国家科学技术学术著作出版基金
NFAPST

森林生态水文

余新晓 张志强 陈丽华 谢宝元 王礼先 等 著

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学术秘书：牛健植　秦富仓

图书在版编目(CIP)数据

森林生态水文/余新晓等著.—北京：中国林业出版社，2004.11

ISBN 7-5038-3849-3

Ⅰ.森…　Ⅱ.余…　Ⅲ.森林—生态系统—水文学—研究　Ⅳ.S715

中国版本图书馆 CIP 数据核字(2004)第 087440 号

森林生态水文

出　　版：中国林业出版社　（100009　北京西城区刘海胡同 7 号）
E-mail：cfphz@public.bta.net.cn
电　　话：66184477
发　　行：中国林业出版社
印　　刷：北京地质印刷厂
版　　次：2004 年 11 月第 1 版
印　　次：2004 年 11 月第 1 次
开　　本：889mm×1194mm　1/16
印　　张：16.5
字　　数：455 千字
印　　数：1～2000 册

定　　价：55.00 元

序

森林是陆地生态系统的主体，具有巨大的经济价值、文化价值和生态价值，是美好家园的创造者；水是生态系统中最为活跃而又不可替代的生态因子，是人类的生命之源，是联系地球系统地圈—生物圈—大气圈的纽带，与森林关系密切；水资源和森林资源匮乏问题是人类进入21世纪所面临的重要资源问题之一，其产生的主要原因在于人类活动破坏了森林与水资源的生态空间。

研究森林与水相互交织的复杂关系是生态学家和水文学家千百年关注的热点，但他们都是有针对性地开展研究工作。进入20世纪90年代，生态学家和水文学家发现单纯从事本领域研究工作，有些问题解释不通，并有局限性，如生态学家们关注水文过程对生态系统功能的重要影响，但忽视了水文过程与生态系统植物群落变化与相互制约的内在联系；水文学家过去关心最多的是洪水与干旱的成因、工程水文的实际设计应用等，但随着对生态与环境问题的重视与提出，他们发现诸如流速如何影响河道内的植物生长、河川径流的情势与滨岸生态环境过程之间是如何相互作用与联系的、如何使水文学研究适应可持续的生态平衡等等也是研究的重点。生态环境保护日益引起人们的关注，人们也越来越认识到与自然生态系统协调共处对人类可持续发展的重要性，而在自然生态系统与人类的众多复杂关系中，水是最为活跃和最具决定性的因素，水资源开发利用所导致的区域水文过程变化将不可避免地对区域生态环境体系产生影响，而区域生态环境变化，尤其是植被生态系统的变化，将势必对区域水文过程产生作用。

社会的需求和人类的进步要求开展水文循环过程的变化与其相关生态环境变化的交叉研究。非常可喜的是，余新晓同志及其合作者编写的《森林生态水文》一书，它是著者们多年研究的结晶，他们以都市水源保护林为研究对象的暖温带森林生态系统定位研究站为基地，以生态过程和生态格局的水文学机制为研究核心，以植物与水分关系为基础理论，将尺度问题贯穿于整个研究之中，以林冠层、地被物层和土壤层的水分关系为基础理论，将尺度问题贯穿于整个研究之中，针对林冠层、地被物层和土壤层的水分运动过程开展研究工作，研究对象涉及径流、侵蚀产沙、侵蚀模拟、生态用水、水质等方面内容，该书深刻揭示了生态格局和生态过程的水文学机制，为水资源可持续利用及有效管理提供了科学依据。我相信，该书的出版将会对同类地区的生态水文研究，对我国生态环境建设，起到一定的技术支持和理论指导作用。

中国工程院院士　关君蔚

2004年6月

前　言

森林生态水文从提出到现在只有60多年的历史，作为一门研究森林与水关系的新兴学科，具有显著的综合性、交叉性和边缘性。在20世纪90年代初期，森林生态水文研究的主要内容是森林植被与水量要素之间的相互关系，进入21世纪，随着社会经济的迅猛发展，人口数量激增，自然资源大量消耗，国际社会出现了资源、环境、人口和发展等重大问题，森林生态水文研究的重点也转向森林生态系统与水资源、水环境和协调人、森林与水的复杂关系，以及为解决重大生态建设工程和生产技术问题提供理论与方法。

