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Preface

Emerging issues in rangeland ecohydrology

Bradford P. Wilcox[1]* and Thomas L. Thurow[2]

[1] *Department of Rangeland Ecology and Management, Texas A&M University, College Station, TX, USA*
[2] *Renewable Resources Department, University of Wyoming, Laramie, WY, USA*

Rangelands are of enormous importance, making up close to half the terrestrial global landscape. Defined as areas capable of producing forage but unable to support rain-fed agriculture, rangelands are amazingly diverse but are generally water-limited for at least part of the year. Another unifying feature of many rangelands—unfortunately—is that they have undergone (and continue to undergo) rapid transformation as a result of factors such as overgrazing, deforestation, woody-plant encroachment, and invasion by nonnative plant species. Each of these factors has altered rangeland water cycles and related biogeochemical processes in ways that appear to be significant but are not well understood. In addition, the demand for scarce water in rangeland environments has increased as human populations and their associated water needs—agricultural, residential, and municipal—have grown, increasing the conflict between human and ecosystem maintenance needs.

Given the challenges posed by these transformations, the theme of this set of papers—*Emerging Issues in Rangeland Ecohydrology*—is especially appropriate. Ecohydrology focuses on the hydrology–ecology interface, i.e. the interrelated dynamics of hydrology and ecology. Research in this area is developing rapidly, addressing temporal and spatial issues across the spectrum of conceptual hierarchies (e.g. organism, population, community, ecosystem, watershed). Research in ecohydrology is strengthening the fundamental scientific insights that are necessary to effectively address environmental concerns (e.g. ecological processes that influence water yield and water quality; hydrological processes that influence succession or desertification). This kind of work is critical if we are to develop innovative restoration strategies for rangelands and provide policy-makers with relevant information about the ecological and hydrological tradeoffs associated with land management decisions.

The catalyst for this Special Issue was a Society for Range Management Symposium, convened to summarize the status of research being conducted across the spectrum of ecohydrological issues that pertain to rangelands. A unifying feature of the 13 invited papers was analysis of the influence of biotic components on the water cycle of a rangeland ecosystem, and how those biotic components are affected by land-use practices. Each of the papers addresses some important aspect of a key issue related to the ecohydrology of rangelands. These include the temporal and spatial components of evapotranspiration (ET); interrelationships between carbon and water fluxes; the influence of vegetation cover and land management on runoff and erosion processes; the implications of woody-plant encroachment for streamflow and recharge; the influence of topographic characteristics on hydrological, ecological, and soil processes; groundwater and surface water interactions as modulated by vegetation; and the societal drivers and ecohydrological implications of desertification. Our hope is that collectively, this set of papers will not only provide a synthetic overview of the state of our knowledge concerning the ecohydrology of rangelands, but will point the way for future research.

* Correspondence to: Bradford P. Wilcox, Department of Rangeland Ecology and Management, Texas A&M University, College Station, TX, USA. E-mail: bwilcox@tamu.edu

The first paper in this series (Owens *et al.*) presents one of the most comprehensive spatial and temporal analyses of the interception process, focusing on a rangeland shrub—Ashe juniper. This work demonstrates how encroachment of tree species with high interception capacity may significantly alter the water cycle. Perhaps even more important, it gives us new insight into the variability of the process and how it is affected by precipitation characteristics.

The second and third papers (Belnap, Bartley *et al.*) highlight the importance of ground cover in modulating runoff and erosion on rangelands. Belnap provides a comprehensive framework for understanding how biological soil crusts alter infiltration and soil loss. The character of these crusts varies with climate and soil type, determining how they affect water and soil retention. Biological soil crusts are susceptible to degradation by air pollution or by disturbance from livestock grazing and human foot or vehicular traffic; such degradation can significantly alter the runoff and erosion characteristics of the rangeland. Similarly, but at a larger scale, Bartley *et al.* explore the importance of the pattern and size of bare patches for runoff and erosion at the hillslope scale. This work is important both because it examines how the size, location, and extent of bare soil patches influence runoff and erosion and because it provides some important baseline information about runoff and erosion processes at the hillslope scale for tropical rangelands in Australia. They found that (1) the arrangement and extent of bare patches can have a huge influence on hillslope water and sediment budgets; (2) the location and arrangement of vegetation cover on the hillslope is more important than the "average" cover condition; (3) bare patches can produce disproportionately high runoff and sediment loss; and (4) moderate to very extensive vegetation patches at the bottom of a hillslope are especially useful for trapping sediment before it can enter the stream network. Incorporating these insights into hillslope models will be a crucial step in improving future runoff simulation.

