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Editorial

Advances in Ecohydrology for Water Resources Optimization in Arid and Semi-Arid Areas

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Abstract: Conserving water resources is a current challenge that will become increasingly urgent in future due to climate change. The arid and semi-arid areas of the globe are expected to be particularly affected by changes in water availability. Consequently, advances in ecohydrology sciences, i.e., the interplay between ecological and hydrological processes, are necessary to enhance the understanding of the critical zone, optimize water resources' usage in arid and semi-arid areas, and mitigate climate change. This Special Issue (SI) collected 10 original contributions on sustainable land management and the optimization of water resources in fragile environments that are at elevated risk due to climate change. In this context, the topics mainly concern transpiration, evapotranspiration, groundwater recharge, deep percolation, and related issues. The collection of manuscripts presented in this SI represents knowledge of ecohydrology. It is expected that ecohydrology will have increasing applications in the future. Therefore, it is realistic to assume that efforts to increase environmental sustainability and socio-economic development, with water as a central theme, will have a greater chance of success.

Keywords: groundwater; transpiration; evapotranspiration; deep infiltration; gully erosion; runoff; forest restoration; compost; silicon; soil water retention

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1. Introduction

In recent decades, most surveys related to soil physics and hydrology have shifted from the laboratory to the field, and have grown from a limited vision, considering only one aspect, i.e., only the physical characteristics of hydrology, to a comprehensive vision that interfaces with the domains of related disciplines, such as meteorology and climatology, engineering, pedology, ecology and geochemistry [1].

Ecohydrology is "... an interdisciplinary scientific field studying the interactions between water and ecological systems. It is considered a sub-discipline of hydrology, with an ecological focus. These interactions may take place within water bodies, such as rivers and lakes, or on land, in forests, deserts, and other terrestrial ecosystems. Areas of research in ecohydrology include transpiration and plant water use, adaption of organisms to their water environment, influence of vegetation and benthic plants on stream flow and function, and feedbacks between ecological processes, the soil carbon sponge and the hydrological cycle" [2].

Conserving water resources is current challenge that will become increasingly urgent in future, due to climate change [3]. The arid and semi-arid areas of the globe are expected to be particularly affected by changes in freshwater availability [4,5]. Consequently, advances in ecohydrology sciences are necessary to enhance understanding of the critical zone hydrology, to optimize water resource usage in arid and semi-arid areas and mitigate climate change [6,7].

The main goal of this Special Issue (SI) was to present advanced research and applications in ecohydrology, with a focus on water resources' optimization in arid and semi-arid areas. Overall, the contributions gathered in this SI account for the ecohydrology of (i) natural areas, including deserts [8,9], wetlands [10], grasslands–rangelands [11] and forests [12], (ii) cultivated areas, including orchards [13] or arable lands [14], or (iii) without specific focus on the environment–vegetation interaction [15–17]. The most common contributions were studies on groundwater and transpiration–evapotranspiration.

Based on recommendations by the scientific editors of MDPI journals, a paper [15] was included among the Editor's choice articles, namely, investigations deemed of particular interest for readers, or important in their field.

A synthesis of the main results archived by the collected investigations is reported in the following section.

2. Overview of This Special Issue

This Special Issue collected 10 original contributions focused on ecohydrology. Almost all concerned field investigations took place in arid and semi-arid areas [8–11,13–16], although some of them were from more humid environments [12]; only one investigated the optimization of water resource in a controlled laboratory environment [17]. Furthermore, half of them were developed in China [8–11,14], while the rest were from Kansas, United States [15], Korea [16], Brazil [12] and Mediterranean Europe (Italy and Portugal) [13,17].

For the reader's convenience, the publications are grouped by general theme: (1) transpiration/evapotranspiration, (2) groundwater/deep percolation, and (3) miscellaneous.

Topic 1 comprises four papers. Darouich et al. [13] estimated the evapotranspiration fluxes and water use in two Mediterranean vineyards, one in northern Italy with a sloping, rainfed crop, and one in southern Portugal in a flat area with irrigation. The SIMDualKc model was successfully applied for both study cases to simulate water use, crop evapotranspiration and the soil–water balance.

Tang et al. [14] investigated the spatiotemporal variability in evapotranspiration and the effects of water and heat on water-use efficiency (WUE), in a natural area of the Eurasian hinterland and on the northwestern border of China (Xinjiang). The results showed that spatial variations in WUE in different hydrological processes were significant, and the WUE trend in most regions showed an upward trend. They also found that, in arid areas, temperature has a positive effect on WUE, while precipitation has a lagging effect on WUE.

Xu and Yu [9] conducted their investigation on the environmental control of the transpiration of a desert ecosystem within an oasis–desert ecotone, where the sap flow from three dominant shrub species and concurrent environmental variables were determined during two growing seasons. Their work provided insights into environmental controls on the water flux of arid and semi-arid regions at the ecosystem scale and implications for diurnal hydrology modeling, specifically diurnal transpiration and water stress modeling.

