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Editorial: Hydrological connectivity and sustainable watershed management in a changing environment

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Editorial on the Research Topic
Hydrological connectivity and sustainable watershed management in a changing environment

Increasing environmental impacts caused by climate change and human disturbances are progressively leading to the degradation of vast areas worldwide, also producing changes in land use dynamics and ecological services. Land and water management are especially critical as the use of upstream watersheds can drastically affect a large number of people living in downstream watersheds, as well as the ecosystem services of the land and waterways on which they depend. Integrated watershed management, which stresses both the importance of landscape processes, participatory planning, and the institutional and technical constraints and opportunities, is therefore necessary.

In recent years, research on multi-scale hydrological connectivity has grown in popularity and has been recognized for its potential to provide an integrated approach to the study of complex land-water systems. As a method to develop a more holistic approach to watershed assessment and management, the concept of hydrological connectivity is often put at the forefront. Hydrological connectivity can be seen as the patterns and strength of the water-mediated linkages between discrete units of the landscape, and as such, it facilitates our knowledge and understanding of the mechanisms driving runoff initiation, cessation, and the flow regimes of receiving waterways and wetlands. Much of the interest attracted by hydrological connectivity is attributed to its potential to enhance our ability to gain insights into multiple areas of expertise, including process dynamics, numerical model building, conceptualization on the effects of human interventions in our landscape, and the development of simplified watershed management tools.

Water-limited ecosystems are undergoing drastic changes in vegetation cover and plant community composition in response to shifts in climatic conditions and anthropogenic

activities on land, therefore, it is necessary to establish close connections between research in the physical and the ecological sciences in order to provide a process-based understanding of the interactions existing between the hydrosphere and the biosphere. At the watershed scale, efficient management requires us to protect vegetation and soil resources and reduce the vulnerability of landscapes to soil erosion. Consequently, raising awareness of issues, causes, consequences, and preventive measures of hydrological processes, and of their impacts on water-limited ecosystems at the watershed scale, is crucial for stakeholders and policymakers around the world.

This Research Topic was proposed with the purpose of collecting the recent methodological developments and studies to detect the influences of anthropogenic activities and climate changes on sustainable watershed management for different regions. This Research Topic of papers gathers novel contributions that explore different research approaches in the field of watershed ecosystem protection and restoration, and new methods/models used in the sustainable watershed management. A total of twelve manuscripts were collected, including studies from China and South America. Different approaches to watershed management research are presented, using new methods, models and tools in the context of both natural and anthropogenic disturbances, and climate change.

In the area of field-based research and *in situ* landscape monitoring, Zhang et al. selected a desert section along the eastern shore of Qinghai Lake as a study area. Plant communities, soil physical and chemical properties, and differences in soil moisture in diverse sand-fixating communities were carefully analyzed. Overall, they explored differences and variations among plant, soil, and water availability, providing scientific support to improve sand-fixation effectiveness by introducing plant species. Further, Li et al. explored the effect of the Porous Fiber Material (PFM, rock wool) on soil erosion and crop growth of winter wheat, based on rainfall simulations and the use of the Entropy-Critic comprehensive evaluation method. The study illustrates the comprehensive application effect of PFM in agricultural production, pollution control and urban landscape, and provides an important basis for promoting the stability of farmland ecosystem. Zhang et al. studied the South-to-North Water Diversion Middle Route Project, a significant infrastructure alleviating water scarcity but suffering from non-traditional sediment sources in Northern China. The characteristics of the sediment and the siltation period were surveyed. Siltation mainly occurs from March to October, while almost no siltation occurs in winter. The main source of siltation in the middle route project is not from traditional sediment sources, but is due to the remnants of the algae that proliferate in large numbers when temperature is suitable, attaching to the sediment particles and gradually growing downstream with the flow.

