



Short communication

Challenges facing socioeconomic development as a result of China's environmental problems, and future prospects

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ABSTRACT

China's policymakers are being forced to balance socioeconomic development with the need for environmental protection. In this paper, we have briefly discussed the main characteristics of the environmental problems that China will face in the 21st century and the challenges that must be met in order to develop policies that will support environmental management. As our discussion in this paper shows, the negative effects of China's economic development on its environment will continue to rise for some time, despite strong efforts to reverse the situation. It will also be necessary to change China's resource-intensive mode of economic development, change the economic development philosophy to one in which controlling pollution is as important as economic development, and raise public awareness of the need for environmental protection.

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1. Introduction

China has experienced explosive economic growth in recent decades, but this is creating severe pressure on the environmental services required to support its people and its economy. Increasing urbanization is another important environmental pressure, since this phenomenon has been one of the most spectacular responses to China's 1978 economic reforms, which became the driving forces behind China's economic growth. Both the economic growth and increasing urbanization have had serious impacts on China's environment, since neither was planned for nor anticipated (Abramson, 2006; Cao et al., 2009c). As a result, these changes have caused consumption of natural resources (including arable land) and generation of pollutants at an increasingly unsustainable rate, in part due to a labor-intensive economic model that uses resources inefficiently (Streets, 2006; Cao et al., 2011).

Government statistics show that China's population grew at an annual average rate of 1.83% from 1952 to 1990, and an average annual rate of 0.22% from 1990 to 2010. This has been

accompanied by average capita income growth rates of 6.7 and 19.7%, respectively, and increases in annual per capita income of 4.9 and 7.1%, respectively (Cao, 2012a). As a result, total energy consumption and coal consumption increased by 15.1% from 1952 to 1990, and by 22.9% from 1990 to 2010. Emissions of industrial pollutants are increased by 14.9% annually from 1952 to 1990 and by 12.2% annually from 1990 to 2010. This has led to severe environmental problems. Unfortunately, the emissions of industrial pollutants grew even faster than China's economy (Zheng and Cao, 2011). The proportion of total pollution emitted by industries was 42.6% from 1952 to 1990 and 43.6% from 1990 to 2010, suggesting that pollution is increasing slowly as a result of technological and industrial development. In 1980, China's emissions of industrial pollution began to decline while the total income growth rate remained high (around 10.0% annually), but the environmental quality continued to deteriorate (CSB, 2012).

The deterioration of environmental quality and increasing pollution of the environment have been important negative side-effects of China's rapid economic development, rapid urbanization, and large population. A large part of the problem has been that China's environmental policy developed belatedly in response to the consequences of economic growth rather than being integrated with the country's economic development policy right from the start. In this paper, we offer an overview of these changes that

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has hitherto been lacking, in the hope that this will help both the Chinese government and the international community to develop more effective policy responses that integrate the need for socioeconomic development with the need to reduce pollution emissions and thereby better protect the environment. We believe that this discussion is relevant to readers of *Ecological Engineering* because many developing countries are seeking to emulate China's economic success, and monitoring will be necessary to detect whether following China's path will adversely affect their ecosystems (i.e., so that measures can be taken to solve the problems before they become serious). In addition, all natural ecosystems are increasingly sustaining impacts from socioeconomic systems, and it's important for researchers and managers to understand the context that produces these impacts; without that understanding, it is impossible to protect endangered ecosystems.

