SPECIAL FEATURE

Ecohydrology of Semiarid Landscapes[1]

Water is a limited commodity in arid and semiarid landscapes, and what water is available is vitally important for both ecosystem functioning and human needs. Virtually every process involved in how much water is available and how it is distributed is affected in some way by interactions with the environment—plants in particular. Current inhabitants of semiarid environments want and need to protect these sensitive ecosystems, but at the same time (as their numbers grow) they require both more water and better water quality. Achieving both goals is possible only through good management decisions, which in turn are possible only through a broad-based understanding of the complex interactions between ecology and hydrology.

Building such a broad-based understanding is the focus of the burgeoning interdisciplinary field of ecohydrology. In this Special Feature, we examine some of the most critical issues related to the ecohydrology of semiarid landscapes, which occupy about 35% of the global landmass. In these regions, the ecohydrological issues are different from those in more humid landscapes because of the acute competition for water and the greater sensitivity to environmental change (as evidenced by the dramatic degradation that has occurred in many semiarid areas over the past century).

In the last decade the term *ecohydrology* has become more common as the subdiscipline has gained visibility and attracted interest. The roots of ecohydrology can be found in diverse disciplines such as forest and rangeland hydrology, landscape ecology, fluvio-geomorphology, soil physics, and aquatic biology. However, its recent popularity arises from the recognition that current and future environmental problems are so complex that interdisciplinary collaboration, particularly between ecologists and hydrologists, is needed to shed light on them. Ecohydrology is fundamentally an applied science driven by real and pressing environmental issues, including water supply, water quality, contaminant transport, invasive species, woody plant encroachment, degradation, and desertification.

This Special Feature is an outgrowth of a specially convened American Geophysical Union Chapman Conference—Ecohydrology of Semiarid Landscapes. Our rationale in convening that conference was simple: there is a need for more, and more direct, interdisciplinary collaboration between ecologists and hydrologists examining water-related issues in semiarid landscapes. The papers in this Special Feature focus on some of the most important environmental problems in semiarid landscapes, with the common thread that they all examine issues related to water fluxes. Broadly speaking, ecohydrological issues in semiarid landscapes can be divided into those pertaining to vertical fluxes and those pertaining to horizontal fluxes. Vertical fluxes encompass evaporation, infiltration, percolation, recharge, and transpiration; horizontal fluxes are related to surface processes of runoff and soil erosion.

The first paper in this Special Feature (Seyfried et al.) focuses on the vertical flux of deep drainage and recharge, paying special attention to how plants modify this flux. The authors explore the role of vegetation—shrubs in particular—in controlling vertical fluxes, which are directly related to the processes of contaminant transport and groundwater recharge. Surprising new research suggests that, for many arid and semiarid landscapes, downward water fluxes below the root zone are small or even zero and may have been so for thousands of years. This phenomenon is attributed to extant xeric shrub communities. Although deep drainage and recharge are seen in certain parts of arid and semiarid landscapes, the climatic, edaphic, and biotic thresholds determining the presence or absence of deep water movement are not well understood. These findings raise important ecophysiological questions concerning the allocation of carbon for root

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growth and water uptake by these shrub communities. Answers may be found in the mechanisms by which the plants redistribute water and compete for nutrients.

The second and third papers (Ludwig et al. and Belnap et al.) deal largely with horizontal fluxes of water and nutrients and how they affect and are affected by vegetation patterns and microbial activity. Ludwig et al. describe interactions between patchy vegetation and surface runoff for semiarid landscapes, while Belnap et al. focus on how nutrient and microbial processes in hillslope areas are linked via runoff with otherwise disconnected riparian areas, and how soil surface features (biological soil crusts, vegetation patterns) affect runoff patterns in semiarid uplands and streams. Both papers rely on the Trigger-Transfer-Reserve-Pulse (TTRP) conceptual model to explain these interactions. This and other recent work on the TTRP model, much of which is summarized in the Ludwig et al. paper, has highlighted the importance of feedbacks between vegetation patches and surface runoff for maintaining the integrity of semiarid landscapes. When the integrity of the vegetation patch structure is compromised, the already limited resources of water, sediment, and nutrients are lost, leading to further degradation. Degraded areas may be restored if the original patch structure can be recovered and resources retained on site.

The Belnap et al. paper uses the TTRP model to show that, in semiarid uplands, the variability and intensity of precipitation as well as soil surface features drive pulses of microbial activity, which are a key factor in the spatial and temporal distribution of nutrients and runoff on the landscape. Further, they extend the TTRP model to the stream network, where patch structure and hydrologic interactions among various parts of the stream–riparian corridor control microbial activity, nutrient gains and losses, and plant growth. The importance of floods on nutrient transfer in the stream–riparian corridor is also highlighted.

The final paper (Huxman et al.) examines the consequences of woody plant enchroachment on biogeochemical and water cycles. The authors address the ecohydrological implications of woody plant enchroachment, a phenomenon occurring on a global scale. In particular, they try to clarify what the implications may be for the water cycle. How might the partitioning of the water budget (recharge, runoff, evaporation, and transpiration) differ with changes in woody plant cover? The answers to this question are directly relevant to issues related to water supply and contaminant transport, as well as those related to other biogeochemical cycles, such as carbon. A set of conceptual frameworks is presented that helps put the potential changes into perspective and highlights where changes are expected to be the greatest.

These papers, we believe, represent an integrated view of ecohydrology that has grown out of cross-disciplinary communication and consensus-building. Collectively, they address some of the most compelling ecohydrology issues for semiarid environments. Although the process of breaking down disciplinary walls is difficult, the fresh insights it engenders will lead to a truly integrated understanding of ecohydrological interactions in semiarid landscapes. As an added benefit, a new interdisciplinary science community is developing around the theme of semiarid ecohydrology. We present these papers in the hope that they will spur the growth of that community and of research with an ecohydrologic perspective.

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Key words: deep drainage; evapotranspiration; landscape ecology; nutrient cycling; rangeland hydrology; recharge; runoff; soil erosion; water budget; water yield; woody plants; xeric shrubs.