京津风沙源治理工程效益

（第二版）

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内 容 简 介

本书是对京津风沙源治理工程（2001～2010年）生态环境和社会经济效益宏观研究核心成果的总结，内容包括植被恢复效果、土壤风蚀控制效果、地表释尘控制效果、土壤水蚀控制效果，以及治理工程对区域社会经济可持续发展的促进作用。

本书可供生态学、地理学、环境科学、水土保持等领域科研和工程技术人员及有关政府部门开展相关工程建设效益评估参考，也可供高等院校相关专业师生参考。

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前　　言

2000年春季连续发生10余次灾害性的沙尘天气，京津地区遭受严重的风沙灾害，我国政府及时启动京津风沙源治理工程。在2002年3月国务院正式批准实施的《京津风沙源治理工程规划》中，明确“京津风沙源区治理工程”的实施范围为北京、天津、河北、山西、内蒙古五省（自治区、直辖市）75个县（旗、市、区），面积为45.8万km^2。在各主管部门、各级地方政府和广大人民群众、科技工作者的不懈努力下，经过10年的治理，京津风沙源治理工程建设取得明显成效，沙漠化出现初步逆转。为了客观反映京津风沙源治理工程实施以来取得的成效，分析和总结经验，为今后的荒漠化防治工作提供科学的参考数据，受国家林业局防沙治沙办公室委托，北京师范大学地表过程与资源生态国家重点实验室、北京师范大学环境演变与自然灾害教育部重点实验室和防沙治沙教育部工程研究中心自2006年以来连续开展京津风沙源治理工程效益研究工作。

《京津风沙源治理工程效益》（第一版，2008年出版）基于2006年现场调查并利用GIS技术和综合建模等方法，宏观研究和计算2001年、2005年京津风沙源治理工程区植被覆盖度、植被净第一性生产力、土壤侵蚀、地表释尘等核心环境问题和区域可持续发展综合指标，客观分析和评价气候要素变化条件下京津风沙源治理工程第一阶段实施5年来的环境效益。该书出版以后，我们继续逐年开展此项评估工作，迄今已积累大量连续性监测数据，这些数据既印证了京津风沙源治理工程取得良好的生态环境效果和社会经济效益，也反映了气候变化和风沙源治理工程实施背景下，工程区植被恢复、地表侵蚀与释尘变化的内在规律性。这是《京津风沙源治理工程效益》（第一版）所欠缺的，而且第一版仅仅评价了前5年的治理成效，鉴于京津风沙源治理工程第一期工程已于2010年年底之前全部实施完成，第一版内容已不足于全面反映工程实施的生态环境效果及其对区域可持续发展的贡献，也不利于读者深入了解京津风沙源区植被生态系统和地表侵蚀过程的一般规律，为对工程10年的成效进行全面总结评价，我们整理、补充2005年以来的后续监测数据并做了相应的综合分析，以《京津风沙源治理工程效益》（第二版）的形式出版，以期为读者提供更为完整的京津风沙源治理工程效益评价结果与方法。同时，我们还对《京津风沙源治理工程效益》（第一版）出现的文字和数据错误进行了详细修正。

本书沿用《京津风沙源治理工程效益》（第一版）内容结构，共6章，各章内容简要介绍如下。

第1章介绍京津风沙源区概况和风沙源治理工程基本情况，提出本书针对京津风沙源治理工程效益研究的内容与方法，并将京津风沙源区划分荒漠草原亚区、典型草原亚区、浑善达克沙地亚区、大兴安岭南部亚区、科尔沁沙地亚区、农牧交错带草原

