

Major Advances, Evolution, and Prospects of Desertification Control Research in China over the Past 45 Years: A Postprint of Bibliometric Visualization Analysis Using Citespace

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Abstract

Desertification control and prevention constitutes the principal focus of China's current "Three-North" Shelterbelt Program construction and represents a crucial measure for fortifying the ecological security barrier in western China. To advance research on key technologies for desertification control and prevention, and to support comprehensive desertification prevention and control as well as key ecological projects such as the "Three-North" Program, this study, employing Citespace software and traditional literature synthesis methods, systematically reviewed research achievements on desertification control and prevention in China over the 45 years since the implementation of the Three-North Program, and analyzed the overall characteristics, evolution of research hotspots, existing problems, and research deficiencies in the literature on desertification control and prevention. The analysis revealed that: (1) The total volume of Chinese and English publications related to desertification control and prevention has exhibited continuous growth, with gradually increasing international influence, and the research demonstrates multidisciplinary and interdisciplinary characteristics. (2) Over the past 45 years, the research has undergone evolution across three periods: 1978-2000, 2001-2012, and 2013-2023. The first stage focused primarily on identifying the causes of land desertification and dynamics of land degradation; the second stage emphasized evaluating the effectiveness of human activities such as artificial sand-fixation afforestation on desertification control; the third stage has concentrated on sustainable development research for sandified land management through industrialized desertification control and natural restoration. (3) The research content primarily encompasses four aspects: driving factors and mechanisms of land desertification, control measures and models, policies and laws and regulations, and the evolution of desertification control concepts. (4) Current research faces challenges in areas including rapid fixation of

shifting sand, new materials, technologies and models for desertification control, biodiversity conservation, valuation of ecological service functions, development of sand industry, and policy mechanisms. Future exploration is required across multiple dimensions, including land use and design, research and development of desertification control equipment, development of sand industry and ecological products, improvement of policy mechanisms, and innovation and promotion of key desertification control technologies.

Full Text

Title and Authors

Major Progress, Evolution, and Future Prospects of Desertification Prevention and Control Research in China Over the Past 45 Years: A Visual Analysis Based on Citespace

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Abstract

Desertification prevention and control represents the primary focus of China's "Three-North" Shelter Forest Program (TNSFP) and constitutes a crucial measure for building a robust ecological security barrier in western China. To advance research on key technologies for desertification prevention and control, and to support comprehensive desertification management and key ecological projects such as the TNSFP, this study systematically reviews research findings from the 45 years since the TNSFP's implementation using Citespace software and traditional literature synthesis methods. The analysis examines the overall characteristics, hotspot evolution, existing problems, and research gaps in the desertification prevention and control literature. The findings reveal: (1) The total volume of Chinese and English publications on desertification prevention and control has grown continuously, with increasing international influence, reflecting the multidisciplinary and interdisciplinary nature of this research field. (2) The research has evolved through three distinct periods: 1978–2000, 2001–2012, and 2013–2023. The first phase focused on identifying the causes of desertification and dynamics of land degradation. The second phase emphasized evaluating the effectiveness of human activities such as artificial sand fixation and afforestation. The third phase concentrated on sustainable development approaches, including industrialized desertification control and natural restoration. (3) Research content primarily encompasses driving factors and mechanisms of desertification, control measures and models, policies and legal frameworks, and the evolution of desertification prevention concepts. (4) Current research faces challenges in rapid mobile sand fixation, new materials and technologies, biodiversity conservation, valuation of ecological services, sand industry development,

and policy mechanisms. Future research should address land use planning and design, equipment development for desertification control, sand industry and ecological product development, policy mechanism improvement, and innovation and promotion of key desertification control technologies.

Keywords: desertification prevention and control; desertification combating; Citespace; hotspot evolution; Three-North Shelter Forest Program (TNSFP)

Introduction

Land desertification is a major global ecological and environmental issue affecting human survival and development, and China is among the countries most severely affected by desertification and sandification. Desertification prevention and control has been elevated to a national priority. Under the backdrop of global climate change, land sandification in China remains serious and challenging. According to the sixth national monitoring survey, China's sandy land area reaches 1.69×10^6 km², significantly impacting national ecological security and sustainable socioeconomic development. Through decades of practice and exploration, China has progressed through three stages: the initial “mobilizing the entire nation to march into the desert” phase, the “national will, project-driven” development phase, and the “external promotion, comprehensive acceleration” steady advancement phase, achieving remarkable accomplishments and markedly improving ecological conditions in sandy regions while enhancing desert ecosystem services.

