VOL. 5, NO. 5 WATER RESOURCES RESEARCH OCTOBER 1969

Net Radiation in a Riparian Mesquite Community

J. M. TROMBLE AND J. R. SIMANTON

Southwest Watershed Research Center, U. S. Department of Agriculture
442 East Seventh Street, Tucson, Arizona 85705

Abstract. Net radiation patterns for a riparian mesquite community are similar to net radiation patterns obtained for a humid forest. The net radiation peak of the open area was 61% of the net radiation peak above the canopy. The net radiation within a mesquite canopy peaked 9% higher but had a lower daily total value than the radiation above the canopy. The differences in net radiation peaks were attributed to differences in the canopy geometry, solar position, and surface reflectance, whereas differences in daily net radiation were attributed to differences in surface reflectance characteristics.

INTRODUCTION

Rationally developed empiric methods of estimating or predicting evapotranspiration, using either net or total solar radiation as the primary variable, approximate solutions based on the conservation of energy or 'energy balance.' The energy budget is an accounting of energy gain, loss, and storage changes determined for the earth's surface or any other level in the atmosphere over a period of time.

This paper presents information on the partitioning of solar energy within and near a mesquite community located on Walnut Gulch, an ephemeral tributary of the San Pedro River near Tombstone, Arizona (N 31°45′ W 110°00′). The experimental area has well-defined mesquite (*Prosopis juliflora* var. *velutina*) groves, which make up the dominant overstory vegetation. Interspersed in these groves are open areas where vegetational cover consists generally of forbs and grasses. All herbaceous vegetation is deciduous and may become lush along the channel during and following the summer rainy season. These data were collected as part of a comprehensive water budget and microenvironmental study of this vegetation community.

Data from energy budget studies dealing with net radiation at different locations in a forest stand have shown that net radiation is greatest directly above the forest canopy and considerably less under the canopy [*Baumgartner*, 1956; *Waggoner et al.*, 1959]. *Baumgartner* [1965] also found that bare soil has about 40% less net radiation than a forest canopy.

Waggoner et al. [1959] found that the canopy of a conifer stand strongly reduces the shortwave radiation, the most important component of incoming radiation but depletes longwave radiation very little. The longwave radiation that does penetrate the canopy is readily absorbed by the soil and plant surfaces. The proportion of incoming solar radiation that is reflected back to the sky is dependent upon surface characteristics. *Bowers and Hanks* [1965] found that dark colored soils have a high radiant absorptive capacity.

RESULTS AND DISCUSSION

Net radiation patterns similar to those measured for a humid forest have been measured for a riparian mesquite community. The net radiation was measured with *Fritschen* [1965] miniature net radiometers and recorded on a millivolt recorder. The net radiation measured at each location by the net radiometers can be described as the difference between the downward flux, consisting of direct and diffuse solar radiation and atmospheric thermal radiation, and the upward flux, consisting of reflected solar and thermal radiation and emitted thermal radiation.

Amounts of net radiation received at three different positions in a mesquite community are illustrated in Figure 1. Two sites were

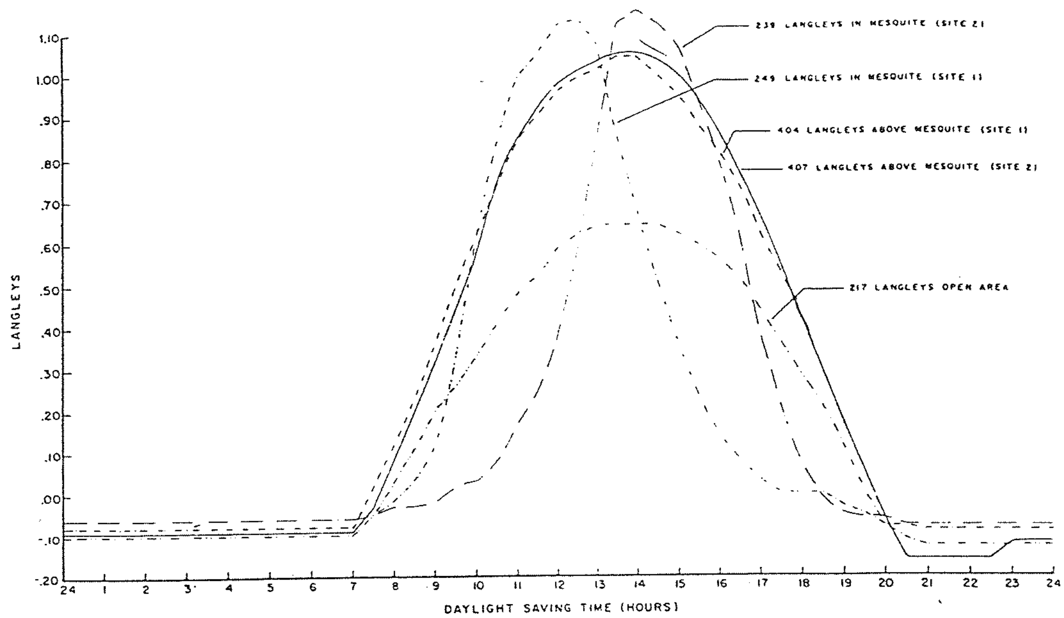

Fig. 1. Diurnal fluctuation of net radiation at three sites in experimental area for June 16, 1967.

located for making measurements above and within the mesquite canopy. The third measurement site was located in an adjacent open area. The amount of net radiation above the vegetational canopy is greater than the amount of net radiation of an adjacent open area and from within the canopy. However, the net radiation within the canopy peaked 9% higher than the net radiation above the canopy.

