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Plantation Forest and Their Silvicature Systems in China

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作者简介

盛炜彤，男，1933年11月出生于江苏海门市；1956年毕业于南京林学院。曾任中国林业科学研究院林业研究所室主任，副所长；中国林学会生态分会理事长，名誉理事长；1994～2009年任国务院参事；现任国家林业局科技委常委，国家林业局专家咨询委员会委员（2003年受聘）；院刊《林业科学研究》主编，《林业科学》常务副主编；中国林业科学研究院研究员，首席科学家，博士生导师。

长期从事森林培育和森林生态方面的研究，为我国森林培育事业，特别是人工林发展做出了重要贡献。在"七五"及"八五"期间担任人工林培育国家科技攻关课题的负责人，对我国森林立地分类、人工林培育及人工林长期生产力保持等方面有深入系统研究。提出的人工林培育上的定向、速生、丰产、优质、稳定和高效6个方向和遗传控制、立地控制、密度控制、植被控制和地力控制等5个控制构成的育林体系，得到了广泛应用，从而为提高人工林造林技术水平和生产力做出了重要贡献。共发表论文65篇，编写著作10部，获奖成果9个。其中"杉木人工林地力衰退防治技术研究"1994年获林业部科技进步一等奖；"用材林基地立地分类、评价及适地适树研究"及"杉木建筑材优化栽培模式研究"分别于1995年及2001年获国家科技进步二等奖。1992年主持编写的《自然科学发展战略调查研究报告——林学》一书，经国家自然科学基金委专家评审，获得了具有科学性、先进性和指导性的高度评价，并成为国家自然科学基金委编写林学学科基金项目的指南和主要依据。国家重点自然科学项目"杉木、桉树人工林长期生产力保持机制研究"通过验收，获"取得突出进展"的评价，成绩为"A"。1990年被评为林业部有突出贡献的中青年专家，1992年被国务院批准享受政府特殊津贴。

前言

我从事人工林研究是从1974年开始的，在此之前我主要从事天然林的野外调查与试验研究，包括西南高山林区和珠穆朗玛峰南坡的云冷杉林、云南林区的云南松林的林型与采伐更新技术，也参加过我国采伐更新规程的制定工作；后来又根据林业部对次生林经营的重视，在甘肃小陇山林场和西秦岭洮坪林场以及安徽黄山进行过次生林抚育改造的研究工作，历时十几年。在1974年前由于全国荒山荒地甚多，而我国森林资源又严重不足，木材供应极为缺乏，因此对人工造林很为重视，从20世纪50年代起就开始了荒山荒地造林绿化工作，根据《全国农业发展纲要》（1956~1967年）要求，在12年内，在自然条件许可和人力可能经营的范围内绿化荒地荒山，在一切宅旁、村旁、路旁、水旁，只要有可能，都要有计划种起树来，从此以后，全国造林灭荒发展迅速。1964~1965年制定了全国用材林基地规划，共规划基地240片。70年代初，农林部又提出在南方发展以杉木为主的用材林和建立用材林基地，并制定了建立大片用材林基地的规划。从20世纪60年代中期开始，全国掀起营建速生丰产林的高潮，但由于投入不足，营建大面积的人工林与速生丰产林技术贮备跟不上造林的速度，发展人工林存在较大的盲目性，加之经营管理强度不高，造林成效低，当时的评估认为造林效果是“三三制”，即好、中、差各占1/3。那个时候造林树种太少，南方集中于杉木，北方集中于杨树，由于树种单一，在造林中又缺乏立地控制，人工林的生产力普遍不高，达不到规划提出的要求。南方杉木人工林不少规划在不适于杉木生长的低丘地带，如湖南省的株石（株洲、石湾）基地就属低丘地带，万亩以上集中连片，形成了不少“小老头林”。由于人工林中低产林多，故林业部提出了对“小老头林”（即低产林）进行改造。在这样的形势下，1974年5月作者和其他五人被派往湖南株洲市朱亭区黄龙乡长岭林场（一个集体林场）去蹲点，一边与农民一起劳动，一边对“小老头林”进行调查，并研究改造“小老头林”的技术。实际上由于当地立地条件差，土壤酸、瘠、板结，虽然采取了一些当时看来可行的措施，也有一定效果，但难有大的改观。从这个时候开始作者从事了人工林的研究，主要是杉木人工林的研究。20世纪70年代末与80年代初及其以后，国家开始重视科研，为了改变我国生产力的落后状态，将科学研究工作放到了十分重要位置，林业科技也因此得到了快速发展，林业科技部门对人工林发展中的问题已开始立项进行研究。如“七五”国家科技攻关设定了“人工林集约栽培技术研究”项目，“八五”又设定了“短周期工业用材林定向栽培技术研究”项目，作者是这二个项目的技术负责人；同时作者在“七五”期间还承担了“杉木人工林集约栽培技术研究”和在“八五”期间承担了“杉木人工林优化栽培模式研究”两个专题的研究。上述“七五”、“八五”两个项目中均设置有主要树种人工林的研究专题，在项目组的统一组织下，有关各树种专题研究的主要内容基本是统一的，而且每年都要集