These achievements have been underpinned by scientific and technological innovation. The academic community has conducted baseline surveys to monitor and evaluate desertification trends, investigated causes and driving forces, and developed control technologies and models for infrastructure protection, including oases, cultural heritage sites, railways, and reservoirs, thereby strongly supporting national desertification prevention and control efforts. On June 6, 2023, President Xi Jinping chaired a symposium in Bayannur, Inner Mongolia, emphasizing that desertification prevention and control should be the main direction of attack, aiming to fight a decisive battle for the TNSFP within about a decade and build it into an unbreakable green Great Wall and ecological security barrier in northern China. This speech affirmed the outstanding role of desertification prevention and control and pointed out the direction for development. Therefore, a systematic review of China's desertification prevention and control research is essential to guide future work and support comprehensive desertification management and key ecological projects.

Previous reviews have typically employed traditional synthesis methods to summarize research progress at national, regional, or project scales, or focused on specific technical fields, without employing bibliometric approaches. While some studies have used bibliometric methods to analyze sand barriers, sand industries, and land desertification, comprehensive national-level reviews using knowledge mapping to analyze research content, problems, and future trends remain scarce.

This gap hinders further advancement in the field. To address this, our study employs Citespace software to systematically analyze literature on desertification prevention and control since the TNSFP' s implementation in 1978, providing technical support for key ecological projects.

1.1 Research Methods

This study utilizes Citespace, a commonly used bibliometric analysis software, to analyze keyword co-occurrence and burstiness, creating knowledge maps that visualize the evolution path, research frontiers, and hotspots in desertification prevention and control research.

1.2 Data Sources and Processing

The China National Knowledge Infrastructure (CNKI) database served as the primary data source. Literature retrieval was conducted on August 30, 2023. Given that the Chinese Core Journals (Beida Core) began in 1992, the study period was divided into two segments: 1978-1991 and 1992-2023.

For the 1978-1991 period, advanced retrieval was performed in CNKI with “academic journals” as the source category, covering January 1, 1978, to December 31, 1991. The initial search yielded 1,247 records. After manually removing non-core journal articles, non-desertification-related studies, conference papers, authorless pieces, submission guidelines, scholar introductions, and news items, 412 eligible papers remained.

For the 1992-2023 period, advanced retrieval was conducted in CNKI' s core journal and CSSCI collections, covering January 1, 1992, to August 30, 2023. The initial retrieval produced 2,856 records. After similar manual screening, 2,312 eligible papers remained.

For English literature, the Web of Science database was searched using a comprehensive query string covering terms like “combating desertification,” “desertification control,” “sand fixation,” and “sand barrier,” with China as the study area. This yielded 1,247 records. After deduplication in Citespace, 412 English articles were retained.

1.3 Overall Literature Characteristics

Annual publication volume shows a consistent upward trend, indicating growing attention to desertification prevention and control. Chinese publications began earlier (around 1984) than English ones (around 1992). Initially, Chinese publications dominated, but English publications surpassed Chinese ones after 2018, demonstrating increasing international influence. Major Chinese journals include *Journal of Desert Research*, *Journal of Arid Land Resources and Environment*, and *Research of Soil and Water Conservation*, while key English journals include *Disaster Advances* and *Sustainability*. The research exhibits

interdisciplinary characteristics spanning forestry, soil and water conservation engineering, ecology, and resource science.

[Figure 1: see original paper] Quantitative distribution of publications of desertification prevention and control

2.2 Analysis of Research Hotspots and Development Trends

Citespace-generated keyword clustering and temporal evolution maps reveal research trajectories. Node size represents keyword frequency, with larger nodes indicating higher frequency. Annual rings show publication distribution across years.

