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Theory of Eco-engineering of Farmland Protective Plantation

农田防护林生态工程学

朱廷曜 关德新 周广胜 金昌杰 著

中国林业出版社

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序

农田防护林的营造在我国和亚欧许多国家有着悠久的历史，近百年来随着人类垦殖活动的增强，植被遭到严重破坏，特别是20世纪中后期，出现世界性的环境恶化，直接威胁到农业的持续发展。30年代美国发生“黑风暴”，曾开展大规模的农田防护林建设，以防止或减轻沙尘暴造成的危害。50年代，前苏联在中亚和西伯利亚营造了大面积的农田防护林。我国20世纪50年代初期，在华北许多省（自治区）开展了农田防护林建设，特别是80年代以来，在三北地区、华北平原、太行山、沿海各省（直辖市、自治区）、长江中上游等地开展了大型林业生态工程建设项目，规模之大，世界瞩目。农田防护林就是这些工程的重要的组成部分，而且在农田防护林地区内适宜的树种选择和合理的分布格局，对于防止风沙灾害、控制沙漠化、改善生态环境、提高生物生产力、保证农牧业稳产高产和持续发展，起着极为重要的作用。

朱廷曜研究员从事农田防护林研究40余年，积累了丰富的经验。特别是20世纪80年代以来，他和他的助手们承担了多项有关该研究领域的国家林业科技重点（攻关）专题和自然科学基金项目，取得10余项国家级和院、部级科技进步奖和自然科学奖，并得到国内外同行专家的高度评价。他们的生态效益研究组和造林组联合组成的“农田防护林组”(shelterbelt group)，于1998年获第三世界科学网络组织（TWNSO）农业技术集体奖。该专著主要是在总结这些研究成果的基础上完成的。生态建设生态学是近几十年来发展起来的新兴学科，是应用生态学的重要内容之一。随着我国大型林业生态工程建设的开展，林业生态学得到迅速的发展。该专著系统地论述了农田防护林生态工程的基础理论、研究方法和应用技术。相信该专著的出版将会在农田防护林生态工程建设中得到广泛的应用，并将在应用中不断完善。读过该专著之后，与同类著作相比，感到有如下几点创新之处：

1. 以往农田防护林主要研究单条林带，或单个林网的生态效益与造林技术。该专著除此之外，还着重介绍了农田防护林体系，区域性（中小尺度）防护效应的概念、评价模型系统及农田防护林地区地面边界层结构特征。

2. 农田防护林生态效益研究，以往多为观测结果的定性描述，或利用回归方程进行统计分析。这种方法物理意义不明确，应用范围也受到一定的限制。该专著则更重视利用大气物理的基本原理和数学分析方法，给出理论模型，使农田防护林的效益评价从定性的描述，提高到理论分析的高度。应用范围也更广泛。

3. 没有实践的理论是空洞的理论，该专著利用第二篇提供的数学模型，提出通过信息化管理的途径，可广泛应用于农田防护林的规划设计、抚育管理、效益评价和预评价中。这一研究成果使林带的结构（包括林带的宽度、疏透度或透风系数、断面形状、高度、林分密度等）、体系的组成与配置、抚育措施（包括修枝高度、疏伐或间伐强度等）等建立在科学的基础上。同时各重要参数均可通过模式计算给出定量的指标，为对农田防护林进行动态管理，保持其始终处于最优结构和最佳配置状态提供了科学依据，使规划设计和抚育管理更具科学性。

该专著也更为详细地论述了林带附近的湍流特征、林带阻力与阻力分布等涉及防护机理的研究结果。在研究方法方面，不仅有一般的小气候观测方法，还介绍了系留气球观测、卫星遥感资料分析、风洞模拟实验和气候统计（或天气动力）分析等研究方法，具有一定的特色和创新。该书的出版必将对我国农田防护林的建设起到重大影响，在付梓之际，乐予为序。

