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Preface

Forest ecohydrological processes in a changing environment

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ABSTRACT

The papers in this issue are a selection of the presentations made at the second International Conference on Forests and Water in a Changing Environment. This special issue 'Forest Ecohydrological Processes in a Changing Environment' covers the topics regarding the effects of forest, land use and climate changes on ecohydrological processes across forest stand, watershed and regional spatial scales. Copyright © 2011 John Wiley & Sons, Ltd.

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THE NATURE AND SCOPE OF THE SPECIAL ISSUE

Forests are well recognized for their role in supplying clean water, sequestering carbon dioxide, stabilizing climate, conserving biodiversity and providing other ecosystem services. The forest hydrology community has a long history in studying the interactions of forest ecosystems, climate and water cycles: the core of ecohydrological science. Although most of the historical studies have been conducted at hillslope and small watershed scales, they have provided a basis for understanding and responding to modern global environmental threats such as climate change and landscape fragmentation.

One of the key challenges facing ecohydrology is to understand the interactions and feedbacks among forest vegetation, climate and hydrology at various spatial and temporal scales under different environmental conditions. These interactions and linkages ultimately determine ecosystem functions and services at multiple scales. For example, at the forest stand level, forest vegetation (type, age and structure) and climate critically control the directions and strengths of energy exchanges and mass fluxes. Research at this scale generally leads to understanding on how different processes interact and identifies critical controlling processes. With increasing spatial scales and greater landscape complexity, interactions among forest cover/land use change, climate and hydrology are more complicated and their effects on ecohydrological processes are cumulative and less understood. Many current planning and management issues are operated at large spatial and temporal scales with a much broader context. Hence, information, tools and models at large spatial scales are increasingly critical for designing forest management and watershed protection strategies to ensure long-term environmental and economic sustainability. Moreover, research conducted at separate spatial scales can help determine the variables or properties which have scale-dependence and cross-scale relationships. Clearly, the critical scientific gap and practical management needs for integrated forest and watershed management in a changing climate call for the in-depth examination of forest ecohydrological processes at various spatial and temporal scales.

This special issue 'Forest Ecohydrological Processes in a Changing Environment' draws 16 selected papers presented at the second International Conference on Forests and Water in a Changing Environment held during 14–16 September 2009 in Raleigh, North Carolina, USA. This collection represents studies on forest ecohydrological processes under various environmental settings that cover a wide range of geographic regions. It first presents two synthesis papers that provide reviews of forest ecological

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science followed by 14 case studies that are organized according to processes and issues addressed at three different spatial scales: forest stands, watersheds and regions.

Vose *et al.* (2011) identified critical research needs in the 21st century. The paper first reviewed key threats to forest water resources and then identified ecohydrological functions at risk, followed by future research needs. They concluded that climate change, land use change and invasive species are among the most critical contemporary issues that affect water quantity and quality. Among the five critical research needs identified, research on ecohydrological processes across scales is clearly needed. Bredemeier (2011) provided an in-depth analysis on forest, climate and water issues in Europe in the ecohydrological context. By examining water supply, water quality and water related hazards, the author demonstrated that climate change will probably cause more flooding problems at the 'wet end' and more droughts at the 'dry end' of Europe. The synthesis also showed that forest management can play an important role in optimizing water retention but with limited influence under very strong and catastrophic events.

Papers on cases studies start with forest ecohydrological processes at the forest stand level. Five papers focused on investigation of various factors influencing tree transpiration, stomatal conductance and water use efficiency (WUE) using field experimental approaches (e.g. sap flow technique). The high number of papers at this scale clearly suggests significant research interest in understanding how different variables affect water fluxes at individual tree or forest stand levels. Those examined variables in this special issue include genetic variants of tree species (e.g. loblolly pine by Aspinwall *et al.*, 2011), structural and physiological control (Ford *et al.*, 2011), elevated carbon dioxide (Warren *et al.*, 2011) and extreme climate events (e.g. spring drought by Dong *et al.*, 2011). In addition, Yoshifuji *et al.* (2011) examined inter-annual variation in transpiration onset in a tropic deciduous forest (teak plantation) based on 8-year sap flow data and found that the inter-annual variation in the date of transpiration onset for this tropical deciduous forest was significantly greater than for deciduous forests in temperate and boreal biomes. This research also showed that soil moisture was an important factor for influencing inter-annual variations in the transpiration onset in their studied forest.