2. Economic development and environmental policy

Environmental degradation is clearly costing China dearly, although the magnitude of this cost has been estimated using a range of techniques that produce different outcomes. For example, the aggregate annual cost of China's environmental damage has been estimated at between 4.5 and 18% of GDP (CSB, 2012). Water pollution alone is estimated to cost between 0.6 and 4.5% of GDP, with estimates averaging around 1.7%, and the cost of air pollution is similar (CSB, 2012). This is an important predicament for policy-makers and environmental managers because it is difficult to focus resources and policies on the correct problems when the problems are not clearly understood. The obstacles that pollution creates for China's rapid economic growth and social development have forced the government to recognize the need for increased investment in environmental protection. The 12th Five-Year Plan (2011–2015) was approved by the National People's Congress, China's top legislature, in March 2011. The central government committed US\$600 billion to growing sectors such as information technology, clean energy, environmental protection, and scientific research and innovation (He et al., 2012). From 2003 to 2008, China invested 1636 billion RMB in environmental conservation (ca. US\$240 billion based on the approximate rate of exchange in 2010). For its Three Lakes (Taihu, Chaohu, and Dianchi) and Three Rivers (Huaihe, Liaohe, and Haihe) programs to restore polluted bodies of water, China invested 96 billion RMB (ca. US\$14 billion) over a 6-year period (Cao et al., 2011). The Chinese government has taken several important additional steps toward pollution control. For example, the government will now punish violators of state environmental regulations who cause serious pollution of the land, the water, or the atmosphere. The penalty is up to 3 years of imprisonment and a large fine; up to 7 years of imprisonment can be imposed in the most serious cases (MEP, 2009).

The concept of sustainable development has been gaining in popularity across many sectors of the Chinese economy and throughout much of China's society (Cao, 2012b). To increase protection of a rapidly degrading environment, the National Environmental Protection Agency (formed in 1987) was elevated to the rank of a full ministry in 2008, and was renamed the Ministry of Environmental Protection (MEP, 2009). Though China's environmental policy is still a work in progress, it is aiming in the right direction (that is, the situation would have been much worse in the absence of this policy) and it has already achieved some successes, including strong investments in renewable energy and significant reductions in the emission of pollutants per unit GDP (Chen and Cao, 2013). Unfortunately, some of the environmental policy has not been effective or has suffered from an implementation gap

(Fang et al., 2009). Part of the problem is that the structure of China's environmental organizations forms a complex grid that is composed of many vertical and horizontal linkages (Guan et al., 2011). In the vertical portion of the hierarchy, each level of government below the national MEP, continuing down to provincial and even municipal levels, has its own Environmental Protection Bureau. The relationship between these Environmental Protection Bureaus and other government authorities is also structured horizontally (Cao, 2010). A good example is the Ministry of Forests, which competes with MEP for budgetary money at a national level and which has policies that sometimes conflict with MEP policies, and similar horizontal relationships and conflicts exist with Environmental Protection Bureaus at progressively more local levels. At all levels, these agencies rely heavily on the corresponding level of government for funding and other forms of support, such as the authority to implement changes or overrule the actions of other agencies (Liu, 2010).

3. The challenge of balancing environmental needs with socioeconomic development

China's struggle against environmental degradation has resulted from the need to simultaneously alleviate poverty and control population growth. Despite China's explosive economic growth, 28.2 million of its people still suffered from extreme poverty in 2009 (Liu, 2010). Because much of China's industry has traditionally been labor-intensive, with low energy efficiency and (until recently) low technological inputs, the current high energy consumption and the high emission of pollutants caused both by energy consumption and industrial processes have led to some of the most severe environmental problems faced by any major country, and these problems are worsening because of the increasing resource requirements to support the country's rapid industrial and urban development (Liu, 2010). The social and economic forces associated with this growth have had a range of effects, from positive (e.g., the recent growth of a software development industry) to negative (e.g., continuing reliance on coal for energy), and the effects have ranged from direct (e.g., discharge of untreated urban wastewater into rivers) to indirect (e.g., increasing depths to the water table in many areas).

China is simultaneously facing severe problems due to desertification that has resulted from a combination of climate change and unsustainable uses of environmentally fragile areas. The government has implemented huge programs to mitigate these problems, but although some of these programs have achieved impressive results, the consequences have not all been positive. For example, although forest cover has increased to about 18% of China's land area as a result of aggressive afforestation programs, timber yield and quality remain lower than elsewhere in the world (Cao, 2011). The estimated mean timber volume in China was 67.2 m³/ha in 2005, versus an average of 81 m³/ha for East Asia, because much of the planting has occurred in regions with insufficient water to sustain tree growth (Yin et al., 2010). Extensive efforts to plant trees in arid and semiarid regions have also caused environmental deterioration when the trees consumed too much of the limited soil moisture; this has led to plantation failures, reduced overall vegetation cover, and increased severity of wind and water erosion (Cao, 2008; Cao et al., 2010a). There is therefore a great need to develop decision-support tools to guide the managers of China's re-vegetation programs to solutions that are more suitable for local environmental conditions (e.g., McVicar, 2007; Wang and Cao, 2011). Better site selection and the consideration of "evolutionary" re-vegetation schemes that account for limits on plant

