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FOREST HYDROLOGY IN CHINA: INTRODUCTION TO THE FEATURED COLLECTION[1]

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BACKGROUND

Chinese people have long recognized the importance of forests and water in environment, societal development, and civilization. The philosophical thoughts are well reflected in many ancient paintings and stories that picture the harmony of forests, water, and mountains, and in fact, well-respected Chinese rulers are known for their contributions to harnessing large rivers such as the mighty Yellow and the Yangtze Rivers in China's 5,000 years' history. Unfortunately, China's natural forests and water resources have been severely damaged in the past century due to overpopulation, years of wars, mismanagement and exploitative use, and global environmental change. As a result, China has suffered chronic environmental problems at the national scale, notably soil erosion, flooding, and water pollution and shortage in its recent history.

While China's unprecedented socioeconomic growth increasingly stresses forest and water resources, it also provides opportunities to reverse earlier damage. In the past three decades, China has implemented several nationwide forest restoration and protection programs such as the "Three North Shelterbelts Project," the "Natural Forest Protection Programme," and the "Green for Grains Program" that aim at reducing soil erosion and flooding, improving water quality, and curbing further ecosystem degradation. Although a full assessment of the projects' success is not available, it is widely believed that they have resulted in positive effects on water resources and overall ecosystem health of headwaters of major river basins. Thanks to massive forestation campaigns, China has the largest plantation forests (53 million ha, an area larger than California) in the world, and its annual growth in man-made forests accounts for over half of the global total. Last year alone, more than two billion trees were planted in China (http://english.people.com.cn/90001/90776/90882/6371092.html). Forest hydrological research to guide these large ecosystem restoration efforts is urgently needed. Assessments of the effects of forestry policy changes on water resources are well sought by the Chinese government to effectively manage both water and forest resources.

Forest hydrology research in China has been limited and western literature was not readily available before the early 1980s when China began economic reform and adopted an "open-door" policy. Since then, large progress has been made in the understanding of forests' role in regulating the hydrological cycle across the vast landscape of this populous nation. Focus was

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placed on the hydrologic effects of forest degradation in the first two decades (1970s and 1980s), and recent research has shifted to studying reforestation hydrology, large-scale watershed hydrology, climate change impacts, and application of hydrological models. The 11 papers collected in this volume represent the key ongoing forest hydrological research activities, and perhaps reflect the state-of-art understanding of forest-water relations in China. The central theme and objective of this collection are to address how management and climate change and variability affect watershed hydrology and forest-water relationships across a large physiographic gradient (i.e., semi-arid Loess Plateau to humid subtropics) at multiple scales ranging from the hillslope, to small watershed, to continental China. It is our hope that this featured collection will serve as a window for the international research community to collaborate with Chinese forest hydrologists to contribute to our understanding of forest-water relations in a changing world.

OVERVIEW OF FEATURED COLLECTION

This featured collection starts with Wei *et al.* (this issue) who give an overview of the progress and lessons learned from forest hydrological research in China during the past 40 years in the context of worldwide literature on forest-water relations. This study concludes that large progress of forest hydrological research has been made so far but a lack of "paired watershed" experimental design and long-term research compromises the conclusions derived from many of the forest hydrologic studies in China. This synthesis paper also offers a few key recommendations to future hydrologic research in China that should include large-scale hydrologic modeling, focusing on reforestation hydrology, and long-term eco-hydrologic monitoring.

