Chapter 3

Asia's Environmental Problems: Common Features, and Possible Solutions

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December 2012

This chapter should be cited as
Howes, S. and P. Wyrwoll (2012), 'Asia's Environmental Problems: Common Features, and Possible Solutions', in Zhang, Y., F. Kimura and S. Oum (eds.), *Moving Toward a New Development Model for East Asia- The Role of Domestic Policy and Regional Cooperation*. ERIA Research Project Report 2011-10, Jakarta: ERIA. pp.55-120

CHAPTER 3

Asia's Environmental Problems: Common Features, and Possible Solutions

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Asia's developing economies are faced with serious environmental problems that threaten to undermine future growth, food security, and regional stability. This chapter considers four major environmental challenges that policymakers across developing Asia must address in the coming decade: water management, air pollution, deforestation and land degradation, and climate change. These challenges, each unique in their own way, all display the features of "wicked problems". First developed in the context of urban planning, and now applied much more broadly, wicked problems are dynamic, complex, encompass many issues and stakeholders, and evade straightforward, lasting solutions. Detailed case studies are presented in this chapter to demonstrate the intricacy and importance of Asia's environmental challenges. The fundamental implication of this finding is that there will be no easy or universal solutions to Asia's environmental problems. This is a warning against over-optimism and blueprint or formulaic solutions. It is not, however, a counsel for despair. We suggest seven broad principles that may be useful across the board. These are: a focus on co-benefits; an emphasis on stakeholder participation; a commitment to scientific research; an emphasis on long-term planning; pricing reform; tackling corruption, in addition to generally bolstering institutional capacity with regard to environmental regulation; and a strengthening of regional approaches and international support.

Keywords: Asia, environment, policy, wicked problem, air pollution, water, deforestation, climate change.

JEL Classification: O44, Q58, Q56, O10, O53, Q28, Q53.

1. Introduction

Towards the end of the 20th century the economic discipline began to seriously acknowledge the central importance of environmental sustainability to the process of economic development (see Arrow, *et al*. 1995, Dasgupta 1996). It is now widely accepted that long-term economic growth requires not just accumulation of technology, physical capital, and labour, but also the preservation of the natural capital base (Brock and Taylor 2005, OECD 2011).

Whereas other factors of production may be replaced and are often substitutable, the ecosystem services provided by waterways, forests, and fertile land are an essential and largely finite resource. Once damaged, they may become unusable for long periods, and their repair is often an expensive and protracted process. As these natural systems are the primary source of economic inputs such as food and clean water, their degradation through pollution and over-use is an enduring brake on economic development. For this reason, academics and policymakers have become increasingly concerned with national accounting procedures that include measures of environmental capital (see Stiglitz, *et al*. 2009).

In 1987 the United Nations report on sustainable development foresaw the need for "a new era of economic growth, one that must be based on policies that sustain and expand the environmental resource base" (WCED, 1987). It has taken a long time for that message to sink in. As the Commission on Growth and Development (2008, p. 135)—chaired by Nobel Laureate Michael Spence and constituted predominantly of senior developing-country economic policymakers (including from China, India, and Indonesia)—put it:

It is only a slight exaggeration to say that most developing countries decide to grow first and worry about the environment later. This is a costly mistake… The poor suffer the most from many kinds of pollution… Early attention to environmental standards serves the interests of equity as well as growth.

There could be no more important message for the world's economic powerhouse, the Asian region[1]. The rising Asian economies are incredibly successful when judged by their rapid growth, but less so when environmental damage is accounted for.[2] They are now confronted by the prospect of a dwindling supply of environmental capital to support the growing demands of a more numerous, wealthier, and urbanized population. Clean and ample water, arable land, and unpolluted air are just some of the vital ecosystem services necessary to maintain Asia's emergence as the engine of the global economy. Yet recent economic expansion has largely been pursued at the expense of the environment, undermining delivery of these ecosystem services in the future. This unsustainable trajectory will, if allowed to continue, progressively hinder future development.

Environmental damage not only undermines the sustainability of growth, putting future welfare at risk, but also exacts a large welfare cost here and now. Low-income groups, particularly in rural areas, disproportionately subsist on environmental services. Poverty limits the ability of poor households to find alternatives to a contaminated water source or harmful cooking fuels. Where the capacity to earn income or receive education is affected, such as health problems related to pollution and food insecurity, environmental problems reinforce poverty. Consequently, environmental degradation is a fundamental development issue in Asia today, as well as to 2030 and beyond.

