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Editorial

Linking Climate-Change Impacts on Hydrological Processes and Water Quality to Local Watersheds

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1. Introduction

Estimation of hydrological processes and water quality is central to water resource management, clean water supply, environmental protection, and ecological services [1,2]. Climate change is a natural phenomenon, but anthropogenic activities such as fossil fuel burning, industrial pollution, land use change, and population growth have accelerated greenhouse gas emissions, which have, in turn, resulted in abnormal climate patterns [3]. These patterns exacerbate hydrologic and water quality uncertainties in predicting droughts, floods, water resource availability, environmental pollution, and ecosystem services. To mitigate such climate-change impacts, water resource managers and decision makers should be able to assess potential threats and develop strategies to adapt for future climatic conditions. Currently, projection of future climate impacts on hydrologic cycles and water quality are generally accomplished through process-based watershed models in conjunction with future climate-change scenarios that are created by the general circulation models (GCMs), regional climate models (RCMs), and coupled model inter comparison project phase (CMIP5). While these scenarios provide invaluable insights into the direction to project the future hydrologic and water quality trends, the limitations on using these scenarios are [4]: (1) They have low spatial resolution and are somewhat difficult to downscale for local watersheds (i.e., smaller than HUC12 level watersheds); (2) They have low temporal resolution (e.g., weekly or monthly time intervals) and are difficult to disaggregate into daily or hourly intervals required by some watershed models; and (3) They are not flexible to answer the "what-if" questions for local watersheds such as: What will happen to streamflow, water quality, and water availability in a small watershed if the abnormal and localized rainfall (cloudburst) events (e.g., very dry in July and very wet in November) occur in the next five years? In order to take those challenges and meet the needs, this Special Issue "Assessment of Climate Change Impacts on Water Quantity and Quality at Small Scale Watersheds", inspired by the Hydrology–H030 Session of the 2019 America Geophysical Union Fall Meeting, was initiated to circumvent the limitations.

2. Aims and Scope

The Special Issue is aimed to link climate-change impacts on hydrological processes and water quality for local watersheds or basins. Emphases are on climate-induced water resource vulnerabilities (e.g., flood, drought, groundwater, evapotranspiration, and water pollution) and methodologies (e.g., computer modeling, field measurement, and management practice) employed to mitigate and adapt climate-change impacts on water resources. In addition, application implications to water resource management were discussed in this Special Issue.

3. Presentation of the Published Papers

This Special Issue solicits 11 studies covering (1) various geographical locations around the world, including Indian subcontinent (northern Himalayan Terai, southern Indian River, and Cauvery and Godavari River basins), sub-Saharan Africa (Ethiopian Rift valley and Nile River Basin), western and southeastern United States (California Central Valley, Alabama, and Mississippi River Basin), and western and southern China (Xinjiang basin and Lijiang River basin); (2) hydrological processes such as springs, streamflow, surface runoff, evapotranspiration, and tree sapflow; (3) climate-change patterns such as drought, warming, and water-energy nexus; (4) surface and ground water quality such as nutrients, organic matter, salinity, and sediment; and (5) water resource management to improve economic, health, and other quality of lives. All eleven papers deal with local scale (or smaller than regional scale) watersheds or basins under the effects of climate change. Eight publications reported watershed modeling results, whereas three publications more or less reported results on experimental measurements. They are categorized into (i) Climate impacts on hydrology, (ii) Climate impacts on water quality, and (iii) Climate implications and adaptation in water resources management.

3.1. Climate Impacts on Hydrology

Hydrological processes at local watersheds are essential to water resource management, water supply planning, and ecosystem restoration and service under changing climate. In this collection, two studies were conducted in India; one analyzed the vulnerability of more than three million springs at the Indian Himalayan basin while the another analyzed the drought vulnerability in the southern Indian River basin. Daniel et al. [5] attempted to conceptualize vulnerability of Himalayan springs and identify the biophysical and socio-economic stressors affected on the springs. The conceptual framework is a useful theoretical construct for enabling policymakers and project managers to follow a structured process for arriving at decisions concerning judicious use of springs resources under changing climate. However, the study did not include specific hydrological processes. Kumar et al. [6] investigated monthly and seasonal drought in four major river basins in south Indian using GRACE-Based Groundwater Drought Index. Their study provided some robust quantitative results of GRACE water storage variations and a new approach to link surface and subsurface conditions when investigating droughts.

Another two studies center on China: one study investigated the spatiotemporal patterns of asymmetric warming in Xinjiang basin of western China using normalized difference vegetation index (NDVI) data, while the other study analyzed the effects of climate change scenarios on hydrological variables (i.e., evapotranspiration and runoff) in Lijiang River Basin by linking the outputs from the GCM with the Soil and Water Assessment Tool (SWAT). Heng et al. [7] analyzed spatiotemporal patterns of climate asymmetric warming and vegetation activities in an arid and semiarid region of Xinjiang basin, China, using the climate and NDVI data. They reported that the warming rates in this region are higher than the world average. Tan et al. [8] assessed the effects of climate change scenarios on evapotranspiration and surface runoff by linking the outputs from the GCM scenarios with the SWAT hydrologic model for a case study in the Lijiang River basin, China. These authors found that precipitation, temperature, and evapotranspiration will increase with uneven distributions under future climate conditions.

