

# RELATIONS BETWEEN NET RADIATION, GLOBAL SOLAR RADIATION, AND SUNSHINE ON THE NORTH COAST OF NEW SOUTH WALES

G. J. Murtagh

New South Wales Department of Agriculture, Wollongbar

(Manuscript received December 1975; revised July 1976)

## ABSTRACT

Data collected at Wollongbar on the north coast of New South Wales were used to establish the relation  $Q_n = 118 + 0.635 Q_t - 714 Q_t/Q_e$  for predicting net radiation ( $Q_n$ ) from daily measurements of global solar radiation ( $Q_t$ ) and tabulated values of extraterrestrial radiation ( $Q_e$ ), expressed in units of  $J\ cm^{-2}\ d^{-1}$ . The inclusion of the atmospheric transmissivity term ( $Q_t/Q_e$ ) in the relation increased the amount of explained variation in  $Q_n$  from 79 to 85 per cent. The data were collected over a green grass sward with an albedo of 0.23.

## INTRODUCTION

Net radiation is an important climatic parameter, especially with regard to evaporation. However, as instrumentation difficulties and standardisation of site surfaces restrict the number of sites where net radiation is recorded, it is frequently estimated from the more easily measured global solar radiation. The reliability of this approach is aided by the high correlation between the two values arising from the inclusion of global solar radiation as an important component of net radiation (Gay 1971). Many workers have found that a simple linear relation can be used to predict net radiation from global solar radiation, but the coefficients in the relation vary between regions. Consequently, it is advisable to use relations which have been established either locally or in a region with generally similar vegetation and temperature.

Fitzpatrick and Stern (1973) described a further refinement of including atmospheric transmissivity (the ratio of daily global solar radiation to extraterrestrial solar radiation on a horizontal surface) in the relation. This inclusion accounts for some of the variation due to differing climatic conditions without requiring additional measurements as extraterrestrial solar radiation is given in standard tables (List 1963). This paper describes relations for predicting net radiation over green pasture on the north coast of New South Wales.

## METHODS

Measurements were made at Wollongbar (latitude  $28^{\circ} 50'$  S, longitude  $153^{\circ} 25'$  E, altitude 180 m) near Lismore, on the north coast of New South Wales. The area is in a sub-tropical temperature zone, with a high (1658 mm annual mean) summer-dominant rainfall.

Global solar radiation was measured with a 'Kipp and Zonen' pyranometer, and net radiation with a 'Funk-CSIRO' shielded net pyrradiometer. Both instruments were exposed at a height of 180 cm, over a clipped, basically kikuyu sward which completely covered the ground and remained green throughout the year. Recorders, based on a variable speed motor, were used to obtain integrated totals of daily radiation from January 1972 to May 1976. A positive-voltage bias was applied continually to the net pyrradiometer circuit to convert all negative signals to a positive form. Reflected short-wave radiation was measured with a second pyranometer, in an inverted position, during February-April 1975. The albedo was calculated as the ratio of daily totals of reflected to incoming global solar radiation. The presence of sunshine was recorded at 6-minute intervals on a 'Rimco-Summer' recorder from March 1972 to May 1976. Both daily totals and weekly means of daily radiation were used to fit the relations between net and global solar radiation. The relation between atmospheric transmissivity of short-wave radiation and relative duration of sunshine was obtained from weekly means only. The ranges of daily values for the different parameters were: net radiation ( $Q_n$ ), 26-1763 J cm<sup>-2</sup> d<sup>-1</sup>; global solar radiation ( $Q_t$ ), 112-3335 J cm<sup>-2</sup> d<sup>-1</sup>; extraterrestrial solar radiation ( $Q_e$ ), 1824-4356 J cm<sup>-2</sup> d<sup>-1</sup>; atmospheric transmissivity ( $Q_t/Q_e$ ), 0.07-0.82.

## RESULTS AND DISCUSSION

Daily totals of  $Q_n$  were obtained from standard tables (List 1963) and for convenience the tabulated values were expressed as a function of time (Eqn 1) which is applicable at a latitude of 30°S.

$$Q_e = 3132 - 1261 \sin(T - 1.415) + 42 \sin(2T - 1.089), \text{ J cm}^{-2} \text{ d}^{-1} \quad \dots 1$$

where T is an angular measure in radians of the day number, with day 1 = 1 January, day 2 = 2 January, etc. Multiplying the day number by a constant,  $2\pi/365 = 0.01721$ , converts it to the angular measure T.