中国工程院院士

李文华

2000 年 12 月 4 日

前　言

农田防护林的营造历史悠久，近百年来有了迅速的发展，特别是20世纪30～50年代，由于黑风暴的肆虐，美国、前苏联等曾营造了大面积的防护林，以改善环境、防止或减轻这种灾害造成的损失。为同样的目的我国北方各省、直辖市、自治区，50年代初期也不同规模的营造了相当面积的农田防护林。20世纪中后期，出现了世界性的环境恶化和土地荒漠化等问题，更直接威胁到农业的持续发展。我国仅三北地区就有约700万hm^2的农田和700hm^2的草场受到风沙的侵袭，致使农牧业产量不高不稳，个别地块或个别年份甚至颗粒无收。近年来北京、天津，甚至南京、上海等地区春、夏之交出现大量降尘，也是沙尘暴的恶果。据研究（朱震达，1994；叶笃正，1992），我国沙化面积达37.1万km^2，且年增长2103km^2。造成的直接经济损失平均每年20亿～30亿元人民币，损失粮食5亿～10亿kg。据联合国环境规划署1987年的统计全球沙漠化旱田面积约19.86亿hm^2，占旱田总面积的61%，年经济损失423亿美元，因此国内外农林界学者大力提倡并推广混农林业，正是针对这一严峻形势提出的持续发展的战略措施之一。

“中国21世纪议程——中国21世纪人口、环境与发展白皮书”在“农业与农村可持续发展”一章中，多次提到要加强“农田防护林体系”的建设。我国70年代随着农业方田化、机械化、水利化等的发展，提出了“山、水、田、林、路”综合治理，建立综合防护林体系的设想。近20年来，三北防护林、长江中上游防护林、平原绿化、沿海防护林等大型林业生态工程陆续开展，各地相继出现许多一县或几县连片的大面积（中小尺度）综合农田防护林体系，仅农田防护林造林面积已达200万hm^2以上，使我国成为世界上营造农田防护林最多的国家。农田防护林已成为广大农牧区生态建设的重要组成部分。实践证明营造农田防护林体系是改善农牧区生态环境、抵御风沙灾害、控制沙尘暴、防止荒漠化、保持水土、提高粮食产量的有效措施。

随着农田防护林建设的开展，农田防护林的研究也不断深入地开展起来。

早期主要是林业的野外调查，1892 年俄国的 A. A. 彼契兴（Бычихин, А. А.）首次利用两台福廷式风速表，巡回观测了林带附近的相对风速，开创了农田防护林效益研究的历史。100 多年来，世界上许多国家的学者对单条林带或单个林网的生态效益，开展了广泛深入的观测研究。斯玛利科（Я. А. Смалъко, 1963）对不同结构林带附近的风速分布做了迄今为止最为详细的野外观测；埃墨恩（Von J. Eimern, et al. 1964）在联合国 W. M. O. 的组织下，搜集了国际上防护林研究的主要成果，撰写了总结性专著；其他如 A. P.，康斯坦季诺夫（1974，中译本 1983）；乌德拉夫（N. P. Woodruff, et al.，1953）；卡包恩（J. M. Caborn, 1957）；严森（M. Jensen, 1961）；江爱良（1958）等，依据各自不同的研究侧面，分析了农田防护林的小气候效应、水文效应、生物效应、作物的增产效益和经济效益等；曹新孙（1983）系统总结了我国农田防护林营造概况、生态经济效益、规划设计和造林技术。上述这些研究着重于观测结果的定性的描述。70～80 年代，普莱特（E. J, Plate, 1971）；张翼等（1984）；卫林等（1984）；朱廷曜等（Zhu Ting－yao, 1986, 1992）等，应用数学分析的方法和地面边界层大气物理特征的基本规律，给出了林带附近气象要素分布的理论模型，分析了林带的动力效应、水文效应等。这些研究使林带防护效应的研究从定性的描述，提高到理论分析的高度。但研究对象依然是单条林带或单个林网。

20 世纪 80 年代以来，我国率先在国家重点科研攻关项目专题研究中，列入了区域性防护效应研究的新内容，也得到了国家自然科学基金的资助。作者的研究组结合我国林业生态工程建设的需要，在探讨农田防护林防护机理研究的同时，重点开展了农田防护林体系区域性防护效应的研究。进行了风洞模拟实验、边界层系留气球观测、天气或气候统计分析以及卫星遥感资料分析等。分析了林网化地区大气边界层的结构特征、动力参数的变化规律，林带阻力分布模型，物质、能量交换过程。提出了新的评价方法和评价模型系统。适用于农田防护林体系的效益评价、经营管理和规划设计，并可提高信息化管理的客观性和科学性。本专著还给出了林带附近风场、流场、湍流结构特征等的观测结果。营造农田防护林的最终目的是改善生态环境，提高农业生产力。农田防护林研究的成果，也应在正确评价农田防护林生态效益、经济效益和社会效益的基础上，使农田防护林的规划设计标准、抚育管理措施，也像其他工程设计一样，可依据其基础理论模式，计算出定量的优化指标。这也是本专著希望达到的目标之一。

