

Challenges to Sustainable Development in China: A Review of Six Large-Scale Forest Restoration and Land Conservation Programs

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Six national programs—including the Natural Forest Protection Program (NFPP), Sloping Land Conversion Program (SLCP), Desertification Combating Program around Beijing and Tianjin (DCBT), Shelterbelt Network Development Program (SNDP), Wildlife Conservation and Nature Reserve Protection Program (WCNR), and Industrial Timberland Plantation Program (ITPP)—were adopted as means to achieve the Chinese Government sustainable development national policy. While the programs have made promising progress circa 10 yr at the national level, problems exist at the regional and local levels. This article, therefore, reviews the achievements and problems associated with the programs and their implementations, and provides recommendations for the full realization of the goals of the programs. We recommend a comprehensive strategy for future

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activities—including promotion of sustainability science, reformation of rigid policies and regulations, adoption of sustainable forestry practices, integrated ecosystem management approach, and formation of new international collaborations.

KEYWORDS large-scale national programs, effectiveness, sustainability, integrated ecosystem management, ecological restoration in China

INTRODUCTION

China's ancient history of deforestation and unsound land use have led to profound ecological consequences including land degradation, soil erosion, loss of biodiversity, desertification, and catastrophic natural disasters (Li, 2004; Liu, Li, Ouyang, Tam, & Chen, 2008; Xi, Bi, & He, 2012). The situation is getting worse in heavily populated areas (Fu, 2008; Liu & Diamond, 2005). The Chinese central government recognized the devastating impacts of these environmental issues to China's development sustainability and declared a national policy of afforestation and land conservation in 1983. Since then, China has increasingly invested in the protection of imperiled forestlands and the restoration of its degraded lands (State Forest Administration of China [SFA], 2009). SFA (2009), and Song and Zhang (2010) have shown that the total forested area on national lands increased from 13.92% in the late 1980s to 16.55% in the late 1990s as a result of this policy.

Along with notable progress made in the 1980s, the Chinese government adopted a new policy which incorporated a "sustainable development" framework in the late 1990s. This new policy resulted in the establishment of six key national forestry programs to protect the existing natural forests and restore China's degraded ecosystems (Li, 2004; SFA, 2009; Yin, 2009). These changes have encouraged progress toward a national sustainable development (Liu & Diamond, 2005; Xi et al., 2012). Following the national policy changes in the early 1990s, local and private sector efforts on forest resource exploitation and conservation have increased to compliment China's forest protection and restoration efforts (Zhang et al., 2000; Yin et al., 2003; Liu et al., 2008; SFA, 2009; Xi et al., 2012). Restoration activities since the late 1990s resulted in an increase of China's total forest coverage, from 16.55% in the late 1990s to roughly 20.36% in 2008 (SFA, 2009; Food and Agriculture Organization of the United Nations [FAO], 2010).

Despite a notable increase in forest coverage, recent studies suggest that conservation and restoration of China's severely degraded forests remain a monumental challenge due to the conflict between protection and restoration of degraded forests, and livelihood and economic growth (Liu et al., 2008; SFA, 2009; Xi et al., 2012). China is the most populated (ca. 1.33 billion)

and forest deficient country in the world (FAO, 2010). China's population represented 19–20% of the total world population in the 1990s but its forests accounted for only 3–4% of the total forested areas in the world (Li, 2004). As a result, per capita forest usage in China is just 0.11 ha, compared with a world average of 0.6 ha (FAO, 2010). Demands for forest resources for development purposes have raised questions about the scope and goal of China's forestry programs as well as how to achieve such programs.

This article provides an assessment of the six operating national forestry programs in China with an emphasis on forestry sustainability development. Through evaluation of program implementation, outcomes, and pending issues, this article will propose recommendations for policymakers regarding forest conservation, habitat protection, and forest restoration in a common conceptual framework pertaining to sustainable development. This article is structured around three questions:

1. What are the most serious ecological and socioeconomic issues in China?
2. How did the implementation of the six key national forestry programs affect the overall ecological conditions in China?
3. In what areas could China make those programs more effective for sustainable development?

ECOLOGICAL AND SOCIOECONOMIC CHALLENGES

The primary ecological challenge currently facing China is land degradation and desertification, which continually threaten both economic development and environmental protection (Fu, Zhuang, Jiang, Shi, & Lu, 2007; Zhang, Yu, Li, Zhou, & Zhang, 2007; Fu, 2008; Xi et al., 2012). In the 1990s, the area prone to soil and water erosion in China accounted for 37.5% of the national territory while the annual volume of soil erosion reached over 5 billion tons (3.3 billion tons are a direct result of farming activities), approximately 19.2% of the worldwide total (Ministry of Water Resources, 2002). Even after government forestry programs increased forest cover by 2.63% during the 1990s, eroded lands continued to increase by over 10,000 km² (Zhang et al., 2000; Li, 2004; SFA, 2009; FAO, 2010). Remote sensing at the end of 2000 found that the total area of soil erosion was roughly 37.42% of the total Chinese territory, amounting to over 3.56 million km² (Xu, Guo, & Zhang, 2002). To give the reader an idea of the scale, Li and Shi (2002) reported that sediment concentrations in the Yellow River was approximately 38 times greater than that found in the Mississippi River, and 49 times greater than concentrations in the Nile River.