中进行学术交流和对研究进展进行检查。通过两个项目的全国性试验研究，我们学习了国际的先进科技，也总结国内的经验，并针对关键科技问题进行共同攻关。通过10年的攻关研究，对我国人工林栽培中存在的关键性科技问题有了较好的解决，改变了我国在人工林科技上的落后状态。如人工林的立地控制、遗传控制、密度控制、地力控制、植被控制、林分的生长模拟、轮伐期的确定，以及优化栽培模式都取得了科学上先进而生产上可行的研究成果，有力地推动了我国人工林栽培科学技术水平的提高。除了“七五”、“八五”外，1997～2001年，作者还承担了国家自然科学基金重点项目“杉木、桉树人工林长期生产力保持机制研究”。这是因为在此项研究之前，国内外普遍提出了人工林存在生物学上的不稳定性和地力退化与生产力下降问题，在1990年召开的国际林联（IUFRO）第十九届大会上还提出了“人工林长期生产力”问题。因此，作者在“七五”的“杉木人工林集约栽培技术研究”专题中对杉木人工林的地力衰退及防治技术开始进行了试验研究。1991年，中国林学会森林生态分会（作者时任理事长）与杉木人工林集约栽培研究专题组共同主持召开了“人工林土壤退化及防治技术学术讨论会”，并编辑出版了以作者为主编的《人工林地力衰退研究》一书。1997～2001年自然科学基金重点项目研究，于2003年通过验收，获得“整个研究工作起点高，系统性强，并有创新，取得了突出进展”的评价，并于2005年出版了《杉木人工林长期生产力保持机制研究》专著。在人工林长期生产力保持机制与人工林地衰退与防治技术研究中，我们对人工林连作生产力下降现状，杉木人工林及其自身特性对土壤肥力的影响，杉木人工林的育林干扰对土壤养分损耗和土壤功能影响，杉木人工林的土壤变化，杉木营养特性与人工林生产力和碳分配，连作杉木人工林生产力、碳分配及养分生物循环，杉木人工林立地生产力下降原因机制及保持长期生产力途径进行了深入研究，并提出了防止地力衰退的方案。

除了上述试验研究外，作者在国内外结合工作需要调研考察了不同人工林培育技术与生长状况，同时参阅了大量有关人工林问题的各种文献资料，并根据长期对人工林发展掌握的情况，我深切地认为中国人工林生产力普遍不高的原因主要在于在培育中未能落实集约育林技术措施，而且不掌握生态系统管理方法，发展中盲目性较大，发展树种过分单一。有些集约的生态育林技术我国虽然是掌握的，但不能在培育中加以实施。作者还深感到，我国人工林在全国已经有了许多研究，成果不少，但缺乏总结，因此我国编写的一些著作和规划、标准等在新的科技应用上仍较滞后，对我国人工林方面新成果反应不足。因此有必要出版一本书，比较系统地结合作者的科学研究，总结我国人工林科技上数十年的研究成就，以此为我国人工林培育科技水平提高作一些力所能及的工作。尽管作者自知能力有限，但愿能为我国人工林科技进步起到一些推动作用。下面就此书的编写作一些介绍。

