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Radiation, aridity and variable moisture regimes in complex terrain: implications for fire regimes, soil and vegetation

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Climate variables such as net radiation and aridity are important in shaping vegetation, soil and fire regimes, and they are therefore a major source of variation in water and carbon dynamics across landscapes. At a global scale, for example, the variations in these variables cause gradients in biomes from rainforest to deserts. At smaller scales in complex terrain, topographic effects on net radiation and orographic precipitation result in local variation in energy and water availability, which can have large implications for ecosystem function and catchment processes. This study calculates the Budyko radiative index of dryness (or aridity index, β) in mountainous terrain in order to predict small-scale variations in microclimate, vegetation structure and moisture dynamics on the forest floor. The aridity index (ratio of the yearly sums of net radiation to those of the latent heat of precipitation) was obtained for a large forested region from gridded rainfall data and from net radiation calculations that take account effects of topography and cloud cover on shortwave radiation. The method utilized satellite-based measures of shortwave radiation to provide spatial coverage and long-term data on incoming shortwave radiation. These data were coupled with a topographic downscaling algorithm to produce estimates of average annual net radiation and aridity at the resolution of a 20-m digital elevation model, thus incorporating topographic effects on net radiation while retaining information on the regional and seasonal trends captured in the satellite data. Sites for monitoring microclimate and moisture content in litter and in near-surface soils were established at four levels of aridity ($0.87 \leq \beta \leq 1.92$) in the Upper Yarra Catchment in southeast Australia. Variations in aridity were obtained by locating sites on different slope aspects. Rainfall and air temperature were similar across the four sites. However, the moisture regimes on the forest floor was highly sensitive to the incoming shortwave radiation, which was up to 6 times higher in the north-facing (equatorial) slopes due to slope orientation and the sparse vegetation compared to vegetation on the south-facing slopes. Differences in shortwave radiation resulted in peak temperatures within the litter that were up to 2 times higher on the north-facing site than those on the south-facing site. For instance, on November 2013 with maximum open air temperature of 35.5 °C, the temperature within the litter layer at the north-facing and south-facing sites where 54.3°C and 32.1°C, respectively, despite air temperature at the two sites differing by less than 2°C. The minimum gravimetric water content in the litter layer on the same day was 21% on the north-facing slope and 85% on the south-facing slopes. Using data from previous research in the region we show that consistent differences in moisture regimes at small spatial scales have large implications for feedbacks between decomposition, site productivity, fire, soil properties and erosion rates. In future work we aim to model landscape heterogeneity in vegetation patterns, soil and landform by linking variations in microclimate to the aridity index more broadly across the landscape.