

FOOTPRINT OF RESEARCH IN DESERTIFICATION MANAGEMENT IN CHINA

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ABSTRACT

Desertification is among the most severe global environmental and the socio-economic problems in the world. This paper is a first attempt to link scientific research to national policymaking on desertification in China. We aim to trace scientific research findings in the national policies and strategies of desertification prevention in China. One example is the large-scale plantation programme in the dust source region threatening Beijing and Tianjin since 1998. It has been suggested that the recent increased forest cover due to plantations in North China has helped reduce dust storm emissions and contributed to mitigating dust storm weather in Beijing and Tianjin. Reforestation/afforestation policy remains in the Chinese national environmental strategies for the new national forestation programme (2011–2020). Overgrazing during recent decades has been blamed for land degradation and desertification in Northwest China by many scholars. Small field experiments prove that vegetation in desertified/degraded land could recover if isolated from human activities. Since 1998, natural recovery has become one powerful national force to prevent land desertification and recover natural vegetation. One example is selected at Cele County, Xinjiang Uygur Autonomous Region to showcase how vegetation could thrive at large scale in natural arid and semi-arid climate if isolated from human intervention. The plantation project has pushed the stakeholders to better understand their negative impact on the environment, especially the overgrazing behaviour. After that, the household income and living level have also been significantly enhanced; however, it is not clear whether the project induced labour migration. Copyright © 2015 John Wiley & Sons, Ltd.

KEY WORDS: desertification; climate change; human activity; scientific management; China

INTRODUCTION

Desertification in arid, semi-arid and dry sub-humid lands can be described as a process of impoverishment of arid, semi-arid and some sub-humid ecosystems by the combined impacts of man's activities and drought (Dregne, 1976), and it is a socio-economic problem as well. Desertification under climate warming in recent decades is of great concern in many regions as it threatens nearly a third of the Earth's land surface with declining agricultural productivity and water shortages (McMichael *et al.*, 2006), reduced vegetation biomass, decreases in species diversity or declining quality of the nutritional value for livestock and wildlife (Thomas & Middleton, 1993; Reynolds *et al.*, 2007; Hansen, 2010). Future climate warming in the late 21st century is expected to exacerbate the progression of desertification worldwide through alteration of spatial and temporal patterns in temperature, rainfall, solar insolation, winds and increased drought frequency and persistence of dry conditions according to Intergovernmental Panel on Climate Change AR4 and AR5 (D'Odorico *et al.*, 2013). Meanwhile, increasing population along with the demand for more food, fodder and fuel woods have also put interrelated economic, social and environmental pressures on land (Wang *et al.*, 2010). This global situation makes desertification not only a global problem,

but also a local problem (Izzo *et al.*, 2013; Salvati *et al.*, 2013; Yan *et al.*, 2013), and several policies are conducted with local and external stakeholders in order to mitigate desertification and land degradation (Bisaro *et al.*, 2014; De *et al.*, 2014; Fleskens & Stringer, 2014). Here, we describe how Chinese people attempt to combat it.

There are 38×10^4 km² of aeolian desertification lands in North China recorded in 2010, and the desertification situation is very severe, among which the slight grade accounts for 33.80%, the moderate grade for 22.84%, the severe grade for 22.16% and the extremely severe grade for 21.21% (Wang *et al.*, 2011; Wang *et al.*, 2012). The problems induced by desertification such as soil quality decline, land resources reduction, dust storm and so on have had a serious impact on food security, loss of biodiversity, soil erosion and water storage (Wang *et al.*, 1999; Wang *et al.*, 2001; Hou *et al.*, 2004; Zhao *et al.*, 2013). Some human-induced problems like population booming, overgrazing and unpaved roads construction will induce the soil loss and land degradation (Cao *et al.*, 2013). Several researches demonstrated that the decline in the frequency of strong wind power due to the warming in Mongolia and the cooling in northern China that reduced the meridional temperature gradient contributes mostly in the recent reduction of dust storms and increased vegetation cover in areas of desertification in northern China since 1970s (Qian *et al.*, 2002; Wang *et al.*, 2007; Mason *et al.*, 2008). As the world's fastest growing economy with an increasingly deteriorating

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environment (Liu *et al.*, 2008), the Chinese government attaches great importance to combating desertification as a major component of sustainable development and the building of an equitable society (Xu *et al.*, 2011). Enormous research has been focused on these areas in recent years to better understand the progress and dynamics of desertification and propose solutions to prevent or reverse it. At the same time, substantial governmental attempts have been made to manipulate local residents' lifestyle and land use practice to prevent the advance of desertification and restore the land desertified since 2000s (Yang & Jiang, 2001; Wang, 2004; Wang *et al.*, 2006). Some achievements in this regard have been reported (Wang & Wei, 1998; Chen & Tang, 2005; Guo *et al.*, 2012).