Desertification is the second critical concern for restoration efforts in China. Recently, areas affected by desertification amounted to approximately 28% of the China's territory, or roughly 2.62 million km² (SFA, 2009). The

proportion of areas at high-risk of desertification in China (>1.03 million km²) is alarming (SFA, 2009). As a result, nearly 400 million people are currently at risk (Xi et al., 2012). Compounding the increasing area of desertified lands in China is their rate of spread which has been steadily increasing from 1,560 km² per year in the 1950s to 2,460 km² per year in 2006 (SFA, 2009).

The economic consequences of such rampant environmental degradation are severe (Xi et al., 2012). In 2000, the total loss was estimated to be 700 billion RMB (ca. US\$110 billion), in which about 470 billion RMB (ca. US\$74 billion) was directly attributed to land degradation and desertification (Wang et al., 2011). The most recent study conducted by researchers at the Chinese Academy of Environmental Planning showed China suffered almost 1.4 trillion RMB (ca. US\$200 billion) loss of economic growth in 2009 due to land degradation, ecological destruction, and pollution—equivalent to 3.8% of GDP (State Environmental Protection Administration of China, 2012).

MAJOR NATIONAL FORESTRY PROGRAMS

A milestone in forest protection and restoration occurred in the late 1990s when China adopted a “sustainable development” framework as a basic national policy (SFA, 2009; Yin, 2009). A 5-yr plan of natural resource and environmental protection soon followed to implement the policy (Xi et al., 2012). The policy with its 5-yr execution plan encouraged fundamental progress in China’s effort to protect its environment and restore its forests (Liu, 2004). In particular, the central government’s response to successive major natural disasters in the late 1990s launched and/or restructured several national ecological restoration programs, which aimed to improve China’s deteriorated ecological conditions and to reduce poverty in the poorest and most ecologically fragile regions. The central government set a 10-yr goal of increasing its forest coverage from 16.55% in 1998 to roughly 19% in 2010, up to 23% by 2020 and 26% by 2050 (SFA, 2009).

To meet these ambitious goals, the SFA initiated the Natural Forest Protection Program (NFPP) in 1998 and the Sloping Land Conversion Program (SLCP) in 2002. In addition, the SFA consolidated some previous or on-going forestry programs into four “new” large-scale ecological restoration programs including the Desertification Combating Program around Beijing and Tianjin (DCBT), the Shelterbelt Network Development Program (SNDP), the Wildlife Conservation and Nature Reserve Protection Program (WCNR), and the Industrial Timberland Plantation Program (ITPP). The six programs (Table 1), also known as “the national priority forestry programs,” are the Chinese government’s focal points in terms of program goals, geographical coverage, and financial support (Xu, Yin, Li, & Liu, 2006; Xu, Xu, et al., 2006).

TABLE 1 Summary of the Six Key Forestry Programs

Program	Period	Scope	Goals	Major activities	Investment (billion RMB)
Natural Forest Protection Program (NFPP)	1998–2010	The upper reaches of the Yangtze River; the middle and upper reaches of the Yellow River; Northeast and Inner Mongolia, including 734 counties and 163 forest enterprises	Ensure 94.2 million ha of forest are under effective protection; reduce timber production by 19.9 million m ³ ; afforest 8.67 million ha	Establishes a complete ban on commercial logging in the upper Yangtze and upper and middle Yellow River basins and sharply reduces commercial harvests in other regions. <ul style="list-style-type: none"> • Other measures include shutting down certain processing facilities, compensating logging firms, and dealing with displaced workers and equipment. • Afforestation and forest management is promoted where necessary. • Administration and law enforcement is strengthened, including forest protection. • The forestry industry is restructured, and the efficiency of timber utilization is improved. 	The initial investment commitment was 96.4

(Continued)

TABLE 1 (Continued)