High-frequency Chinese keywords include desertification prevention and control, desertification combating, desertification, sand industry, sandy desertification, sustainable development, windbreak and sand-fixing forests, sand-fixing forests, prevention and control, causes, soil microorganisms, ecological engineering, soil properties, desert management, and ecological restoration. Major English keywords include *Community, Water, Impact, Field, Management, Desertification, Vegetation, Grassland, Ecosystem, Stabilization, Diversity, Ecological Restoration, Model, Performance, Dynamics, Nitrogen, and Carbon stock*.

[Figure 2: see original paper] Temporal evolution of Chinese keywords in land use and ecological environment effects in desertification prevention and control

[Figure 3: see original paper] Temporal evolution of English keywords in land use and ecological environment effects in desertification prevention and control

Before 2000, Chinese keywords focused on desertification, sandy desertification, desertification combating, and sand industry. The 2001–2012 period saw increased attention to climate change, ecological engineering, soil properties, ecological restoration, and low-coverage sand control, while English keywords emphasized soil water, wind erosion, atmospheric deposition, and groundwater accumulation. After 2013, Chinese keywords shifted toward ecological security, income increase for farmers, and models, while English keywords highlighted human activities, negative impacts, community development, water and soil resources, land use, vegetation protection and restoration, predictive models, soil erosion, biodiversity, carbon sequestration, and sustainable development.

3. Major Research Progress in Desertification Prevention and Control

Over the past 45 years, domestic research has focused on four areas: driving factors and mechanisms of desertification, control measures and models, policies and legal regulations, and conceptual evolution.

3.1 Research on Driving Factors and Mechanisms of Desertification

The causes, extent, and classification of desertification have remained persistent research hotspots. Studies have evolved from examining sandstorms, wind erosion, and climate change to investigating land degradation dynamics, rocky desertification, and environmental degradation. Research methods combine historical and modern approaches, macro and micro analyses, qualitative and quantitative studies, and theoretical and experimental research. Findings indicate that desertification drivers include natural factors (geographical environment, climate, earth movements), human factors (unsustainable resource use, population and livestock growth, overgrazing), and combined factors. In some localities, human factors outweigh natural ones, while the reverse holds true elsewhere.

Desertification monitoring and assessment have progressed from ground surveys using indicators like soil moisture and vegetation degradation to regional evaluations of shrub dune development and land use types, and further to remote sensing, UAV technology, and AI-based image classification and vegetation indices. Spatiotemporal dynamic monitoring commonly employs field surveys, remote sensing analysis, and linear regression of spectral indices like MSAVI to calculate vegetation coverage and assess desertification degrees.

3.2 Research on Control Measures and Models

Technical measures constitute the core of desertification prevention and control research. Studies have examined engineering, biological (plant), and chemical approaches. Engineering measures, particularly sand barriers, form the foundation for plant-based measures. Early research focused on barrier shapes, materials, and technologies, as well as desertification control machinery. Subsequent work developed integrated static and dynamic sand fixation methods, combining traditional materials (straw checkerboards, clay, gravel) with new chemical materials, followed by vegetation establishment. This has yielded effective models like the low-coverage sand control system and desert railway protection systems. Current research emphasizes comprehensive control schemes adapted to different climate zones and ecological-economic construction needs.

Biological measures include developing suitable plant species for sandy areas and exploring biological soil crust and soil microorganism technologies. Evaluation methods such as expert scoring, analytic hierarchy process, and comprehensive assessment help identify optimal ecological restoration models. Studies typically compare restoration effects of different models, focusing on vegetation recovery and soil quality improvement through integrated aboveground and belowground characteristics.

The sand industry has emerged as crucial for economic development and ecological improvement in desert regions. Research covers sand industry theory, models, development strategies, and regional characteristics, employing entropy methods and grey correlation analysis. Photovoltaic sand control represents a rapidly developing approach that combines sand fixation with solar power gener-

ation, creating a desert energy ecosphere with significant economic, social, and ecological benefits.

3.3 Research on Policies and Legal Regulations

Policy serves as both a cause of and solution to desertification. Research examines how technical assessments inform policy formulation and how policy discourse reveals political power dynamics and socioeconomic benefits. Studies analyze legislative effectiveness through comparative case studies and explore transboundary cooperation mechanisms. Scholars emphasize that desertification prevention and control is not a zero-sum game but a community of shared destiny requiring multilateral cooperation and ecological compensation mechanisms.