本书共分四部分，第一部分是中国人工林概况，主要叙述了中国树木栽培与人工林发展历史和主要人工林树种分布、资源、生长量与基地。关于人工林的发展历史，重点讲了杉木人工林的发展历史，因为从人工林发展看，杉木人工林是我国发展历史最早，规模最大，对社会经济影响也最明显，杉木造林在我国人工林发展上是最有代表性，而且一直延续至今。杉木人工林在明末清初，大约距今400年上下已经广泛、大规模种植，形成的产区多，而且已经在栽培制度及产、运、销等方面形成了体系。因此可以认为明末清初时期是我国人工林发展的历史起点。

关于我国人工林资源，我国造林树种是丰富的，而且造林面积大、发展快，速生丰产林达到了基地化与规模化。但由于经营强度不够，生产潜力未能得到发挥，主要表现为生长量不高。中国由于自然地理条件优越，树种资源丰富，林木立地生产潜力很高。书中列出了我国主要造林树种、品种生长量表，对制定我国今后人工林培育中生长量指标很有参考价值。

第二部分是人工林生态学基础。这一部分共分为九章。这九章包括人工林分布、生长与气候、地形、土壤的关系，中国人工林森林立地分类，中国人工林森林立地质量评价，人工林的生长区（产区），人工林生态系统能量利用，人工林养分循环，人工林群落，人工林生长发育与生产力，人工林生态功能。这一部分的九章内容，在人工林方面虽有不少研究报道，但多分散，不系统，缺少归纳提炼，因而在理论上未能获得明显提高。书中对人工林生长区形成的原理与区划的依据及其作用，对我国人工林树种与基地布局的重要意义；人工林养分循环对于人工林地力维护的重要性；速生短周期培育的人工林、中长期培育的人工林、南方针叶林、北方针叶林和阔叶林枯落物分解与养分循环速率和养分释放能力存在的差别，以及针叶林与短周期人工林地力维护中存在的问题均引证了大量资料，并做了详细的阐述。在书中对不同树种养分元素含量，林木养分元素的归还，人工林的地球化学循环，人工林养分循环中的问题进行了归纳，提出了短周期人工林、针叶人工林引起地力衰退的原因机制。

在人工林群落中提出了杉木、马尾松、油松、落叶松人工林群落类型，人工林群落结构，并对人工林形成的三种不同群落类型的情况及其经营价值进行了分析。这三种类型：一种是栽植于荒山荒地的人工林，常形成乔、灌、草型群落结构；另一种是栽植于天然林区的人工林，在这种人工林中有各种乡土有价值的阔叶树种更新，形成了混交林和多层的群落结构；第三种是农林混作栽培，形成人工林与林下作物群落结构。在培育人工林中要充分利用这三种群落类的型育林特性，发挥各自生产潜力和维护地力的能力。

在总结中长培育周期的人工林生长发育中，按照林分从量变到质变的变化过程，划分了五个阶段：即幼龄阶段、森林形成阶段、林木激烈竞争阶段、林木生长减速并趋于稳定阶段、林分衰退阶段，并分析了各自的特征与生态、生长状况。同时发现了人工林生长发育阶段形成中的五个重要过程：一是郁闭度的变化，是林分产生质变的关键过程；二是林木发生自然整枝和自然稀疏过程，也是林木产生质变的重要过程；三是随郁闭度和自然整枝、自然稀疏的变化，林下植被发育也跟着变化的过程；四是由一、二两个过程的变化，同时发生着叶生物量（光合器官）或是叶量与叶面积指数的增长与消减过程；五是随着林分发育阶段变化土壤质量的变化过程。上述五个过程也是本书提出的人工林生长发育五个阶段的主要理论依据。在育林过程中一定要了解掌握不同林分的这五个过程以指导实践，通过林分密度控制等措施，调节林分的生长发育及地力维护的进程。