Program	Period	Scope	Goals	Major activities	Investment (billion RMB)
Sloping Land Conservation Program (SLCP)	1999–2010	1,897 counties, about 97% of national total	Convert 14.67 million ha farmland into forests; afforest 17.33 million ha of barren lands and mountains	<p>Sloping or desertified croplands are converted into ecological or economic forests, and grasslands; ecological forest should account for 80% of the converted land.</p> <ul style="list-style-type: none"> • The central government subsidizes farmers with seeds or seedlings, grain, and cash. • Subsidies last 8 yr for ecological forest creation, 5 yr for economic forests, and 2 yr for grasslands. The annual cash subsidy is 300 RMB/ha, and the annual grain subsidy is 1,500 kg/ha in the Yellow River basin and 2,250 kg in the Yangtze River basin. • The central government also makes fiscal transfers to compensate subsequent losses to local fiscal revenues. 	The original estimate of total investment is 225

Desertification Combating Program around Beijing and Tianjin (DCBT)	1998–2010	596 counties in 13 provinces in the north, northeast, and northwest China	Control 10.12 million ha of sand-affected areas; increase forest/grass areas by 5.21 million ha	Desertified land is converted into forestland and grassland through flexible, diversified measures based on the local conditions. <ul style="list-style-type: none"> • Herding and animal husbandry practices are changed to control overgrazing and rehabilitate degraded grassland. • Irrigation projects are developed, and people are resettled away from fragile areas. • The provision of technology and energy is included. • Desertification monitoring systems and dust storm forecasting systems are implemented. 	Projected total investment is 57.7
Shelterbelt Network Development Program (SNDP)	1998–2010	596 counties in 13 provinces in north, northeast, and northwest China	Afforest 9.5 million ha shelterbelt	This program includes the “Three Norths” (i.e., the Northwest, North, and Northeast), the Yangtze River basin, the Zhujiang River basin, and the Taihang Mountain Range. <ul style="list-style-type: none"> • Public agencies, civil society, and individuals are mobilized to participate in shelterbelt development and tree planting. • Regional government investment, local labor contributions, and the adoption of new silvicultural techniques are encouraged. 	Projected total investment is 70

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TABLE 1 (Continued)

Program	Period	Scope	Goals	Major activities	Investment (billion RMB)
Wildlife Conservation and Nature Reserve Protection Program (WCNR)	2001–2050	Nationwide	Increase number of nature reserves to near 2,500, with a total area of 172.8 million ha or 18% of the total land area in China	<p>Priority protected areas are administered by the central government, while smaller and less critical areas are managed by regional governments.</p> <ul style="list-style-type: none"> • The number of established reserves will reach 1,800 by 2010, 2,000 by 2030, and 2,500 by 2050. • Also included are wetland protection and restoration measures, ecotourism development, and wildlife breeding initiatives. • Encouraging domestic and international participation and contributions, including broad involvement of the private sector. • Strengthening the role of science and technology, particularly regarding the monitoring and evaluation of nature reserves and biodiversity. 	Projected total investment is 135.65 over the first 30 yr; roughly a half of this investment is covered by the central government

<p>Industrial Timber Production Program (ITPP)</p>	<p>1998–2015</p>	<p>1,000 counties in 18 provinces in eastern, central, and southern China</p>	<p>Afforesting 13.33 million ha of fast-growing and high-yield timber plantations</p>	<ul style="list-style-type: none"> ● Market-driven and profit-orientated efforts are developed for increasing domestic timber supply. ● As much as 70% of the investment may come from loans subsidized by the National Development Bank. ● Tax incentives are provided. ● Active participation is encouraged from various enterprises, including state and collectively owned firms, shareholder-based organizations, and fully private businesses. ● The planned area of establishment is 4.69 million ha by 2005, 9.2 million ha by 2010, and 13.33 million ha by 2015. 	<p>Projected total investment is 71.8</p>
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Although the six programs have made unprecedented progress toward forest conservation and restoration in China, they differ significantly in terms of their missions, durations, financial commitments, and relative success. Nonetheless, the SLCP is by far the largest. The program covers 1,897 counties in the country and plans to establish 76 million ha in new tree plantations, which make this program unprecedented in history in terms of its scope and investment. Except for the SLCP and the NFPP, none of these programs is new or even recently initiated. Rather, their various predecessors have been in existence much earlier but were consolidated in recent years either for more effective administration or for more focused targeting (SFA, 2009). For example, the SNDP was originally launched in various regions during the 1970s and the 1980s. It was only in 2001 that it was brought under a single SNDP umbrella.