Recognizing these risks, policymakers throughout Asia are giving increasing weight to environmental concerns. The economic imperative for environmental protection is now a principal policy issue. China's 12th Five Year Plan (2011–2015) places "green growth" at the centre of the country's development path, with ambitious targets for renewable energy, carbon intensity, water and energy efficiency of production, emissions of major pollutants, among others (see NDRC 2011). The Indian government has similar goals, and views water security in particular as

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[1] In the present study, we focus on the major developing economies in Asia, namely China, India, and the Association of Southeast Asian Nations (ASEAN).

[2] China's one-off attempt to calculate a "Green GDP" found that environmental pollution cost 3.05% of GDP in 2004, or around one-third of GDP growth in that year (GoC, 2006). Although such estimates are unavoidably speculative, it is indicative of the true magnitude of damage that this particular figure encompassed only direct economic losses (such as agricultural production and health) and not natural resource degradation or long-term ecological damage (see GoC, 2006).

fundamental to economic development (GoI, 2009, ADB, 2007), whilst ASEAN members formally recognize the necessity of environmentally sustainable growth (ASEAN, 2007). All through Asia, there is now talk of the need for "rebalancing," a wide-ranging agenda which includes giving greater attention to environmental problems.

However, progress will not be easy. Asia faces a range of diverse environmental problems and threats, which this paper's case studies illustrate. What they have in common is their complexity. We have argued elsewhere (Howes and Wyroll, 2012)[3] that it is useful to think of these complex environmental challenges as "wicked problems", a concept taken from the social planning literature, and now deployed more broadly. One characteristic of wicked problems is that there are no easy solutions. Certainly, one cannot expect any of these problems to lessen, let alone disappear, as Asia grows. To the contrary, without sustained policy effort, they will persist if not worsen. While in general an automatic relationship between environmental quality and income per capita does not exist (Stern, 2004, Carson, 2010), the sort of problems which Asia is facing will not, by and large, reduce with growth. Growth will help make more resources available to direct at these problems. However, without effective environmental management, growth will simply heighten the divergence across many facets of economic activity between private and social cost.

More broadly, however, it is not only growth that will not solve Asia's environmental problems. Their nature as wicked problems means that there *are* no straightforward solutions. The set of proposed solutions is dominated by ones which are politically impossible and/or untested. The message of this paper is that green growth and rebalancing will be needed, but will not be easy. This paper attempts to move the debate forward by proposing some general guidelines which go beyond the aspirations of green growth and rebalancing, and which might help us move towards a solution for Asia's complex environmental problems.

This is not the first survey of the environmental problems facing Asia. Coxhead (2003) analyzed the features of the relationship between economic growth and

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[3] This paper draws on the analysis of Howes & Wyrwoll (2012), but without the detailed demonstration that Asia's environmental problems are indeed wicked ones. It extends the analysis to consider "green growth" and "rebalancing" as policy responses to these environmental problems.

environmental resources in different parts of the region. Zhang (2008) reviewed environmental degradation due to burgeoning energy demand across Asia, and recommended several policies to address the increasing prominence of this issue as economic expansion continues. Bawa, *et al*. (2010) discuss the competitive use of resources by India and China, the need for inter-state cooperation over environmental issues, and the impact of these major players on the broader region. The present analysis differs from these studies by drawing out the common features of Asia's environmental problems in terms of their complexity, and formulating a range of policy responses across the major environmental issues. This study also takes a combined thematic and case-study approach which enables us both to look across the breadth of environmental problems which Asia faces and to consider some key problems in depth.

The following section demonstrates the importance of Asia's natural resource base to economic development, through an analysis of four major environmental challenges to 2030. Section 3 presents seven in-depth case studies. Section 4 explores the implications and presents some general strategies for environmental reform, and links the issue of environmental management to development policy. Section 5 concludes. Note that throughout the paper Asia is defined as India, China and the ASEAN countries.

