Short communication

Redlines for the greening of China

Yihe Lü *, Zhimin Ma 1, Liwei Zhang 2, Bojie Fu 3, Guangyao Gao 4

State Key Laboratory of Urban and Regional Ecology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, China

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Conservation-development conflicts are problems that challenge global society and are important issues for conservation ecology research. A redline paradigm has evolved at the central government level in China as a new attempt for better resolution of conservation and development conflicts, including redlines for cropland conservation, forestland conservation and development, prohibited development zones, restricted development zones, and key ecological function zones. However, significant overlaps among these redlines and other land resource demands are key sources of hot debates about practicality. To advance the redline paradigm as a practical resource and environmental management tool, we propose recommendations including (1) strengthening the executive capacity of redline management by rule of law, (2) developing closer collaborations among different governmental sectors, (3) creating multi-source economic incentives through payment schemes for environmental services, and (4) promoting public participation. The advancement of the redline paradigm in China may serve as an example of conflict resolution for other nations.

1. Introduction

The global human population has been increasing continuously since the second half of the 18th century, although the growth rate slowed in the late 1960s (Guzmán et al., 2009). By the mid-21st century, the global human population is predicted to reach 9–11 billion, depending on different scenarios (Lutz and Samir, 2011; Pimentel and Pimentel, 2006), which implies that 2–4 billion more people will live on the earth in the next 40 years. Approximately 40% of the ice-free surface of the earth is impacted by humans (Bridgewater et al., 2011), who impose large ecological footprints. Additionally, landscapes transformed by agriculture and human settlements cover approximately 75% of Earth’s ice-free land and incorporate nearly 90% of terrestrial net primary productivity (Ellis and Ramankutty, 2008). The ever-increasing population and human activity have profoundly changed our environment, which has experienced biodiversity declines, natural resource depletion, ecological degradation, and environmental pollution. Nature and environmental conservation have been advocated as the main approaches to
mitigate these severe problems. For these approaches, priority setting or systematic conservation planning are concrete steps to allocate the usually limited resources (Knight et al., 2008; Orsi and Geneletti, 2010; Langford et al., 2011). As a result, over 12% of the global land surface has been designated as protected area, and this figure is forecasted to be 15–29% by 2030 (McDonald and Boucher, 2011). Unfortunately, a meta-analysis of over 4000 protected areas across the globe revealed that over 40% of them were not as effective as expected (Leverington et al., 2010). Conflicts between conservation and development have been recognized as one of the most important root causes for the low effectiveness of protected areas (Mora and Sale, 2011).

Reconciling the conflicts between conservation and development is one of the most complex challenges for human societies, especially developing nations. At a local scale, community-based conservation and integrated conservation and development projects have been widely adopted for conflict resolution even though their effectiveness still must undergo a systematic assessment (Garnett et al., 2007; Brooks et al., 2012). At a national scale, integrated planning and policy instruments that harmonize ecological, environmental, and socioeconomic needs are the most promising approach for solving the conservation and development dilemma (Salafsky, 2011).

China, as the largest developing country, has experienced ecological degradation largely driven by an imbalance between high population and economic growth pressures as well as limited natural resource reserves and environmental capacity (Fu, 2008). The estimated economic costs of the interrelated problems associated with ecological degradation (e.g., resource depletion, environmental pollution, and ecological degradation) have amounted to over 13% of the national gross domestic product ( Shi et al., 2011). The widespread ecological degradation has raised serious concerns from both the Chinese government and the general public. As a result, the Chinese government has launched several large-scale ecological rehabilitation and conservation programs since the late 1990s, including the Grain to Green and Natural Forest Protection programs (Liu et al., 2008). With the promotion of these programs, China is becoming a greening nation. Here, greening means the process of ecosystem restoration as measured by the increasing greenness of land cover (de Jong et al., 2011). The extended meaning of greening is the overall improvement of the ecological and environmental qualities of a region. In the forest sector, a logging ban in natural forests has facilitated their restoration (Yu et al., 2011), and, concurrently, large areas of tree plantations have been established (Wang et al., 2007; Yin and Yin, 2010). A national-scale assessment indicated that over 64% of the land mass in China experienced an increase in greenness during 2000–2010 (Liu and Gong, 2012). Along with the greening trend, a paradigm of redlining in natural resource and ecosystem management has emerged. Here, redlining is the planning for natural resource use and conservation with certain targeting constraints, such as the lowest level of a natural resource or ecosystem reserve that needs to be preserved.