IMPLEMENTATION AND OUTCOMES

National Level Progress

At the national level, the six key national forestry programs have made promising progress in achieving overall project goals including profound positive impacts on China's economy, environment, and society (Yin, 2009). Over the last decade, China has invested 500 billion RMB (ca. US\$70 billion) to implement the six programs (SFA, 2009; Figure 1). The conditions of natural forest resources in China are much improved due to these programs, as reflected by increases in forest cover, wildlife habitat, protection, and species abundance; as well as in the reduction of sandstorms, flood

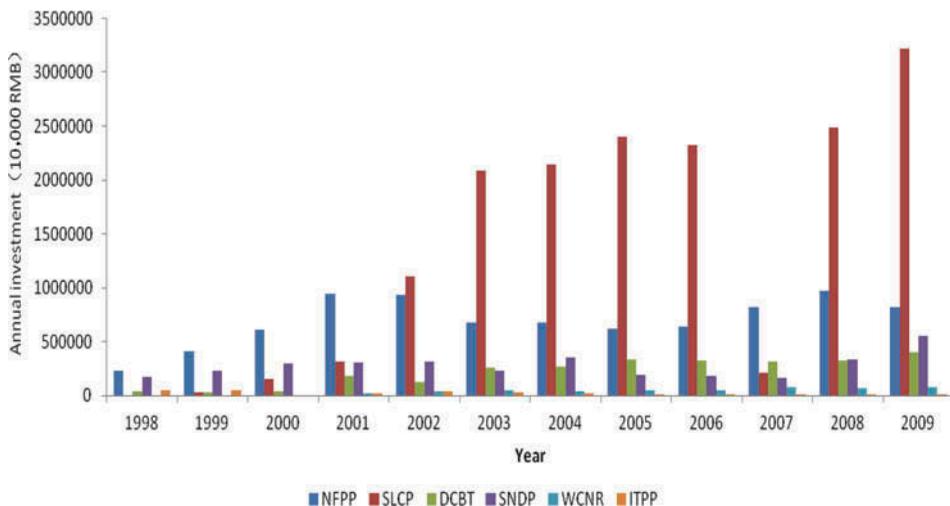


FIGURE 1 Annual investment of the six national forestry programs from 1998 to 2009.

occurrences, and rates of soil erosion (Peng, Dong, Zhang, & Zhou, 2005; Wang, Ouyang, et al., 2007; Wang, Lu, Fang, & Shen, 2007; Liu et al., 2008; Xi et al., 2012). Substantial amounts of degraded farmland and grassland have been recovered or rehabilitated, while land area under forest and grassland has expanded. China's total forest coverage increased from 16.55% in the late 1990s, to 20.36% in 2008 (FAO, 2010; SFA, 2009).

As a result of these programs, the economic resource structure in China has been fundamentally adjusted, as indicated by the growth of nontimber forest products, an increase in ecotourism and recreation, the diversification of local economies, the acceleration of labor transfer, an increase in income and living standards, and a reduction in poverty (FAO, 2010; SFA, 2009). Additionally, these programs have greatly raised awareness of the need for conservation and restoration of natural forests throughout China (Li, 2004; Liu et al., 2008; Xi et al., 2012).

Project Level Assessment

Roughly 60% of the total forested area in China, 6.33 million ha of forests are newly established stands and net stocking by volume has increased to 186 million m³ (SFA, 2009; Figure 2). From 1999 to 2006, forested lands increased by 8.1 million ha, and stocking volume grew by 466 million m³ in areas covered by the NFPP. About 92.66 million ha of forests have been effectively managed and protected on NFPP lands (SFA, 2009). A complete commercial logging ban has been placed on natural forests in 13 provinces and autonomous regions in ecologically threatened areas along the upper Yangtze and Yellow Rivers as well as the middle reaches of the Yellow River.

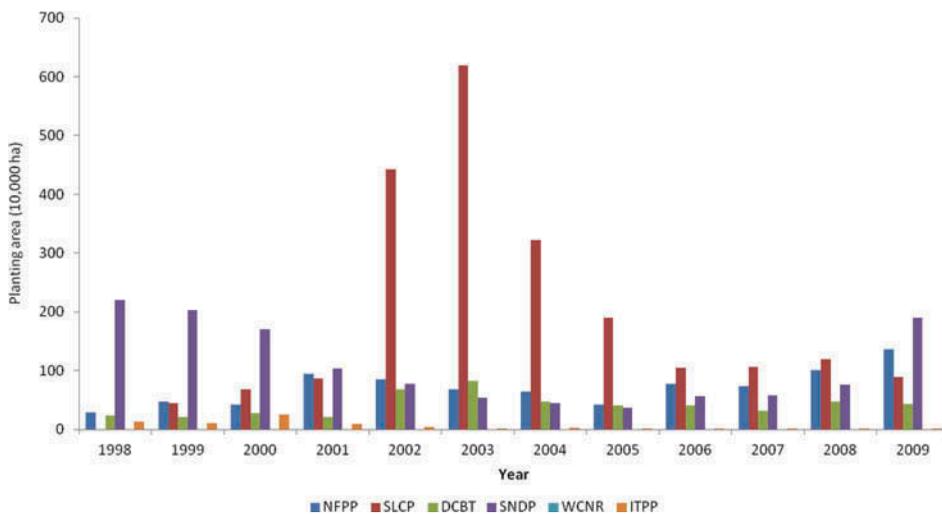


FIGURE 2 Total planting area of the six national forestry programs from 1998 to 2009.