亚区、晋北山地丘陵亚区和燕山丘陵山地水源保护区 8 个亚区。

第 2 章分析退耕还林、退耕还草、封禁保护、围封造林等治理措施对植物多样性、群落结构及其稳定性的影响，计算京津风沙源治理工程实施前后的植被盖度、植被净第一性生产力和植被固碳量。结果表明，围栏禁牧、退耕还林还草等植被恢复措施效果明显。围封禁牧退化草地的盖度、高度和地上生物量在较短的时间内都有明显的增加，生物多样性提高，一、二年生植物在群落中的比例有所降低，群落稳定性增加。退耕还林和还草样地在退耕 5～7 年时盖度增加明显，退耕还林样地群落层片由单一的草丛植被或灌草丛植被变为乔、灌、草或灌、草结合的复合植被系统，生物量增加。随退耕时间的延长，一、二年生植物所占比例逐渐降低趋势明显，植物群落趋于稳定。沙地围封后植被盖度和生物量明显增加，但受人类活动特别是放牧的影响较大，围封沙地一经放牧，植被盖度、灌木层生物量和草本层生物量都显著下降，一、二年生植物比例迅速增加。治理区 2001 年、2005 年、2010 年植被总盖度分别为 40.91％、52.65％、49.07％，各亚区植被盖度普遍高于治理前。其中，荒漠草原亚区、农牧交错带草原亚区和晋北山地丘陵亚区 2010 年植被总盖度相对于 2001 年增长幅度超过 30％，典型草原亚区、浑善达克沙地亚区和燕山丘陵山地水源保护区 2010 年植被总盖度增长幅度为 10％～30％，大兴安岭南部亚区和科尔沁沙地亚区植被盖度变化幅度最小（不足 5％）。2001～2005 年属于治理工程实施的第一阶段，由于治理前植被退化严重，工程实施初期的效果特别明显，植被盖度增长幅度较大。此阶段内植被盖度的提高主要归功于草场封育、禁牧、退耕还林等风沙源治理工程措施。在第一阶段治理工程的基础上，2006～2010 年植被盖度在波动中趋于稳定，基本处于 50％的较高值。2001 年、2005 年和 2010 年植被净第一性生产力总量分别为 1.94 亿 t、2.14 亿 t 和 1.98 亿 t。2005 年比 2001 年提高 10.1％，2010 年比 2001 年提高 2.2％，但比 2005 年有所下降。与 2001 年相比，2005 年典型草原亚区和浑善达克沙地亚区植被净第一性生产力增长幅度最大，分别达 59.5％和 40.9％；燕山丘陵山地水源保护区增长幅度最小，仅为 1.1％。2010 年除大兴安岭南部亚区植被净第一性生产力有所降低外，其他各治理亚区植被净第一性生产力均比 2001 年有不同程度的提高，增大了区域植被固碳量。2001 年、2005 年、2010 年治理区植被净第一性生产力固碳总量分别为 1.06 亿 t、1.16 亿 t、1.08 亿 t，分别相当于固定 CO_2 温室气体的量为 3.87 亿 t、4.17 亿 t、3.96 亿 t。2001～2010 年，植被净第一性生产力固定的 CO_2 温室气体总量达 39.7 亿 t。以 2001 年为参照，2002～2010 年整个治理工程区植被净第一性生产力累计净增长 0.503 亿 t；固碳量净增长 0.270 亿 t，相当于多固定 0.992 亿 t 的 CO_2 温室气体。

第 3 章通过计算京津风沙源区 2001～2010 年地表风蚀模数及其时空变化，评估治理工程对区域土壤风蚀的控制效果。2001～2010 年平均风蚀模数为 26.63t/(hm^2 · a)，总体处于中度风蚀状态。其中，沙地年均风蚀模数为 216.5t/(hm^2 · a)，属剧烈风蚀；林草地年均风蚀模数为 9.06 t/(hm^2 · a)，属轻度风蚀；耕地风蚀明显强于林草地，但还达不到中度风蚀的水平，平均风蚀模数为 18.48t/(hm^2 · a)，约为林草地风蚀模数的两倍。工程区 2001 年、2005 年、2010 年平均土壤风蚀模数分别为 26.34 t/(hm^2 · a)、 22.01 t/(hm^2·a)、18.71 t/(hm^2·a)，土壤风蚀总量分别为 11.91 亿 t、9.5 亿 t、8.46 亿 t。2010 年土壤风蚀强度比 2001 年降低 29.0%，比 2005 年降低 15.0%，风蚀量分别减少 3.45 亿 t 和 1.49 亿 t。相对于 2001 年土壤风蚀量，2002～2010 年累计净减少 7.28 亿 t，相当于 2003 年全年土壤风蚀量。2001 年以来大部分区域土壤风蚀强度呈减弱趋势，如典型草原亚区、浑善达克沙地亚区、大兴安岭南部亚区，但也有风蚀加剧的区域，如荒漠草原亚区和农牧交错带草原亚区。土壤风蚀强度的上述变化，既与风沙源治理工程有关，也与风力环境的变化有关。扣除风力环境变化的影响，2005 年、2010 年治理工程抑制的土壤风蚀量分别为 1.00 亿 t 和 3.42 亿 t。