The objectives of this paper are (1) to reveal the evolution of the redline paradigm in resource management at the central government level in China and (2) to analyze the problems and potential solutions of the redlines as management approaches. We believe that these contributions are beneficial to improve resource and environmental management both in China and other nations facing similar tensions between conservation and development.

### 2. The start and evolution of the redline paradigm

The cropland area in China is continuously decreasing, driven by the increasing human population, urbanization, industrial development, rural settlement expansion, and ecological restoration. For example, the annual loss of cropland is estimated to be 6946 km² during 1996–2007 (Zhao et al., 2010). Cropland loss caused a significant loss of food production. In the Huang-Huai-Hai Plain, one of the major food production regions in China, the annual grain production losses due to shrinkage of cropland area was 4.30 and 2.63 million tons during 1990–2000 and 2000–2005, respectively (Shi et al., 2013). In the 11th five-year plan launched in early 2006, China set the target area for cropland protection at 120 million ha for 2010 (Yan, 2006), and this figure was later extended to 2020. This plan initiated the redline paradigm on natural resources and environmental management at the central government level. It is the strictest cropland protection policy to date and is the basis for safeguarding food security in China.

A National Ecological Functional Zonation (NEFZ) program was jointly launched by the Ministry of Environmental Protection and the Chinese Academy of Sciences in 2008 as a stepping stone to accelerate and facilitate innovations for improving environmental conservation and management in China at the central government level (Wu, 2007). The main objectives of this zonation are (1) to partition ecological-function-oriented zones at a national scale based on a comprehensive analysis of the status and spatial differentiation of ecosystem types, ecological problems, ecological sensitivity and vulnerability, and ecosystem services and (2) to provide guidelines for ecological conservation, ecosystem management, and ecologically friendly socioeconomic development for the different ecological functional zones (Wan, 2011). Fifty Key Ecologically Functional Zones (KEFZ) were recognized, totaling 2.34 million km² (covering 24.3% of the Chinese terrestrial surface) after the ecological functional zonation process. These zones play key roles in water provisioning, soil conservation, desertification control, biodiversity conservation, and flood mitigation, all of which need to be considered when determining redlines for ecological and environmental conservation.

In the 11th five-year plan, China also put forward Major Function Oriented Zoning (MFOZ) to optimize the spatial pattern of regional development and conservation (Fan and Li, 2009). The unbalanced regional development, which is mainly represented as a widening regional socioeconomic development gap, uncontrolled urbanization, and disordered spatial development, led to an increase in resource-use pressure, the degradation of ecosystems and environmental quality, unsatisfactory economic operation and urbanization quality, questionable healthiness of regional development, and intensified social conflicts (Fan et al., 2010). These problems directly motivated the launch of the MFOZ task. In 2010, the Chinese
Central Government formally issued the MFOZ report, which demarcated the Development Prohibited Zones (DPZ, 12.5% of China’s landmass) and Development Restricted Zones (DRZ, 40.2% of China’s landmass). The DPZ include national nature reserves, national forest parks, national geo-parks, national tourism resorts, and world cultural and natural relics. Therefore, industrial and urban development is generally prohibited in DPZ to sustain good ecological functioning and environmental quality. With the establishment of new national nature reserves and parks, the DPZ will be enlarged accordingly. The DRZ are composed of 25 regions with high potential for ecological functions, including biodiversity conservation, fresh water provision, soil and nutrient conservation, and carbon sequestration. The DRZ host 8.5% of the human population in China, and the functional roles of the DRZ include ecological conservation and demonstrating the harmonization of human–nature relationships; subsequently, large-scale and intensive resource extraction, urbanization, and industrial development are highly restricted in DRZ.

With the central government’s approval of the “Planning Guidelines for Forestland Protection and Utilization 2010–2020,” redlines for forestland were formally publicized in June 2010. The redlines by the end of 2020 include: (1) an increase in forestland to 312 million ha, accounting for over 32.5% of China’s land surface; and (2) forest area amounting to 223 million ha, with the national average forest coverage exceeding 23%. These redlines for forestland and forest ecosystems are the targets for national-scale forest conservation, development, and management in the coming decade; they have to be realized as concrete goals for climate change adaptation, forest product provisioning, and ecological and environmental quality improvement (Yao and Zhou, 2012). They are founded on the greening trend and will contribute to more greenness in China.