In the SLCP, 2.16 million ha of barren mountains, wastelands, and croplands have been afforested or converted into grassland. The State Forestry Administration verified that 97.56% of plantation areas (~2.1 million ha) were successful establishment of plantation, and 87.36% of the plantations (~1.8 million ha) met to the program criteria as plantation (SFA 2009).

Progress of the DCBT is also impressive. Total investment in the program reached 13.6 billion RMB (ca. US\$2.14 billion) from 2000 to 2006 (SFA, 2009). Most of the investment was used for subsidized conversions of cropland into forests and grassland. As of 2006, afforestation expanded by 2.8 million ha through planting and aerial seeding with an additional 1.3 million ha through mountain closure (SFA, 2009). In addition, about 1.5 million ha of grassland have been rehabilitated, 0.5 million ha of small watersheds have been managed, and over 101,000 poverty-stricken people have been resettled to places where basic livelihood can be sustained (SFA, 2009).

Likewise, the WCNR has made tremendous advances. The amount of nature reserves has increased steadily, and the conservation of wild plants and animals has also been enhanced. Under the WCNR, 167 nature reserves have been established. Conversion of forest areas protecting wild fauna and flora to natural reserves has increased to 1,740 separate locations with the total area of approximately 116 million ha, nearly 12.60% of the country's land area (SFA, 2009).

Similarly, from 2001 to 2006, implementation of the SNDP expanded afforestation, reforestation, and other land rehabilitation programs by 3.25 million ha in the Three-North region and over 3.05 million ha in the Yangtze River basin (SFA, 2009). The Three-North Shelterbelt Development Program has mitigated over 1.58 million ha of desertified lands. In comparison, less than 0.4 million ha of industrial timber plantations were established during the same period under the ITPP, indicative of very slow development from the ITPP (SFA, 2009).

CHALLENGES AND ISSUES

While national statistics and reports from various government agencies have revealed sound achievements from these national forestry programs, many challenges remain due to the complexity of the problem. The following sections discuss those challenges and the strategies which could improve the effectiveness of on-going programs as well as similar programs in the future.

Financial Sources and Reform of Forestland Tenure Issues

According to the SAF (2009) report, the total investment in forestry activities from 2003 to 2010 was 839.8 billion RMB (ca. US\$132 billion). Since the early 2000s, government investment has prioritized restoration and conservation

efforts: annual budget increases are indicative of this as the rates of increase have been consistently higher than the average national economic growth (Li, 2004; SFA, 2009; Zhuang, 2001). Even with prioritization by the central government, the SFA is expected to accrue a 1.45 trillion RMB (ca. US\$222 billion) deficit from 2011 to 2050 (National Forestry Key Ecological Projects Socio-economic Forecast Center, 2005). The lack of full financial support from the government has greatly limited China's forest protection and restoration efforts.

The current land ownership and tenure-rights in forest management discourages local farmers and other potential investors to take further action on long-term investment on the lands. Unclear land tenure-rights have been identified as both a driver of deforestation and a prerequisite for effective forest protection and restoration (Liu, 2004; Wang et al., 2001). Reforming forestland tenure is the first step toward attracting investment from multiple sources.

Mixed Outcomes at the Local Levels

While assessments at the national scale are supported by the national statistical data, the extent to which the programs have changed local ecological and socioeconomic conditions are still poorly understood, as local statistics on programs are often not available or unreliable. Cao, Chen, and Yu (2009) reported that SLCP increased vegetation cover significantly from 29.7% in 1998 to 42.2% in 2005 in arid and semi-arid northern Shaanxi province, a twofold increase over the national average. However, a study in the late 1990s in Minqin and Yanchi counties revealed that:

1. the SNDP did not give adequate consideration to land productivity and environmental heterogeneity when selecting plots;
2. more than half of the reforested locations were on flat cropland (slopes of less than 5°) and;
3. in five of the eight townships, net income on reforested lands were substantially above or below that realized from previous crops, raising questions about the efficiency of fund allocations to farmers participating in the program (Wang & Maclaren, 2012).

Further studies are required at the local level to determine if new policies, approaches, or specific techniques would be adopted to improve outcomes and participation by the local people.

Independent Evaluations

Comprehensive independent assessments of program impacts by the scientific community are not yet available for most of the program areas. Available evidence indicates that there are some disparities between government and scientific studies regarding the success of the Three-North Forest Shelterbelt program. While the SFA claimed the program achieved dramatic rehabilitation in the arid and semiarid eco-region of China throughout the past three decades, Wang, Lu, et al. (2007) refuted the Three-North Forest Shelterbelt program's effectiveness at combating desertification and controlling dust storms. They postulated there are two primary reasons why the program may have failed to meet its goals. First, the decreased desertification and frequency of dust storms in arid and semiarid China in the postproject period may have been caused primarily by climatic change, not human activity such as the program. Second, a relatively low proportion of the region was affected by the program, the survival of the planted trees and shrubs has been low, and the afforestation did not target the areas responsible for the majority of dust production, or areas most at risk of desertification in the Three-North region (Wang, Lu, et al., 2007).