In this paper, we reviewed the recent research on the status of desertification and desertification prevention efforts in China. One of the main objectives is to trace the role of scientific research in policymaking in China and hopefully shed some insight on the link of science and policy. Our findings could be helpful for land desertification prevention worldwide, particularly for countries with similar climate background. We will introduce briefly the status of desertification and related research in China. Then two examples were listed to discuss in detail how research is applied in actual programme planning and implementation.

MATERIAL AND METHODS

Knowledge on the spatial distribution and driving mechanisms for desertification in China has dramatically increased in recent years. Papers on desertification or desertification management studies in China between 1990 and 2012 were compiled through searching via Web of Knowledge and the biggest Chinese literature searching engine: Chinese National Knowledge Infrastructure. Desertification status in China and the desertification research in China are summarized based on these publications. Two examples are chosen to link the research in the two areas and the ecological projects implemented on the ground. As this is the first attempt as such to discuss how research been used in policy or practice in terms of desertification prevention in China, we need to put much of our personal understanding in the discussion.

RESULTS

Desertification Status in China

Landsat images, spatial and temporal statistics and regional systematic investigation have been applied to the desertification monitoring (Xu *et al.*, 2012; Bai *et al.*, 2013; Wang *et al.*, 2013). It has been estimated that about 25% of dryland areas of the world are affected by desertification, a major cause of stress in human societies (D'Odorico *et al.*, 2013). The risk of desertification is characteristically high around the margins of deserts. Deserts in China occupy an area about 262 million km², contain a total of 498 counties (cities and banners) in 18 provinces and account for 27%

of the country's land area with over 400 million residents (Wang *et al.*, 2012). Desertification has usually occurred in the northern and western parts of China and is determined by inherently harsh physical conditions, such as sparse vegetation, continental climate, sandy soils and water deficiency (Yan *et al.*, 2004; Chen & Tang, 2005; Wang *et al.*, 2009). The main desertification areas include the Taklimakan in Xinjiang, Badain Jaran in Inner Mongolia and Kumutage deserts in western China, some parts of the Tenngger, Ulan Buh and Hobq deserts, and most parts of the Gurbantunggut, Mu Us, Otindag, Horqin, Hulunbuir and Nen jiang deserts in northwestern, central and northeastern parts of China (Figure 1). In 2005, desertification triggered economic losses of up to €6 billion in 10 provinces in North China, most seriously in Inner Mongolia (Ma *et al.*, 2008).

Desertification Research in China

United Nations Conference on Environment and Development (UNCED, 1992), Agenda 21, chapter 12 emphasizes land degradation through desertification, and the international community, particularly through UN organizations, has launched several activities to address it (Eswaran *et al.*, 2001). In 1994, the Chinese state council joined the UNCCD's (United Nations Convention to Combat Desertification) convention to address the problem of desertification as an important environmental problem for the first time (<http://www.unccd.int/en/resources/Library/Pages/FAQ.aspx>). The Chinese scientific community had started to study desertification trends and management strategies long before this, for example, Ma (1966) experimented with the use of irrigation and fertilizer application to transform desertified land into grassland in the Gansu Province between 1959 and 1960 (Ma *et al.*, 1966). Since the 2000s, the first official desertification research institute has been built in the Chinese Academy of Forestry, and a national key laboratory of deserts and desertification was also established in the Chinese Academy of Sciences. Several national research projects have been funded, for example 'Research progress on Aeolian desertification process and controlling in north of China (2000-10-2005-09)', 'Oasis in arid areas, the process of the desertification, regulation and its response to human activities and climate change (2009CB421300)', 'Global change impact of desertification on Tibetan plateau (2009CB421300)' and the national desertification prevention and control plan (2005-2010) by the state council. These institutes and state projects (Table I) bring together hundreds of researchers working in the field of desertification.