在人工林生态功能这一章中，就人工林的理水功能、人工林保护生物多样性功能、人工林维护地力功能及人工林碳汇功能做了系统论述。对中长培育周期人工林的地力维护功能，按五个生长发育阶段，阐明了土壤肥力的变化过程，分析了不同生长发育阶段影响地力维护能力的关键因素：包括林木生长速率，林分郁闭度，林下植被发育，枯落物量，林木的养分吸收与归还变化和土壤肥力的变化。同时还揭示了人工混交林有利于地力维护的原理：高的生物多样性与生物量，组成复杂的枯落物与高的枯落物量，土壤中各种生物种

群与数量多，枯落物分解与养分循环速率快，从而改变了土壤物理性、持水能力，改善了林木养分的供给，并图解了这些因素间的相互关系。

第三部分为人工林长期生产力保持，系统讲述了提出人工林长期生产力保持的背景与研究现状，育林干扰对土壤养分损耗和土壤功能影响，人工林地力退化的过程与连作，人工林与病虫害和自然灾害，人工林生产力不能长期保持的原因分析这五章。通过这部分的分析，比较系统地介绍了人工林长期生产力保持问题的国内外背景及其研究现状与进展，深入分析了人工林生产力不能长期保持的原因，为人工林长期生产力保持提供了理论与实践依据。关于人工林生产力不能长期保持的情况，在第三部分中提出七个原因：①育林干扰对土壤养分损耗与土壤功能的影响；②传统的育林措施第一代人工林就存在地力退化，连作更加速了退化进程；③人工林抗病虫与自然灾害的能力弱；④人工林单作；⑤针叶树人工林比例大；⑥植被类型的空间配置在区域（或景观）上失衡；⑦人工林一些育林措施不当。对每一个原因均作了较为详细的表述，并例举了相关例证。这些为提出人工林长期生产力保持措施提供了宏观到微观的有力证据和科学依据。

第四部分是育林体系。这部分育林体系是在研究分析了上面人工林生态学基础和人工林长期生产力保持问题后提出的，第二、三两部分是第四部分的理论与实践基础。这部分最为关键，实际要解决提高人工林的稳定性，要保持人工林长期生产力，必须实施本书提出的人工林育林体系。这个人工林的育林体系是：①遗传控制；②立地控制；③密度控制；④植被控制；⑤地力控制，并概括为“五控制”育林体系。这五个控制提出是在科研、调研及实践中不断完善的，20世纪80年代开始提出的前三个控制和地力维护，当时已经在科技部门广泛应用与推广，并认为是有创新意义和实践基础的我国人工林育林技术的概括，易于被生产上接受。其后大量的科学试验与调研中，发现人工林稳定性和地力退化与林分的植被结构和人工林区的植被配置关系密切，植被的控制直接关系到人工林生物多样性，而生物多样性又是人工林稳定性与地力维护的基础，因此在20世纪90年代以后提出了五个控制，使这个育林体系更为完善了。在人工林的植被控制中，着重地论述了：①我国人工林发展中的植被管理问题；②人工林植被管理措施，其中提出了中国需要并适宜栽培的主要阔叶树种和珍贵树种104种，并注明了分布和用途；③人工林区的树种和森林类型的合理布局。只要认真做到这五个控制，人工林的稳定性和长期生产力可以得到提高，人工林可持续经营可以得以实现。在这第四部分对育林体系中的每项控制均作了明确的理论与实践上的阐述，而且提出了我国人工林实施五个控制育林技术体系的建议。

第四部分的第二十二章，论述了人工林优化栽培模式，人工林各种技术措施的采用采取什么样的组合最为合理，即使产出多经济效果高。人工林是商品性质的，我们提出“五个控制”的最终目标仍然是要有高的产出和高的经济效果，这也是保持长期生产力的目标。同时还因为我国以往育林措施不讲究优化组合和经济效果，常常成本高而经济效果低。作者以为人工林经营中也应该将技术措施的优化组合和栽培经济分析作为重要内容，只有这样才能保证人工林经营在经济上也是可持续的。

盛炜彤

2013年11月

Preface

I started my plantation studies in 1974, before it I mainly worked on field survey of natural forest and experimental studies, including spruce and abies forests in southwestern alpine forest region and south slope of the Mountain Everest, and Yunnan pine forest in Yunnan forest region, as well as technologies for their harvesting and regeneration. I also took part in the formulation of the national regulation for harvesting and regeneration. Later due to the request for attention to secondary forest by the Ministry of Forestry I worked on tending and improvement of secondary forests in Xiaolongshan Forest Farm in Gansu, Taoping Forest Farm in West Qinling Mountain and Huang Mountain in Anhui for more than 10 years.