2. Major Environmental Issues for Asia to 2030

The major environmental problems that confront Asia are grouped in the present study under four themes: water management, deforestation and land degradation, air pollution, and climate change. Marine ecosystems and resources, biodiversity, waste management, and other issues are also important, but in our judgement the four areas above present the most pressing challenges to Asia's development over the next two decades.

For the purpose of analyzing these four broad themes, we present seven related case studies.

- The challenge of water management is illustrated by dam construction on the Mekong River and groundwater extraction in India.
- The challenge of deforestation and land degradation is illustrated by case studies on deforestation in Indonesia and afforestation programs in China.
- The challenge of air pollution is illustrated by regulatory reforms of air pollutants in Delhi, indoor air pollution and improved cookstoves, and the Indonesian deforestation case.
- Climate change crosses all of the above challenges and associated cases, and is also the focus of a section covering climate change mitigation in China.

Before turning to the detailed case studies, the four themes are briefly introduced in the following subsections.

2.1. Water Management

Fresh water is essential to agricultural and industrial production. It is a basic requirement for human life, as well as for other organisms and biological processes. Water resources generally have multiple uses and users, and inadequate management of competitive use has frequently facilitated their over-exploitation and degradation. The depletion and contamination of these resources generates large economic costs, not just by increasing the cost of obtaining a direct input to production, but also through damaging impacts to environmental systems and human health. Consequently, water management is viewed not only as an environmental issue, but as a major challenge to economic development, particularly in Asia's larger economies (see ADB, 2007, NDRC, 2011, GoI, 2009).

Excessive groundwater extraction, pollution from human waste and industry, poor infrastructure, and dam-building are among the factors contributing to degradation of the region's fresh water sources. Major improvements have occurred with regards to water access and sanitation in Asia over the last two decades, but as large numbers still have inadequate facilities (see Table 1 below). Supply- side issues such as these are set to be compounded by altered rainfall patterns due to climate change, particularly with respect to weakening of the Indian and East Asian monsoons (IPCC, 2007). Within the next three decades, the peaking of glacial melt rates during the dry season is likely to transform the major rivers originating in the

Himalayas—such as the Brahmaputra, Ganges, and Yangtze—into seasonal rivers (Asia Society, 2009, Immerzeel, *et al*. 2010).

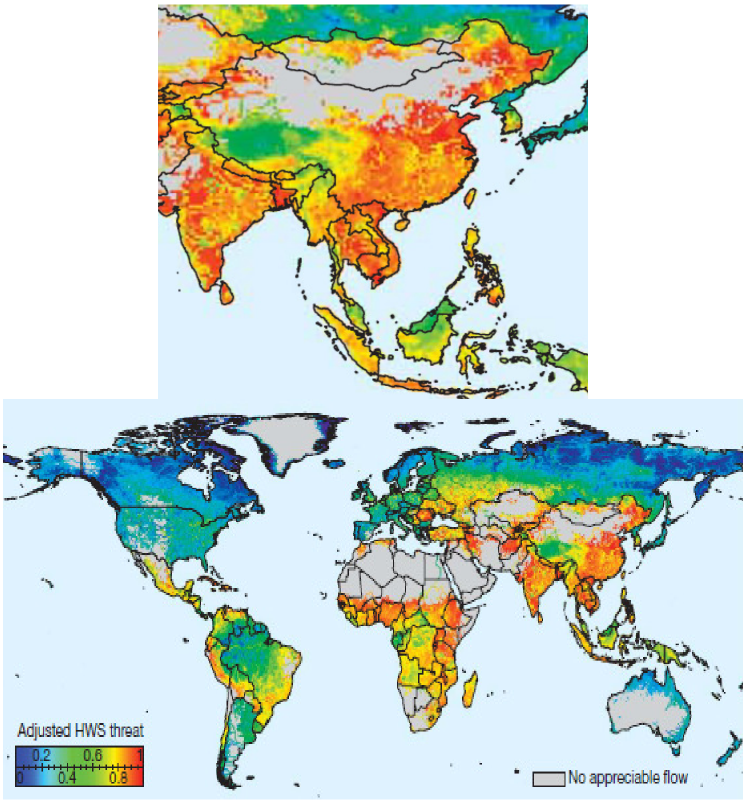
On the demand side, United Nations projections to 2030 estimate that the total population of ASEAN, China, and India—currently comprising 46% of the world's total population—will rise by another 462 million people (UN, 2010). The attendant rises in agricultural, industrial, and urban usage will place even greater strain on dwindling supplies throughout these economies. The scale of this challenge is emphasized by the estimate that by 2030, under current management policies, water demand will exceed supply in China and India by 25% and 50% respectively (WRG, 2009).