Figure 2 demonstrated the number of relevant papers published in Chinese and English on desertification and desertification management from 1990 to 2012. Publication numbers in both Chinese and English have increased during the past 20 years. The publication numbers in Chinese are much larger than those written in English and have increased rapidly in the last 10 years at a rate of 31 pieces per year. One-sixth to one-fifth of the papers look into the possible management solutions or evaluate the effect of management projects during 1990 to 2012.

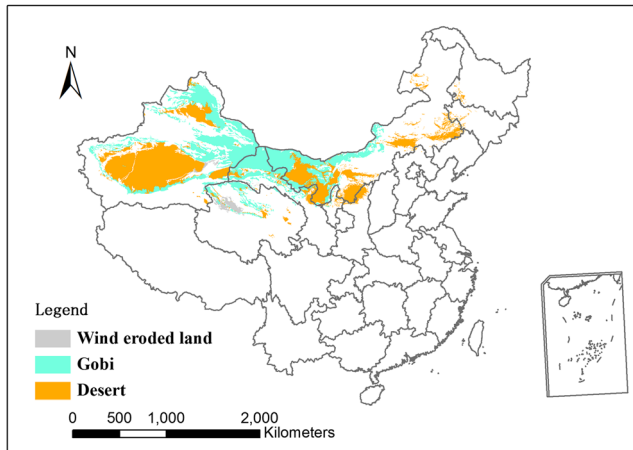


Figure 1. The map of desert distribution in China. This figure is available in colour online at wileyonlinelibrary.com/journal/ldr.

Most of the desertification research papers were inspired by the requirement of desertification prevention and the protection of environment and society. The findings from these scientific papers were intended to provide the knowledge base relevant for policymaking. Plantations and natural recovery methods are the two mostly frequently mentioned and effective solutions suggested by the scientific community (Fan & Zhou, 2001; Carle *et al.*, 2002; Akiyama & Kawamura, 2007; Zheng *et al.*, 2010). Desertification management strategies have developed from small pilot studies at the very start (1949–1978) through state special desertification investment (1978–2000) and then to comprehensive environmental management since 2001 (Guo & Zhou, 2010). In the next section, we will discuss two case studies to illustrate how research is being applied in practical policymaking.

Case 1: Control of Desertification in Dust Storm Areas by Plantation

It is said the accelerating development of desertification will enhance the frequency of dust storm events (Wang, 2001; Yang, 2004). Dust storm events in Beijing have been recorded since the Yuan dynasty (1271–1368) and have occurred about 60 days per year since the 1950s (Li & Gao, 2001; Song, 2002; Zheng, Yang & Li, 2004; Gou *et al.*, 2012). The scientific community has identified that the dust source areas are mainly the Gobi desert region on the Mongolian Plateau, the Loess Plateau and the northwest of China (Li & Gao, 2001; Zheng, Yang & Li, 2004; Gou *et al.*, 2012). Increasing vegetation coverage proves not only to be an effective measure to control dust storms, but also could improve the soil quality and restore the desertified area (Zhao *et al.*, 2013).

Plantations are a globally effective measure to protect and restore natural grassland and forests from degradation (Carle *et al.*, 2002). To improve ecological conditions in the Chinese dust storm source regions, a series of afforestation programmes have been implemented since 1970s which are named as ‘Beijing-Tianjin Sand and Dust Engineering’

(one project in Table I); additionally, 12 March was selected as the ‘Chinese National Plantation Day’ since 1979 to encourage nationwide plantation activities. Prior to 2008, the government total investment was €41.2 billion, and the project covers 458,000 km² including Beijing, Tianjin, Hebei, Shanxi and Inner Mongolia (109°30′–119°20′E, 38°50′–46°40′N) (http://www.gov.cn/jrzq/2012-10/07/content_2238556.htm). Figure 3 lists the plantation area per year from 1998 to 2010 during the Beijing-Tianjin Sands and Dust Engineering (BTSDE) project. Expansions of more than 1 million hectares in plantation area occurred in 1999–2001 and 2009–2011.