Before 1974, there were many barren mountains and lands throughout the country, China's forest resources were in severe shortage and timber supply was extremely inadequate, therefore plantation received great attention. Afforestation in barren mountains and barren lands had been carried out since the 1950s, according to the "National agriculture development outlines (1956—1967)", the barren mountains and barren lands will be afforested within 12 years if the natural conditions allow and within an artificially manageable area, and all areas around houses and villages, along roadside and river banks should be planted with trees, as long as possible, within 12 years. Since then, the barren sites disappeared quickly due to afforestation.

During 1964 to 1965, the national plan for timber production bases were developed, establishment of a total of 240 such bases were proposed. In early 1970s, the Ministry of Agriculture and Forestry requested to establish timber plantations mainly of Chinese Fir and timber production bases in south China, and made a plan for establishing large land of timber production bases.

Since the mid 1960s, Establishment of fast-growing and high-yielding plantations has been give particular importance nationwide. However, due to insufficient investment, technical capacity for establishing large area of plantations and fast-growing and high-yielding plantations could not match up with the speed of afforestation. There was somehow blindness in the development of plantations, coupled with weak management strength and poor effectiveness of afforestation. The quality of plantations was evaluated as "Three-thirds system", i. e. good, moderate and bad each accounts one third.

At that time, very few species were available for afforestation. In south China, attention was focused on Chinese Fir and on Poplars in the north. Due to singularity of tree species and lack of control of site conditions, the productivity of plantations was generally not high, cannot meet the specifications of the plan.

In south China, many Chinese-fir plantations were planned to be grown in low hilly areas where site conditions were regarded unsuitable for growing Chinese-fir. For example, the Zhuzhou-Shiwan plantation base of Hunan Province is located in low hilly areas, where grown continuous plantations with an area of over 10, 000 Mu, however, many of these plantations finally become "Never-grow-up tree".

Because there were many low-productivity forests among plantations, the Ministry of Forestry requested to improve the "Never-grow-up tree". Under such conditions, I was sent to Changling Forest Farm (Collectively owned forest farm) located in Huanglong Village, Zhuting District, Zhuzhou of Hunan Province together with other 5 persons for residence practices, investigating the "Never-grow-up tree" and developing techniques for improvement while working together with farmers. However, only little impact was achieved due to poor site conditions such as soil acidity, infertility and compactness even feasible measures were taken, indicating difficulty to obtain obvious improvement. Since then, I started my studies in plantation, focused on Chinese Fir plantations.

From late 1970s to early 1980s and afterwards, scientific research received greater attention throughout the country, in order to change the situation of low productivity, scientific research was placed on a very important position. As a result, forestry science and technology also achieved rapid development. Studies in issues in plantation development were funded by forestry science and technology authorities. For example, the project "Studies on intensive plantation cultivation technologies" was funded by the 7^{th}5-year national key science program and the project "Studies on cultivation technologies specifically directed to short rotation industrial timber forest" was funded by the 8^{th}5-year national key science program, I was the technical leader for both projects, each of which I undertook a sub-project respectively "Studies on intensive cultivation technologies for Chinese Fir plantations" and "Studies on optimal cultivation models for Chinese Fir plantations".

Each of the 2 projects contained sub – projects on major plantation species. Under the overall management by the project team, the research contents were generally consistent among different species. Each year the subprojects were reviewed for academic exchange and progress report. Through these 2 projects that carried out nationwide experimental studies, we learned from foreign advanced technologies and also summarized domestic experiences, key scientific problems were identified for joint studies.

By the 10 years of joint studies, some critical problems existing in China's plantation cultivation were better solved, improving the situation of lag-behind plantation cultivation technologies, such as site control, genetic control, stocking density control, soil fertility control, vegetation control, simulation of stand growth, determination of rotation age, and optimized cultivation model for plantations, all these have revealed scientifically advanced and practically feasible research achievements, and evidently upgraded the level of China's plantation cultivation science and technology.