Although access to a secure and clean supply of freshwater resources will be a common challenge across Asia to 2030, the nature of this issue will vary in different settings. Increased demand may play a large role in some locations, for instance growing mega-cities like Shanghai. In others, supply-side concerns, such as lower dry-season rainfall or polluted water sources, may dominate. In most settings, some combination of both demand and supply factors will be present. Consequently, the term "water management" used here encompasses a broad mix of water-related issues which also includes: efficiency of water usage; degradation of water resources through pollution or over-use; allocation between competing uses such as agriculture, drinking-water, natural ecosystems, and industry; flood control; coordination between users at a local, national, and international level; treatment of waste water; and water storage, among many others.

The welfare implications of degraded water resources in Asia are substantial. As approximately 70% of water is currently used in agriculture (ADB, 2007), water shortages undercut food security and the incomes of rural farmers. Illness associated with contaminated water reduces labor productivity and causes other health related costs. If supplies continue to deteriorate as demand rises, the costs of obtaining usable water, such as drilling for groundwater, will rise accordingly. Without improved management of pollution, expansion of industrial water usage, particularly in China (see WRG, 2009), may diminish availability for human consumption and other uses. Furthermore, conflict over access to this increasingly scarce resource could arise between and within states (Asia Society, 2009); plans for several China dams on the Tsangpo-Brahmaputra River upstream of the Indian border are perceived as a key threat to the stability of bilateral relations between the two countries (Morton, 2011).

Figure 1 below is a map of human water insecurity which demonstrates the extent of Asia's current water scarcity problems from a global perspective. Table 1, underneath the map, presents statistics highlighting the importance and scale of water management issues in Asia.

Figure 1: Water Security in Asia and the World



Notes: Human water security (HWS) threat index (on a scale of 0 to 1) adjusted for the level of existing technology investment in water infrastructure. This adjustment is made to account for the fact that water security is not simply a function of rainfall patterns (or 'physical scarcity'), but also the level and quality of water infrastructure, such as transmission facilities and storage dams. For further details see Vorosmarty, *et al.* (2010).

Source: Vorosmarty, *et al.* (2010).

Table 1: Selected Water Management Statistics for Asia

Issue/Variable	Location	Description/Value	Source
Water resources per capita[1] (m^3/inhabitant/year)	China	2,112	FAO (2011b)
	Beijing, China	230	World Bank (2009)
	India	1,618	FAO (2011b)
	ASEAN	11,117	FAO (2011b)
	Global Median	4,042	FAO (2011b)
Water pollution	China	28% of rivers and 48% of lakes unfit for any use (including industrial).	World Bank (2009)
	China	~ 300 million rural inhabitants rely on unsafe drinking water	World Bank (2009)
	India	Over 200 districts in 19 states have severely contaminated groundwater	GoI (2009)
Population gaining access to improved water source[2] (1990–2008)	China India ASEAN	425 million 419 million 173.5 million	WHO/UNICEF (2008)
Population without access to improved water source[2] (2008)	China India ASEAN	147 million 142 million 80.2 million	WHO/UNICEF (2008)
Deaths/year of children < 5 years attributable to water source, poor sanitation.	China India ASEAN	49,200 403,500 74,600.	WHO (2011)[3]
Excess water demand by 2030 (as % of demand)	China	25% (199 billion m^3) (2005: - 35%)[4]	WRG (2009)
	India	50% (754 billion m^3) (2005: 18%)	WRG (2009)

Notes: [1] The Food and Agriculture Organization (FAO) standard for water scarcity is 1,000m^3 (FAO 2011b). National or broad-scale aggregates can conceal local or seasonal shortages. For example, ASEAN overall has a relatively high level of per capita water resources, but some cities, such as Manila, or particular areas commonly experience shortages. [2] "Improved water source" refers to: household connections, public standpipes, boreholes, protected dug wells, protected springs, and rainwater collection (WHO/UNICEF 2008). Although the implication is access to a safer water source, this measure does not involve a direct assessment of water quality. [3] Refers to data from 2004. [4] -35% indicates that in 2005 China as a whole was estimated to have an excess supply of water equivalent to 35% of total water demand at that time.

