

Feature Article

The need of ecohydrological research in tropical forests for healthy watersheds

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Abstract

Tropical forests play a critical role in providing clean water and maintaining healthy watersheds, yet they face numerous threats such as deforestation, land use change, and climate change. To address these challenges, there is a growing need for ecohydrological research that can inform land use planning and management strategies for healthy watersheds. Ecohydrology is an emerging science that seeks to understand the functional interactions between hydrology and biota. It quantifies and explains the relationships between hydrological processes and biotic dynamics as well as linkages among upland, riparian, and aquatic components on a watershed scale. However, most of the ecohydrological studies have been concentrated on temperate regions, and for tropical regions, such studies are lacking. This article argues that there is a high time to launch research for identifying critical ecohydrological functions and driving forces that regulate the quality and quantity of water, and their role in providing water-based ecosystem services in tropical watersheds. The article outlines the main challenges facing tropical forests and watersheds, and highlights the importance of interdisciplinary collaboration and long-term monitoring for effective ecohydrological research. It also provides examples of successful ecohydrological research projects in tropical forests, and discusses the potential benefits of investing in ecohydrological research for tropical forest conservation and watershed management. Overall, this article emphasizes the importance of ecohydrological research in tropical forests for healthy watersheds and calls for more attention and resources to be devoted to this field.

Keywords: Ecohydrology, Tropical forests, Watersheds, Water resource management, Ecosystem services

1. Introduction

Tropical forests play a critical role in providing essential ecosystem services, including carbon sequestration, biodiversity conservation, and water regulation (Chandrathilake, 2019; Chazdon et al., 2016; Ewers et al., 2015; Gibbs et al., 2010). Among these services, the provision of clean water for human consumption and ecosystem health is perhaps the most vital. Healthy watersheds are essential for the sustainable management of water resources, as they help regulate water quantity and quality (Cerda et al., 2018; Keesstra et al., 2018). Unfortunately, tropical watersheds are increasingly threatened by a range of factors, including deforestation, land use change, and climate change (Brooks et al., 2019; Lees et al., 2020; Naeem et al., 2015). Deforestation and land use change can lead to soil erosion, sedimentation, and altered hydrological regimes, while climate change can exacerbate the impacts of these threats and lead to changes in precipitation patterns and increased water stress (Gupta et al., 2019; Poff et al., 2016; Shrestha et al., 2019).

Furthermore, tropical watersheds face significant water-related challenges, such as water scarcity, water pollution, and water-borne diseases (Hodges et al., 2020; World Health Organization, 2019). These challenges can have severe impacts on human health, particularly in low-income communities

that rely on natural resources for their livelihoods (Hodges et al., 2020; World Health Organization, 2019).

Therefore, it is imperative to understand the factors that affect water quality and quantity in tropical watersheds to develop effective management strategies and ensure the sustainability of water resources. Ecohydrology is an interdisciplinary field that aims to understand the interactions between ecological and hydrological processes and their feedbacks, with the goal of informing sustainable management of water resources (Scanlon et al., 2013; Sivapalan et al., 2019). The term 'Ecohydrology' was first coined in the early 2000s, although the concept of studying the interplay between ecosystems and water has a long history dating back to the 19th century (Blöschl et al., 2019; Zalewski, 2000). However, it wasn't until the late 20th century that the term gained popularity and emerged as a distinct field of study (Bonell and Bruijnzeel, 2004; Savenije, 2004).

Thus, Ecohydrology is an emerging field that can help address these challenges by studying the interactions between water, vegetation, and soil (Chandrathilake, 2019; Jenerette et al., 2016; Sivapalan et al., 2012). Ecohydrology has theoretical and practical significance in addressing current water management challenges. It offers a holistic approach to water management by considering the biotic and abiotic components of an ecosystem and their interactions with the water cycle. Ecohydrological principles have been applied to improve water management practices in various settings, including natural and agricultural ecosystems, urban areas, and river basin management. For instance, ecohydrology has been used to develop water management strategies that consider both the quantity and quality of water required for various ecosystem services (Gibert et al., 2010). It has also been used to promote sustainable land use practices and reduce the negative impacts of human activities on water resources (Jiang et al., 2019). Compared to traditional hydrology approaches, ecohydrology provides a more comprehensive understanding of water systems and their interactions with ecosystems, which can improve the effectiveness of water management practices (Sivapalan et al., 2012).