On November 17, 2011, the State Council released an announcement on reinforcing the key environmental protection tasks, clarifying the need to demarcate ecological redlines in important zones of ecological functions, environmentally or ecologically sensitive areas, and ecologically or environmentally vulnerable areas. A research project managed by the Ministry of Environmental Protection has been approved to carry out this task, including the spatial determination of the redlines for species conservation, ecosystem conservation, and the conservation of KEFZ. The KEFZ establish national and regional ecological security patterns to guarantee socioeconomic and environmental sustainability. The resulting ecological redlines can be used as key areas for coordinated and improved ecological and environmental conservation by the Ministry of Environmental Protection and local governments. The demarcation of spatially explicit redlines for ecological and environmental management will facilitate institutional innovation toward establishing an integrative ecosystem and environmental management system in China (Rao et al., 2012).

It is clear that redlining is a tool to safeguard a certain amount of resources for the sake of sustainability. Therefore, the redline paradigm exists for the management of natural resources, ecosystems, and the environment at the central government level. However, the effectiveness of these policy endeavors is still open for discussion and requires evaluations of the performance of real-world implementation.

3. Overlap and debates on redlines

With the rapidly growing economy and increasingly large population, land resources in China have become more and more scarce. Different sectors are increasingly competing for land resources, and 20% more land was occupied by urbanization in 2008 compared to 2000 (Liu et al., 2012a). A road system of 3.38 million km will be built across China by the end of 2020 (NDRC, 2008), and according to the national land-use plan launched in 2008, urban and rural construction land will reach 372.4 thousand km² (11.4% increase compared to 2010); another 13.3 thousand km² of land will be occupied by transportation system development by 2020 (The State Council, 2008). The total percentage of land declared for redline management (land resources on which large-scale urbanization and intensive industrial development are not allowed or restricted) by the central government on cropland (12.5%), forestland (32.5%), DPZ (12.5%), DRZ (40.2%), and KEFZ (24.3%) has reached 122% of the land mass in China. Together with the construction land, grassland, and plantations, the summed percentage of different land demands on China’s land mass will be 154.4% (Fig. 1). Accordingly, it is evident that significant overlaps exist among different types of redlines. Take the relationship among redlines that include the national nature reserves (data source similar to Wu et al., 2011) of DPZ, DRZ, and KEFZ as a typical example; the union set of DPZ, KEFZ, and DRZ covers approximately 41.1% of the land surface in China, and the overlaps between DPZ and KEFZ, DPZ and DRZ, and KEFZ and DRZ account for 9.7%, 13.1%, and 34.1% of the union set, respectively (Fig. 2). Moreover, the development of socioeconomic sectors will compete with redlines for land resources. This may necessitate management innovations at the central government level to facilitate collaborations among different ministries involved in the management of conservation redlines and other land-use demands.

There are also debates about certain redlines. There are two viewpoints regarding the redlining of cropland conservation, where one holds that the 120 million ha redline is not necessary because food security can be fulfilled by agricultural technological development and imports; in contrast, the other viewpoint warns of the possibility of cropland quality
degradation because of the inevitable occupation of high-quality cropland for other uses while compensating for cropland loss with newly reclaimed low-quality cropland (Kong, 2011). In the latter situation, food security will still be at risk even if the 120 million ha redlined for cropland conservation is not violated. In reality, the strict cropland protection policy still failed to curb the loss of cropland to other uses. The national average cropland loss rate was 6.04% from 1998 to 2007, approaching 120 million ha redlined for cropland conservation (Song, 2011). Cropland occupation by other uses (mainly construction [53%] and ecological restoration [45%]) and cropland reclamation from other land sources coexisted with high spatial variation. The cropland change during 2000 and 2008 resulted in a net loss of 44 million tons of grain production because the area and productivity of the new reclaimed croplands were inferior to those occupied by other uses (Yang et al., 2010). Along with the quantitative loss of cropland, soil quality decline and soil pollution are less obvious threats to the cropland redline management and put food production and human health at risk (Chen, 2007; Tang et al., 2010; Wang et al., 2012b).