2.2. Deforestation and Land Degradation

Widespread deforestation and land degradation are highly visible examples of the unsustainable use of natural resources in Asia. These issues are intrinsically linked. Unsustainable tree removal practices, such as clear-felling, lead to erosion and soil salinity, as well as disturbance of the groundwater table. In dry-lands, deforestation facilitates the transformation of fertile areas into barren land, a process known as desertification[4]. Once land is sufficiently degraded, it may be unable to support forests again, or even the agricultural use that often drives deforestation in the first place.

[4] Other drivers of desertification include climate change, natural weather variability, and unsustainable farming practices such as intensive cropping and excessive irrigation in lands with poor drainage.

Deforestation and land degradation throughout Asia are caused by various factors, including: demand for timber products and palm oil, intensive farming, and urban sprawl. Poor regulation and, in some cases, corruption have commonly allowed unsustainable practices. However, it has become increasingly apparent throughout the region that the enduring economic costs from unsustainable land-use ultimately overwhelm the more immediate gains. Once sufficiently degraded, woodland ecosystems require time and large expense to recover, effectively eliminating future sources of wood and causing other problems that curb the productivity of the natural resource base. Over-cultivation of agricultural land is increasingly leading to declining soil productivity and, consequently, lower output and, in some areas, food insecurity.

At a regional level, the situation with regards to deforestation is clearly improving. This is due, in large part, to concerted afforestation and forest protection efforts in China, and also, to a lesser extent, India and Viet Nam.[5] China now has the largest area of planted forest in the world and, if anything, the government is elevating its level of ambition in this area. Yet these promising trends are at odds with those in Indonesia, Malaysia, Myanmar, and Cambodia, where deforestation continues on a massive scale (see Table 2). In fact, it would seem that improved regulations elsewhere in Asia, particularly China, are contributing to continuing deforestation in the latter ASEAN countries (Demurger, *et al*. 2009). For example, the expansion of palm oil plantations is a major driver of deforestation in Indonesia and Malaysia (Fitzherbert, *et al*. 2008), and these two countries alone produce over 85% of global palm oil exports. China and India account for 45% of global imports (FAO, 2011b). Limits to expansion of agricultural land in the latter are, to some degree, "exporting" former deforestation problems. Similar trends in the Asian timber trade have also emerged from recent analysis (see Meyfroidt, *et al.* 2010).

Land degradation is a major economic issue primarily because, like sufficient water, productive land is a necessary determinant of food security. Access to food not only supports labour participation, well-being and, hence, development and economic growth, but also other factors such as political stability. At present, the

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[5]See Table 2 for recent estimates of deforestation for particular countries.

quality and quantity of arable land across Asia is continuing to deteriorate, affecting large swathes of the population (see Bai, *et al*. 2008).

In India, the government estimates that nearly half of the country's land is degraded (GoI, 2009). Poor management practices, particularly in agriculture, have caused soil erosion, rising salinity and contamination by pesticides, amongst other issues (see GoI, 2009, p. 10–15). In China, despite extensive land restoration projects, the area of arable land continues to fall as erosion and pollution spread (Liu and Raven, 2010). Of particular concern is the advance of desertification in the north, which, although driven principally by climate change and geomorphological processes, has been directly exacerbated by human activities and threatens the livelihood of over 200 million people (Wang, *et al*. 2008b).

Throughout South East Asia, draining of swampy peatland, usually intended for agricultural purposes, has caused land to subside, become highly acidic, and, hence, be unfit for any use (ASEAN, 2011). Beyond peatlands, an array of problems, including intensive farming, has contributed to high rates of decline in agricultural soil quality, particularly in Viet Nam and Thailand (Coxhead, 2003). The Food and Agriculture Organization estimates that in two-thirds of ASEAN nations (excluding Singapore) 40% of land is suffering either severe or very severe degradation due to human activities (FAO, 2011b).