Ecohydrology is particularly relevant to tropical forests, as these ecosystems are characterized by high biodiversity and complex hydrological processes (Köhler et al., 2019; Loescher et al., 2018). Ecohydrological research can help identify the critical functions and driving forces that regulate water quality and quantity in tropical watersheds, as well as the role of forests in providing water-based ecosystem services (McDonnell et al., 2020; Scott et al., 2019). By combining interdisciplinary approaches and long-term monitoring, ecohydrology can provide valuable insights for the sustainable management of tropical watersheds and the conservation of tropical forests.

Ecohydrology is a rapidly evolving field that spans the disciplines of ecology, hydrology, and biogeochemistry. As a result, there are now several journals dedicated to publishing research related to ecohydrology. These journals include *Ecohydrology*, *Hydrology and Earth System Sciences*, *Ecohydrology and Hydrobiology*, *Journal of Hydrology*, and *Water Resources Research*, among others. The existence of these dedicated journals underscores the growing recognition of the importance of ecohydrology in understanding the complex interactions between water and ecosystems. Furthermore, it highlights the need for interdisciplinary research to address critical issues related to water availability, water quality, and the sustainability of aquatic and terrestrial ecosystems. Guswa et al. (2020) emphasizes the importance of interdisciplinary collaboration and diverse methodologies in ecohydrology research to address the complex challenges facing freshwater systems. Jun et al. (2021) provided a comprehensive review of the progress, challenges, and future directions of ecohydrology research in China, highlighting the need for a more holistic approach to water resources management, including the incorporation of socio-economic and ecological factors. Together, these studies underscore the critical role of ecohydrology in addressing the urgent challenges of freshwater resource management and the need for interdisciplinary collaboration in research.

Ecohydrology is an emerging field of study that seeks to understand the complex interactions between hydrological processes and biotic factors in natural ecosystems. It provides a framework for understanding the role of vegetation, soil, and water in regulating water quantity and quality, and how these processes can be influenced by human activities (Sivapalan et al., 2019). Ecohydrological research has shown that tropical forests play a critical role in regulating water flows and water quality, and that changes in land use and climate can have profound impacts on these processes (Bruijnzeel et al., 2011; Jauch et al., 2020).

Wright et al. (2017) conducted a comprehensive review of ecohydrology, highlighting the importance of interdisciplinary collaboration and the need for a more nuanced understanding of the feedback mechanisms between ecological and hydrological processes. They emphasized the role of ecohydrology in addressing critical challenges such as water scarcity and ecosystem degradation, and stressed the need for a more holistic approach to water resources management that incorporates both human and ecological needs.

In this article, we highlight the importance of healthy watersheds and the crucial role of tropical forests in providing clean water for human and ecosystem health. We also provide an overview of the emerging field of ecohydrology and its relevance to tropical forest ecosystems. Specifically, we discuss the need for more ecohydrological research in tropical forests to better understand the complex interactions between hydrology and biota, and to inform sustainable land use and water management strategies. We highlight the importance of interdisciplinary collaboration and long-term monitoring for effective ecohydrological research, and provide examples of successful ecohydrological research projects in tropical forests. Overall, this article emphasizes the urgent need for increased investment in ecohydrological research to ensure the long-term sustainability of tropical forest ecosystems and the watersheds they support.

2. Methodology

To write this feature article, we conducted a comprehensive literature review using various academic databases, including Web of Science, Scopus, and Google Scholar. We used a combination of keywords such as "tropical forests," "watersheds," "eco-hydrology," "water regulation," "land use change," "climate change," and "water quality" to search for relevant articles published in peer-reviewed journals, reports, and books.

Focus was given on articles that discussed the importance of tropical forests in providing ecosystem services, including water regulation, and the threats facing tropical watersheds. At the same time articles that discussed the concept of ecohydrology and its relevance to tropical forest ecosystems were also considered. After careful selection, we reviewed articles that provided insights into the complex interactions between hydrological processes and biotic factors in tropical watersheds, and the role of ecohydrological research in informing sustainable land use and water management strategies. After reviewing and analyzing the literature, we synthesized the findings and identified the main themes and key points to be addressed in the article. We then developed an outline and drafted the article, using the introduction, methodology, results, discussion, and conclusion format.

