Modeling vegetation cover in drylands: linking ecological continuum theory and spatial hydrology

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Abstract. Vegetation cover is an important ecosystem factor regulating soil development, erosion processes, landform evolution, and many other ecosystem processes and conditions. In order to address the implications vegetation cover has upon ecosystem functioning, a modeling approach was developed that links vegetation distribution to soil properties and topography in arid and semi-arid landscapes.

In dryland environments (average annual precipitation < 400 mm), availability of soil moisture is in many cases the critical limit upon vegetation growth. A hydrology model component was developed to estimate the spatial distribution of soil moisture across a landscape using a grid-based landscape conceptualization. Soil moisture accumulates from precipitation and from overland flow (runon) infiltration and is lost by either evaporation or transpiration, with solar radiation exposure playing an important regulating role. A new landscape moisture index (LMI) integrates solar radiation with runon, runoff, and infiltration, which are calculated downslope within a catchment using a recursive, grid-cell accounting scheme.

Within the model ecology component, ecological continuum theory is employed with species abundance distributed in response to a moisture resource gradient. Because multiple species are present in natural ecosystems, competition occurs among plants for available soil moisture. Thus, the plant species distribution in a multi-species landscape is a function of the available moisture (indicated by the LMI) and the species' abilities to compete for that moisture. The summation of individual plant species information provides the total vegetation cover characteristic for a particular location.

Soil, vegetation, and topographic data collected for six small watersheds in Utah, Idaho, Wyoming, and Arizona were used to test model concepts. The LMI moisture index was found to be a better indicator of the spatial distribution of vegetation than either a ln(a/tan b) index or a solar radiation index. Species distributions along the LMI gradient compare well to those specified by ecological continuum theory.

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