The special issue also includes two case studies conducted at the forest-stand-level with different approaches. Xu *et al.* (2011) used an isotopic method (deuterium isotopic composition) to partition water sources (e.g. precipitation and groundwater) of tree uptake in a subalpine dark coniferous forest community in southwestern China. They found that the water use strategies of three vegetation species at different vertical layers (dominant canopy, mid-story and understory) in the studied forest community were complementary, and such strategies can promote species co-existence and maintain community resilience. Based on an evapotranspiration (ET) data set estimated from eddy flux and sap flow measurements for 13 ecosystems across a large climatic and management gradient from USA, China and Australia, Sun *et al.* (2011) established a general predictive model for estimating monthly ecosystem ET using three variables: leaf area index, precipitation and potential evapotranspiration (ET_0). Although the model was derived at the forest stand level, it can be effectively used to estimate monthly ET dynamics and consequently water balance at watershed and regional scales.

Watershed-scale studies focuses on cumulative effects of land cover change and climatic variability on hydrologic fluxes. Boggs and Sun (2011) studied the impacts of urbanization on hydrology through comparing an urbanized watershed ($0{\cdot}70\ km^2$) with a fully forested watershed ($2{\cdot}95\ km^2$) in Central North Carolina. Their study found that urbanization generated about 75% more streamflow and higher peak flows than those in the forested watershed, mainly due to differences in growing season ET rates between the two contrasting watersheds. Using the modelling approach (soil and water assessment tool), Wang and Kalin (2011) quantified the effects of land use/cover change on hydrology in the Wolf Bay watershed ($130\ km^2$), Alabama, USA. The modelling analysis was able to show a clear flow threshold of around 1% exceedance where the relative change was at its maximum. In comparison, Wang *et al.* (2011) applied a combination of water balance and statistical method to estimate the effect of forestation on annual runoff and ET based on 59 data sets from various sized watersheds (ranging from 28 to 29 600 km^2) in the Loess Plateau of China. This study demonstrated that forestation had reduced annual runoff, which may have important implication on water management in the studied dry region. The impact of climate change on glacier melting and water resources was examined by Zhang *et al.* (2011), who took statistical approach (artificial neural network) in a natural large-scale basin, the Niyang River Basin in the Southeast Qinghai-Tibet Plateau, China. An important finding is that climate change had caused acceleration of glacier melting which resulted in increased streamflow and summer water cooling.

At a regional scale, a numerical modelling study conducted by Liu (2011) evaluated the hydrological effects of forest restoration in the southern United States. At such a large scale, the study successfully developed the linkage between forest restoration and precipitation change (overall precipitation decreasing in July and increasing in January in response to reduction in the corresponding prevailing winds). Wehmeyer *et al.* (2011) also studied land use change and their effect on hydrology in Iowa, USA. Instead of analysing streamflow data, they estimated how land cover change affected runoff curve number, a term commonly used to predict peak runoff from rainstorms. The study showed that hydrological alternation and degradation of aquatic resources were likely to have been much higher during the 30 years of initial settlement than in the subsequent period of 126 years in the studied region. Using a process-based ecosystem model,

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DLEM (Dynamic Land Ecosystem Model), Tian *et al.* (2011) quantified how climate variability and land use change over the past century had affected net primary production (NPP), ET and WUE in the terrestrial ecosystems of Monsoon Asia (South, Southeast and East Asia). They found that NPP decreased by 12% from the 1900s' level, and WUE by 15% in the past century. ET was reduced by climate change alone, but this decline was partly offset by land use change (Tian *et al.* 2011).

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