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Editorial

Hydrological Processes under Climate Change and Human Activities: Status and Challenges

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1. Introduction

Climate change, driven by the intricate interplay between natural variability and anthropogenic activities, emerges as one of the paramount challenges of the 21st century [1]. It is an undeniable reality that transcends geographical boundaries and affects all aspects of our planet, prominently including the hydrological processes that sustain life as we know it [2]. As humanity grapples with the ubiquitous consequences of climate change and the escalating impacts of anthropogenic activities, research that delves into the interplay between these processes and hydrological dynamics is of paramount importance [3].

The Earth's hydrological cycle, a nexus of complex interactions between land, water bodies, and atmosphere, has exhibited significant alterations as a result of pervasive climate change. Manifestations include shifts in precipitation patterns, glacier retreat, changes in snowmelt regimes, and alterations in river flows [4]. Concomitant with these perturbations are the anomalies observed in the frequency and intensity of extreme weather events like storms, droughts, and floods, each carrying profound implications for water resource management [5]. The repercussions of such disruptions transcend mere environmental concerns, extending to the domains of agriculture, urban development, and public health, thereby necessitating a holistic approach to water cycle studies within the context of climate change [6].

Compounding the quandaries induced by climate change are the prevalent human activities which have remodeled the landscape and, consequently, the hydrological processes therein. The ebb and flow of civilizations through deforestation, urbanization, and agricultural expansion, among others, have introduced non-trivial modifications to the surface and sub-surface hydrology [7]. Land use changes notably influence evapotranspiration rates, soil infiltration capacity, surface runoff, and groundwater recharge [8]. Industrial effluents and agricultural return flows introduce additional layers of complexity by affecting the water quality and ecological health of aquatic systems [9].

The intersection of climate change and human activities illuminates a suite of challenges that confront modern hydrological sciences. These challenges include advancing the predictability of hydrological extremes, refining the understanding of coupled human–water systems [10], discerning the impacts of land use change on hydrological services [11], and developing adaptive strategies that ensure water security amidst climatic unpredictability [12]. Furthermore, there is a pressing need to tailor policies and interventions to bolster ecological resilience and to harmonize human water use within the bounds of sustainable development.

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This exploration into the state and challenges of hydrological processes under changing climate and human activities is underpinned by the need for an integrated scientific response. It calls for leveraging advancements in remote sensing technology [13], hydrological modeling [14], and data analytics [15]. The inclusion of diverse and high-resolution datasets promises to add to the granularity and precision of hydrological assessments. Interdisciplinary collaborations between hydrologists, climatologists, ecologists, socio-economists, and policymakers are key to piecing together this intricate puzzle [16].

Moreover, a forward-looking discourse on hydrological processes must recognize and incorporate the intrinsic variability and uncertainty associated with climate models and project future scenarios that encompass a range of plausible outcomes [17]. The research community is thus impelled to optimize hydrological models [18], embed robust decision support systems [19], and engage in knowledge transfer to decision-makers and stakeholders [20], thereby ensuring that science directly informs adaptive management and policy formulation.

The papers presented within this compendium have undergone meticulous selection to encompass a wide spectrum of research endeavors, showcasing diverse geographic locations and hydro-climatic contexts. Collectively, they illuminate the latest advancements in comprehending how shifting climate patterns, shaped by both natural forces and human activities, are unfolding in hydrological systems across the globe. These investigations delve deeply into the intricate mechanisms governing alterations in precipitation patterns, the dynamics of snow and ice melt, shifts in river and groundwater regimes, and the ensuing repercussions on water resource management and ecosystem sustainability. Moreover, this Special Issue delves into the pivotal role played by human activities in exacerbating or mitigating the effects of climate change on hydrological processes. Land-use modifications, urbanization, deforestation, and water management practices all undergo scrutiny as their implications for hydrology are elucidated. The integration of state-of-the-art remote sensing and modeling techniques provides valuable insight into the hydrological responses to these evolving conditions, thereby facilitating the development of adaptive strategies to confront the impending challenges.

2. An Overview of Published Articles

A total of 23 manuscripts were submitted to this Special Issue, underscoring the profound interest and engagement of the research community in this critical subject matter. The review process for each manuscript was meticulously conducted in strict adherence to the journal's exacting standards. Ultimately, a total of 17 papers were accepted and subsequently published within this Special Issue. These publications offer the latest findings concerning the intricate interplay between climate change, human activities, and their impacts on hydrological processes and water resources.