3. Results and discussions

Through our literature review, we have identified several key findings from ecohydrological research in tropical forests that shed light on the complex interactions between hydrological processes and biotic factors. This section will summarize the main results and provide an in-depth discussion of the implications of these findings for the sustainable management of water resources in tropical watersheds.

We will focus on the effects of deforestation, land use change, and climate change on water quality and quantity, as well as the role of forests in providing water-based ecosystem services. We will also discuss the importance of interdisciplinary collaboration and long-term monitoring for effective ecohydrological research and provide examples of successful ecohydrological research projects in tropical forests.

3.1 The challenges facing tropical forests and watersheds.

Tropical forests and watersheds face numerous threats that are adversely affecting their ecological health and water provisioning services. Deforestation, land use change, and climate change are among the main challenges that these ecosystems are facing (Bruijnzeel et al., 2011; Lees et al., 2020; Ochoa-Gaona et al., 2014; Pielke et al., 2011). Deforestation and land use change can alter the water cycle by reducing infiltration, increasing runoff and soil erosion, and changing the amount and timing of streamflow (Bruijnzeel et al., 2011; Ranaivoson et al., 2020). These changes can lead to reduced water availability and quality, affecting both human populations and biodiversity (Bruijnzeel et al., 2011; Ranaivoson et al., 2020). Climate change is also affecting the hydrological cycle and exacerbating the effects of land use change, leading to more frequent and severe droughts, floods, and landslides (Davidson et al., 2012; IPCC, 2018). The loss of forest cover and the degradation of ecosystems are accelerating these impacts and threatening the resilience of these systems (Bruijnzeel et al., 2011; Lees et al., 2020). It is therefore essential to address these threats and promote the conservation and restoration of tropical forests and watersheds to maintain their ecological health and water provisioning services.

These threats to tropical forests and watersheds have important implications for water availability and quality, which are critical for human and ecosystem health. Reduced water availability can lead to increased competition for water resources and conflicts among water users, while degraded water quality can pose risks to human health and aquatic ecosystems (Vörösmarty et al., 2010; Walsh et al., 2017). Furthermore, water scarcity and pollution can have negative impacts on economic development and food security (Falkenmark et al., 2007; Schreier et al., 2018). It is therefore essential to address these threats and protect the health and functioning of tropical watersheds for the benefit of present and future generations.

3.2 The role of ecohydrological research in tropical forests

Ecohydrological research in tropical forests aims to address key questions related to the functioning of forested watersheds and their response to environmental change. These questions include understanding the hydrological processes that govern water availability and quality in tropical forests (Bruijnzeel et al., 2011), the role of vegetation and soil moisture in regulating water fluxes (Jackson et al., 2019), and the potential impacts of land use change and climate change on water resources (Huang et al., 2021). Ecohydrology also seeks to identify critical ecosystem services provided by tropical forests, such as carbon sequestration and biodiversity conservation, and to quantify the trade-offs between these services and water resources (McDonnell et al., 2020). Ultimately, the objective of ecohydrological research in tropical forests is to inform management strategies for healthy watersheds and sustainable use of water resources (Silvestri et al., 2013).

Ecohydrological research provides critical information for developing effective land use planning and management strategies to maintain healthy watersheds in tropical forests. By understanding the hydrological processes and biotic dynamics within watersheds, ecohydrology can provide insights into the impacts of land use changes on water quantity and quality, and identify ways to mitigate negative effects on ecosystems and human communities (Van Dijk and Keenan, 2015). For example, ecohydrological research has been used to evaluate the effectiveness of riparian buffer zones in mitigating sediment and nutrient pollution in waterways (Merritt et al., 2010). Ecohydrological models can also be used to predict the impacts of land use changes on water availability and quality, and inform land use planning decisions (Lees et al., 2020). By providing evidence-based information,

ecohydrological research can support the development of sustainable land use practices that balance conservation and human needs in tropical watersheds.