In addition to the projects undertaken during the 7^{th} and 8^{th} 5-year periods, I conducted a project "Studies on maintenance of long term productivity of plantations of Chinese Fir and Eucalypt" during 1997 to 2001 funded by the National Natural Science Foundation. Before this project, the biological instability, land degradation and productivity decline of plantations received worldwide concern. The 19^{th} IUFRO world congress held in 1990 also raised the question of "long term productivity of plantations". Therefore, in the sub-project "Studies on intensive cultivation technologies for Chinese Fir plantations" during the 7^{th} 5-year period, I started to conduct experimental studies on land degradation and its control for Chinese Fir plantations. In 1991, the Forest Ecology Branch of the Chinese Forestry Society (when I was the President) and the sub-project "Studies on intensive cultivation technologies for Chinese Fir plantations" jointly organized a "Workshop on land degradation and its control for plantations", and published a book "Studies on land degradation for plantations" of which I was the chief editor.

The National Natural Science Foundation funded project conducted during 1997 to 2001 was reviewed in 2003 and commented as "High starting point, systematical, innovative and significant progress". The monograph "Long term productivity maintenance of Chinese Fir plantations" was published in 2005. The book presented the following studies: Current status of plantation productivity decline due to succession cropping, impacts of Chinese Fir plantation and its inherent characteristics on soil fertility, silvicultural interventions on Chinese Fir plantation on soil nutrition loss and soil functions, Changes in the soil of Chinese Fir plantation, Nutrition characteristics of Chinese Fir and its plantation productivity and carbon allocation, impacts of succession cropping on Chinese Fir plantation productivity, carbon allocation and biological cycling of nutrients, Mechanisms for productivity decline of Chinese Fir plantation and approaches to maintenance of long term productivity, strategies for land productivity degradation control.

In addition to the above studies, I conducted study tours in China and other countries to investigate cultivation technologies and growth performance of different plantations. Meanwhile, I read a lot of literature related to plantation. Based on my long term studies on plantation development, I deeply feel that the main reason for low plantation productivity was no application of intensive silvicultural measures. Furthermore, the approach of integrated ecosystem management was not used, leading to blindness and singularity of tree species. Even though some intensive ecological silvicultural techniques were available in China, but they were not applied in practical operations. I also deeply feel that there were already many studies on plantation throughout the country and quite a few research results, but there were lack of overall review and analysis of the results, and the application of new technologies was not well presented in some publications and technical standards, leading to poor reflection of new research achievements. Therefore, I thought that there is a need to publish a book, in combination with the existing studies, to systematically review and analyze the research achievements from tens of years of plantation studies, intending to contribute to the improvement of plantation cultivation in China. I know my capacity is limited, but I hope through my efforts to promote progresses in plantation science and technology in China. Following is a brief introduction to this book.

This book consist of 4 parts, part 1 presents a general introduction of China's plantation, mainly describes tree cultivation, history of plantation development, and distribution, resources, growth and production bases of main plantation species. The history of plantation development mainly focused on Chinese Fir, which is the earliest species used in plantation and has the largest plantation area and most significant socioeconomic impacts. Afforestation using Chinese Fir is most representative in China's plantation development history, and has been continued up to now. Chinese Fir plantation was widely established in large scale since late Ming Dynasty and early Qing Dynasty about 400 years ago, forming diverse production regions and systems of cultivation, harvesting, transportation and marketing. Therefore, late Ming Dynasty and early Qing Dynasty was the start point of plantation development in history.

In respect to plantation resources, China has rich tree species, with large plantation areas and rapid development. Production bases of large scale fast-growing and high-yielding plantations were established. However, the production potential was not fully elaborated due to inadequate management intensity, this was mainly reflected by that the growth was not high. China has very advantageous natural geographic conditions and rich resources of forest tree species, the production potential is very high. This book presents tables of growth of main afforestation species and varieties in China, which can provid a valuable baseline of growth for future plantations in China.