The next four papers present case studies on the semi-arid Loess Plateau in northwest China, a region that suffers severe soil erosion and water shortages and contributes most of the runoff and sediment to the Yellow River basin. The paper by Y. Wang *et al.* (this issue) quantifies water yield reductions under different afforestation schemes using both plot-scale field manipulation experiments and the lumped-parameter forest hydrology model, BROOK90. They suggest that sustainable afforestation practices in the Liupan Mountain region must consider vegetation type, plant species, and soil water carrying capacity. The two papers by S. Wang *et al.* (this issue) and Z. Zhang *et al.* (this issue) examine a 21-year record of streamflow dynamics, land cover recovery, and climate variability in an overland flow dominated small watershed near Tianshui City using a statistical and physically based modeling approach (MIKE SHE model), respectively. Both papers use the same dataset. The former concludes that annual streamflow and climate did not change significantly over the study period, while small improvement in land cover from soil and conservation measures occurred. The authors also conclude that precipitation and potential evapotranspiration (ET) have variable effects on streamflow at the annual and monthly scales, and future changes in climate will significantly impact water resources in the Loess Plateau region that is already experiencing a decreasing trend in water yield. In recognizing that a physically based hydrological model should be able to describe all hydrologic processes regardless of climatic, soil, and topographic conditions, the authors of the latter paper evaluate the distributed MIKE SHE model. They conclude that the model can capture the overland flow-dominated runoff process of the small watershed that receives precipitation characteristic of intense summer rainstorms. However, they acknowledge the limitations of the existing measured data in fully assessing the model's performance, and suggest that more tests are needed before the model can be used for regional applications. Bi *et al.* (this issue) present a detailed long-term study on the spatial soil moisture distribution of a complex terrain in Ji County in the middle reach of the Yellow River basin. They conclude that the slope gradient and aspects of a hillslope are the most important factors in affecting soil moisture at different soil depths. The results of this study are relevant to and useful for reforestation planning and design, parameterization of distributed hydrology models, and land productivity assessment.

Three papers follow that address hydrologic effects of forest vegetation changes in the subalpine region of the Upper Minjiang River, a major tributary of the Yangtze River, in southwestern China. P. Sun *et al.* (this issue) examine the seasonality and long-term trend of time-integrated Normalized Difference of Vegetation Index (TI-NDVI) and its effects on streamflows. They find that monthly accumulated growing degree days and TI-NDVI have an upward trend and warming causes an increase in vegetation activity particularly in alpine vegetation types. This study suggests that climate warming itself and warming-induced increases in vegetation activity explain the decrease trend of annual discharge in the study basin. Using two ET models, Y. Zhang *et al.* (this issue) evaluate the effects of several afforestation schemes prescribed by the Sloping Land Conversion Program (SLCP) on water yield. They conclude that large-scale implementation of the SLCP by converting crop lands to broadleaf forests would cause significant water yield reduction in the study area under a dry climatic condition. Careful selection of suitable forest types for SLCP can potentially minimize water loss while maintaining important ecological benefits. L. Zhang *et al.* (this issue) examine the ET characteristics of four meso-scale watersheds (1,700-5,600 km^2) by using the traditional water balance approach aided with data derived from remote sensing and Geographical Information Systems (GIS). They found that the ET/precipitation ratios of the study basins are much lower than reported values in Chinese forest hydrology literature, mostly due to the low potential ET and unique terrain characteristics (i.e., deep valley) that support dark forests.

The next paper reports on a case study result on forest watershed hydrology in the Yangtze River basin with a subtropical climate. G. Sun *et al.* (this issue) examines a rare 27-year hydrometerological dataset for a small forested watershed in Xiushui County, Jiangxi Province, southern China. They find that annual watershed ET increases significantly due to forest composition and structure shifts from degraded forest stands to fast growing shrubs and grasses during the study period (1967-1993).

