate speed, and on interpolation between instantaneous ET measurements taken over periods of seconds. Determining plot or paddock ET requires a means of overcoming spatial variability in ET which might be considerable over short distances. While this might be a problem with the RCM in some situations, the ability to be able to characterise this variation might be advantageous in others. The RCM was found to give similar results to the Bowen ratio method in wheat, and to ET calculated from profile water loss in pasture. The three pasture treatments considered did not differ in ET during the period of observation.

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