Significant reduction of dust storm events in Beijing during recent years are believed to be related with afforestation and reforestation in the dust source regions (Song 2002; Ding *et al.*, 2005; Yin *et al.*, 2007). Vegetation recovery is not only due to plantation area increase, as there are some other simultaneous measures in the same region including prohibition of animal grazing by enclosure of grassland (Zheng *et al.*, 2005), conversion of cropland to forest or grassland (Uchida *et al.*, 2005) and enforced policies on crop rotation (Brogaard & Xueyong, 2002). Chinese ecological projects are the largest on the planet and were implemented on a massive scale, encompassing 97% of Chinese counties, and planned investment will eventually exceed €84.5 billion since 1978 (Wu *et al.*, 2013). Positive effects of these projects that have been reported include increase of vegetation coverage (Song, 2002; Ding, Li & Dong, 2005; Yin *et al.*, 2007), reduction of soil erosion (Paul *et al.*, 2002), increase of water yield (Sahin & Hall, 1996) and enhancement of carbon sequestration (Nilsson & Schopfhauser, 1995). Scientific research has played a role in all the policy making, implementing and evaluation processes. This also supports the extension of the plantation projects in these areas in coming years.

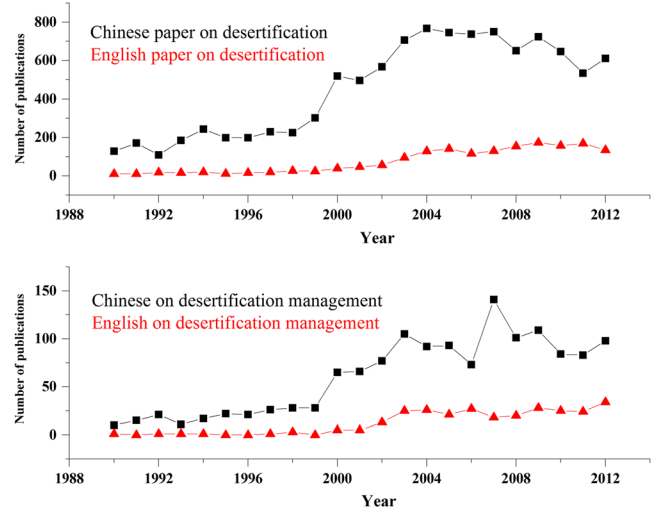
Case 2: Combating Desertification by Nature Recovery

Overgrazing has been blamed for causing desertification in the semi-arid sandy grassland in northern China (Akiyama & Kawamura, 2007; Zhang *et al.*, 2008). The hypothesis of nature recovery in non-irrigated areas is that local habitat could re-seed and grow by itself within a certain time interval if isolated from external human influences (Zhang & Du, 2006). Pilot studies in several places in Xinjiang Uygur and Inner Mongolia Autonomous Regions, the Loess Plateau and the Tibetan Plateau confirmed the success of this hypothesis. We choose Cele County as one representative of arid area to demonstrate how it works. A Chinese national ecosystem observation and research station was built at Cele in 1983 to study the desertification processes and find ways to guard the local socioeconomic environment.

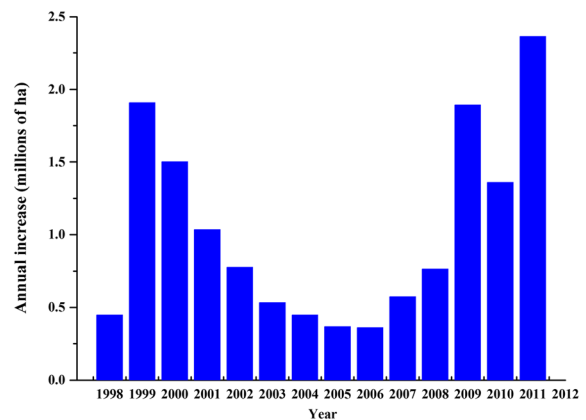
As one of the three extreme drought regions in the world, Cele County is located at the south edge of Tarim basin and is a typical oasis in the desert transition zone between the Tarim and Tuha basins. Annual total precipitation in this area is only 35 mm while the potential total evaporation is 2595 mm, and this area suffers sandstorm weather for 20 days in May every year (Zeng *et al.*, 2002; Wan *et al.*, 2009). The scientists at the station have monitored the local

Table I. List of the national key projects against the desertification and land degradation

Projects	Time period	Area	Funding (Billion RMB)	Application	References
Three-Norths Protective Forest Program	1978–	Northwest, North and the Northeast of China	10	Convert farmland to natural grassland or forest through subsidizing local farmers to alleviate the increasingly aggravated situation of soil erosion in China	(Zhang <i>et al.</i> , 2004)
Natural Forest Conversion Program	1998–2010	China	96.2	Protect and restore natural forests through such means as logging bans	(Liu <i>et al.</i> , 2008)
Grain for Green	1998–2010	China	430	Conserving natural forests and grassland from farmland and subsidizing local farmers	(Liu <i>et al.</i> , 2008)
Beijing–Tianjin Sands and Dust Engineering	2000–2012	Beijing, Tianjin, Hebei, Shanxi and Inner Mongolia	41.2	Grassland and forest plantation	(Shi <i>et al.</i> , 2009)

