Introduction to the Special Issue “Ecohydrologic Feedbacks between Vegetation, Soil, and Climate”

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1. Introduction

Vegetation transitions on arid and semi-arid landscapes present unique opportunities for examining structural and functional (pattern and process) ecohydrologic feedbacks that regulate site ecological resilience. Runoff and soil loss on well-vegetated sites are commonly low due to the complex spatial patterning of hydrologic and erosion sources and sinks. Infiltration, soil water recharge, and nutrient retention on these landscapes enhance vegetation productivity, ground cover recruitment, soil quality, and overall ecological resilience. Disturbances or perturbations that coarsen the plant community structure commonly amplify runoff and soil erosion rates and, when respective conditions are sustained, can propagate long-term soil loss and site degradation. Common examples include woody plant encroachment, drought, desertification, over-grazing, deforestation, and frequently recurring wildfire. This Special Issue explores aspects of these dynamic relationships and advances in associated predictive technologies and tools from a suite of studies spanning the USA, Israel, Germany, and China. Here, we provide a brief summary of the Special Issue papers, organized into three topic areas: (1) vegetation, soils, and hydrology and erosion feedbacks, (2) land cover change and subsurface flow process interactions, and (3) advances in erosion prediction and soil water content measurement. Although these papers are a small sample, they provide unique and interesting insight into complex ecohydrologic relationships that commonly occur around the World.

2. Vegetation, Soils, and Hydrology and Erosion Feedbacks

Williams et al. [1] examined the long-term effectiveness of tree removal treatments (13 year post-treatment) to re-establish a shrubland vegetation community and associated ecohydrologic function at multiple sites in the Great Basin Region, USA. Sites in the study were historically well-vegetated by a mixture of sagebrush shrubs (*Artemisia* spp.) and perennial bunchgrasses but had transitioned to pinyon (*Pinus* spp.) and juniper (*Juniperus* spp.) woodlands with extensive bare ground and high rates of hillslope runoff and soil erosion [1]. Pinyon and juniper trees commonly encroach into sagebrush shrublands over prolonged fire-free periods and subsequently outcompete sagebrush shrubs and understory herbaceous plants for limited water and soil nutrients. As described by the authors, encroaching trees can dominate site resources over time and thereby establish a woodland overstory with extensive bare area and high runoff and erosion throughout the intercanopy between trees [1]. Williams et al. [1] found that conifer removal by fire and mechanical methods (cutting and shredding) enhanced herbaceous foliar and basal plant covers and reduced bare ground expanse. The increased spatial distribution of cover throughout previously bare intercanopy areas improved soil hydraulic properties and overall ecohydrologic function. Increases in vegetation and improved ecohydrologic function

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were generally greater for burned than mechanical treatment areas. The authors discuss the various ecohydrologic tradeoffs in the respective treatment options for the conservation of sagebrush steppe and similar shrubland communities [1].

Stavi et al. [2] evaluated the long-term impact of ancient (Roman and Byzantine ages) water-harvesting stone structures on vegetation and soil quality in Negev drylands of southern Israel. The authors found that intact terraces upslope of residual water-harvesting structures had significantly greater shrub and herbaceous vegetation cover and enhanced soil quality relative to 'natural' lands without structures and to degraded terraces upslope of collapsed structures. Stavi et al. [2] attributed greater vegetation production on intact terraces to effective water capture and storage in soil upslope of residual structures. Precipitation approximates 90 mm annually at the study sites and is a primary control of vegetation production. Stavi et al. [2] ascribed greater soil quality on intact terraces to enhanced shrub cover. Soils in shrub patches were associated with greater aggregate stability, particulate organic carbon, and microbial and mesofaunal abundances relative to bare inter-shrub patches. Overall, vegetation cover and soil quality were the greatest for intact terraces and were 'generally degraded' on terraces with collapsed structures compared to 'natural' lands [2]. Collapsed structures showed evidence of downslope rilling and associated losses of water and soil [2]. As noted by the authors, the study clearly demonstrates conservation structures on drylands can enhance vegetation structure and improve soil quality through water conservation but may also promote water and soil losses where not adequately maintained.

The studies by Williams et al. [1] and Stavi et al. [2] collectively elucidate the potential effects of structural/functional ecohydrologic feedbacks in enhancing or degrading plant community resilience and soil quality on water-limited lands.