Part 2 presents an introduction to the ecological basis for plantation. It consists of 9 chapters, including the relations of distribution andgrowth of plantations to climate, land form and soil, classification of forest sites, quality assessment of forest sites (mainly for plantation), growing regions of plantations (production regions), energy use and its efficiency of plantation ecosystem, nutritional cycling of plantation, types of plantation communities, plantation growth productivity, ecological functions of plantation. Although there are quite a few studies of plantation in these 9 aspects, however, most of them were not focused and non-systematic, lacking insightful analysis, and therefore these studies have not achieved significant theoretical progress. This book presents a comprehensive review of literatures and elaborates in detail the principles for plantation production regions and their demarcation and functions, the importance of species selection and distribution of plantation bases, the significance of nutritional cycling to site productivity for plantations, the differences in litter decomposition and rate of nutritional cycling as well as release of nutrients among fast-growing short rotation plantation, medium rotation plantation, conifer forest in south China, conifer forest and broad-leaved forest in north China, and problems existing in maintenance of site productivity for conifer forest and short rotation plantation. Regarding plantation nutritional cycling, the book presents analyses of contents of nutrients in different tree species, re-capture of nutrients from trees, geochemical cycling of plantation, and problems existing in plantation nutritional cycling. The causes for degradation of site productivity of short rotation plantations and conifer plantations were identified.

In the studies of plantation communities, types and structures of plantation communities of *Cunninghamia lanceolata*, *Pinus massoniana*, *Pinus tabulaeformis*, and *Larix* plantations were analyzed, three types of plantation communities and their management values were identified. The three community types are: Plantations grown in barren mountains and barren land, usually consisting of arbor trees, shrubs and grasses; Plantations grown in natural forest regions, where exists regeneration of various valuable indigenous broad-leaved trees, forming mixed forest and multi-layered community structure; Inter-cropping agro-forestry system, with a community structure featured as plantation and understory crops. The silvicultural characteristics of these three community types should be fully understood in order to give a full play of their potentials and capacity of maintaining site productivity.

To summarize the growth development of medium and long rotation plantations, according to the sequence of changes from quantitative to qualitative, I divided the changing process into 5 phases: Young plantation, forest formation, strong tree to tree competition, growth-reduction stabilizing, and stand degradation, and the ecological conditions and growth status were analyzed for each of the 5 phases. At the same time, 5 key processes formed during plantation development were determined: The first process is the change of closure, which is a critical process; The second process is the natural pruning and natural thinning, also an important process of qualitative change; The third process is the understory vegetation changes with the changes of stand closure, natural pruning and thinning; The forth process is the increase and decrease of leaf biomass (Photosynthesis organ) or leaf quantity and leaf-area index due to changes of the above 2 processes; The fifth process is the change of soil quality with stand development phases. These 5 processes were the main theoretical basis for my proposal of 5 development phases of plantation. The 5 processes should be fully understood and used to guide practices when taking silvicultural measures, by controlling stand stocking density, the process of stand development and productivity maintenance can therefore be regulated.

In the chapter of ecological function of plantation, the functions ofrainwater reallocation, biodiversity conservation, maintenance of site productivity and carbon sinking were comprehensively elaborated in detail. For the maintenance of site productivity of medium and long rotation plantation, the process of soil fertility changes in response to the 5 development phases was made clearly. And the key factors that affect the maintenance of site productivity during different development phases include stand growth rate, stand closure, understory vegetation development, quantity of litters, changes in uptake and returning of nutrients by trees, and soil fertility changes. Meanwhile, the principle that mixed forest favors maintenance of site productivity was also revealed: high biodiversity and biomass lead to complex and large quantity of litters, the diverse and large number of organisms in the soil speed up the decomposition of litters and nutrition cycling, therefore leading to changes in physical properties and water holding capacity of the soil and improvement of nutrition supply in the trees. The inter-relations among these factors were well illustrated.