第 4 章根据土壤风蚀量计算结果，估算工程区 2001 年、2005 年、2010 年地表向大气的释尘量（$D\leqslant 20\mu m$），以及该区释放可能到达北京城区的尘量，评估风沙源治理工程对地表释尘的实际控制效果。结果表明，工程区 2001 年、2005 年、2010 年地表释尘总量分别约为 3124.20 万 t、2629.14 万 t、2650.13 万 t，2010 年释尘总量比 2001 年减少 474.1 万 t，但比 2005 年略有增加。2010 年相对 2005 年释尘量增大的原因，一是 2010 年农牧交错带以南区域风力显著增强，二是 2010 年植被盖度略小于 2005 年，两个因素导致农牧交错带以南区域地表风蚀加剧。2010 年风力同样强于 2001 年，但 2010 年植被盖度远高于 2001 年，因此释尘量显著减少。扣除风力环境变化对释尘量的影响，2005 年、2010 年治理工程抑制的地表释尘量分别为 356 万 t 和 816.68 万 t。2001 年、2005 年、2010 年可能到达北京城区的总尘量分别约为 149.4 万 t、110.7 万 t 和 131.4 万 t，其中，98%以上的尘粒为粒径小于 10μm 的细颗粒，是大气颗粒污染物的主要成分。8 个亚区中，农牧交错带亚区、荒漠草原亚区和浑善达克沙地亚区对可能到达北京城区总尘量的贡献最大，占整个治理区可能到达北京城区总尘量的 80%以上。2005 年京津风沙源区地表释放可能到达北京城区的总尘量比 2001 年减少 1/4 以上（38.7 万 t），其中，治理工程抑制可能到达北京城区的尘量约为 25.6 万 t。2010 年治理工程抑制可能到达北京城区的尘量约为 22.6 万 t，但由于指向北京城区的风力大为增强，致使可能到达北京城区的总尘量只比 2001 年减少 18.0 万 t。

第 5 章利用通用土壤流失方程（USLE）计算工程区 2001 年、2005～2010 年土壤水力侵蚀强度及其空间分布，评估治理工程对区域土壤水蚀的控制效果。结果表明，工程区内水蚀面积为 995.85 万 hm^2，约为治理区总面积的 21.7%；年均水蚀模数为 3.04 t/(hm^2·a)，总体属于轻度水蚀。但由于降水侵蚀力、土壤可蚀性等水蚀因子的空间差异，各亚区水蚀强度差异很大，其中，三个森林亚区水蚀量合计占治理区水蚀总量的 80%以上，其他亚区水蚀量不足治理区水蚀总量的 20%，荒漠草原亚区、典型草原亚区和浑善达克沙地亚区的土壤水蚀甚至可以忽略不计。京津风沙源治理工程实施以来土壤水蚀强度基本呈持续降低的趋势。其中，2001 年、2005 年、2010 年土壤水蚀总量分别为 3.52 亿 t、1.73 亿 t、1.10 亿 t。2005 年、2010 年水蚀总量分别比 2001 年减少 1.79 亿 t 和 2.43 亿 t，减幅分别高达 50.7%和 69.0%。治理工程由于改善了植被状况而在 2005 年和 2010 年分别抑制 2.65 亿 t 和 14.67 亿 t 的土壤水蚀流失量。