National Policy-Related Issues

There has been debate among Chinese ecologists that rigid policies by the government may, in some regions, cause new ecological problems. Cao et al. (2009) have argued that in arid and semi-arid China, where trees that are not adapted to the local environment were planted, the current afforestation policy including large-scale seedling and sapling planting projects may actually damage the ecological conditions because the newly planted trees do not improve the environment and may instead contribute to environmental degradation. They further argued that large-scale afforestation in the vulnerable arid and semi-arid regions could increase the severity of water shortages, decrease vegetation cover in afforestation plots, and negatively affect species diversity (Cao et al., 2009). Regulations and policies should be more flexible regionally within the national programs, and local governments should strive to create local (county, township, and village) level self-sustainable projects under the framework of the national program guidelines.

Systematically Inventory

In order to evaluate China's forest restoration efforts, implementing both short- and long-term monitoring approaches is essential to China's future restoration success (Xi et al., 2012). Currently, the government has not given adequate attention to systematic monitoring or evaluation of these programs. Although progress has been made throughout the past 20 yr, the effectiveness of restoration projects and the results of restoration efforts have

not yet been fully understood (Xu et al., 2006; Yin, 2009). Environmental impact assessments are rarely conducted before implementing a restoration project and in many cases, no such technical protocols or assessment standards exist (Liu et al., 2008). Establishing standards for assessing ecosystem health is another key issue in the ecological restoration arena (Xi et al., 2012). The scientific community in China is setting up monitoring networks to reevaluate the long-term ecological impacts based on temporal data and have also called for more emphasis on the quality of reforestation programs rather than just their scale (Yin, 2009).

LONG-TERM STRATEGIES AND RECOMMENDATIONS

Policy and Regulation

Based on the current ecological, social, and economic structures, China adopted a sustainable approach for its forestry development. This approach requires modern scientific knowledge and the application of new technology to create comprehensive plans and ensure sustainable use of all involved components—such as timberlands, agriculture lands, and conservation areas. However, China is currently lacking many of the tools necessary for effective integration of involved players, in particular stakeholders, farmers, and investors. In addition, China needs to establish an effective participatory mechanism to coordinate and guide participation from various sectors in society.

If China plans to correct and fill current gaps in the restoration efforts, time and resources can be saved by prioritizing the gaps according to need. China's forest protection and restoration policy needs transformation in its approach, and should prioritize comprehensive, sustainable forestry and agricultural goals as well as establish self-sustaining, multifunctional landscapes (Wang, Ouyang, et al., 2007; Wang, Lu, et al., 2007; Xi et al., 2012). An improved legal system is also needed in order to effectively regulate forestry practices.

A shift in China's approach from the current hierarchical decision tree to a grassroots effort involving local farming communities is a major change needed for the effective and sustainable development of future programs (Li & Shi, 2002; Xi et al., 2012). For example, the current protocol of the SLCP allows for less than 20% of forests to be economically managed. However, the current programs offer local farmers little input as to the types of forests restored (Yin, 2009).

Research Priority

A major limitation for China's sustainable forestry development is insufficient scientific research and technical support, especially those involving original innovation (Li, 2004; Li & Shi, 2002; SFA, 2009). A top research priority for

guiding future restoration in China must be understanding China's restoration potential (i.e., the original vegetation or reference conditions) and the driving factors which have influenced previous restoration efforts (Xi et al., 2012). Research on China's reference conditions is rare and will likely be a difficult task due to China's long and complex history of land use. More research on this subject is needed and will provide a realistic goal for future forest restoration efforts.

Second, forest planning is critical as the impacts of various activities not only change with region, they also are usually associated with regionally specific consequences (Xu & Cao, 2002). China's natural and socioeconomic conditions vary considerably by region. Therefore, under the direction of the national forestry programs, regional projects should focus on regionally specific conditions and needs. Research classifying ecological restoration zones is essential when determining suitable restoration measures across different regions. To understand the potential forest restoration needs of a specific area, the severity of damage to the forest areas needs to be examined in detail.

Several past studies in China have provided promising progress in this direction. Four ecological restoration zones have been identified based on key limiting factors (e.g., soil water availability, annual precipitation) for the growth of plants; and 13 subzones were identified based on soil erosion and landforms (Cai, Zhang, & Chen, 2004). Detailed zoning work helped to identify key areas and prioritized restoration planning and assessment efforts. In China, certain key areas have been identified for conducting forest restoration. Examples of such areas include the Beijing and Tianjin vicinity of ecological restoration area, the Northwest Loess Plateau-water erosion ecological restoration area, and the middle reaches of the Yangtze River ecological restoration area (Chen, Zhang, & Niu, 2003; Peng et al., 2005).

