

Plant density, litter and bare soil effects on actual evaporation and transpiration in autumn

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ABSTRACT

An experimental site was established to investigate the effect of plant density, litter and bare soil on the rate and partitioning of actual evaporation and transpiration. Evaporation and transpiration rates were measured using the rapid chamber method on spaced plants of wallaby grass (*Austrodanthonia linkii* cv. Taranna) with wet and dry surface conditions. Measured evaporation ranged from 1.1 to 3.5 mm/day, and transpiration from 0.5 to 2.6 mm/day. Bare soil evaporation on a wet surface was reduced from 3.5 to 2.3 mm/day by the presence of 3000 kgDM/ha of litter. Highest pasture transpiration (2.6 mm/day) was recorded in those plots with plants growing under dry soil conditions. Albedo (α) ranged from 0.13 to 0.24, increasing with litter levels and was highest on dry soil plots with high litter. Surface soil water content and the presence of litter markedly effected the partitioning of evaporation and transpiration leading to higher rates of transpiration.

KEYWORDS

Evaporation, transpiration, litter, albedo, ground cover.

Introduction

Grazing industries in northern NSW face many sustainability issues including the threat of developing dryland salinity, loss of perennial pasture species and declining soil health. Studies have been initiated in the Sustainable Grazing Systems (SGS) Key Program (2) to improve grazing management in terms of the soil water balance, with the aim of maintaining or improving productivity.

Actual evapotranspiration (ET_a) is the largest term of the soil water balance on the North-West Slopes of NSW accounting for 93% (659 mm) of the average annual rainfall of 708mm in a long term modelling study (6). The SGS Pasture Model being developed within the program has shown that in 1998 bare soil evaporation could be as high as 51% of annual rainfall depending on ground cover conditions (1). Clearly, ET_a is a very important term of the water balance and it also has substantial implications at the landscape level.

Accurate measurement of ET_a is important when assessing deep drainage in the water balance of an agricultural system. Deep drainage is the most difficult term to measure and is usually estimated, implying that all other components have been accurately accounted for. If the determination of ET_a is in error by as little as 5%, deep drainage could be over or underestimated by as much as 32 mm per year.

The partitioning of evaporation and transpiration within ET_a is highly important for agricultural production. If soil evaporation is reduced and pasture transpiration increased, dry matter production can increase, improving the water use efficiency of the system. In the reported study, the effects of litter and ground cover on the partitioning of evaporation and transpiration are examined under dry and wet soil surface conditions for an autumn period.

METHODS

An experimental site was established at the Tamworth Centre for Crop Improvement (31°09'S., 150°59'E.; elevation 434 m) to measure net radiation, albedo (α) and ET_a for a range of pasture, litter and bare soil situations. Four levels of each treatment (high, medium, low, none) were randomly allocated to 12 plots (2 m by 2 m) in an unbalanced design. Levels of plant density were achieved by sowing spaced plants of wallaby grass (*Austrodanthonia linkii* cv. Taranna) at densities of 25, 12.5, 4 and nil plants per m² (H, M,

L, None, respectively). Litter collected from native pastures was evenly spread across plots at 3000, 1500, 500 and 0 kg DM/ha (H, M, L, None, respectively). Litter was applied 3 days before the experimental period. Differing bare soil levels were achieved by a combined effect of plant density and litter mass, (Table 1).

Table 1. Combinations of plant density, litter mass and level of bare soil allocated to the 12 treatment plots.

Treatment	Plot	Plant density	Litter mass	Bare soil
T1	6	H	L	L
T2	9	H	None	M
T3	4	H	H	None
T4	3	M	M	None
T5	1	M	None	M
T6	2	L	L	L
T7	10	L	None	H
T8	7	L	H	L
T9	12	None	L	H
T10	5	None	M	M
T11	11	None	H	L
T12	8	None	None	H

Measurements were taken on the 3 April 2000 (dry soil) and 4 April 2000 (wet soil) after overnight irrigation. Volumetric soil water content (θ_{vol} %, $\theta_g \times P_b$) of the surface 2.5 cm was determined at the beginning of each day. Evapotranspiration from each treatment plot was measured at one hour intervals from sunrise to sunset using the rapid chamber technique described by McJannet et al. (3) and McLeod et al. (4). The chamber used 950 mm in diameter, equipped with two electric fans to mix the air and had a Vaisala HMP35A sensor that recorded temperature ($^{\circ}\text{C}$) and relative humidity (%) inside the dome at one second intervals. Measurements were taken on each treatment plot for a period of 45 seconds. Actual daily evapotranspiration was calculated as the sum of the hourly values for each plot.

Radiation data were recorded from a height of 55 cm above each plot for a five minute period immediately following each evapotranspiration measurement. Net radiation was measured by a Middleton CN1-R net

pyrradiometer between wavelengths of 0.3 and 60 μm . The albedo value (α) was calculated as the ratio of incident to reflected radiation as recorded by a Middleton EP16 albedometer (0.3 to 3 μm). Data were recorded on a "Tain Micropower Automatic 8 channel Mark III" data logger at 30 second intervals and summed to give daily values.

Actual pan evaporation was measured at hourly intervals in a standard Class A evaporation pan located in a weather station adjacent to the experimental site and summed to give daily values. Potential evapotranspiration was calculated from weather data using the modified Penman method (8).

Results

Weather conditions for the observation period were fine, mild and sunny with light winds Table 2.

Table 2. Weather conditions for 3 and 4 April 2000.