第 6 章计算工程区 2001 年、2005 年、2010 年的区域社会经济可持续发展指数，

评估资源环境子系统对可持续发展的贡献率。2001 年区域可持续发展综合指数为 56.9，2005 年达到 68.9，增幅为 21.0%，其中 8.5%的增量来自于资源环境子系统；2010 年进一步提高到 74.3，与 2001 年相比增幅达到 30.6%，其中 5.8%的增量由资源环境子系统获得。在可持续发展评价的三个子系统中，经济子系统和社会子系统得分呈稳定增长的趋势，对区域可持续发展的贡献相对较为稳定，而资源环境子系统得分具有一定的波动性。在综合评价的 5 个盟（市）中，锡林郭勒盟、赤峰市、承德市和张家口市社会经济稳步发展，风沙源治理工程的实施促使资源环境子系统得分稳定提高，对区域可持续发展指数增长的贡献趋于合理，经济、社会、资源环境子系统有望实现同步发展；位于治理工程区西北部的乌兰察布市社会经济处于稳步发展中，但资源环境对气候变化仍非常敏感，资源环境子系统得分及其对可持续发展指数增长的贡献率年际波动明显，表明该区生态环境治理工程亟须加大力度。

本项评估工作一直是在国家林业局防沙治沙办公室的统一组织指导下开展的，得到国家林业局防沙治沙办公室刘拓主任、杨维西（原）总工程师、屠志方总工程师、李梦先处长、潘红星副处长，国家林业局荒漠化监测中心孙涛处长、武健伟副处长、刘旭升高级工程师等的大力支持、帮助和指导。国家林业局荒漠化监测中心为本研究提供自 2001 年以来的 MODIS 影像数据和 NDVI 数据。在此，谨对上述部门和个人表示衷心的感谢！

本书由北京师范大学地表过程与资源生态国家重点实验室、北京师范大学环境演变与自然灾害教育部重点实验室和防沙治沙教育部工程研究中心高尚玉、张春来、邹学勇、伍永秋、黄永梅，佛山科学技术学院魏兴琥教授，中央民族大学石莎和北京师范大学管理学院李汉东等共同撰写完成。写作过程中，北京师范大学史培军教授、武吉华教授、刘宝元教授、刘学敏教授、李晓兵教授、武建军教授，中国科学院寒区旱区环境与工程研究所董光荣研究员、董治宝研究员、屈建军研究员，中山大学董玉祥教授和高全洲教授，佛山科学技术学院李森教授提供了宝贵意见和建议。先后参加工作的还有河北师范大学常春平副教授，内蒙古农业大学王六英教授，北京师范大学严平教授、哈斯教授、程宏副教授、亢力强副教授、张峰工程师和苏格日乐、夏虹、刘晓晨、刘明、汪言在、吴晓旭、潘星慧、郑影华、苟诗薇、杨硕、周娜、钱江、王仁德、张加琼、刘永刚、马晓洁、张景慧、张艺磊、王焕芝、张健枫、黄文敏、展秀丽、郭金蕊、吴志正、武志涛同学，以及内蒙古农业大学高强、赵淑文同学，佛山科学技术学院雷俐、周红艳、徐喜珍同学，鲁东大学高丙舰、袁昭同学。在此一并致谢！

本项研究和成果的出版受国家林业局荒漠化和沙化监测专题项目、国家自然科学基金项目（40871015）、教育部新世纪优秀人才支持计划（NCET-08-0059）和“十一五”科技支撑课题（2006BAD26B03）资助。书中关于大范围风蚀量、地表释尘量以及定向输尘等计算问题，均为探索性研究，不足之处，敬请广大读者批评指正！