长期以来，在科技部、国家林业局和北京市的大力支持下，作者一直致力于森林生态水文领域的研究，近年来又获得了国家自然科学重点基金和中德、中奥等国际科技合作项目的资助，使对森林植被与水（包括水量、水质和泥沙）关系的研究不断深入。1987年北京林业大学和北京市林业局在北京市密云县共同建立了以都市水源保护林为研究对象的暖温带森林生态系统定位研究站，十余年来，通过长期野外观测实验、采样分析、建立模型和利用地理信息系统及与“3S”技术相结合，从径流小区、坡面径流场和小流域等不同尺度层次，系统地研究了森林植被对径流、水质和土壤侵蚀的影响，强调尺度分析和综合分析；从森林植被冠层、地被物层和林木根系分布层等不同作用层次，深入分析了森林植被林冠截留、枯枝落叶层持水、林地土壤水分运动规律、林地坡面地表径流过程和森林生态系统的水量平衡，强调过程分析和机制分析；从生物地球化学循环入手，阐明森林植被对降水化学性质的影响和主要养分元素的生物地球化学循环规律，强调功能分析和作用分析；从森林植被生态用水的角度，建立了森林植被生态用水的理论，强调生态分析和应用分析。综合长期工作的研究，将多年来的成果进行系统总结，编撰此书，期待对我国该领域的研究起推动作用，并在我国林业生态工程建设中发挥积极作用。

本书立足于国际森林生态水文学科前沿，以长期和大量的第一手实验数据为基础，系统论述了森林生态水文过程—尺度—机制—功能的基本理论。全书共分10章，第一章从森林植被变化对水量的影响、森林植被对流域径流形成机制的影响、森林植被控制土壤侵蚀机理研究、森林生态系统生物地球化学循环研究、森林水文模型研究进展和生态用水研究现状与发展趋势等方面论述了森林生态水文国内外研究进展；第二章通过森林林冠截留的实验分析，从森林植被冠层的水文机理和枯枝落叶层的水文机理两个方面论述了森林植被冠层与地被物层水文机制；第三章分析了森林植被对天然坡面和小流域等尺度对地表径流的影响；第四章建立了森林植被生态用水的理论，进行了生态用水的计算与分析和生态需水的预测与分析；第五章论述了径流小区尺度森林植被对土壤侵蚀产沙的影响、天然坡面尺度森林对

土壤侵蚀产沙的影响、试验小流域尺度森林对土壤侵蚀产沙的影响和森林对土壤侵蚀影响的空间尺度效应；第六章通过试验流域地理信息数据库的建立和小流域侵蚀过程空间联系的分析，建立了试验流域土壤侵蚀模型系统，对森林小流域土壤侵蚀过程进行了模拟和检验；第七章从大气降水化学性质、森林植被降水格局、森林生态系统降水化学性质、森林土壤层透过水化学性质、浅层地下水(潜水)及河流断面水化学性质监测分析和河川径流、地下水与大气降水中化学元素特征比较等方面论述了森林植被对降水化学性质的影响；第八章分析了刺槐林、油松林和板栗林主要营养元素的生物地球化学循环，对不同森林类型主要营养元素生物地球化学循环进行了比较；第九章对森林水质影响评价进行了分析；第十章对土地利用(森林植被)变化的水文响应进行了分析。

森林生态水文许多重要理论和实践问题的研究尚在探索之中，随着研究的不断深入，必将对森林生态水文理论体系的发展和应用起到积极的推动作用。作者殷切期望本书的出版能引起有关人士对该研究领域的更大关注和支持，并希望能对从事森林生态水文及相关学科的专家学者有所裨益，共同将这一重要的科学领域推向新的发展阶段。

本书的研究资料的积累过程实际上就是作者从事森林生态水文科研和研究生教学的过程，曾先后得到关君蔚院士、沈国舫院士、蒋有续院士、朱金兆教授、尹伟伦教授、周心澄教授和于志民教授等诸位先生的指导，在此一并表示衷心的感谢！

本书的出版得到了国家科学技术学术著作出版基金的资助，以及国家“十五”科技攻关计划“退耕还林还草工程区水源涵养型植被建设技术研究与示范”和农业科技成果转化资金项目“水源保护林培育与经营管理综合配套技术”的资助，也是国家林业局首都圈森林生态站监测成果的总结。鉴于森林生态水文研究的复杂性及作者的知识和能力有限，书中难免有不妥之处，敬请读者不吝赐教。

余新晓

2004年5月于北京

Foreword

Only around sixty years has gone since the subject of Forest Ecological Hydrology put forward. As a newly developed subject focusing on studying the relationship between forest and water, forest ecological hydrology shows its apparent characteristics in terms of synthesis, borderline and cut-cross. Before 90s of the 20st century, researches were mainly on relationship between forest cover and basic factors affecting water yield. But since then, particularly after entering the 21st century, along with rapid socio-economic development and growth of population as well as large consumption of natural resources, serious problems emerged in the aspect of resource, environment, population and development all over the world. The forest ecological hydrology thus shifted its focal researches to studying the relationship between forest ecosystem and water resources, harmony between water environment and human life, forest and water, as well as developing theories and methods for implementing ecological construction program and solving technical problems in production activities.

