INCOMING SOLAR RADIATION PATTERNS AND VEGETATION RESPONSE: EXAMPLES FROM THE NATAL DRAKENSBERG*

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Introduction

Many plant ecological studies in South Africa, particularly those undertaken in hilly terrain, have drawn attention to the relationships that exist between vegetation and the aspect and inclination of slopes (e.g. Killick 1963, Edwards 1967, Kruger 1974). (Aspect as used in this paper is synonymous with slope exposure or orientation.) Few attempts have been made, however, at quantifying this observed interrelationship, which results largely from differences in the amounts of light, i.e. solar radiation, intercepted by different slopes. These variations in solar radiation are known to affect not only surface energy budgets (Gamier 1968) and temperatures but also the soil moisture balances. As such topographically induced incoming radiation differences may be regarded as being one of the most fundamental variables of the plant environment and it is possible under certain circumstances to anticipate variations in plant response to these differences in light amounts.

The primary objective of this paper is to describe a simple method of accurately estimating and mapping patterns of incoming radiation fluxes on slopes using data from standard meteorological instruments, and secondly, to show how the results of the radiation maps produced can be related to a specific example of vegetation successional changes, and more generally to plant community distributions that have been observed at Cathedral Peak in the Natal Drakensberg mountain range, South Africa.

Conceptual framework to incoming radiation estimations on sloping terrain

Incoming solar radiation consists of a direct and diffuse radiation component. On a horizontal surface the intensity of direct radiation ($F_d, \text{figure I}$) depends on the intensity of radiation at the top of the atmosphere ($A_h$, a function of the solar constant and the earth's radius vector) which is attenuated by the earth's atmosphere ($B_h$, a function of water vapour, aerosols in rural areas mainly dust particles, and altitude), the angle at which the sun's rays strike the earth's surface ($C_h$, a function of the latitude of the locality, the time of year and the time of day) and clouds ($D_h$). The intensity of diffuse radiation ($E_d$) has been shown to be related to the sun's inclination (Archer 1964). The various formulae, derivations and assumptions implied above, and which have been summarised in the top half of Fig. 1, have been expounded on in a series of contributions by one of the authors (Schulze 1974, 1975, 1976).

To obtain incoming radiation amounts (or loads) of, say, a particular day, the radiation intensities, which are expressed in minute time intervals, would be summed for cloudless and cloudy periods of the day from sunrise to sunset.

In order to achieve estimations of radiation intensity and load the daily suncards from a Campbell-Stokes sunshine recorder, of which over 150 are in operation in South Africa at the present time, are analysed at convenient short time intervals. Taking, for example, every 20 minutes, the burn on the card indicates whether or not cloud was present and for that particular 20 minute interval the mean inten-
sity is then computed by applying the various formulae and inputs given in Fig. 1. Results for Pietermaritzburg, South Africa, where the techniques and formulations just described and illustrated were tested against a calibrated Kipp solarimeter, have been given elsewhere (Schulze 1976).

When the intensity of direct radiation on sloping terrain is considered, only one component of the intensity equation changes, viz. the angle at which the sun’s rays strike the surface (tan a in Fig. 1). Not only does the solar altitude have to be considered, but also the inclination and orientation of the slope. By employing unit co-ordinate vectors to express the geometrical relationship between the sun’s rays and slope (Garnier 1968), this problem can be resolved mathematically (Garnier & Ohmura 1968, Fuggle 1970, Schulze 1976). In the case of diffuse radiation on uneven terrain a correction factor derived by Kondrat’yev (1965) is applied to the slope (E, in Fig. 1). Again, as with radiation interception on horizontal surfaces, the daily load of incoming radiation fluxes is obtained by summing intensities per unit time period from sunrise to sunset.

For any given slope insolation may commence after sunrise, stop before sunset or cease temporarily for part of day if the slope is shaded. During the time that the receiving surface is shaded a ‘skyline correction’ is applied and only diffuse radiation is recorded for the slope. This correction becomes part of the programming routine for those periods of the day when both solar altitude is lower than the slope gradient and the difference between solar azimuth and the slope aspect is less than 90.

Radiation mapping

Radiation mapping on sloping terrain was carried out at the Department of Forestry’s Hydrological Research Station