The simple linear relation between daily values of  $Q_n$  and  $Q_t$  explained 79 per cent of the variation, with a standard error of 182 J cm<sup>-2</sup> d<sup>-1</sup>, which is 23 per cent of the mean  $Q_n$ .

$$Q_n = -70 + 0.507 Q_t, \text{ J cm}^{-2} \text{ d}^{-1} \quad \dots 2$$

The inclusion of  $Q_t/Q_e$  in the relation explained an additional 6 per cent of the variation. All coefficients in Eqn 3 were highly significant ( $P < 0.01$ ) and the standard error of the estimate was 154 J cm<sup>-2</sup> d<sup>-1</sup> (19 per cent).

$$Q_n = 118 + 0.635 Q_t - 714 Q_t/Q_e, \text{ J cm}^{-2} \text{ d}^{-1} \quad \dots 3$$

When the relations were established from weekly means of daily radiation, there was only a small change in the coefficients of  $Q_t$  but the coefficient of  $Q_t/Q_e$  and the constant terms varied considerably. However, when the differences in scale of the various parameters were considered, the changes to all coefficients were approximately of equal importance.

$$Q_n = -157 + 0.561 Q_t, \text{ J cm}^{-2} \text{ d}^{-1} \quad \dots 4$$

$$Q_n = 255 + 0.624 Q_t - 921 Q_t/Q_e, \text{ J cm}^{-2} \text{ d}^{-1} \quad \dots 5$$

Eqn 4 (Eqn 5) explained 79 (88) per cent of the variation, with a standard error of 146 (113) J cm<sup>-2</sup> d<sup>-1</sup> which is 18 (14) per cent of the mean  $Q_n$ .

The albedo was 0.23 (SE = 0.027) which is similar to the generally accepted value of 0.25 for well-watered grass (Linacre 1969). Daily estimates of albedo were not obviously related to time or any climatic measure.

Many studies have shown that the coefficient of  $Q_t$  in the regression equation approximates to 0.6-0.7 when daily or longer-term mean values are used to relate net and global solar radiation. Davies (1967) obtained a coefficient of 0.62 using data from 14 centres throughout the world, and the  $Q_t$  coefficients in Eqns 2, 3, 4, and 5 are in general agreement with other studies. However, daily or longer-term mean values usually provide no values near the origin. If such values are used when fitting the relation, as when hourly values are used, the  $Q_t$  coefficient will increase considerably (Idso, Baker, and Blad 1969). Further increases in the precision of the relation can be obtained by accounting for variation in albedo with varying solar position, but models without albedo are equally effective for daily totals (Nkemdirim 1973).

The improved precision resulting from the inclusion of atmospheric transmissivity in the relation probably reflects the effect of cloudiness on net long-wave radiation since the measurement of  $Q_t$  already takes atmospheric transmissivity into account. Variation in net long-wave radiation would influence measurements of  $Q_n$  but not  $Q_t$ . Fitzpatrick and Stern (1973) also obtained a substantial increase (19 per cent) in the coefficient of determination by including atmospheric transmissivity in the relation at one site, but the increase was only 2 per cent at a second site. Since the inclusion of the atmospheric transmissivity term requires no additional measurements, it should be included in equations to predict net radiation.

Duration of sunshine ( $n$ ) can be used to estimate global solar radiation, usually in a relation of the form

$$Q_t/Q_e = c + d (n/N) \quad \dots 6$$

where  $N$  is the maximum possible duration of sunshine and  $c$  and  $d$  are coefficients. Data from Wollongbar gave  $c$  and  $d$  coefficients of 0.30 and 0.50, respectively, but the coefficient of determination was only 42 per cent and the standard error of the estimate of  $Q_t/Q_e$  was 0.09. Linacre (1967) noted that the  $c$  and  $d$  coefficients vary between locations, and that  $d$  is also influenced by the latitude. The Wollongbar coefficients are similar to the mean coefficients of 0.28 and 0.49 for  $c$  and  $d$  respectively given by Linacre for the 18 to 30° range of latitude. They are also similar to the coefficients of 0.27 and 0.50 respectively given by Hounam (1969) in a general equation for Australian locations.

### ACKNOWLEDGMENTS

My thanks are due to Mr H. Gahan for maintaining the meteorological equipment and to Mr A. Dilley of CSIRO, Aspendale, for advice on the circuitry. The radiation sensors and recorders were purchased with funds supplied by the Australian Dairy Produce Board.

### REFERENCES

- Davies, J.A. 1967. A note on the relationship between net radiation and solar radiation. *Quart. Jl R. met. Soc.*, 93, 109-15.
- Fitzpatrick, E.A. and Stern, W.R. 1973. Net radiation estimated from global radiation. In *Plant Response to Climatic Factors*, Proc. Uppsala Symp. UNESCO, Paris, 403-10.
- Gay, L.W. 1971. The regression of net radiation upon solar radiation. *Arch. Met. Geophys. Bioklim.*, B, 19, 1-14.

Hounam, C.E. 1969. Revised regression equations for estimation of solar radiation over Australia. *Aust. Met. Mag.*, 17, 91-4.

Idso, S.B., Baker, D.G., and Blad, B.L. 1969. Relations of radiation fluxes over natural surfaces. *Quart. Jl R. met. Soc.*, 95, 244-57.

Linacre, E.T. 1967. Climate and the evaporation from crops. *J. Irrig. Drain. Div. Am. Soc. civ. Engrs*, 93, 61-79.

Linacre, E.T. 1969. Net radiation to various surfaces. *Jnl appl. Ecol.*, 6, 61-75.

List, R.J. 1963. *Smithsonian Meteorological Tables*, 6th rev. ed. (Smithsonian Institution: Washington, D.C.)

Nkemdirim, L.C. 1973. Radiative flux relations over crops. *Agric. Met.*, 11, 229-42.