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Desert vegetation and timing of solar radiation

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Abstract

Timing and amount of solar radiation were examined as factors influencing the distribution of seven perennial plants on a small mountain located in the Chihuahuan Desert. Average direct beam solar radiation fluxes at differing times throughout the day and year were estimated with computer calculations. Principal components analysis was used to reduce the number of solar radiation parameters and include the maximum available information with a manageable number of variables. The remaining solar radiation parameters were compared to plant distributions using redundancy analysis and generalized additive models. Unimodal, bimodal, and monotonic responses were all found depending upon the species and solar radiation parameter. Niche separation at this location depends upon the timing as well as the amount of solar radiation.

Keywords: Solar radiation; Water stress; Evapo-transpiration; Chihuahuan desert

1. Introduction

The importance of slope, aspect, and topographic variations to the distribution of terrestrial plant and animal communities has been noted by many authors (Cantlon, 1953; Yeaton and Cody, 1979; Lieffers and Larkin Lieffers, 1987). Mapping of vegetation spatial patterns at large scales based upon moisture and calculated solar

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radiation has been attempted with remote sensing technology (Dymond and Johnson, 2002). Vegetation patterns as affected by slope and aspect in the Chihuahuan desert were investigated by Mata-Gonzalez et al. (2002). They concluded that topographic variations were an important influence on plant distributions. Weiss et al. (1988) examined solar radiation influence on the life cycle of Euphydryas butterflies. Theoretical modeling of the amount and timing of solar exposure was combined with experimental and observational studies of the phenologies of life stages and host plants. The study found a correspondence between life cycles, senescence and solar radiation timing.

In many ecosystems, especially in semi-arid climates, soil moisture deficit is often the most important stress factor for vegetation. Heat stress, e.g. is most important after the cooling effect of transpiration has been reduced by moisture deficit. Stephenson (1998) explains climatic variation in plant distributions in terms of actual evapo-transpiration and moisture deficit. Porporato et al. (2001) and Rodriguez-Iturbe et al. (2001) have developed models of the interaction of soil moisture dynamics and plant response under conditions of water stress. Goldberg and Novoplansky (1997) explain the two-phase resource dynamics hypothesis which predicts that critical conditions for desert plants correspond to periods of water stress and the timing of water stress. In both models timing of precipitation and evapo-transpiration are predicted to be primary predictors of plant niche separation.

One of the primary variables influencing evapo-transpiration and thus soil moisture in semi-arid regions is the amount of solar radiation (Monteith, 1973). Veera (2004) calculated potential evapo-transpiration (PET) for 230 sample sites located on two small volcanoes in the West Potrillo Mountains, NM located in the Chihuahuan Desert. He found that solar radiation and PET were highly correlated and both offered essentially the same prediction of plant distributions. Qiu et al. (2001) found a positive correlation between the cosine of the aspect (shows north–south trends) and soil moisture content in a semi-arid region of China.

Sunlight is more complex on a small mountain than generally appreciated. Fig. 1 shows the path of the sun at different times of the year at the location of the study site. The zenith angle is the angle between vertical and the sun, azimuth is the compass direction to the sun with North = 0°, East = 90°, South = 180°, and West = 270°. Slope and azimuth (aspect) must be considered in combination with shading. For example, a flat or south-facing site could be located just to the north of a cliff. This occurs, e.g. near a subsidiary peak on the south side of the study site. Flat sites can occur at a mountain top, with no shading, or at the base of a mountain or cliff where shading reduces radiation during some times of the day and year.

Instantaneous versus daily averaged radiation may be important. The sun follows a curved arc across the sky with the arc being most noticeable in the summer. Fig. 1 is calculated for the latitude of the study site. A steep south-facing slope receives sunlight throughout the day in the winter and is at a favorable angle (normal) to the sunlight angle during the winter. At the spring and fall equinox the sun rises and sets exactly to the east and west but spends the rest of the day to the south, but to a lesser degree than in the winter. Around the summer solstice the sun rises in the north-east, moves slightly to the south at solar noon, and in the afternoon moves westward and