3. Land Cover Change and Subsurface Flow Interactions

Wiekenkamp et al. [3] evaluated subsurface flow behavior before and after partial deforestation of a small headwater catchment in Eifel National Park, Germany. The study site was primarily forested with Norway spruce (*Picea abies* L.) and Sitka spruce (*P. sitchensis*) before treatment and historically received 1200 mm annual precipitation. The authors applied soil moisture response time methodologies to soil moisture data collected at soil depths of 5 cm, 20 cm, and 50 cm for conditions 3 years before and 2 years after tree removal by cutting to investigate deforestation impacts on water flow within the vadose zone. The authors found that partial deforestation increased occurrences of both preferential flow (wetting front velocity $> 100 \text{ mm h}^{-1}$) and piston flow (wetting front velocity $< 100 \text{ mm h}^{-1}$) and reduced occurrences of no flow (no change $> 1 \text{ vol. } \%$) over the sampled depths with respect to forested conditions receiving the same total precipitation [3]. The authors suggested that treatment-induced increases in preferential flow were due to reduced precipitation interception following deforestation [3]. Wiekenkamp et al. [3] attributed piston flow responses to amplified antecedent soil moisture throughout the soil profile and lesser precipitation interception following tree removal. Overall, the authors found that soils were generally wetter after rainfall events in the deforestation treatment and responses to rainfall were more substantial [3]. The authors discuss potential benefits and ramifications of increased preferential and piston flow occurrences following deforestation, including more rapid delivery of water and nutrients to soil layers and export of dissolved organic carbon and nutrients to ground water.

4. Advances in Erosion Prediction and Soil Water Content Measurement

In a laboratory study, Nouwakpo et al. [4] evaluated the effect of shallow subsurface hydrology on soil transport capacity. They developed a new methodology to quantify transport capacity based on changes in soil surface microtopography. Elevation change maps and flow hydraulics data were derived from laboratory concentrated flow erosion experiments and used to calculate the probability of erosion at regular flow hydraulics intervals and an exceedance threshold for transport capacity, where probability of erosion

= probability of deposition. Nouwakpo et al. [4] found that erosion patterns during experiments were not readily explainable by commonly applied transport capacity-based concepts. Based on their experiments, the authors presented a new framework for transport capacity that addresses dynamic conditions associated with concentrated flow and subsurface processes. The study demonstrates the application of increasingly accessible surface digital elevation data to evaluate and improve upon existing erosion prediction concepts and technologies.

Lastly, the study by Zhou et al. [5] developed and assessed a high-precision detection technology to determine shallow soil water content. In a laboratory setting, the authors utilized a 2-GHz high-frequency Ground Penetrating Radar (GPR) antenna approach to predict shallow soil water content for various soil textures. Zhou et al. [5] show that soil water content predictably influences the attenuation of wave energy and velocity of the GPR and substantially affects the soil dielectric permittivity. The authors discuss many other factors that affect soil dielectric permittivity, and that must be accounted for, including soil physical, mechanical, and chemical properties. Modeled relationships between soil dielectric permittivity and soil water content clearly show the GPR approach effectively estimates depth-averaged soil water content over diverse hydrologic conditions [5]. The authors point out the GPR approach ‘bridges the gap’ between point-scale and remote sensing soil water content measurements and that the application is appropriate at the field-scale. The study provides a scientific basis for applying the studied technology for measuring soil water content, a variable of critical importance in assessing feedbacks between vegetation, soils, and climate.

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References

1. Williams, C.J.; Johnson, J.C.; Pierson, F.B.; Bursleson, C.S.; Polyakov, V.O.; Kormos, P.R.; Nouwakpo, S.K. Long-term effectiveness of tree removal to re-establish sagebrush steppe vegetation and associated spatial patterns in surface conditions and soil hydrologic properties. *Water* **2020**, *12*, 2213. [[CrossRef](#)]
2. Stavi, I.; Rozenberg, T.; Al-Ashhab, A.; Argaman, E.; Groner, E. Failure and collapse of ancient agricultural stone terraces: On-Site effects on soil and vegetation. *Water* **2018**, *10*, 1400. [[CrossRef](#)]
3. Wiekenkamp, I.; Huisman, J.A.; Bogena, H.R.; Vereecken, H. Effects of deforestation on water flow in the vadose zone. *Water* **2020**, *12*, 35. [[CrossRef](#)]
4. Nouwakpo, S.; Huang, C.H.; Bowling, L.; Owens, P.; Weltz, M. Inferring sediment transport capacity from soil microtopography changes on a laboratory hillslope. *Water* **2021**, *13*, 929. [[CrossRef](#)]
5. Zhou, L.; Yu, D.; Wang, Z.; Wang, X. Soil water content estimation using high-frequency ground penetrating radar. *Water* **2019**, *11*, 1036. [[CrossRef](#)]