Figure 2. Scientific research papers on desertification and desertification management in China published in Chinese or English. This figure is available in colour online at wileyonlinelibrary.com/journal/ldr.

ecology at the oasis for more than 20 years and the dynamic root growth at different water gradients (Zeng *et al.*, 2002; Zhang *et al.*, 2013). Together with the local community and local government, the scientists achieved great success in extending coverage of the shrub *Tamarix chinensis* by irrigation and transformed a huge desert area into an oasis. In 1995, the Cele station was awarded the ‘Saving the Drylands’ certificate by the United Nations Environment Programme for its outstanding contribution in combating desertification and controlling land degradation in dryland environments. Figure 4 is a photo taken at the boundary of the area prohibited from grazing. It clearly shows the recovery of habitat due to the restriction of grazing within the protected area while there is almost no grass outside the fence which has lots of sheep dung. Zhang *et al.* (2011) compared the natural restored community in the protected area in Cele and found that the biomass under natural recovery was much higher than with artificial recovery of the herbaceous community over the past 10 years (Zhang *et al.*, 2011).

Figure 3. Records of plantation area increase in the Beijing and Tianjin dust storm resource areas from 1998 to 2011. This figure is available in colour online at wileyonlinelibrary.com/journal/ldr.

Meanwhile, a regional study of natural recovery in typical steppe indicated that species biodiversity increased during the 5 years after the implementation of the project (Xu *et al.*, 2008; Zhang *et al.*, 2011). An appropriate level of enclosure or fencing persistently is an effective approach to reduce the high alpine soil-moisture evaporation and degradation of alpine wetlands and should be taken to maintain the grassland's eco-function in the future (Yang *et al.*, 2010). During natural recovery project implementation, flexible measures to help the local community were also applied to provide adequate living allowance. Migration to other regions away from the desert areas and a change from reliance on herding to farming was also encouraged (Li *et al.*, 2004; Meng & Bao, 2004; Bao, 2006; Shi, 2008).

DISCUSSION

Desertification in China has received great attention, especially the northwestern part of China (Lee and Zhang, 2004; Wang *et al.*, 2004; Wang *et al.*, 2006; Wang *et al.*, 2010). The desertified area in China has increased since the 1950s and reached its maximum during the 1970s and early 1980s. Since then the area of deserts have decreased continuously to the present (Wang *et al.*, 2008). Some researchers claim that human activities are unlikely to be the key factors responsible for desertification or rehabilitation (Wang *et al.*, 2008). Others agree that human influence on desertification was basically in a subordinate position before the Qing dynasty compared with climate change (Ma *et al.*, 2011), but human activity has changed into a main social-economic factor in modern times (Zhang *et al.*, 2003). Interestingly, reconstructed evidence shows close relationships between expanding desertification and the collapse of Chinese dynasties (Wang *et al.*, 2010). It is clear that stable governance environment promotes better land use than more anarchic conditions in China (Chen & Tang, 2005; Wang *et al.*, 2008; Xu *et al.*, 2011).



Figure 4. Photo was taken in Cele Xinjiang on 17 May 2013. Steel fence was set up to stop grazing on the right side. This figure is available in colour online at wileyonlinelibrary.com/journal/ldr.

There are considerable differences in the views of desertification and land use management between the experts and local farmers (Lee and Zhang, 2004). The knowledge of local farmers could be very helpful in defining criteria for the land qualities (Messing *et al.*, 2001); however, local farmers tend to increase unlimitedly the number of their own animals for economic interest, that may have led to overgrazing and land degradation and could not fully consider long-term sustainable development for their offspring (Sneath, 1998). The total investment for ecological project by the Chinese Government has reached €11 billion annually to mitigate overgrazing and other serious environment problems since the 1990s. It has proved to be effective and resulted in the repair of about 20% of the pre-existing desertified land with substantial ecological and socioeconomic improvements (Liu *et al.*, 2008; Wang *et al.*, 2012; Li *et al.*, 2014). During the implementation of these projects, local farmers could receive subsidies for the protected area and free training on non-agricultural skills to help them look for short-term jobs in towns and cities. According to the national official document, people residing in the Yangtze River basin and south China received one-time subsidies about 105 yuan. While in the Yellow River basin and the Northern China, people received the one-time subsidies about 70 yuan. The household could obtain an extra 20 yuan per Mu per year (The ecological forest for 8 years, the economic forest for 5 years and the grassland subsidies for 2 years). Quite a number of studies showed that the farmers' net income increased, benefiting from the ecological projects, especially for low-income and medium-income households (Li *et al.*, 2011; Miao *et al.*, 2014). The improvement of environmental conditions will also prompt the awareness of local farmers to maintain the sustainable development to their own good (Wei *et al.*, 2009).