作　者

2011 年 12 月

Preface

As the frequent occurrences of the disastrous dust events in the spring of 2000 had caused serious air pollution in and around the region of Beijing-Tianjin, our government launched the Beijing-Tianjin Sand Source Control Engineering in due course. In March 2002, the State Council of the People's Republic of China officially approved the implementation of *Beijing-Tianjin Sand Source Control Engineering Plan*. This document definitely points out that the Beijing-Tianjin Sand Source Region covers 75 counties in Beijing, Hebei, Inner Mongolia, Shanxi and Tianjin with an area of 458 000 km^2. After ten years of the tireless efforts of local people, governments at all levels and scientists, the engineering has been accomplished and sandy desertification reversion within the engineering region has achieved initial success. In order to objectively reflect the results of the Beijing-Tianjin Sand Source Control Engineering and provide scientific reference for future practice of desertification prevention and control, State Key Laboratory of Earth Surface Processes and Resource Ecology (Beijing Normal University), MOE Key Laboratory of Environmental Change and Natural Disaster (Beijing Normal University) and MOE Engineering Research Centre of Desertification and Blown-sand Control (Beijing Normal University) carried out benefits study of the Beijing-Tianjin Sand Source Control Engineering.

This book is the second edition of the published book *Benefits of Beijing-Tianjin Sand Source Control Engineering* (2008), which calculated such core environmental issues as vegetation coverage, net primary production of plant (NPP), soil erosion, surface ground dust-emission and the regional Social and Economic Sustainable Development Index within the engineering region in 2001 and 2005 respectively on a macro-scale. It also analyzed the environmental benefits brought out by the implementation of the engineering under the changing climate. After its publication, the authors continued the evaluating work year by year so that accumulated amount of successive surveyed data. These data not only proved that sand control engineering obtained favorable eco-environmental effects and social economic benefits, but also revealed some general rules of vegetation recovery and soil erosion under the background of climatic change and implementation of sand control engineering. The latter is lack in *Benefits of Beijing-Tianjin Sand Source Control Engineering* (2008). Because Beijing-Tianjin Sand Source Control Engineering had been accomplished by the end of 2010, the published edition could not fully reflect the effects of the engineering on eco-environment and the contribution to regional sustainable development. It is not favorable for the readers to understand the rules of vegetation recovery and soil erosion in this area as well. Therefore the authors coordinated and supplemented the follow-up data since 2005 and made the consequent analysis into the new edition so that present more completed evaluating methods and results regarding to the benefits of Beijing-Tianjin Sand Source Control Engineering. In this new edition, the mistakes of words and numbers occurred in 2008 edition will be totally corrected.

Content structure of this book follows the old edition that consists of the same six chapters.

Chapter 1 gave a general introduction about the Beijing-Tianjin Sand Source Region and the Sand Source Control Engineering, and put forward the contents and methods involved in the benefits study. The engineering region was divided into 8 subareas, including desert grassland subarea, typical grassland subarea, Hunshan Dak sandy land subarea, south Daxing′an Mountain subarea, Korqin sandy land subarea, agro-grazing ecotone grassland subarea, Northern Shanxi's mountainous subarea and water source protection area in Yanshan mountainous region.

Chapter 2 analyzed the effects of vegetation restoration measures on biological diversity of species, community structure and stability. The results showed that the measures such as afforestation or grass on abandoned farmland, rangeland enclosure, afforestation in enclosed zone had obtained good effects. Vegetation coverage, plant height and aboveground biomass increased in the limited period after enclosure and grazing prohibition. In the enclosed rangeland, species diversity increased, the proportion of annuals and biennial plants in the community reduced, and the stability of community improved. In abandoned farmland, the coverage obviously enhanced after stopping farming for 5 to 7 years, community lamellar changed from single community of grass-layer or shrub vegetation into complex system of arbor, shrub and grass or shrub and grass system. With time going, the proportion of annuals and biennial plants in the community reduced gradually and the community tended to be stable. Similar changes occurred in the enclosed sandy land, but the stability of community was more sensitive to such human activities as grazing. This Chapter also calculated vegetation coverage, net primary production and carbon sequestration in different stages of Beijing-Tianjin Sand Source Control Engineering. Total vegetation coverage of the engineering area in 2001, 2005 and 2010 was 40.91%, 52.65% and 49.07%, vs. total amount of NPP is 0.194 billion、0.214 billion and 0.198 billion tons, respectively. Vegetation cover in each subarea improved after implementation of the engineering. Compared with vegetation coverage in 2001, the coverage increased more than 30% in desert grassland subarea, typical grassland subarea, agro-grazing ecotone grassland subarea and