For a long time, with the support of the Ministry of Science and technology, the State Forestry Bureau and Beijing government, the author has been continuously working on researches of forest ecological hydrology. In recent years, in-depth work is being carried out to study the relationship between forest and water (yield, quality and sediment) with additional support from the Key National Foundation for Natural Science and international technical cooperation such as Sino-German and Sino-Austrian cooperation project. In 1987, taking the urban headwaters protection forest as the study object, a warm temperate forest ecosystem research station was established in Miyun County of Beijing jointly by the Beijing Forestry University and the Beijing Forestry Bureau. Therefore, different researches have been conducted in a long-term basis at the station, i.e. systematic researches on impact of forest on runoff, water quality and soil erosion in scales of runoff plot, slope plot and watershed through field observations, sampling analysis, modeling, GIS and 3S technology, with emphasis on scale and synthetic analysis approaches; in-depth analysis of interception of forest crown and litter-layer, water flux in soil, process of overland flow of forested slope, water equilibrium of forest ecosystem, with emphasis on process and mechanism analysis approaches; researches on impact of forest on chemical characteristics of rainfall and on bio-geochemicalcycle of the main nutrient elements, with emphasis on function and effect analysis approaches; developing the theory of ecologic water requirement of forest, with emphasis on ecological and applicable analysis approaches. Based on the previous work, the author tries to summarize his researches results systematically into this book edition. The author hopes this book can contribute to promoting research in this field and also can play a certain role in implementing the forest ecological construction program of our country.

This book describes the basic theory of process-scale-mechanism-function of forest ecological hydrology systematically, standing at the front of the subject of forest hydrology in the world and making use of plenty of first hand data obtained from long-term researches. The book contains ten chapters all together. In Chapter 1, reviewing the research development of forest hydrology in the world, with respect to impact of forest change on glow yield and on mechanism of watershed flow generation, mechanism of forest in soil erosion con-

trol, bio-geochemical cycle of forest ecosystem, progress in moeeling researches as well as research status and trend of ecological water requisement; in chapter 2, through experimental analysis of forest crown interception ,describing the hydrological mechanism of forest crown and ground cover based on studies on hydrological mechanism of forest crown and litter; in chapter 3, analyzing the impact of forest on overland flow of natural slope and watershed scame; in chapter 4, developing the theory of ecological water requirement of foresu and conducting the calculation and analysis of ecological water requirement, as well as prediction of ecological water requirement; in chapter 5, discussing the impact of forest of runoff plot, natural forested slope and experimental watershed on soil erosion and sediment generation, and the spatial scale effect of forest on soil erosion; in chapter 6, establishing the soil erosion model of expesimental watershed and also the modeling and verification of soil erosion process of forested watershed; in chapter 7, discussing the impact of forest on rainfall chemical characteristics based on analysis of atmospheric rainfall chemical characteristics, rainfall pattern of forest, rainfall chemical characteristics in forest ecosystem, chemical characteristics of infiltrating water of forest soil, chemical characteristics of shallow groundwater and river intersect under monitoring, comparison of chemical elements characteristics among river flow, underground water and atmospheric rainfall; in chapter 8, analyzing the bio-geochemical cycle of the main nutrient elements of Robinia pseudoacacia, pine and chestnut forest and comparison among different type of forests; in chapter 9, discussing the assessment of impact of forest on water quality; in chapter 10, analyzing the response of hydrology on land use and forest vegetation change.

No doubt, there are still many other aspects of theory and practice of forest ecological hydrology under exploring. Obviously, deepening research will play an active role in promoting the theory system development and application of forest hydrology. The author sincerely hopes that the publication of this book can attract more attention and support to this scientific subject, and also expects the book can benefit those expertise and scholars working on forest ecological hydrology and relevant fields, in order to increasingly promote the development of this significant science into a new stage.

The accumulation of the data referred to the book actually reflects the author's work on researches and education for postgraduates. During this period, the author has obtained valuable guidance from the academicians of Mr. Guan Junwei, Mr. Shen Guofang and Mr. Jiang Youxu, professors of Mr. Zhu Jinzhao, Mr. Yin Weilun, Mr. Zhou Xincheng and Mr. Yu Zhimin. Here, the author expresses his gratitude to all of them.

The publication is financed by the State Publication Foundation, "Tenth Five-Year Plan" National Key Projects in Science and Technology (Grant No. 2001BA 510 B 02 - 02) and the project of the Commercialization of Agricultural Research Findings(Grant No. 02 EFN216700779). Due to the complex of forest ecological hydrology research and the author's limitation in his knowledge and capability, the book is far from perfect, thus comments and suggestions are always welcome.

Prof. Dr. Yu Xinxiao

Beijing, May 2004

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