The aforementioned papers can be categorized into four distinct groups. The initial cluster of papers places its primary focuses on the intricate spatio-temporal dynamics of climate change in specific regions. Notably, the investigation presented by Li et al. (contribution 1) offers valuable insights into the Tianshan Mountain Region based on 10-day air temperature data collected from meteorological stations between 1961 and 2020. It reveals a general warming trend over the last five decades, coupled with localized areas experiencing cooling phenomena. Similarly, Ren et al. (contribution 2), concentrating on the source region of the Yellow River Basin, delved into the increasing trend of wetness since the early 1980s, with implications for water resources and ecological balance downstream. The findings of the study indicate an overall state of wetness in the study area, showing an increasing trend since the early 1980s. In a similar vein, Wei et al. (contribution 3) meticulously investigated the temporal dynamics of soil moisture from 1982 to 2015 and quantified the contributions of climate change and human activities to soil moisture trends in karst areas of Southwest China. The principal findings of this investigation reveal a drying trend in soil moisture within the study area, with human activities accounting for 59% and climate change accounting for 41% of this drying trend. Notably, the research

highlighted the negative impact of vegetation restoration on soil moisture, despite significant efforts having been made through the Grain for Green Project, indicating the need for careful consideration of vegetation restoration density and types in order to balance water resource management and ecological restoration in karst areas. Finally, by studying the Ayazma River basin in the Marmara Region of Turkey, Seddiqe et al. (contribution 4) provided a comprehensive analysis of the impacts of climate change on the Mediterranean region. The study found that the Mediterranean region is highly vulnerable to climate change, with significant changes expected in temperature, precipitation patterns, and extreme weather events. These changes are projected to have wide-ranging effects on various sectors, including agriculture, water resources, ecosystems, and human health. The authors emphasized the need for integrated approaches to address these challenges, involving multiple stakeholders and considering both short-term and long-term strategies. To summarize, the above studies on this topic underscore the critical importance of factoring in microclimatic variations when addressing climate change challenges and highlights the urgency of taking action to mitigate greenhouse gas emissions and develop adaptive measures to minimize the negative consequences. The findings can inform policymakers, researchers, and practitioners in their efforts to address climate change and its impacts on various regions across the globe.

The second group of papers explores hydrological processes and water resource management. In particular, Guo et al. (contribution 5) conducted a comprehensive examination of the hydrological variables and the consequential impact of substantial silt dams on the hydrological processes within the Chabagou River watershed. The paper provides an exhaustive analysis and delineation of stages within the time series change in river watershed runoff. This, in turn, allows for valuable insight into shifts in subsurface conditions and the overarching hydrological processes. The results of this study significantly contribute to an enhanced comprehension of the hydrological system within the Chabagou River watershed over the past 30 years, highlighting the importance of large silt dams in shaping hydrological variables and rendering the information gleaned from this study invaluable for water resource management and planning. Meanwhile, Qin et al. (contribution 6) developed a water-quality model for Jingpo Lake, a representative lake in the cold northern region of China. The primary objective of this research endeavor is to construct a numerical simulation model leveraging the environmental fluid dynamics code (EFDC) to simulate the transport and diffusion of the chemical oxygen demand (COD_{Mn}) and ammonia nitrogen (NH_3N) during ice-covered and open-water periods. The overarching conclusion drawn from this study underscores the utility of the developed numerical model as a powerful tool for scrutinizing the dynamics of water pollutants, particularly during challenging ice-covered periods. Furthermore, it has the potential to make substantial contributions to the management of both water quantity and quality within cold regions. In a complementary vein, Wang et al. (contribution 7) utilized data from the normalized difference vegetation index (NDVI), meteorological records, and nighttime light data from 2001 to 2020 to study the spatial and temporal characteristics and the driving force of NDVI. The authors applied statistical analyses to investigate the spatial–temporal variation characteristics and future trends of NDVI, the variations of climate and human activities in the basin, and the influences of different driving forces on NDVI. The results revealed that there has been an increase in the average NDVI in the growing season, with a growth rate of 0.002 per year. The spatial differences in NDVI are primarily influenced by topography and climate factors, followed by human activities. These findings hold profound implications, bearing a direct relevance to the stewardship of the Minjiang River Basin. In the realm of modeling, Xuan et al. (contribution 8) introduced an innovative approach for the estimation of hydraulic parameters within the van Genuchten model, a pivotal tool for characterizing the soil water retention curve (SWRC) in soil science. The results showed that the developed Markov Chain Monte Carlo (MCMC) method exhibits superior robustness and accuracy when tasked with estimating the van Genuchten model parameters, even when the available data pertaining to soil matric potential are limited. The study contributes to improving