本专著由朱廷曜主持撰写，审阅全书，并最后定稿。第一、二、八章由关

德新负责，朱廷曜参加第八章的撰写。其余各章由朱廷曜负责；周广胜、关德新参加第五、六章的撰写，金昌杰参加第七、十章的撰写。

中国科学院沈阳应用生态研究所开展农田防护林研究40余年，本专著吸纳我们近期的科研成果，主要包括“七五”以后的科技攻关和国家自然科学基金的研究成果。“七五”之前，本人作为曹新孙研究员的主要助手，是《农田防护林学》的主要撰稿人和定稿人，在防护林研究和林学方面，得到先生许多有益的教诲；60年代初，原室主任王正非研究员，倡导并积极支持开展风洞模拟实验，在他的支持下，建立了农田防护林实验用的低速风洞实验室，以后的许多研究成果是在风洞实验中取得的。李文华先生、贺庆棠先生在本专著的酝酿期间给予了很大鼓励，在此一并感谢。也感谢我们防护林组的伙伴们，研究员王述礼、徐文铎；高级实验师孔繁智、卢耀波；工程师丁桂芳等在实验观测中，认真负责，数据资料的整理，一丝不苟。20余年来共同完成了各项研究任务，没有他们的努力工作，难以取得后来的成果。他们虽未参加本书的撰写，但功不可没。感谢进行合作研究的北京大学的陈家宜、张霭琛、刘树华、尹洁芬、王新英教授，东北林业大学的向开馥教授，原林业部森林生态环境开放实验室的徐德应教授、中国科学院兰州沙漠所风洞实验室的刘贤万教授、沈阳农业大学程德昌教授等。

由于业务水平和其他条件所限，不足之处在所难免，有些研究还刚刚开始，有待同行学者进一步深入探索，诚望读者提出宝贵意见和建议。

朱廷曜

2000年8月

Preface

Farmland shelterbelts have been existing for a long time, and spread rapidly during recent hundred years. Especially from 1930's to 1950's large area shelterbelts were established in USA and the former USSR in order to ameliorate the environment and reduce the losses caused by dust storm. Most of shelterbelts were constructed in the north of China in early years after liberation. In the middle and latter of the twentieth century, worldwide deterioration of environment and desertification of land have been directly threatening the sustainable development of agriculture. Only in "Three-north regions" (northwest, north and northeast regions of China) around 7×10^6 hm^2 farmland and 7×10^6 hm^2 grassland were invaded by strong wind. The yields of agriculture are low and unstable. Some of the land has no harvest under the years with seriously strong wind. Dust rain attacked Beijing and Tianjin in recent years, even invaded Nanjing and Shanghai. Desertification area in China is up to 3.71×10^5 km^2 with annual increment of 2103 km^2 (Zhu Zhenda, 1994; Ye Duzheng, 1992). Loss of crop yield is from 5×10^8 to 10^9 kg and the economic loss from 2.0×10^9 to 3.0×10^9 RMB. The desertificated farming area in the world reaches about 1.986×10^9 hm^2 according to the United Nations Environment Program in 1987, occupying 61% of the total dry farming area in the world. The annual loss is about 423×10^8 US $. Thus, the scientists in the fields of agriculture and forestry around the world advocate to develop agroforestry, which is one of the strategies against desertification.

In the chapter "Sustainable development of country and agriculture" of *Agenda of China in 21th Century—White Paper of population, environment and development*, the establishment of protective plantation system on farmland is emphasized. In the management of agriculture during 1970's, the synthetic protective plantation system was put forward in order to systematically manage the hill, water, farmland, forest and road, in which shelterbelts are the main component. In resent 20 years the large area forest eco-engineering has been carrying out, such as protective plantation in "Three-north regions", protective plantation in middle and up stream areas of Yangtze River, plain afforestation, protective plantation along coast and so on. Large area continuous synthetic protective plantation systems could cover one county or several counties. The afforestation area has got to 2×10^6 hm^2. At this stage China has become the country with the largest area of

farmland protective plantation. The farmland protective plantation system has become the important part of ecological construction in agricultural and husbandry areas. The practices have proved that the protective plantation systems are the efficient measures of ameliorating environment, mitigating the harm of strong wind and sand, controlling dust storm, preventing desertfication, conserving water and soil and increasing crop yield.