Third, the impacts of forest landscape restoration to the environment are profound and comprehensive. To a certain extent, these effects are still unclear and need to be evaluated further. Therefore, more research on the impacts of restoration activities is imperative to improve the effectiveness of restoration efforts. These impacts may include effects on the watershed-level eco-hydrology processes, regulatory mechanisms, water flow modeling under different restoration scenarios, material movements, nutrient cycles, quality of soil, forest succession, changes in species diversity, comprehensive effects on natural resources, and consequent changes in microsite conditions due to restoration activities. These related issues need to be clarified and further addressed (Weyerhaeuser, Wilkes, & Kahrl, 2005).

Further work is also needed to balance forest resource protection with regional and local economic development. In order to maintain the benefits of a multifunction forest with diverse forest products, it is important to manage and maintain forest resources in a sustainable manner. Specifically, while engaging local farmers to protect existing forests as valuable resources, regional and local governments should also encourage and assist farmers to

develop and maintain a strong forest-based economy (such as growing fruit trees or other forms of agroforestry). In some suitable areas, eco-tourism could be an approach to fulfill an increasing leisure demand, maintain a sufficient level of forest productivity, and provide a stable income for the local populations.

International Collaborations

International collaborations have been and should be an important part of China's sustainable forestry development. In the past 20 yr, numerous international and nongovernmental organizations have made great progress which has assisted China's capacity for sustainable forestry. China should continue to collaborate with international organizations and concerned countries at various levels and through diversified channels—including scientific research and technology transfer, professional training, and exchange of personnel. The international community has an opportunity to create profoundly positive impacts in China's efforts in sustainable forestry (Li, 2004; Li & Shi, 2002; Xi et al., 2012).

CONCLUSION

Since the late 1990s China has adopted a national sustainable development strategy, reformed forest tenure rights, adjusted forest policies, and increased investment to support the protection of its existing natural forests and the restoration of its degraded lands. The results are significant and have generated successful outcomes and experiences in forest conservation and protection of degraded farmland. However, the current national forestry programs have problems that need to be resolved properly. Although some progress has been made, China's total forest cover (18.21%) is still inadequate compared to its goal of 26% in 2050. In many places, forest exploitation is getting worse due to increasing population and economic development, and these are a source of stress on remaining natural resources. In order to alleviate this trend, China needs to increase its forestry budget and enhance preproject planning and postproject evaluation and monitoring. Further, long-term financial investment and management plans are needed in addition to scientific research, technological support, silvicultural management, and program advocacy. To be sustainable in its endeavors, China must continue the current sustainable development strategy which emphasizes ecological restoration of degraded forests and farmlands. China should take a more balanced and integrated approach toward natural resource conservation and preservation. China should strive to increase the effectiveness of the current natural forest protection and restoration programs by promoting integrated ecosystem management, expediting land tenure reform, facilitating collaboration between the central government and all affected parties, as

well as enforcing forestry laws and regulations more strictly. In addition, international collaboration should be strengthened.

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REFERENCES

- Cai, J. Q., Zhang, C. Y., & Chen, F. Y. (2004). Study on restoration zones in China. *China Water Resources*, 4, 46–48. (In Chinese)
- Cao, S., Chen, L., & Yu, X. (2009). Impact of China's Grain for Green Project on the landscape of vulnerable arid and semiarid agricultural regions: A case study in northern Shaanxi Province. *Journal of Applied Ecology*, 46, 536–543.
- Chen, F., Zhang, C., & Niu, Z. (2003). Approach to ecological rehabilitation of soil and water conservation conducted region by region in China. *Soil and Water Conservation in China*, 8, 2–3. (In Chinese)
- Food and Agriculture Organization of the United Nations. (2010) *State of the world's forests*. Rome, Italy: FAO Forestry Department.
- Fu, B. J. (2008). Blue skies for China. *Science*, 321, 611.
- Fu, B. J., Zhuang, X., Jiang, G., Shi, J., and Lu, Y. (2007). Environmental problems and challenges in China. *Environmental Science & Technology*, 42, 7597–7602.
- Li, W. H. (2004). Degradation and restoration of forest ecosystems in China. *Forest Ecology and Management*, 201(1), 33–41.
- Li, W. H., & Shi, P. L. (2002). Promoting sustainable forestry. In *Area studies-China: Regional sustainable development review-Vol. II. Encyclopedia of life support systems*. Paris, France: Eolss.
- Liu, J. C. (2004). Forestry development and forest policy in China. *Journal of Forest Economics*, 10(4), 159–160.
- Liu, J., & Diamond, J. (2005). China's environment in a globalizing world—How China and the rest of the world affect each other. *Nature*, 435, 1179–1186.
- Liu, J., Li, S., Ouyang, Z., Tam, C., & Chen, X. (2008). Ecological and socioeconomic effects of China's policies for ecosystem services. *Proceedings of the National Academy of Sciences*, 105(28), 9477–9482.
- Ministry of Water Resources of The People's Republic of China. (2002). *The second national remote-sensing investigation data of soil and water loss*. Retrieved from <http://www.chinawater.com.cn>
- National Forestry Key Ecological Projects Socio-Economic Forecast Center. (2005). Surveillance report on social and economic benefits of national key forestry ecology project. *Green China*, 10, 7–12. (In Chinese)
- Peng, Z., Dong, S., Zhang, X., & Zhou, J. (2005). Analysis of vegetation restoration strategies in severe soil erosion area of the Loess Plateau in China. *Forest Research*, 18(4), 471–478. (In Chinese)