Northern Shanxi's mountainous subarea in 2010, whereas the growth in typical grassland subarea, Hunshan Dak sandy land subarea and water source protection area in Yanshan mountainous region ranged from 10% to 30%. The growth of vegetation coverage in other two subareas is the least (< 5%) . Compared with primary production in 2001, NPP increased 10. 1% in 2005 and 2. 2% in 2010. Except for south Daxing'an Mountain subarea, where NPP decreased a little, NPP in other subareas enhanced to different degree in 2010. Since natural vegetation had been degraded seriously before 2001, in the first stage of the engineering (2001~2005), the effects of the engineering were remarkable with high growth in vegetation coverage and NPP. Improvement of vegetation in this period was mainly due to management engineering such as rangeland fencing and forestation or grass in abandoned farmland. On the basis of engineering achievement of the first stage, the coverage tended to stabilize to a high value of 50% with undulation. Increase of NPP enhanced regional plant carbon fixation consequently. Total annual fixed carbon by plants in the engineering area was 0. 106 billion tons, 0. 116 billion tons and 0. 108 billion tons in 2001, 2005 and 2010, respectively, implying that 0. 387 billion tons 0. 417 billion tons and 0. 396 billion tons greenhouse gas CO_2 were absorbed by plants during each year. Making use of amount of plant carbon fixation in 2001 as a reference, net increase of NPP accumulated 50. 3 million tons during 2002~2010 and net increase of plant carbon fixation accumulated 27. 0 million tons, which means additional 99. 2 million tons greenhouse gas CO_2 were absorbed by plants during 2002~2010.

Chapter 3 calculated the soil wind erosion modulus and its distribution in the Beijing-Tianjin Sand Source Region from 2001 to 2010 and assessed the effects of the engineering on wind erosion control. Annual soil wind erosion modulus was 26. 63 t/(hm^2 · a) averaged from 2001 to 2010, therefore soil wind erosion in this area was in a situation of moderate erosion as a whole. Among different land types, wind erosion on sandy land belongs to severe erosion with a mean wind erosion modulus of 216. 5 t/(hm^2 · a); on forestry and rangeland and farmland, wind erosion belongs to mild wind erosion with a mean modulus of 9. 06 t/(hm^2 · a) and 18. 48 t/(hm^2 · a), respectively. Obviously, wind erosion on farmland is much stronger than that on forestry and rangeland. Wind erosion modulus varied year by year. The spatially averaged wind erosion modulus in 2001, 2005 and 2010 were 26. 34 t/(hm^2 · a), 22. 01 t/(hm^2 · a) and 18. 71 t/(hm^2 · a), and the total soil loss by wind erosion were 1. 191 billion tons, 0. 95 billion tons and 0. 846 billion tons, respectively. Compared with wind erosion in 2001, intensity of soil wind erosion in 2010 reduced by 29. 0% and the amount of soil loss reduced 0. 345 billion tons. Using amount of soil loss by wind erosion in 2001 as a reference, net decrease of soil loss accumulated 0. 728 billion tons during 2002~2010, which was equivalent to the total soil loss by wind erosion in 2003. Generally, wind erosion in large part of the engineering area had tended to reduce since 2001, e. g. typical grassland subarea, Hunshan Dak sandy land subarea, south Daxing'an Mountain subarea; however, there still existed regions with intensifying wind erosion such as desert grassland subarea and agro-grazing ecotone grassland subarea. Above mentioned variations of soil wind erosion resulted from both sand control engineering and the changes of wind force. Cross calculations implied that the environmental management engineering controlled 0. 100 billion tons and 0. 342 billion tons of soil loss in 2005 and 2010, respectively.