Additionally, ecohydrological research can inform the development of payment for ecosystem services (PES) schemes that incentivize conservation practices in tropical forests. These schemes compensate landowners for providing ecological services such as water regulation, carbon sequestration, and biodiversity conservation (Wunder, 2019). Ecohydrological research can provide the scientific basis for designing and implementing PES schemes that are effective in achieving conservation goals while also benefiting local communities (Lees et al., 2020). In this way, ecohydrological research can contribute to the development of sustainable economic models that promote both environmental and social well-being.

There have been several successful ecohydrological research projects in tropical forests that have demonstrated the importance of this field in understanding and managing watersheds. One such project is the Luquillo Critical Zone Observatory in Puerto Rico, which has been studying the hydrological and biogeochemical processes in a tropical rainforest ecosystem for over 25 years (Brantley et al., 2017). The research has identified the complex interactions between vegetation, soils, and water resources, and their role in regulating the hydrological cycle. Another example is the Amazon FACE project, which is investigating the effects of elevated carbon dioxide levels on the water cycle and ecosystem dynamics in the Amazon rainforest (Keller et al., 2020). The research aims to improve our understanding of how tropical forests will respond to future climate change and inform management strategies for maintaining healthy watersheds. These and other successful ecohydrological research projects demonstrate the importance of interdisciplinary collaboration and long-term monitoring for understanding the complex dynamics of tropical watersheds and developing effective management strategies.

3.3 The need for more ecohydrological research in tropical forests

Despite the critical importance of tropical forests in providing clean water and maintaining healthy watersheds, there are still significant gaps in our understanding of the ecohydrological processes that underlie these services. Guswa et al. (2020) argues that current knowledge gaps in ecohydrology research are particularly acute in tropical regions, where the complex interplay of hydrology and biota can vary significantly across different forest types and climates. To effectively manage and protect these valuable ecosystems, it is essential that we invest in more interdisciplinary ecohydrological research that focuses on understanding the fundamental mechanisms that regulate water quality and quantity in tropical watersheds.

Long-term monitoring and interdisciplinary collaboration are also crucial for advancing ecohydrological research in tropical forests. This is because ecohydrology requires the integration of various disciplines such as hydrology, ecology, biogeochemistry, and geomorphology, which often require long-term data collection and analysis (McDonnell et al., 2015). The development of new technologies such as remote sensing, modeling, and data visualization tools can aid in this effort and help to build a more comprehensive understanding of the complex interactions between hydrology and biota in tropical forests (Turner and Sabine, 2019). Furthermore, recent research has emphasized the importance of incorporating indigenous knowledge and perspectives into ecohydrological research and management practices in tropical watersheds (Ackerly et al., 2021). By valuing and integrating diverse forms of knowledge and experience, ecohydrology can help to support more equitable and sustainable approaches to watershed management.

Investing in ecohydrological research in tropical forests can provide numerous benefits for both conservation and watershed management efforts. By identifying critical ecohydrological functions and driving forces that regulate the quality and quantity of water, this research can inform the development of land use planning and management strategies that balance human needs with ecological sustainability.

Furthermore, understanding the hydrological processes in tropical watersheds can help to predict and mitigate the impacts of climate change and land use change on water resources (Bruijnzeel, 2004; Turner and Sabine, 2019). Ultimately, investing in ecohydrological research can help to ensure the long-term sustainability of tropical forests and the vital ecosystem services they provide (Ackerly et al., 2021).

4. Conclusion

In conclusion, tropical forests play a vital role in providing clean water for human consumption and ecosystem health, but are facing significant threats such as deforestation, land use change, and climate change. Ecohydrological research offers a promising approach to better understand the complex relationships between tropical forests, watersheds, and water resources. By providing insights into the hydrological processes that underpin healthy watersheds, ecohydrological research can inform land use planning and management strategies that promote sustainable watershed management. However, there are still many gaps in our knowledge and research on ecohydrology in tropical forests, which underscores the need for interdisciplinary collaboration and long-term monitoring efforts. Investing in ecohydrological research can not only benefit tropical forest conservation and watershed management but also promote more sustainable use of natural resources in the face of global environmental change.

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