Part 3 describes the maintenance of long term plantation productivity in a systematic way by 5 chapters, background and current research status of maintenance of long term plantation productivity, the impact of silvicultural intervention on soil nutrition loss and soil functions, the process of plantation productivity degradation and successive cropping, diseases and pests of plantation and natural disaster, and analysis of reasons for the difficulty in maintaining long term plantation productivity. This part provides a systematic introduction of the background, current status and progress in studies of maintenance of long-term plantation productivity in China and abroad, an in depth analysis of reasons for the inability of maintaining plantation productivity for long time, laying a theoretical and practical basis for long-term maintenance of plantation productivity. In the part 3, 7 reasons were identified: ① The impacts of silvicultural interventions on soil nutrition loss and soil functions; ② Traditional silvicultural measures leads to site degradation for the first generation plantation, successive cropping accelerates the process of degradation; ③ Plantation is weak in resisting diseases, pests and natural disasters; ④ Monoculture of plantation; ⑤ Conifer plantation accounts for a larger proportion; ⑥ Imbalance of deployment of vegetation types in the scale of region (or landscape); ⑦ Inappropriate silvicultural measures for plantation. Each of the 7 reasons was explained in detail with relevant examples. The analysis provides a strong evidence and scientific basis for developing measures of maintaining long-term plantation productivity from micro to macro point of views.

Part 4 is about silviculture system. It is based on the plantation ecology and the studies of maintaining long-term plantation productivity described in previous parts. Part 2 and part 3 are the theoretical and practical basis for part 4. This part is most critical. To maintain the stability and the long-term productivity of plantation, the silvicultural system proposed in this book should be implemented. The silvicultural system for plantation includes: ① Genetic control; ② Site control; ③ Stocking density control; ④ Vegetation control; ⑤ Soil fertility control. The system was briefly called "Five controls" silvicultural system. The five controls were continually improved in scientific studies, investigations and practices. The first three controls and the soil fertility maintenance were proposed in the 1990s and widely used by research organizations. They were considered a summarization of innovative and practically applicable silvicultural techniques in China, easily acceptable in operation. Since then many scientific experiments and studies found that plantation stability and soil fertility degradation were closely related to the vegetation structure of stands and vegetation deployment of plantation areas. Vegetation control is directly related to biodiversity of plantation which is the basis for plantation stability and maintenance of soil fertility, therefore five controls were proposed since the 1990s, making the silvicultural system further improved. In the vegetation control for plantation, following issues were emphasized: ① Problems existing in vegetation management in China's plantation development; ② Vegetation management measures for plantations, in which 104 major broad-leaved and high-value tree species were identified as needed and appropriate in China, together with their distribution and uses; ③ Appropriate deployment of tree species and forest types in plantation region. I think that as long as the five controls are carefully enforced, the plantation stability and long-term productivity can be enhanced and sustainable plantation management can be achieved. In part 4, each control of the silvicultural system was clearly described from theoretical to practical point of view, meanwhile, recommendations on implementation of the five controls of were provided.

In the part 4, chapter 22 is devoted to optimization model of plantation cultivation. This is to ensure that appropriate technical measures andoptimal combinations of the measures are used, maximizing the output and economic benefit. Plantation is for commercial purposes, the ultimate goal of the five controls are still to achieve more output and better economic benefit, this is also the goal of maintaining long-term plantation productivity. In the past, optimal combination of silvicultural measures and economic benefit were not given sufficient attention, often leading to high cost and low economic benefit. I think that optimization of silvicultural measures and economic analysis of cultivation models are important considerations in plantation management, if the sustainable plantation management can be economically sustainable.

Sheng Weitong

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致谢

这本书从编写到出版花了近三年的时间，在这三年的时间里，林业研究所的孟平所长与张建国所长始终给予有力的支持，使我有信心完成书稿资料的收集、整理、研究写作与修改，直至出版。这里我还要特别感谢邓丹荔女士，她为这部书稿的打印、修改在三年时间里付出了大量辛劳，十分耐心地帮助我完成了书稿的初稿，直到付梓。《林业科学研究》编辑部詹春梅副编审也一直帮助我进行书稿资料与参考文献的收集。此外，段爱国副研究员也在这本书的修改、付梓过程中给予了许多帮助。还要感谢我这本书中引用的不少参考文献的作者，是他们这些宝贵的文献资料印证并支撑了我书中提出的许多研究成果，虽然在书中列出了参考文献，但仍然不足于表达我心中的感激之情。

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