our understanding of soil water dynamics and provides a valuable tool for practitioners and researchers in soil science, and, therefore, has significant implications for the study of soil water dynamics; it can contribute to more accurate predictions of water and material fluxes in unsaturated soil media. In another study, Wang et al. (contribution 9) presented a novel approach for studying the hydrology of the Yarlung Zangbo River, the highest river in the world. The researchers acquired high-resolution ICESat-2 altimetry data, enabling precise determination of the water levels and calculation of the water surface slope. The outcomes of this investigation reveal that the water surface slope exhibits its maximum values during the summer and autumn seasons, with notable disparities apparent among distinct river sections. This research underscores the potential of ICESat-2 satellite altimetry data as a foundational reference point for comprehending the hydrology of the Yarlung Zangbo River. Furthermore, the methodological approach outlined herein holds significant promise for application to other rivers grappling with analogous issues in data acquisition. In summary, the insights derived from this research hold profound significance for an array of stakeholders, including researchers and practitioners who are deeply engaged in water-resource management and environmental conservation efforts within frigid regions. The research serves as a foundational resource for informed decision-making concerning ecological conservation in light of the evolving dynamics induced by climate fluctuations and human influence, and the findings enrich our comprehension of the hydrological dynamics of rivers while concurrently highlighting the versatility of the proposed methodology for broader application across rivers worldwide.

Transitioning to the third group of papers, the focus shifts to human interventions within environmental systems. Xie et al. (contribution 10) delve into the intricate landscape of the Yellow River basin, where they expound upon the implementation of horizontal eco-compensation as a policy for promoting regional ecological and environmental cooperation. The Yellow River basin is faced with challenges such as water resource shortages, low utilization efficiency, and weak water environmental capacity. To address these challenges, the authors propose a framework for horizontal compensation based on integrated water rights transactions (IWRs). The framework aims to unify the "quantity" and "quality" attributes of water resources by integrating the transaction between water use rights and pollutant discharge rights. Through the implementation of this framework, the authors found that revenue increased, water use efficiency improved, and the overload situation of water resource carrying was relieved in certain areas of the river basin. The study highlights the importance of market mechanisms and sustainable funding sources in eco-compensation initiatives. Guo et al. (contribution 11), on the other hand, provided a comprehensive analysis of the transformation of lakes in Inner Mongolia, China, over the past three decades. The study utilized Landsat images, water census data, and geological maps to examine the changes in lake area and number. The findings indicated a significant reduction in both the area and number of lakes in Inner Mongolia. Specifically, the number of lakes larger than 1 km^2 decreased from 384 in 1990 to 301 in 2018, while the total area of lakes above this threshold decreased from 4905.74 km^2 to 4187.45 km^2 during the same period. The most pronounced shrinkage occurred in the West Liaohe Plain and the northern Inner Mongolian Plateau. This study adeptly identifies several pivotal factors influencing these transformative trends. In the southeast coastal region of China, Wang et al. (contribution 12) presented a novel method for the identification and delineation of aquaculture pond regions within Jiangsu Province. The rapid and accurate determination of these pond regions holds paramount importance in ensuring sustainable development while mitigating adverse environmental repercussions. To accomplish this, the authors utilized field survey data and a decision-making model constructed on the Google Earth Engine (GEE) platform, achieving an overall accuracy of 93% and a Kappa coefficient of 0.86. This investigation shed light on the spatial distribution and density of aquaculture ponds in both the Guangdong and Jiangsu regions, which are subject to stringent regulatory oversight for their effective management. This newfound knowledge carries significant implications for the advancement of structured pond management and the promotion of

scientific development in the field of fishery aquaculture. The results herein make a substantial contribution to the domain of aquaculture management by providing an effective and efficient means for the extraction of aquaculture pond areas. In a study conducted in southwest China, Zhou et al. (contribution 13) provided a comprehensive analysis of the water quality and nutritional status of lakes in Guizhou Province. Over a period spanning from 2013 to 2018, the researchers meticulously collected water samples from three distinct bodies of water: Hongfeng Lake, Baihua Lake, and Aha Reservoir. These samples were acquired at regular intervals, either monthly or once every three months. They analyzed the samples for various water quality indicators such as total phosphorus (TP), total nitrogen (TN), suspended solids (SD), chemical oxygen demand (CODMn), and chlorophyll-a (Chla). Subsequent to these indicators, the research team derived an appropriate water quality index for each of the lakes based on the concentrations of these parameters. Furthermore, this paper introduced a classification system to assess the nutritional states of these lakes, which ranged from oligotrophic to hyper-eutrophic. The insights gained from these analyses were then employed to elucidate the intricate relationship between land use, topography, and water quality. The results of this paper represent a significant and invaluable contribution to the water quality and nutritional status of lakes in Guizhou Province, holding substantial promise for guiding future efforts aimed at the management and conservation of these vital natural resources. In the Reno and Lamone River Basins and related coastal areas, Northern Italy, Meli and Romagnoli (contribution 14) investigated the impact of anthropogenic and natural signals on hydrological processes and sea-level changes. This work significantly advances our comprehension of the intricate dynamics involving human activities, natural processes, and sea-level dynamics in a sprawling European coastal expanse. The insights derived from this research possess far-reaching implications for the effective management of river basins and the safeguarding of coastal sites, particularly in the face of the ever-pressing challenges posed by climate change and anthropogenic influences. The last article within this group (contribution 15) presents an ecological health assessment of a river reach following the retirement and renovation of small hydropower stations. The study establishes an ecological health index system based on the environmental characteristics of the river before and after the hydropower station modifications. This study presents a novel methodology that amalgamates both subjective and objective weighting approaches to enhance the precision of weight allocation in the context of ecological health assessment. The outcomes of this investigation illuminate the comprehensive and judicious nature of the ecological health assessment index system. The study underscores the pivotal significance of conducting rigorous evaluations of river ecosystems subsequent to the retirement and refurbishment of small-scale hydropower stations, with particular emphasis on mountainous regions. In conclusion, the findings of this group of studies contribute to ongoing efforts to achieve sustainable development and ecological protection in river basins, and the insights derived provide invaluable guidance for the prudent utilization of water resources and the preservation of riverine ecological well-being within analogous geographical domains. These findings have the potential to inform decision-making processes concerning the exploitation of water resources and the safeguarding of ecosystems in analogous regions.