- Song, C., & Zhang, Y. (2010). Forest cover in China from 1949 to 2006. In: H. Nagendra & J. Southworth, (Eds.), *Reforesting landscapes: Linking pattern and process* (pp. 341–356). Dordrecht, The Netherlands: Springer.
- State Environmental Protection Administration of China. (2012). *China green national accounting study report 2009*. Beijing, China: Author.
- State Forest Administration of China. (2009). *China forestry development report*. Beijing, China: China Forestry Press. (In Chinese)
- Wang, C., & Maclaren V. (2012). Evaluation of economic and social impacts of the sloping land conversion program: A case study in Dunhua County, China. *Forest Policy and Economics*, 14, 50–57.
- Wang, C., Ouyang, H., Maclaren, V., Yin, Y., Shao, B., Boland, A., & Tian, Y. (2007). Evaluation of the economic and environmental impact of converting cropland to forest: A case study in Dunhua County, China. *Journal of Environmental Management*, 85, 746–756.
- Wang, X., Lu, C., Fang, J., & Shen, Y. (2007). Implications for development of grain-for-green policy based on cropland suitability evaluation in desertification-affected north China. *Land Use Policy*, 24(2), 417–424.
- Wang, X., Xu, C., Liu, F., Liang, W., Han, G., & Zhang, Z. (2001). Problems and countermeasures on restoration of forest ecological environment of Jilin Province. *Journal of Forestry Research*, 12(2), 109–114. (In Chinese)
- Weyerhaeuser, H., Wilkes, A., & Kahrl, F. (2005). Local impacts and responses to regional forest conservation and rehabilitation programs in China's northwest Yunnan province. *Agricultural Systems*, 85(3), 234–253.
- Xi, W., Bi, H., & He, B. (2012). Forest landscape restoration in China. In J. Stanturf, P. Madsen, & D. Lamb (Eds.), *A goal-oriented approach to forest landscape restoration* (pp. 65–92). Dordrecht, The Netherlands: Springer.
- Xu, F., Guo, S., & Zhang, Z. (2002). Soil erosion in China based on the 2000 national remote sensing survey. *Journal of Geographical Sciences*, 12(4), 435–442.
- Xu, J., & Cao, Y. (2002). The sustainability of converting the land for forestry and pasture. *International Economic Review*, 2, 56–60. (In Chinese)
- Xu, J., Yin, R., Li, Z., & Liu, C. (2006). China's ecological rehabilitation: Unprecedented efforts, dramatic impacts, and requisite policies. *Ecological Economics*, 57(4), 595–607.
- Xu, Z., Xu, J., Deng, X., Huang, J., Uchida, E., & Rozelle, S. (2006). Grain for green versus grain: Conflict between food security and conservation set-aside in China. *World Development*, 34(1), 130–148.
- Yin, R. (Ed.). (2009). *An integrated assessment of China's ecological restoration programs*. Heidelberg, Germany: Springer.
- Yin, R., Xu, J., & Li, X. (2003). Building institutions for markets: Experiences and lessons from China's rural forest sector. *Environment, Development and Sustainability*, 5(3–4), 333–351.
- Zhang, K., Yu, Z., Li, X., Zhou, W., & Zhang, D. (2007). Land use change and land degradation in China from 1991 to 2001. *Land Degradation and Development*, 18, 209–219.
- Zhang, P., Shao, G., Zhao, G., Master, D. C. L., Parker, G. R., Dunning J. B., Jr., & Li, Q. (2000). China's forest policy for the 21st century. *Science*, 288, 2135–2136.
- Zhuang, Z. F. (2001). The current situation and existing problems of China Natural Forest Protection Project. *World Agriculture*, 5, 11–12. (In Chinese)