Table 2: Selected Deforestation and Land Degradation Statistics for Asia

Issue/Variable	Location	Description/Value	Source
Annual rate of change in forest area (2000–2010)	China India Indonesia Malaysia Cambodia Myanmar	1.6% (2,986,000 ha) 0.5% (304,000 ha) -0.5% (-498,000 ha) -0.5% (-114,000 ha) -1.3% (-145,000 ha) -0.9% (-310,000 ha)	FAO (2011a)
Percentage of national territory subject to land degradation (1981–2003)	China India Thailand Indonesia	22.86% 18.02% 60.16% 53.61%	Bai et al. (2008)
Percentage decline in area of arable land (1990–2008)	China India Thailand	14% (~15 million ha) 2.9% (~4.6 million ha) 15% (~2.2 million ha)	FAO (2011b)

2.3.Air Pollution

Access to clean air is a principal determinant of human health, as well as the overall condition of other organisms and environmental processes. Outdoor air pollution is a common by-product of industrial production, motorized transport, and, in fact, the central processes underpinning global economic growth over the last century or so. On the other hand, indoor air pollution is often associated with a lack of development. Absence of affordable alternatives encourages the burning of solid fuels such as dung and timber for energy, despite their harmful effects. Consequently, air pollution is a primary cause of illness and death in both the growing cities and the poorer rural areas of Asia. The widespread nature of this problem undermines the productivity and income of the labor force, exacting a heavy economic toll. For example, a recent study estimates that in 2005 the annual welfare loss associated with air pollution in China amounted to US$ 151 billion (2010 dollars)[6] (Matus, *et al*. 2011).

Air pollution commonly exceeds safe levels across the cities of developing Asia (see Figure 2 and Table 3). Emissions of noxious gas and particulate matter from motor vehicles, industry, and other causes—plus the rising urban population exposed to them—are increasing the regional burden of respiratory illnesses and cancer (HEI, 2010). On a global basis, it is estimated that 65% of urban air pollution mortality occurs in Asia (Cohen, *et al*. 2005). At an aggregate level there have been significant improvements in recent times (CAI, 2010), but without renewed mitigation efforts, such as tighter emissions standards and stronger monitoring programs, the situation across the region could deteriorate substantially. And this may already be occurring in some major cities. The United States Embassy in Beijing reports hourly air quality readings for PM 2.5 (or very fine particulate matter) and ozone; readings indicating 'hazardous' or 'very unhealthy' air quality (the most dangerous ratings) have become increasingly frequent during winter months (see Beijing Air, 2012).

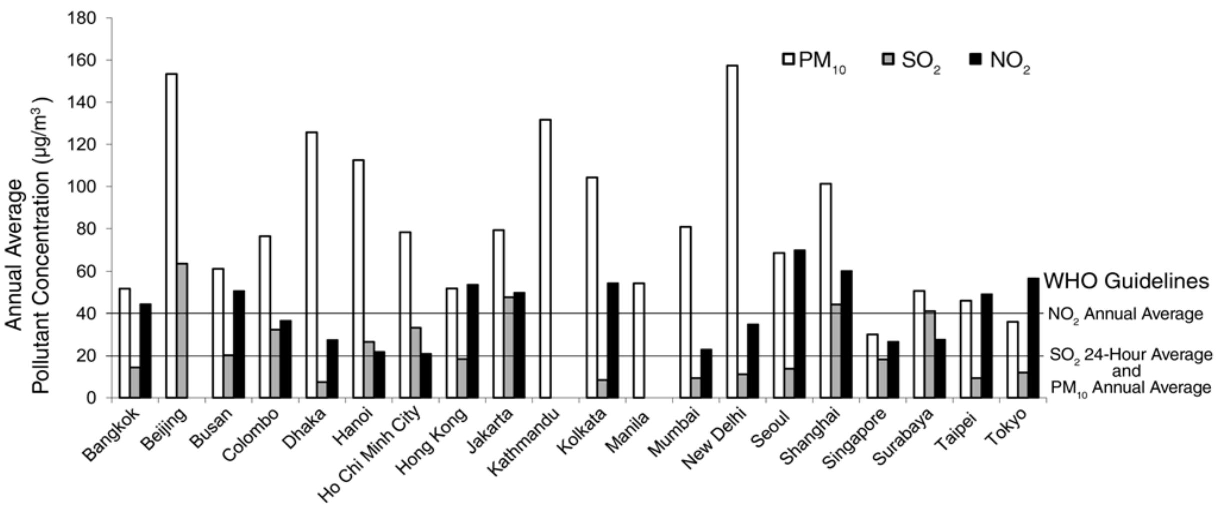
The urban population of China, India, and ASEAN is set to increase by 50% between 2010 and 2030 (UN, 2009). This rapid urbanization and a growing middle class are causing an explosion in motor vehicle ownership in Asia, which, on recent trends, is projected to create a rise in vehicles on China's roads of 130 to 413 million between 2008 and 2035, and a corresponding increase of 64 to 372 million in India (ADB/DFID, 2006). Higher incomes will also raise demand for energy intensive consumer goods, such as air conditioners, and, where industrial and energy