Concluding this Special Issue, the fourth group of papers, including the notable study conducted by Jiang et al. (contribution 16), presented a novel approach to the development of an integrated water resource scheduling model using the Wudu Diversion and Irrigation Area in China as a case study. The authors addressed the challenges associated with current water resource scheduling models, such as long development times and poor outcomes. They proposed a development mode based on software reuse, employing a "platform system + model plug-in" approach. The core components of this approach were the plug-in modules and interface integration. The authors utilized a web application mode to implement standardized interfaces, ensuring seamless connection to the system platform. The effectiveness of the proposed model was verified through simulations using data from two flood periods. The results demonstrate the convenience of gate operation

and the achievement of the target water level within the allocated time. This confirms the value and effectiveness of the plug-in modules. The authors also discuss different modes of application for hydraulic numerical models, including stand-alone, web, and cloud platform modes. They explore the integration and management of hardware and software resources in a cloud platform, which represents an advanced form of application. This paper underscores the pivotal significance of adopting a plug-in-based development approach for integrated water resource scheduling models. The Wudu case study yields invaluable insights into the pragmatic implementation of this approach, enriching the field of water resource management. Consequently, the findings presented herein stand to inform and guide future research and development endeavors in similar contexts. Lastly, Qu et al. (contribution 17) transport us back in time to the nascent years of the Qing Dynasty in Shanxi Province. This historical, retrospective study presents an investigation that focuses on historical drought events during the early years of the Qing Dynasty in Shanxi Province, China. The objective of the study was to reconstruct the historical drought records and evaluate their impact on the region's water resource management. The researchers used hydrological reconstructions and meteorological data from the early years of Guangxu in the Qing Dynasty. The variable infiltration capacity model was utilized to simulate the monthly runoff and soil water sequence from 1875 to 1879, allowing for reproduction of the hydrological and soil conditions during that period. The findings of this study shed light on the presence of a pronounced and severe hydrological drought spanning from 1875 to 1877. This enduring drought event was associated with the manifestation of widespread drought conditions across the region. This research endeavor represents an innovative approach to examining historical drought occurrences, yielding profound insights with substantial implications for regional drought prevention, mitigation, and water resource management. By means of the meticulous reconstruction of historical drought records, it becomes conceivable to scrutinize the evolution, spatiotemporal variations, hydrological characteristics, and drought resilience inherent to these critical events. The information arising from this research is pivotal for making judicious decisions concerning sustainable water management and ensuring the prosperity of agricultural production activities. The study leverages state-of-the-art modeling techniques in tandem with historical data, providing invaluable insight into the historical drought events occurring in Shanxi Province, China, during the nascent stages of the Qing Dynasty. The ramifications of this research transcend its immediate scope, representing a seminal contribution to the field and establishing a sound scientific foundation for the pursuit of drought prevention and mitigation initiatives within the region.

3. Conclusions

The collective insights from this Special Issue illustrate the breadth and depth of environmental research in the present era. The intricate relationship between climate change, hydrological processes, and water resource management is evident in these studies, emphasizing the need for integrated and adaptive approaches. They underline the importance of considering microclimates and local factors when addressing global climate change issues and the impact of human activities on the environment. As we move forward, it is crucial to consider the lessons learned from these papers and to apply them to develop effective strategies for environmental conservation and sustainability. This compilation of studies provides a valuable foundation for future research and policy decisions, offering a holistic view of the complex interactions within our environmental systems. It is a testament to the critical role that environmental science plays in our ongoing efforts to safeguard the planet for future generations.

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