growth imposed by local environmental constraints are desperately needed (Cao et al., 2009b; McVicar, 2010).

However, important though desertification and reforestation may be, these are not the only significant problems, nor are they necessarily the most important problems. In the rest of this section, we will discuss three examples of crucial problems that China faces: pollution and overuse of the water resource, air pollution, and changes in land use and urbanization. There are obviously other problems, such as the need to increase protection of biodiversity and wildlife, but here we will focus on aspects related to pollution.

3.1. Water shortages and contamination

China's water resources are in short supply, severely polluted, and often wasted. The available per capita water volume is 2200 m³, only 25% of the global average (MEP, 2009; Shao et al., 2006). This water shortage is exacerbated by serious pollution, since more than 80% of China's rivers have at least some degree of contamination. China's State of the Environment Report for 2008 (MEP, 2009) noted that 38.8% of the river sections, 55.8% of the lakes, and 19.8% of the reservoirs that were monitored were unfit for human contact (i.e., pollution levels were at or above the levels defined in the country's Grade IV standard). More than 60% of China's 669 large cities (cities with a population >100 000) are experiencing water shortages, and the situation is severe in 110 of these cities (Liu, 2010). Water resource problems alone cost China an estimated 2.3% of GDP in 2008 (World Bank, 2009), but other estimates are as high as 4.5% of GDP (CSB, 2012). In addition, little urban and industrial wastewater is treated before being released back into the environment: the situation is best in Shanghai, where about 10% of the discharge is treated, but there is virtually no treatment for >75% of the water used by China's people (Liu and Diamond, 2005). The increasing wastewater discharge that has accompanied rapid industrial growth and urbanization exacerbates the water scarcity by contaminating water that might otherwise be suitable for human use (Zheng and Cao, 2011).

As a result of this pollution, water is now a public health risk in China. More than half of China's people drink water contaminated with chemical and biological wastes such as petroleum, ammonia nitrogen, volatile phenols, and mercury. The health impacts of this water pollution cost an estimated US\$3.9 billion annually, and there is evidence of increasing cancer incidence associated with pollution of the drinking water supply (Liu and Diamond, 2005). Furthermore, water is used inefficiently. China's GDP per unit of water consumption is only about 33% of the world average (Fu, 2007). Since 2005, water consumption per unit GDP has gradually decreased, and the central government's goal was to reduce water consumption per unit GDP by 20% between 2006 and 2010 by modifying the national development model and industrial structure (World Bank, 2009).

3.2. Air pollution

Increasing attention is being paid to "carbon pollution" by China (i.e., increasing emission of greenhouse-effect gases such as CO₂ and CH₄) and the resulting contribution to global warming (CRAES, 2009). In 2009, CO₂ emissions by China amounted to 67.2 Gt per year (CRAES, 2009). Although China plans to reduce CO₂ emissions per unit of GDP by 40–45% from the 2005 levels by 2020 (Xinhua Net, 2009), and there are encouraging signs of progress, this progress is jeopardized by the fact that GDP is increasing so rapidly; even if the emissions per unit GDP decrease drastically, total emissions are likely to continue increasing for some time.

Thus, reducing the absolute amount of CO₂ emissions by transforming the economic development model (e.g., by replacing some of the current industrial economy with a growing "knowledge economy") will be essential for China to achieve sustainability.