Date	TMax	TMin	Wind Run (km)	Pan Evap. ¹ (mm)	ET _p ² (mm)
03/04/2000	29.4	15.6	155	3.0	3.7
04/04/2000	29.4	17.6	121	2.5	4.2

¹ Total measured in daylight hours

² Calculated for 24 hours

Evaporation (E_a) rate from bare soil were highest (3.5 mm/day) when surface soil conditions were wet, with the rate being three times higher than that recorded for dry soils (1.1 mm/day, Table 3). Rate of E_a was inversely proportional to litter weight when surface soil conditions were wet. With dry soil moisture conditions, E_a increased as θ_{vol} % increased (Table 3).

Table 3. Actual evaporation (E_a , mm/day), transpiration (T_a , mm/day), net radiation (R_{net} , MJ/m²), albedo (α) and soil volumetric water content (θ_{vol} %) for 6 different treatment plots with differing levels of plant density (P), litter mass (L) and bare soil (BS) with wet and dry soil conditions.

Treatment	Dry soil conditions (03/04/2000)					Wet soil conditions (04/04/2000)							
	P	L	BS	E_a ¹ mm	T_a ¹ mm	R_{net} ¹ MJ/m ²	Albedo α	θ_{vol} %	E_a ¹ mm	T_a ¹ mm	R_{net} ¹ MJ/m ²	Albedo α	θ_{vol} %
T12	0	0	H	1.1 ²		12.5	0.18	9.6	3.5 ²		9.1	0.13	39.0
T9	0	L	M	1.6 ³		10.8	0.20	10.7	3.5 ³		10.2	0.17	35.2
T10	0	M	L	2.4 ³		11.5	0.22	16.7	2.7 ³		8.6	0.19	38.8
T11	0	H	0	2.1 ³		11.5	0.24	13.2	2.3 ³		9.1	0.21	35.0

T2	H	O	L	1.1 ⁴	2.6	13.0	0.17	9.2	3.5 ⁴	0.5	8.1	0.16	30.4
T3	H	H	O	2.1 ⁴	1.9	11.8	0.19	11.6	2.3 ⁴	1.4	10.5	0.18	26.4

1. Measured during daylight hours.
2. Bare soil evaporation only.
3. Both bare soil and litter evaporation.
4. Bare soil, litter and plant canopy evaporation.

Presence of pasture plants increased total ET_a with a maximum of 4.0 mm/day recorded on both days (Table 3). Soil surface conditions affected the partitioning of E_a and T_a , with ET_a increasing most under dry soil conditions when transpiration was the major component (48-70%) of ET_a . With wet soil conditions, evaporation was the major component of (63-87%) of ET_a .

Albedo increased in proportion to litter mass with both wet and dry conditions. Albedo was highest under dry soil conditions with 3000 kgDM/ha litter. In plots with plants, albedo ranged from 0.16 (wet) to 0.19 (dry) with high litter weights (Table 3). Net radiation received at the soil surface was higher under dry compared with wet conditions (Table 3).

DISCUSSION

Long term water balance modelling has indicated the importance of evaporation on the North-West Slopes of NSW (6). Lodge et al. (1) using the biophysical SGS Pasture Model indicated that bare soil evaporation can be high on low ground cover pastures. These studies provide measurements of the actual partitioning of evaporation and transpiration within evapotranspiration for a range of conditions. With dry surface conditions, available surface soil water had been evaporated and so E_a was below calculated potential and pan evaporation. However, with wet surface conditions, bare soil evaporation was high, equalling potential and exceeding pan evaporation. As surface soil water content decreased, the rate of evaporation decreased. To improve the accuracy of soil water balance modelling it would be important to include a function to alter soil evaporation according to surface soil water content.

Pasture litter can reduce bare soil evaporation when soil surface conditions are wet. Soil water retained underneath the litter would be available for pasture growth. High litter did not appear to stop evaporation; rather it retained soil water and released it over a longer period of time. Under dry soil conditions, evaporation was directly proportional to the water content of the surface soil. Bare soil and low litter plots had low soil water resulting in soil limited evaporation being lower than potential and pan evaporation. High evaporation rates from wet soil surfaces highlights the importance of conserving soil water after summer rainfall on the North-West Slopes. High litter in pastures may be more efficient at retaining soil water after rain by reducing evaporation rates at that time.

Accurate partitioning of evaporation and transpiration is significant for the prediction of a long term soil water balance. With dry soil conditions, T_a dominated ET_a as plants had water available for transpiration within the root zone. When surface soil conditions were wet, E_a was dominant as water was readily evaporated from the wet soil surface, although litter moderated this slightly in T3 (Table 3). In a study of evapotranspiration from different pasture types, McLeod et al. (4) proposed that E_a and T_a might be similar when surface conditions were wet. For accurate water balance modelling it is suggested that soil water content at the surface and within the root zone be used for partitioning of ET_a into components of E_a and T_a .

The albedo of a crop or pasture defines the proportion of short wave radiation and associated energy reflected from the system. At higher albedo, less energy is available to drive evapotranspiration. Albedo

was increased by high amounts of litter under both dry and wet surface conditions. The wet bare soil surface had the lowest albedo (0.13) that is consistent with other published data (5). The highest albedo for plots that had both plants and litter was 0.19. This value is well below the albedo (α) of 0.23 used in the Penman-Monteith calculation of reference evapotranspiration (7), and for accurate calculation of potential ET of a pasture system, albedo values representative of that pasture system should be used.

Conclusion

The rate and partitioning of E_a and T_a was dependent on surface soil water content, litter weight and plant density. Wet soil surfaces led to higher E_a while dry soil surfaces led to higher proportion of T_a compared with E_a . The accuracy of soil water balance modelling may be improved by incorporating these factors when determining ET_a from a reference ET. Further studies have been initiated to investigate the rate and partitioning of E_a and T_a on native pastures of the North-West Slopes, including investigation of seasonal differences.

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