On a watershed-scale study of eco-hydrological processes using hydrological modeling, Bai et al. conducted a comparative analysis in two adjacent catchments in Northwestern China. The influences of precipitation and land use change on streamflow were studied for the period 1956–2019. The results of this work shed light on the quantitative understanding of streamflow changes in small catchments, offering a scientific basis for sustainable water management in other inland river basins. Yu et al. determined appropriate thresholds of ecological runoff in the middle reaches of the Bailong River (northwest China) under the influence of human activities. Using data from long-term hydrological stations, seven suitable hydrological methods were applied to analyze ecological discharge in the middle reaches of the river. The runoff satisfaction degree was studied, and monthly ecological flows and thresholds for the river were determined in the study area. These results provide a useful reference for ecological restoration and ecosystem management in the middle reaches of the Bailong River Basin and other similar areas. Ju et al. proposed a coupled soil-moisture and heat-transfer model in terms of the physical processes of water and heat movement in frozen soil. Measured data on soil temperature and frost/thaw depth at 19 stations in and around the Three-River Source Region of China were used for model calibration and validation. The results showed that this frozen-soil model can accurately capture freezing-thawing processes acting in this region. The relationship between model parameters, climate conditions and vegetation factors was identified using both observation and remote sensing data. The proposed method can be applied to other cold regions with little observation data to obtain parameters and simulate soil freezing-thawing processes. Zhou et al. developed an improved module of the WetSpa model, which they used for the simulation of runoff at different time scales for the Hanjiang River Basin. Reservoir inflow data correction and water storage/outflow calculation without measured data were considered in the improved model. Their results showed that the improved WetSpa model has good applicability in the Hanjiang River Basin, thus suggesting that predictions of the future runoff variations using this model will be more accurate. Hou et al. analyzed the evolution of both historical and future water yield coefficients in the Yiluo River Basin. Water yield was simulated for 2000–2020 and 2030–2050 under four Shared Socioeconomic Pathways (including SSP126, SSP245, SSP370 and SSP585). A geographical detector model was used to study the impacts of climate, land use and terrain factors on the water yield coefficient. Land use showed the strongest explanatory capacity to determine water yield coefficient for 2000–2020, and will increase its influence for 2030–2050. This research provides scientific support for adopting precise watershed management of water and land resources.

In terms of regional-scale hydrological and geomorphological processes and water resources research, Rojas et al. examined the hydrogeomorphology of the Peruvian tropical wetland of Pacaya Samiria in Western Amazonia, and its role in the distribution of aquatic habitats. The hydrogeomorphological connectivity that bounds the Pacaya Samiria National Reserve is characterized by ancient to modern processes. The effect of geomorphology on the spatial distribution of fishing zones was assessed. This methodological approach, based on understanding wetland connectivity, hydrogeomorphological behavior and their influence on commercial fisheries, was developed and shown to support decision-making in conservation actions for Amazonian environments. Xu et al. proposed a scenario-based framework for a PLES (production, living, and ecological spaces) water resources assessment, analyzing the temporal and spatial changes of land and water resources on the North Slope of Tianshan Mountain, China. They indicate that the vulnerability of regional ecosystems should be taken into account in the future socio-economic development of the North Slope of Tianshan Mountain, where production should be controlled according to the existing water resources and ecological capacity to reduce the pressure on the regional environment. Qin et al. presented an evaluation of the water-resources carrying

capacity for the regional economic development of Chicheng County, Zhangjiakou City, China. The carrying capacity of water resources for both present and future planned conditions does not exceed total water consumption, therefore satisfying the economic and social development of the region. However, problems such as river pollution, low sewage treatment capacity and weak pollution supervision need to be solved urgently. This research provides a basis for regional water resources management, contributing to the stability of water ecological environments. Last but not least, Chen et al. reviewed the progress of phytoplankton population ecology research in the Pearl River Estuary, discussing the main environmental factors affecting phytoplankton growth. Species diversity of phytoplankton generally shows a downward trend in the region. Further, the abundance of phytoplankton in the nearshore waters is higher than that in open waters, suggesting that human activities have a great influence. Overall they conclude that relevant guidelines must be developed and implemented for promoting the ecological health of the Guangdong-Hong Kong-Macao Greater Bay Area and ensuring its sustainable development.

In the past few decades, a wide range of *in situ* monitoring, methodological, and hydrological tools have been developed to help locals to develop sustainable watershed management. However, as shown by the contributions to this Research Topic, methods accounting for the influence of connectivity on the structure and function of ecosystem are under-developed. Although these contributions help to understand the relationship between climate change and the hydrological cycle, research on connectivity and integrated watershed management needs to be strengthened in the future, so as to provide a basis for the formulation of watershed management strategies.

Author contributions

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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