The last two papers explore forest-water relations at a regional to a continental scale by using large-scale computer simulation models. Y. Liu *et al.* (this issue) apply a regional climate model to simulate the potential climatic effects of large-scale reforestation of the "Three North" Forest Shelterbelt Project that stretches 7,000 km long in northern China. Their results suggest that the project when fully implemented is likely to improve the overall hydroclimatic conditions by increasing precipitation, relative humidity, and soil moisture, and by reducing prevailing winds and air temperature. They conclude that the shelterbelts could reduce water yield in northwest and northern China during spring seasons, but could cause an increase in water yield in the northeastern and southern regions, offset some greenhouse effects, and reduce the severity of dust storms. The last paper by M. Liu *et al.* (this issue) demonstrates how a simulation model can describe the combined influences of multiple factors affecting water resources at a large scale. They apply an integrated ecosystem model, Dynamic Land Ecosystem Model (DLEM) in conjunction with spatial data of Land Use/Land Cover (LUCC) to estimate the LUCC effects on the magnitude, spatial and temporal variations of ET, runoff, and water yield across China. Their study indicates that deforestation and subsequent conversion to paddy or irrigated crop lands averagely increase ET but decrease water yield by 138 mm/year, and that reforesting irrigated croplands averagely decrease ET by 422 mm/year. They conclude that to better understand LUCC effects on China's water resources, it is needed to take into account the interactions of LUCC with other environmental changes such as ground-water use, climate, and atmospheric composition.

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LITERATURE CITED

Bi, H., X. Liu, X. Li, J. Li, M. Guo, L. Lin, and C. Guo, 2008. Spatial Dynamics of Soil Moisture in a Complex Terrain in the Semi-arid Loess Plateau Region, China. Journal of the American Water Resources Association 44(5):1121-1131.

Liu, M., H. Tian, G. Chen, W. Ren, C. Zhang, and J. Liu, 2008. Effects of Land-Use and Land-Cover Change on Evapotranspiration and Water Yield in China During 1900-2000. Journal of the American Water Resources Association 44(5):1193-1207.

Liu, Y., J. Stanturf, and H. Lú. 2008. Modeling the Potential of the Northern China Forest Shelterbelt in Improving Hydroclimate Conditions. Journal of the American Water Resources Association 44(5):1176-1192.

Sun, G., C. Zuo, S. Liu, M. Liu, S.G. McNulty, and J.M. Vose, 2008. Watershed Evapotranspiration Increased Due to Changes in Vegetation Composition and Structure Under a Subtropical Climate. Journal of the American Water Resources Association 44(5):1164-1175.

Sun, P., S. Liu, H. Jiang, Y. Lu, J. Liu, Y. Lin, and X. Liu, 2008. Hydrologic Effects of NDVI Time Series in a Context of Climatic Variability in an Upstream Catchment of the Minjiang River. Journal of the American Water Resources Association 44(5):1132-1143.

Wang, S., Z. Zhang, G. Sun, S.G. McNulty, H. Zhang, J. Li, and M. Zhang, 2008. Long-Term Streamflow Response to Climatic Variability in the Loess Plateau, China. Journal of the American Water Resources Association 44(5):1098-1107.

Wang, Y., P. Yu, W. Xiong, Z. Shen, M. Guo, Z. Shi, A. Du, and L. Wang, 2008. Water-Yield Reduction after Afforestation and Related Processes in the Semiarid Liupan Mountains, Northwest China. Journal of the American Water Resources Association 44(5):1086-1097.

Wei, X., G. Sun, S. Liu, J. Hong, G. Zhou, and L. Dai, 2008. The Forest-Streamflow Relationship in China: A 40-Year Retrospect. Journal of the American Water Resources Association 44(5):1076-1085.

Zhang, L., H. Jiang, X. Wei, Q. Zhu, S. Liu, P. Sun, and J. Liu, 2008. Evapotranspiration in the Meso-Scale Forested Watersheds in Minjiang Valley, West China. Journal of the American Water Resources Association 44(5):1154-1163.

Zhang, Y., S. Liu, X. Wei, J. Liu, and G. Zhang, 2008. Potential Impacts of Afforestation on Water Yield in the Sub Alpine Region of Southwestern China. Journal of the American Water Resources Association 44(5):1144-1153.

Zhang, Z., S. Wang, G. Sun, S.G. McNulty, H. Zhang, J. Li, M. Zhang, E. Klaghofer, and P. Strauss, 2008. Evaluation of the MIKE SHE Model for Application in the Loess Plateau, China. Journal of the American Water Resources Association 44(5):1108-1120.