The higher net radiation peak within the canopy was influenced by the direct rays from the sun entering through the canopy and striking the top of the net radiometer while the surface area under the radiometer was still in shadow. Thus the variability with time of the net radiation values obtained would be a function of the geometry of the canopy as well as the solar position. This would in effect cause a low amount of back radiation while the top of the radiometer was receiving greater amounts of incoming radiation, producing an increase in the net radiation value within the canopy. Even though the net radiation peaks were 0.10 langley higher within the canopy than above it, the total daily amount of net radiation measured was considerably less. This radiation pattern occurred at both site 1 and site 2 on several days.

The net radiation values for the three positions in the mesquite community may best be analyzed by referring to the reflectance differences of the surfaces involved. Since the net radiometer in the open area and the net radiometer above the canopy received essentially the same amount of incoming radiation, the most logical explanation for the differences in both peak and total amount of net radiation is that the radiometers are receiving different amounts of outgoing radiation. The surface of the open area probably reflects 25% to 45% of the incoming radiation [*Budyko*, 1956]. The mesquite canopy, using Budyko's percentage for a deciduous canopy, reflects 15% to 20% of the incoming radiation. From the data given in Figure 1, the net radiation peak in the open area is 61% of the canopy net radiation peak. Utilization of reflectance values 0.45 soil, 0.20 canopy, given by *Budyko* [1956] shows that the open area net radiation peak would be 69% of the canopy net radiation peak. This value is in the same order of magnitude as obtained from actual data.

The dark colored soils under the mesquite canopy apparently absorb large amounts of radiation; therefore less incoming radiation will be reflected. The peak of the net radiation curve is therefore greatly influenced by this decrease in outgoing radiation.

The other explanation for the high peak of net radiation found within the mesquite canopy is the variation of solar position. For the mesquite community, the azimuth changes from 63° at sunrise to 297° at sunset with a maximum altitude of 85° at solar noon. From sunrise to solar noon the angle of radiation reflectance decreases, causing an increase in radiation absorptance. From solar noon to sunset, the angle of reflectance increases, causing a decrease in radiation absorptance. The amount of vegetation that incoming radiation must penetrate also affects the quantity of incoming radiation measured within the canopy. As the sun progresses toward solar noon, radiation passes through a lesser amount of vegetation, thus increasing the radiation striking the net radiometer. As the sun progresses toward sundown the vegetation density increases, causing a decrease in radiation penetration. Thus increase, peak, and decrease of net radiation are much more drastic within than above the canopy or over the open area. The small differences in net radiation values and peak times of the two sites within the canopy are probably due to differences in canopy geometry and solar position.

The negative values of net radiation at night from the three sites are due to the earth's being warmer than the atmosphere: a net loss of longwave thermal radiation occurs. This radiation loss is related to the amount reaching the surface during the day and the coolness of the atmosphere at night. The reduction in radiation at night is probably also influenced by the cover directly over the radiating surface. The decrease in net radiation value in the open area and above the mesquite canopy is essentially the same except for the period shortly after sundown, when the net radiation values for the canopy are 8% lower than those in the clearing. This difference is probably due to the greater amount of net radiation above the canopy than above the open area. Radiation loss at night from within the canopy is less than the nightly loss of radiation from either the open area or above the canopy. This may be due to the lower amount of net radiation received within the canopy during the day, and it may also be due to the canopy's acting as a barrier to radiation loss to the atmosphere, causing the radiation to be reflected back from the canopy to the soil surface.

REFERENCES

Baumgartner, Albert, Untersuchungen uber den Warme- und Wasserhaushalt eines jungen Waldes (translation 3760 by Dr. E. Pichler, Victoria, Australia), *Deut. Wetterdienstes Ber.*, *5*, 4–53, 1956.

Baumgartner, Albert, Energetic bases for differential vaporization from forest and agricultural lands, *International Symposium on Forest Hydrology*, Pergamon Press, Oxford, 1965.

Bowers, S. A., and R. J. Hanks, Reflection of radiant energy from soils, *Soil Sci.*, *100*(2), 130–138, 1965.

Budyko, M. I., The heat balance of the earth's surface (translation for U. S. Weather Bureau, 259 pp., 1958), Leningrad, 1956.

Fritschen, Leo J., Miniature net radiometer improvements, *J. Appl. Meteorol.*, *4*(4), 528–532, 1965.

Waggoner, P. E., A. B. Pack, and W. E. Reifsnyder, The climate of shade, *Connecticut Agr. Exp. Sta. Bull. 626*, 39 pp., 1959.

(Manuscript received April 21, 1969; revised May 28, 1969.)