Several papers in this set examine ET processes and how they are coupled with biological activity. Except for precipitation, ET is easily the most important component of the water budget on rangelands. Typically, more than 90% of the precipitation is evaporated, as either transpiration or evaporation from the ground or plant surface; and in riparian areas it can be even higher. Although bulk ET is generally well quantified, we know surprisingly little about the relative importance of its two components or their relationship to plant-carbon uptake. Working in an Arizona shrubland, Scott *et al.* used complementary measurements to determine the ratio of evaporation to transpiration and how these different ET pathways were related to components of the carbon budget for an entire growing season. They found that in this ecosystem, transpiration made up about 60% of total ET and the efficiency of water use (ratio of net CO_2 gain to net water loss) increased as the T : ET ratio increased during the summer growing season.

Two papers (Williams *et al.* and Cleverly *et al.*) explore the implications of vegetation change in riparian communities. Working on floodplains of the San Pedro River (in southern Arizona) that have recently converted from grasslands to mesquite woodlands, Williams *et al.* found that ET and gross ecosystem production are essentially independent of precipitation during the growing season, whereas decomposition of litter and soil organic matter are strongly related to monsoonal rainfall. Cleverly *et al.* evaluate some of the recent vegetation changes in the Middle Rio Grande of New Mexico and assess their implications for the water budget.

The papers by Wilcox *et al.* and Huang *et al.* discuss the influence of shrubs on streamflow. These studies conclude that where springs are present, streamflow may be augmented by management practices designed to decrease woody-plant cover (thereby reducing losses through interception and transpiration). The response of streamflow to shrub cover is especially sensitive to changes in woody-plant cover on sites where groundwater is close to the surface and/or deep drainage occurs (because of high precipitation and/or bypass flow through the soil), making soil water accessible to shrubs. Therefore, riparian sites have a greater potential for increased streamflow through conversion of woodland cover to grassland than do upland sites where groundwater is not accessible.

The papers by Gutierrez-Jurado *et al.* and by Seyfried and Wilcox discuss soil-water fluxes and the role of vegetation management in soil-water storage and recharge. Slope aspect affects hydrologic fluxes in the root zone, and these fluxes reinforce the development of soil profiles—

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leading to feedbacks between plant establishment, soil-water fluxes, and geomorphic processes within a catchment. With conversion from woody plants to grasses, the effective rooting depth decreases, which can lead to the development of a wetting front deeper than the effective rooting depth; when this happens, a change in soil-water storage or deep drainage is more likely.

The papers by Scanlon *et al*. and Newman *et al*. are oriented toward groundwater recharge issues in semiarid rangelands. Scanlon *et al*. present a compilation and synthesis of global estimates of recharge rates in these regions. They discuss important controls on the variability of recharge, including climate (especially interannual variability related to extreme El Niño phenomena), vegetation, soils, and geology. Groundwater recharge tends to be highly episodic and limited to a small percentage of a rangeland basin. However, changes in land use and land cover can produce substantial shifts in recharge, with important consequences for both water supply and quality.

The paper by Newman *et al*. focuses on surface water–groundwater interactions in semiarid rangelands. The authors first describe how landscape-scale factors, such as geomorphologic processes, control the distribution and density of drainages—and thereby the distribution of surface water and groundwater and the nature of their interactions. They then discuss interactions between hydrological and biogeochemical processes that occur within semiarid drainages, at both the reach and patch scales. They conclude by presenting a set of alternative conceptual models that describe surface water–groundwater interactions within semiarid drainages, and discuss areas where additional research is needed.

The topics discussed in this series of papers provide insights that can be applied to sustainable resource management and restoration ecology. In a case study from Mexico, Huber-Sannwald *et al*. discuss the links between the hydrologic cycle and desertification. They propose an approach for assessing the interplay of the human and environmental drivers and thresholds that contribute to desertification. Identifying and mitigating these processes are necessary for sound resource management and a precondition for crafting restoration strategies.

There are many information gaps in the current state of our knowledge, and these limit our ability to predict how hydrological and ecological processes interact on rangelands. Ecohydrology as a science is well positioned to fill these gaps, which will enable us to attain rangeland management objectives such as the optimization of water yields and restoration of degraded areas. The 13 articles in this series not only reveal some of the complexity of the relationships within the sphere of ecohydrology, but also establish some guideposts for the future direction of research in this field.

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