Researches of protection plantation system on farmland are deeply carried out with its establishment. Field forestry investigation was focused in the beginning. In 1892 Russian scholar Biqixin (Бычихин, А. А.) carried out a circuit measurement of wind speed near shelterbelt using two Fortin anemometers. Many researchers in the world made studies on the ecological effects of a single shelterbelt or a single sheltetbelt grid for more than one hundred years from then on. Smalico (Я. А. Смалько, 1963) did the most detail field measurement of wind speed distribution near shelterbelts with different structures. Von. J. Eimern, et al. (1964) collected the international achievements and composed the summarizing monograph under the organization of WMO. A. P. Kanstanjinov (Константинов, А. Р. 1973), N. P. Woodruff, et al. (1953), J. M. Caborn (1957), M. Jensen (1961), Jiang Ailiang (1958) etc. analyzed the effects on microclimate, hydrology, biology, crop yield and economic in their study fields. Cao Xinsun (1983) systematically summarized the establishment, ecological and economic effects and afforeastation techniques. These studies mainly focus on qualitative descriptions. In 1970's and 1980's E. J. Plate (1971), Zhangyi et al (1984), Weilin et al (1984), Zhu Tingyao et al (1986) develop some theoretical distribution models of some meteorological factors by mathematical methods and basic laws of surface boundary layer and analyze aerodynamic and hydrological effects of shelterbelts. These enhance the studies to the theoretical level from qualitative descriptions. But the study objectives also focus on a single shelterbelt or a single sheltetbelt grid.

During the 1980's the regional effects of protective plantation system was firstly listed in the research area of related national key project. It was also emphasized by National Natural Science foundation of China. The research group of this monograph focused on this study using the wind tunnel experiments, tied balloon observation of surface boundary layer, synoptic and climatic analyses and remote sensing technology. The studies include the structure and dynamic parameters of the boundary layer of shelterbelt network region, drag distribution model of shelterbelt, mass and energy exchanges. New assessment methods and models are put forward. All these provide the ways of effect assessment, management, programming and design of farmland protective plantation, and improve the information management objectively and scientifically. The monograph also gives the data

of wind speed field, streamline field and turbulence near shelterbelts. One of the objectives of the monograph is to provide optimal indices to the establishment and management of the protective plantation by theoretical models, just like the design and evaluation of other engineering.

Zhu Tingyao presided over the writing of the monograph, checked and finalized the manuscript. The chapter one, two and eight are sponsored by Guan Dexin and chapter eight is partly written by Zhu Tingyao. The others are sponsored by Zhu Tingyao. Chapter five and six are partly written by Zhou Guangsheng and Guan Dexin. Chapter seven and ten are partly written by Jin Changjie.

Institute of Shenyang Applied Ecology, the Chinese Academy of Sciences (CAS) devoted to the studies on farmland sheltrbelts more than 40 years. The monograph selects the update achievements, including that resulted from the national key projects during the seventh five-year-plan and the projects funded by National Natural Science Foundation of China. Before 1985 I was the assistant following Professor Cao Xinsun and was the main writer and compiler of the monograph *Theory of Farmland Shelterbelts*. From these I got much beneficial education. The former Director of the Department of Forest Meteorology Wang Zhengfei advocated and supported to construct the lab of wind tunnel. A lot of achievements come from the experiments of the wind tunnel. I would like to give my great appreciation to Acadimician Li Wenhua and Professor He Qingtang for their encourage during the preparation of the monograph. I would also give my appreciation to Senior engineers Kong Fanzhi, Ding Guifang, Lu Yaobo and Professors Wang Shuli, Xu Wenduo for their responsibility in the experiments, measurements and data processing. A lot of achievements may not be obtained without their efforts although they does not take part in the writing of the monograph. We also thank the co-operators including Professors Chen Jiayi, Zhang Aichen, Liu Shuhua, Yin Jiefen, Wang Xinying of Beijing University, Professor Xiang Kaifu of Northeast Forestry University, Professor Xu Deying, Director of open lab of Forest Ecological Environment, Professor Liu Xianwan, Director of wind tunnel lab, Institute of Desert, CAS, and Professor Cheng Dechang of Shenyang Agricultural University.

Shortcomings and mistakes may appear because of the limitations of knowledge and other conditions. Some researches may be even preliminary and further studies should be expected. We honestly wish readers give us opinions and suggestions.

Zhu Ting-yao

Augst, 2000

目　录

第三篇 农田防护林生态工程体系规划设计与信息管理

Contents

Volume Three Programme, design and information management of eco—engineering system of farmland protective plantation

第一篇

农田防护林生态工程体系营造概况与研究方法