3.4 Evolution of Desertification Prevention and Control Concepts

Since 1978, China's desertification prevention concepts have evolved through distinct phases: the "returning farmland to forest and grassland" phase (1978–2000) focused on large-scale afforestation through the TNSFP; the "sustainable development" phase (2001–2012) established legal frameworks and engineering governance; the "scientific development" phase (2013–2020) created stable investment mechanisms and long-term monitoring systems; and the current "Xi Jinping Ecological Thought" phase (2021–present) emphasizes the "lucid waters and lush mountains are invaluable assets" concept and systematic governance of mountains, rivers, forests, farmlands, lakes, grasslands, and deserts. This phase promotes the Belt and Road Initiative for desertification prevention, integrates multidisciplinary approaches, and combines efficient management mechanisms with high-tech production processes to advance high-quality sand industry development.

4. Research Gaps and Future Prospects

4.1 Research Gaps

Despite progress, several shortcomings persist:

First, research on rapid mobile sand fixation technologies remains insufficient. Current studies lack digital, intelligent, low-cost, and high-efficiency sand barrier installation equipment. Existing machinery like straw checkerboard robots suffers from stability and adaptability issues. Moreover, integrated multi-technology sand fixation methods require further exploration.

Second, research on new materials, technologies, and models lags behind. While comparing different control models remains a focus, studies often neglect cross-regional model comparisons and integration applications. New approaches like microbial sand control and photovoltaic sand control need more investigation, as do shelterbelt models adapted to modern agriculture. The concepts of scientific

and precision sand control require clarification to prioritize systematic planning before technological advancement.

Third, policy mechanisms remain imperfect. Current research emphasizes policy content but neglects policy tool analysis and implementation mechanisms, hindering sustainable development. Studies on effectively improving control outcomes through combined government and profit incentives are scarce. Research on voluntary and hybrid policy tools to encourage public participation also needs strengthening.

Fourth, comprehensive studies on biodiversity and ecological service functions of ecological projects like the TNSFP are lacking. Research on ecological benefits often overlooks biodiversity protection and dynamic evaluation of ecological services. Issues such as single tree species selection, “one-size-fits-all” approaches, and artificial forest degradation require deeper investigation.

Fifth, coupling research between high-level protection and sand industry development in sandy areas is insufficient. Most studies examine protection and development separately rather than integratively. Regional development coordination and cross-regional collaboration mechanisms for sand industry development need further exploration.

4.2 Future Prospects

First, innovation and practice of new desertification control models should be prioritized to promote comprehensive sand industry development. Future research must strengthen theoretical and practical integration while emphasizing multidisciplinary approaches. Special attention should be paid to developing mature technical systems for the sand industry, exploring key technologies, and investigating integration models like photovoltaic sand control combined with new energy development. Research should also address direct utilization of aeolian sand and pathways from sand control to sand management and utilization.

Second, research and development of desertification control equipment should be enhanced to improve economic, ecological, and social efficiency. Digital and intelligent straw checkerboard installation machinery with high stability and adaptability is urgently needed. Future research should promote government-enterprise-academia-research collaboration to accelerate new technology development and application.

Third, monitoring and evaluation of ecological service functions of artificial sand-fixing forests should be strengthened, with in-depth research on desert ecosystem biodiversity protection. Studies should focus on high-level protection technologies and industrial development to fully exploit ecological service functions and achieve biodiversity conservation and sustainable development in desert ecosystems.

Fourth, policy mechanism research should be intensified through digital simulation of human activity impacts. While China has achieved land sandification

reversal through evolving national policies, the situation remains severe. Future research should employ AI technology for digital simulation and dynamic monitoring to study the impacts and driving mechanisms of human activities and natural factors. This will help build a more comprehensive global desertification prevention and control system and ensure sustainable utilization of desert ecosystems. Additionally, transnational and transcontinental policy research and practice should be developed to construct diversified engineering-technical models, improve ecological compensation mechanisms, and advance sand industry development to address new challenges.

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