In China, the consumption of energy resources (mainly coal) increased from 510 Mt standard coal equivalents (sce) in 1978–2650 Mt sce in 2007, an increase of more than 400% (CSB, 2012). This increase in energy consumption has resulted from the energy demands created by rapid economic growth, and air pollution is growing worse in direct proportion to energy consumption. Coal is one of China's dominant forms of energy, but its combustion contributes to air pollution through the production of both particulate matter and gases such as sulfur dioxide (SO₂), which contributes to acid rain. Acid rain fell in 252 of 477 Chinese cities that were monitored in 2008 (Fu, 2007). China's cumulative carbon emissions from fossil fuel combustion between 2006 and 2020 will total more than 33 Gt (i.e., an average of about 2.4 Gt annually, not accounting for compound growth rates), compared with an annual baseline of 1.6 Gt in 2005 (Gregg et al., 2008). Thus, the government has proposed an official target of creating an additional carbon stock of 683 Mt in woody biomass (created through nationwide tree-planting programs) to counteract some of this increase; unfortunately, this only amounts to about 2% of the country's cumulative CO₂ emissions during the same period (Wang and Cao, 2011).

3.3. Land use and urbanization

Urbanization is rapidly accelerating as a result of the increasing number of people moving from rural areas to urban areas in search of jobs and better living conditions (Zhong et al., 2013). However, this process is placing increasing pressure on the environment that sustains the rapidly expanding cities (Cao et al., 2010b). From 1998 to 2005, the area of farmland decreased by 7.6 million ha due to urban expansion, amounting to a loss of 6.2% of China's total arable land (Cao, 2008). But this rapid urbanization has not solved another serious problem: 48.7% of China's population was rural in 2011, and nearly all rural residents use highly polluting biomass fuels and coal for their household cooking and heating (CSB, 2012). The indoor air pollution that results from the use of these fuels is responsible for an estimated 420,000 premature deaths (i.e., deaths at ages younger than the average expected lifespan) annually (Cao, 2011). In 2002, China introduced an indoor air quality standard (CMEP, 2002) to limit the level of indoor particulate matter (PM₁₀) to 150 µg m⁻³. However, the number of rural households and their distance from government offices means that enforcement of the standard will be nearly impossible outside of large cities. More seriously, in the absence of alternative fuels at an affordable cost, most rural residents will be forced to continue using highly polluting fuels, with serious consequences for their health.

This situation is expected to continue, and the pollution rate may even increase during the coming decades if the economic growth rate remains larger than the decrease in pollution per unit of GDP. A related problem is the desire of increasingly affluent urban residents to own a car. This has led to a rapid increase in the number of urban cars, with China's vehicle population reaching 199 million, including more than 8.5 million urban cars, by 2010 (Xu et al., 2011). This has been accompanied by major traffic congestion. The personal ownership of cars currently totals only 70 million, which is lower than Japan's 75 million cars and equivalent to one-quarter of the U.S.'s 285 million cars (Xinhua Net, 2010). In China, as is the case elsewhere in the world, individual use of cars is less efficient than the use of public transportation such as buses, thereby increasing per capita air pollution in cities.

4. Challenges and future prospects for China's economy and environment

China's reforms have led to a transition in which a gradual decentralization of power has shifted the responsibility from the central government to local levels of government, thereby empowering local governments to develop distinct regional models of development (Guan et al., 2011). Local officials now have substantial flexibility to pursue economic goals for their areas of responsibility. In many cases, this local flexibility has been a key factor underlying the rapid growth of China's economy. Unfortunately, the resulting lack of consistent, strongly enforced environmental regulations has led to severe impacts on China's environment, which is becoming increasingly degraded in some regions as economic development continues to accelerate. This environmental degradation is also beginning to create impacts on economic development, such as the large GDP losses described in Sections 2 and 3 of this paper. This has led to a significant increase in government interest in mitigating the problem, but has also increased public awareness of the need to improve the environment.