Jia et al. [10] reported the research results for an environment at risk of desertification in Inner Mongolia, northwestern China. They investigated: (i) the evapotranspiration of groundwater (ETG) using estimates from multiple observation wells and soil moisture fluctuations at different sites, (ii) the temporal and spatial variations in ETG, and (iii) the sensitivity of ETG to water table depth for different types of vegetation (i.e., Phreatophytes).

Topic 2 comprises three papers. Ternes [15] examined how private water wells influenced the conservation of a high Plains aquifer in Midwestern states such as Kansas, and how this groundwater resource was tapped beyond its natural replenishment rates. Comparing the watering technologies of well-owners to those of non-well-owners across

the state, and analyzing well ownership, facilitated an assessment of the relationships that exist between infrastructural conditions and water-conservation.

Park et al. [16] quantified the different silicon fractions in volcanic ash soils on Jeju Island (south Korea) that may affect groundwater silicon content, and compared them with those in forest soils in mainland Korea. The idea comes from the fact that silicon may be dissolved and leached through the soil profile into the groundwater. A high concentration of silicon, along with calcium and potassium in drinking water, improves water taste and benefits human health. Their results indicate that silicon is more soluble in the Andisols of high-precipitation regions and that Andisols on Jeju Island potentially affect groundwater silicon concentration.

The paper by Cheng et al. [8] aimed to explore the redistribution process of precipitation moisture in shallow soil in an arid sandy region (Ulanbuh desert, northern China), as fragile ecosystems in arid sandy regions are extremely sensitive to water deficits. The authors identified the characteristics of water dynamics and transformation in the arid area of the Ulanbuh Desert. Their results can serve as a guideline for the quantitative assessment of water resources in arid sandy regions.

Topic 3 comprises three papers that outlined some other important research issues. Li et al. [11] dealt with the general issue of the sustainable development of arid rangeland in Central Asia, and how gully erosion, flooding, and droughts jointly restrict the sustainable development of arid rangeland. This paper shows that the applied rainwater harvesting (RWH) system in a gully was a flexible practice that alleviated complex environmental problems. The authors proposed some suitable low-cost RWH techniques to restore degraded grassland and promote community development. Their study could provide suggestions for ecological restoration and pasture management in arid regions of Central Asia.

There has been an increase in secondary tropical forests in recent years, due to forest restoration in degraded areas. However, the success of forest restoration processes depends on the presence of a healthy soil environment in which seedlings and trees can successfully develop. In this research context, the study by Pereira al. [12] aimed to answer this question: is passive restoration capable of improving soil-saturated hydraulic conductivity (K_s), as well as the physical attributes of the soil superficial horizon? Consequently, they investigated the behavior of K_s and some soil physical properties in forests of different ages in Rio Claro (São Paulo State, Southeast Brazil), which were undergoing passive restoration by natural regeneration, a degraded forest fragment, a pasture, and a sugarcane field. The authors confirmed what has been suggested in the literature, namely that the recovery of soil hydro-physical functioning is a slow process and varies according to the type of soil attribute, previous land-use and its degradation legacy.

Finally, Bondì et al. [17] investigated the reliability of indicators of soil physical quality, including pore-size distribution parameters, to assess the effectiveness of compost amendment on hysteretic water retention curves in a sandy loam soil. Hysteresis refers to a soil-attributed phenomenon wherein the soil water content at a given pressure head is higher during drying than during wetting. The authors concluded that compost addition could trigger positive effects on soil hydrological processes and agronomic services, since water infiltration was favored during wetting and water storage during drying.

3. Conclusions

The 10 original manuscripts contained in this SI have reported experimental results for sustainable land management and water resources' optimization in fragile or at-risk environments. Overall, environments investigated from the ecohydrology perspective included European vineyards, desert areas and fragile ecosystems in Asia, South American forests, and various other contexts. Most of them have not been extensively investigated to date, probably due to relatively low levels of economic interest. However, the growing awareness of the critical need to safeguard marginal or fragile environments, or restore degraded ones, for future generations, can multiply research efforts.

The collected manuscripts were summarized by grouping them into three main topics to show research advances in specific fields, such as (1) transpiration/evapotranspiration [9,10,13,14], (2) groundwater or deep percolation [8,15,16], and (3) miscellaneous [11,12,17]. The research aims and main results were also summarized.

The manuscripts collected in the SI provided results from specific environments worldwide, but all have stressed the possibility of extending the results to similar environments. More broadly, the collected results represent an enhancement of our understanding of critical zone hydrology, to optimize water resources' usage in arid and semi-arid areas, and to mitigate the impacts of climate change.

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