More heated debates surround the designation of DPZ and DRZ under MFOZ. DRZ accommodated 110 million people in 2008, and the livelihood needs of the large population and the socioeconomic development momentum have challenged the management of DRZ. The designation of DPZ was believed to be problematic, unnecessary, and impractical because of its overlook of the characteristics of natural resources, ecological functioning, human activities, and conservation requirements (Wang et al., 2009). The designations of DRZ and DPZ have been perceived by the local governments in these zones as a huge opportunity cost because of restricted or prohibited industrial development. Therefore, they are less willing to cooperate in curbing development and strengthening conservation in a practical sense without suitable economic compensation (Dai et al., 2013). In actuality, DPZ, KEFZ, and DRZ are all newly introduced spatial management objects to strengthen ecological conservation and environmental protection. The only approach for practical management of these areas so far is financial incentive from the central government. For example, financial support from the central government has been provided to the 451 counties in the DPZ, KEFZ, and DRZ areas since 2008, with an increasing trend to 30 billion RMB (approximately 4.8 billion USD) in 2011 (Qian et al., 2012). This money has been used as economic incentives for county-level governments that have made evident progress in improving ecological and environmental quality under their administration. However, a holistic and comprehensive management framework for effective implementation of DPZ, KEFZ, and DRZ is still being researched from multi-dimensional perspectives, such as ecological compensation (internationally known as payment for ecosystem or environmental services) (Dong, 2009; Chen et al., 2010a), management effectiveness monitoring and assessment (Qian et al., 2012; Wang et al., 2012a; Li et al., 2013), population policy (Niu, 2009; Lou and Hou, 2012), environmental management policy (Guo and Wang, 2011), and the rule of law (Bai, 2011; Meng and Chen, 2011).
4. **Redlining from the management paradigm to practical tools**

The redline paradigm for resource and environmental management at China’s central government level resulted from the degradation of resources and environmental conditions, growing national economic prosperity, and the popularization of environmental awareness. The redline paradigm designated targets for the amount of resources or regions important for management and conservation, and largely includes quantity-based strategies for resource and environmental management. Significant overlaps and high socioeconomic pressures are evident (Figs. 1 and 2) because of inadequate communication and collaborations among different sectors as well as insufficient legal and institutional capacity building. These are the same problems that are thought to hinder the effectiveness of pollution control (Liu et al., 2012b). Environmental quality and management effectiveness need to be taken seriously to advance the redline paradigm further as a long-term practical resource and environmental management tool. Therefore, a paradigm shift from quantity-based to quality-based redline management strategies for resource use and environmental conservation is urgently needed. To facilitate this transition, trade-offs in multi-objective land management need to be recognized (Bradford and D’Amato, 2012), and several steps need to be taken.

Legally, it is crucial to strengthen the executive capacity of redline management by rule of law. Problems with environmental pollution and ecological degradation largely result from an inadequate legal framework and weak enforcement (Zhang et al., 2011). It is even recognized that environmental responsibility needs to be shared by multiple stakeholders, including the public administration of central and local authorities and all natural and legal persons (Petrescu-Mag and Petrescu-Mag, 2010). Government leadership and control play key roles in natural resource and environmental management because of the common resource properties of natural and environmental capital. Furthermore, research has revealed that enhancing environmental responsibility and the commitment of governmental agencies is important in fostering environmental friendly behaviors across society (Fahlquist, 2009; Davies and White, 2012). Therefore, the liabilities of different levels of government regarding resource and environmental management, which is contemporarily quite weak, need to be clearly defined and enforced during the advancement of the legal system related to resource use and environmental conservation in China. Based on the successful reduction of pollutants emissions, including sulfur dioxide, and the chemical oxygen demand, legislation needs to better incorporate the environmental target responsibility system on both pollution control and ecological conservation at the central government level. In addition, while forming the redline management paradigm, strict performance assessment mechanisms need to be established to gauge the enforcement of environmental laws and policies by local governments. These measures will help ensure the real-world effectiveness of ecosystem and environmental management (Liu et al., 2012b).

Administratively, developing closer collaborations among different governmental sectors is crucial to enforce the management of resource and environmental redlines. Successful cases of collaborative management have been reported both in China and internationally. In China, collaborations have been improved in local governments – especially at the county level – for concerted and effective implementation of ecological restoration and conservation projects, such as reforestation and soil and water conservation (Liu, 2010). Typical international cases include local-scale coastal zone management (Ruttenberg and Granek, 2011), the national oceanographic partnership program in the United States of America (Decker and Reed, 2009), and the successful collaborative forest research and management in Canada (Thompson and Pitt, 2003). In China, three levels of government are important for natural resource and environmental management, including the central, provincial, and county governments. The responsibilities of different natural resource and environmental management areas are scattered in various governmental agencies, such as in the sectors of forestry, agriculture, hydrology and water resources, and environmental protection. However, natural resources and environmental quality are closely interconnected as integrative ecological and environmental systems, and the overexploitation or degradation of one part of the system will definitely impact the whole. Therefore, natural resource and environmental management requires an ecosystem approach, which has been advocated as a powerful and holistic strategic framework for developing environmental policy for the management and sustainable use of land, water, and living resources (Holt et al., 2011). The ecosystem approach requires close collaborations among different levels of government and the affiliated sectors responsible for natural resource and environmental management. Collaborations at the central government level will improve the legislation and macroscopic policy making, setting a blueprint for a sustainable future that acknowledges the redlines as important approaches to natural resource and environmental management. The collaborations among local governments will contribute to the specialization of the resource and environmental management vehicles under the central government’s legal and policy framework according to the local socio-ecological settings.