In Western countries, non-governmental organizations (NGOs) formed of citizens often serve as watchdogs, encouraging governments to develop and implement new policies, but in China, local governments are reluctant to allow NGOs to operate. Nonetheless, growing public awareness of the problem may lead to the emergence of such NGOs. A recent survey of 5000 Chinese citizens (Cao et al., 2009a) revealed a high level of awareness of the importance of the environment; although responses differed between groups with high and low annual incomes and between urban and rural residents, the overall results suggest that 78% supported government programs such as Grain for Green that are designed to protect the environment, and 76.2% believed that the environment was at least as important as the economy. Unfortunately, though many Chinese urban residents are environmentally aware, fewer are willing to take action to improve the situation because there is a gap between their values and their actions. One reason is that they believe the government will take care of the mess and that there is no need for them to act. This seems to be a negative outcome of China's traditionally centralized environmental governance model (Harris, 2006).

Sustainable land use is another policy issue that must be addressed by all levels of government and is therefore a shared responsibility. National land management policies and plans are one of the best ways to ensure efficient and equitable distribution of land resources because they set a similar standard for all parts of the country (Ma et al., 2013). The empowered local governments still retain their ability to choose the solutions that are most appropriate for local conditions, based on their superior knowledge of those conditions, but must develop plans that meet strict national standards. The national land management policies must address both mid- and long-term national directions for the distribution and utilization of land, and must seek ways to promote decentralized development that relocates urban expansion to areas that can best sustain the new urban uses. For example, urban development should not replace farmland, areas such as wetlands that protect a region's water resources, or other sensitive or environmentally important land.

In response to rising public expectations, China's national work plan for 2010 was announced in late March at the country's two major annual meetings. This plan emphasized environmental protection. At the National People's Congress, officials announced plans to spend more than 140 billion RMB (about US\$20.7 billion) on engineering solutions (e.g., sewage treatment plants) to solve the country's environmental problems. New initiatives are also being planned for health and food safety (Xin and Stone, 2010;

Wang et al., 2013). In the preparations before China's participation in the Copenhagen Climate Summit, China pledged to reduce energy consumption per unit GDP by 40–45% from 2005 levels by 2020 (Yin et al., 2010). Because of the environmental costs of reliance on fossil fuels, renewable energy is becoming an increasingly important part of China's environmental policy. Wind energy and other forms of renewable energy such as hydroelectric and solar power have been proposed as alternatives to coal for the generation of electricity, and if these technologies can replace a significant amount of China's current coal consumption, this initiative has the potential to create substantial reductions in CO₂ emissions. For example, it has been estimated that wind power alone could fully meet the projected increase in demand for electricity that will occur between now and 2030; this will be crucial, since the projected demand for electricity in 2030 is about twice the current consumption level (McElroy, 2009).

China has begun rapidly building capacity for renewable energy, with more than 350 billion RMB invested in the development of wind farms, hydroelectric power, and solar power (DCSP, 2011). Strategically, China is trying to establish a decision-making mechanism that integrates environmental protection with economic development. The country is also attempting to change its mode of economic development both to encourage sectors that have low energy demands, such as computer software development, and to promote a more sustainable economy that emphasizes increased efficiency of resource use and increased resource recycling (Beddoe, 2009). For these efforts to succeed, China must modify an important aspect of how its government functions: currently, government officials are rewarded for actions that increase economic growth, with no reward for environmental protection and with indirect penalties when efforts to protect the environment slow economic growth.

Instead, officials must be rewarded for efforts to harmonize socioeconomic development with protection of the environment; in some of the most severely endangered areas of the country, it may even be necessary to shift the balance wholly toward rewarding efforts to protect the environment. This will create a favorable sociopolitical environment in which officials feel comfortable making and enforcing policies and laws that are oriented toward sustainable development. This will be part of an overall shift in attitude based on the recognition that continuing growth of China's economy will require increased investment in the ecological and environmental sectors to improve the protection and rehabilitation of China's environment.

China's progress toward environmental sustainability remains difficult, with negative factors currently outweighing positive ones (Liu, 2010). Given its increasing global economic and environmental importance, China must clearly accept a more active leadership role in steering the world into a sustainable future.

Disclaimer

The opinions expressed here are those of the authors and do not necessarily reflect the position of the government of China or of any other organization.

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