Studies in US cover drought and streamflow. He et al. [9] projected changes in water year types and hydrological drought in California's Central Valley in the 21st century using water year index classification approach. They found that hydrological droughts in the snowmelt season and wet season exhibit upward and downward trends, respectively. Quansah et al. [10] assessed streamflow due to future climate change in the Alabama River basin for the mid- and late-21st century by using climate-change scenarios in conjunction with SWAT model. They argued that while the simulation results are prone to inherent uncertainties, they could provide some critical information for stakeholders on sustainable water resource management under the changing climate. Both studies are warranted to circumvent the limitations of climate-change scenarios as stated in the Introduction of this editorial summary.

Many water-energy models are not able to be applied in developing countries due to the lack of measured data, computational capacity, and skill requirement. However, Yimere and Assefa [11] developed a model to assess the Water-Energy relationship in the Nile River basin, Africa under future climate change scenario. Nonetheless, their study has limitations due to incomplete and inadequate data usage for model calibration and verification. Few studies have been devoted to investigating hydrological processes under changing climate through experimental measurements in this Special Issue. Using their field measured tree sapflow and weather data, Ouyang et al. [12] developed Structural Thinking and Experiential Learning Laboratory with Animation (STELLA) model to assess eastern cottonwood water flow using adjusted vapor pressure deficit under the changing climate conditions.

3.2. Climate Impact on Water Quality

Three studies in this collection dealt with water quality. Godebo et al. [13] assess water quality for irrigated agriculture, alongside perceptions and adaptations of farmers to climate change in the main Ethiopian Rift valley. Using data from 147 farmers and 162 surface and ground water quality samples, they reported that most groundwaters were unsuitable for long-term agricultural use due to their high salinity and sodium adsorption ratio. This is one of the major consequences of global warming/climate change that agriculture stakeholders including irrigation researchers are not being seriously considered yet. Pérez-Gutiérrez [14] investigated nutrient and sediment loads at a tailwater recovery ditch in Mississippi, US by using the annualized agricultural non-point source (AnnAGNPS) model. However, climate-change impacts on water quality have not been fully addressed in their study. Dewey et al. [15] performed field measurement to estimate the sources of sediment and organic matter fluxes in intermittent rivers and ephemeral streams (IRES) of a subtropical watershed in Mississippi, USA. They stated that climate-induced changes in precipitation and discharge may impact organic carbon fluxes from IRES.

3.3. Implications and Adaption

All papers except one [14] in this collection linked the research findings to climate-change implications and adaptions. Some of the climate implications and adaptions are very general, while others are specific and concrete. For example, the study on springs in the Indian Himalayas [5] synthesized climate stressors, indicators, and the conceptualization of vulnerability that provide a general evidence-based decision support system for better management of Himalayan springs under the changing climate, whereas the study on field measurement and STELLA modeling of tree sapflow using vapor pressure deficit [12] would provide a specific and new paradigm for researchers to predict tree sapflow under the changing climate by using the commonly available vapor pressure deficit data. Furthermore, the study on water quality threats due to climate change in the Ethiopian Rift valley [13] highlighted the complex nexus between high groundwater salinity and climate change, which provides a concrete direction for climate adaption to farmers.

4. Conclusions

The papers collected in this Special Issue tackle multiple aspects on how hydrological processes and water quality at local watersheds could be affected by climate change through hydrological modeling, statistical analysis, and field measurement. In addition, climate-change implications and adaptions based on research findings are discussed and are highly beneficial to local water resources managers and stakeholders. In addition, the studies in this collection provide a variety of research methods and approaches to tackle challenging questions faced by local watersheds under various climate change scenarios. Many of the studies emphasized the advantages of geospatial engineering and technology, i.e., geographic information systems (GIS), remote sensing, global navigation satellite system

(GNSS) application in solving water resources management issues that occurred in consequence of climate change. As water resources management decision support is essentially of spatio-temporal nature, GIS and GNSS helps in localized analyses and remote sensing data helps analyzing temporal changing scenario. STELLA, AnnAGNPS, SWAT, GRACE, and especially, GCM models used in the research papers in this special issue for water resources management decision support are all of spatio-temporal analytics models. As seen with wide-range of articles published in the Special Issue, climate-centric researchers engaged in the said topics will be highly benefitted. Readers of the Special Issue articles will get insight on geospatial engineering and technology and other advanced models usage in their future research on climate change affected hydrologic DSS development.

Today, most climate change studies focus on large regional and global scales or using climate change scenarios that have low flexibility with inaccurate data for local scale watersheds. The topics in this Special Issue provide a new research direction in dealing with local watersheds under changing climate and will receive a global interest for years to come. As the research articles in the Special Issue encompass various spatially (geographically) differentiated watersheds, covers developed, developing, and even poor countries with different watershed management conditions available to them due to funding availability, the research results, especially the decision supports developed through the studies, will be very beneficial in furthering watershed hydrologic research under changing climate. Studies in the Special Issue included heterogeneous environmental features, such as land use, soils, topography, climate/weather pattern, and above all hydrological scenarios, can help future studies that glean research methods from them.

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