Economically, the enforcement of redline management will incur costs for the residents, firms, and local governments in terms of the loss of natural resource and environmental service uses, which are largely common goods. This situation often leads to conflicts among different stakeholders because of the unbalanced share of the costs and benefits for implementing redline management. This is typical in the field of conservation and can be exemplified by the traditional conflicts faced by protected area management and more recently by the bargaining on the extent of DRZ and DPZ in the demarcation of MFOZ in China (Liu et al., 2006; Ma et al., 2009a; Fan et al., 2012). Therefore, economic incentives need to be created to make redline management work smoothly on the ground through payment schemes for environmental services (PES). These payments can be supported financially by the government, the industrial sector, voluntary donations, and international aid. PES has been advocated globally as an important approach to encourage land managers to protect
and enhance the environment (Chen et al., 2010b; Gibbons et al., 2011). China has already had some experience in project-based PES, such as the Natural Forest Protection Program and the Grain to Green Program implemented since the late 1990s, and positive ecological and economic results have been reported (Liu et al., 2008). However, redline management is region-based and calls for more integrated approaches for the design, implementation, monitoring, and assessment of PES to improve the effectiveness and cost-efficiency. From the international knowledge and experiences in PES, the integrated approach needs to incorporate at least the regional differentiation of ecosystem service provisions and socio-economic contexts, policy adaptability to the regional characteristics, payment methods, sources of financial supports, capacity building, and scale issues (Wunder et al., 2008; Corbera et al., 2009; Clements et al., 2010; Gibbons et al., 2011; Armsworth et al., 2012).

Socially, public participation in redline management should be facilitated through the best available approaches. Societal support has proven to be an important factor influencing environmental management effectiveness (Tang et al., 2012). Evidence indicates that a lack of transparency and public participation severely limits the effectiveness of an environmental impact assessment as a basic tool for environmental management in China (Tang et al., 2005). Under a state-led environmental reform process, public participation is vital for further environmental improvements (Martens, 2006). Positive signs of public participation in environmental governance have been observed in China (Zhong and Mol, 2008; Ma et al., 2009b), though the mechanisms and capacity for public participation are still quite weak (Song et al., 2011). With the formation of the redline paradigm at the central government level for resource and environmental management, public participation needs to be promoted as a formal tool to improve the capacity and performance of redline management. Legal and institutional arrangements are urgently required for the design of public participation mechanisms based on procedures such as environmental information disclosure, stakeholder involvement, and participation channels (Gunes and Coskun, 2010; Song et al., 2011; Kelly et al., 2012; Liu et al., 2012).

5. Conclusion

With a rapidly growing economy and a greening nation with over one fifth of the world population, China will continue to contribute to global human wellbeing and environmental sustainability. The evolution of the redline paradigm for resource and environmental management and its enforcement are efforts made by the Chinese central government to act sustainably. These efforts are potentially good solutions for conflict resolution between conservation and development under harsh human–nature relationships. Theoretically, the targets for redline management are socio-ecological systems with overwhelming complexity. From the present analysis, we find significant overlaps among different conservation redlines and other land development requirements. The established redlines are imperfect and subject to hot debates. Therefore, we suggest to improve the redline management paradigm from legal, administrative, economic, and social participation perspectives. Legally, to improve the effectiveness of ecosystem and environmental management effectiveness, the environmental legislation at the central government level and the holistic environmental target responsibility system at the local government level urgently need to be strengthened. Administratively, management collaborations as required by the ecosystem approach need to be enhanced among different levels of governments and their environment-related agencies. Economically, payment schemes for ecosystem services need to be established according to the spatial heterogeneity of ecosystem supply and demand, the allocation of environmental conservation costs and benefits, and the heterogeneity of stakeholders. Socially, public participation needs to be defined as an important environmental policy to encourage social resources in supporting environmental conservation and society-wide supervision of environmental behaviors of natural and legal persons and local governments. These four approaches need to be closely linked to bring about highly efficient and effective ecosystem and environmental management. These approaches may also be informative to other nations with similar conservation and development situations. Furthermore, economic globalization may have important impacts on ecosystem conservation (Lenzen et al., 2012). International exchange and cooperation are thus needed to disentangle the complexity of socio-ecological systems for effective and sustainable natural resource and environmental management in China, which could potentially benefit the whole world.

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