Chapter 4 calculates dust emission to the atmosphere ($D \leqslant 20\mu m$) resulted from soil wind erosion in the engineering region and the possible amount of dust arriving at the city zone of Beijing from this region. The annual total amount of dust emission in 2001, 2005 and 2010 were 31. 24 million tons, 26. 29 million tons and 26. 50 million tons, respectively. Dust emission in 2010 reduced by 4. 74 million tons compared with that in 2001 but increased a little over 2005. The main cause of the increase in 2010 over 2005 is that wind force in areas south of agro-grazing ecotone grassland subarea strengthened remarkably in 2010 and the vegetation coverage was a little lower than 2005, so that wind erosion in the southern area exacerbated seriously, which enhanced the overall level of wind erosion in the engineering area. Wind force in 2010 was also stronger than that in 2001, but vegetation coverage much higher than 2001, so dust emission in 2010 remarkably reduced. The possible amount of dust arriving at the city zone of Beijing from the Beijing-Tianjin Sand Source Region was about 1. 49 million tons in 2001, 1. 11 million tons in 2005 and 1. 31 million tons in 2010. More than 98% of the dust arriving at the city zone of Beijing are fine particles with size less than $10\mu m$, which are the main component of atmospheric particulate pollutants. Among the eight subareas, agro-grazing ecotone grassland subarea, desert grassland subarea and Hunshan Dak sandy land subarea accounted for more than 80% of the total amount of dust that could arrive at the city zone of Beijing. This chapter also assessed the effects of the environmental management engineering on controlling dust emission. The environmental management engineering controlled 3. 56 million tons and 8. 17 million tons of dust emission in 2005 and 2010, respectively. Within the total reduced amount of dust that could arrive at the city zone of Beijing in 2005 compared with that in 2001, the engineering controlled 0. 256 million tons in 2005. In 2010, the engineering controlled 0. 226 million tons of dust that could arrive at the city zone of Beijing but the total reduced amount was only 0. 18 million tons compared with that in 2001 since wind force pointed to Beijing city zone strengthened greatly.

Chapter 5 calculated soil water erosion and its distribution in the engineering area making use of universal soil loss equation (USLE) and assessed the effects of the engineering on soil water erosion control. Results of 2001 and 2005～2010 indicated that the area of water erosion is about 9.96 million hectares, 21.7% of the total engineering area. Soil water erosion in the engineering area belongs to mild erosion as a whole with a mean annual water erosion modulus of 3.04 $t/(hm^2 \cdot a)$. However, spatial variation of rainfall erosive force and soil erosivity led to great spatial changes in water erosion. The forestry subareas, namely south Daxing'an Mountain subarea, Northern Shanxi's mountainous subarea and water source protection area in Yanshan mountainous region, accounted for more than 80% of the total amount of soil loss by water erosion, whereas water erosion in desert grassland subarea, typical grassland subarea, Hunshan Dak sandy land subarea was so weak that could be neglected. Generally, water erosion in the engineering area has tended to decrease since 2001. The total soil loss by water erosion in 2001, 2005 and 2010 were 0.352 billion tons, 0.173 billion tons and 0.110 billion tons, respectively. Soil loss in 2010 reduced 0.243 billion tons compared to 2001. Under the conditions of rainfall erosive force in 2010 nearly two times higher than that in 2001, the engineering controlled 1.467 billion tons of soil loss by water erosion through vegetation improvement.

Chapter 6 calculated the Regional Social and Economic Sustainable Development Index and evaluated the contribution of the resources and environment subsystem to regional social and economic sustainable development. The index increased from 56.9 in 2001 to 68.9 in 2005 and further increased to 74.3 in 2010. In 2005, the increment was 21.0% compared to 2001, of which 8.5% resulted from resources and environment subsystem. In 2010, the increment was 30.6%, of which 5.8% resulted from resources and environment subsystem. Evaluation scores of the economic subsystem and social subsystem showed a steady growth tendency and their contributions to regional sustainable development was relatively stable, while the score of resources and the environment subsystem varied with undulation. Among the five synthetically evaluated prefecture-level cities, Xilin Gol League, Chifeng, Chengde and Zhangjiakou were characterized by steady development in social economy and the score of resources and the environment subsystem increased steadily, therefore the three subsystems tended to develop simultaneously. In Wulanchabu League, social economy developed steadily but resources and the environment were still very sensitive to climatic changes so that its contribution to regional sustainable development maintained a relatively low level with large inter-annual fluctuations, implying that the eco-environment treatment project need to strengthen in this subarea.

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The authors
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