In terms of the impacts of plantation and natural recovery projects on regional economic structure, one important indicator is the labour migration during the period that spans through the project and afterwards, which could reveal the composition of family income and help the government adjust the composition of rural population. Labour migration, particularly part time labour movement between towns and nearby villages is very difficult to accurately monitor. Miao *et al.* reviewed quite a number studies conducted in Gansu, Henan, Ningxia, Sichuan and other provinces and found the plantation projects usually deduct the cultivated area and, therefore, create more surplus labours, among which mostly young people would move to the cities to look for jobs (Miao *et al.*, 2014). However, this is not always the case. From the case study in Qinghai province, Du found that if the subsidies cannot meet daily cost of food, clothing, education and transportation, the local farmers would tend to return to the previous extensive grazing activities after finishing the programme (Du, 2012). A case study in Zhouzhi County, Shaanxi Province of China also echoes Du's results (Li *et al.*, 2011). This mixed phenomenon implies that subsidy is important but not enough to lead to the success of these projects if without strategies to change the local economic structures, for example, the portion of non-agricultural

income in the family. Another thing worthy of mention is that labours who moved to cities often work in low-technology jobs like construction, catering or transportation, which is normally paid at quite low wages without insurance and social benefits (Peng *et al.*, 2007; Miao *et al.*, 2014).

Our study has attempted to link scientific research with desertification prevention project. It clearly shows the strong link within the two cases we chose. Dust storm events are reduced, and natural resources recover in a suitable environment; on the other hand, desertification impact on local ecology and influence human welfare and society. Desertification is a worldwide environmental stress; in a vicious circle, poverty exacerbates desertification, and in turn, desertification aggravates poverty. The natural process of desertification is common to many regions. Better scientific understanding and international collaboration will help address the issues for other countries. For example, China is sharing desertification prevention knowledge with Africa in the Sino-Africa Summit 2012. But the policy of prevention needs local indigenous knowledge and needs to consider the local community. More researches in local areas are needed, although the programmes in China have achieved many positive ecological and socioeconomic outcomes, like increased value of ecosystem functions and economic output. However, experience has shown that continued implementation of these laws and regulations on desertification still requires better management, and successful desertification prevention needs better cooperation between various stakeholders (Li *et al.*, 2014). China's efforts and success in controlling desertification has been remarkable in the world, not only on the list of numbers and pictures in front of us; thousands of special scientists have been trained in desertification prevention by the main institutes like Chinese Academy of Sciences and the state forestry administration. Scientists have created well-established theory on desertification assessment and management in China. Long-term field experiment stations have been established and more will be developed through future investment. All these successes will provide some useful guidelines for other countries, particularly the ones with similar climate in Africa and the Republic of Mongolia. Moreover, the importance of better attempts to achieve sustainable management, particularly involving all stakeholders, also needs more focus.

CONCLUSIONS

Natural and human-induced desertification has been severe and affected most northern parts of China. Northwestern China has seen a decrease of desertified area in the past decade. This paper used two case studies to demonstrate how scientific research has been applied in national desertification management. Plantation in the dust storm source region is proved to be a meaningful tool to effectively reduce dust storm days, reverse land quality degradation and increase species biodiversity. Comparative trials indicated that natural recovery in the arid area of Cele County in Xinjiang could enhance the ecosystem biomass

directly. We found that scientific research played an important role in the planning, implementation and evaluation processes of these two desertification prevention programmes. The link between scientific research and desertification prevention projects in China will increase confidence in future environmental management worldwide. The plantation projects prove to be a sustainable land management method to mitigate excessive consumption of natural resources and significantly improved the living standard of the local farmers.

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