[6]Present authors' conversion of reported estimate of US$ 111.5 billion (1997 dollars).

production occurs in proximity to cities, potential pollution from these sources increases accordingly.

Urban air pollution in large cities is not simply a localized or a health issue. Air transport of urban pollutants causes problems further afield. For example, acid rain originating from sulfur dioxide emissions in cities degrades farm land in regional areas, as well as contaminating groundwater. Air pollution problems in one city may be compounded by activities in others. Major incidents of air pollution in Hong Kong, China over the last two decades have coincided with northerly winds transporting pollutants from the major industrial areas on the mainland (Huang *et al.*, 2009). Other activities or events outside cities, such as forest fires, can add to urban problems. At a regional level, air pollution from cities has mixed with that from other sources (including indoor air pollution) to form atmospheric brown clouds (ABCs) over Asia. These combinations of aerosols and partially combusted (or black) carbon have been shown to affect regional and global climate, crop production, as well as health (see UNEP, 2008).

Figure 2: Air Pollutant Concentrations in Major Asian Cities (2000–2004)



Notes: PM_{10} refers to particulate matter <10 µm in diameter, SO_2 is sulfur dioxide, NO_2 is nitrogen dioxide. WHO Guidelines for annual concentration averages is 20 µg/m^3 for PM_{10} and SO_2, and 40 µg/m^3 for NO_2. Data is a five year average from 2000-2004.

Source: HEI (2010, Figure 24).

Whilst ABCs are a shared outcome of urban and indoor air pollution, and both are a significant regional health risk, the latter is distinct as a symptom of underdevelopment. Poverty causes over 2 billion people in developing Asia to use solid fuels (including biomass and coal) for cooking and heating (IEA, 2010). Particulate matter, carbon monoxide, and other harmful airborne substances damage the lungs of householders, causing a variety of illnesses including cancer. Exposure to particulate matter has been estimated to be 8 to over 100 times daily World Health Organization (WHO) safe levels (Rehfuess, *et al*. 2011). As a consequence of such exposure levels, the WHO estimates that over 1 million deaths in China, India, and ASEAN are directly attributable to indoor air pollution each year (WHO, 2009).

The disproportionate impact upon women and children of this problem impedes the workforce participation of the former group, and limits the prospects for the latter. Although this problem has been long recognized, widespread change in Asia is yet to take place (IEA, 2010). Indoor air pollution is a major development issue because it not only affects the welfare of poor households in the present; it affects their prospects for the future. Whilst promising developments are on the horizon, particularly as the co-benefits of black carbon mitigation and improved cookstoves gain prominence (see UNEP/WMO, 2011), indoor air pollution will continue to afflict a large proportion of poor households in Asia over the next two decades (IEA, 2010), despite regional economic growth.

Table 3: Selected Air Pollution Statistics for Asia

Issue/Variable	Location	Description/Value	Source
Average PM_{10} concentration	230 Asian cities	89.5 $\mu g/m^3$ (WHO standard is 20 $\mu g/m^3$)	CAI (2010)
Percentage of Asian cities exceeding WHO SO_2 concentration standards	230 Asian cities	24%	CAI (2010)
Acid rain	China	258 of 488 cities experienced acid rain in 2009. In 53 of these cities >75% rainfall was acidic.	MEP (2010)
Proportion of population using solid fuels (2007)	China India Indonesia Laos, Myanmar, Cambodia Thailand, Viet Nam	71% (rural), 48% (total) 88% (rural), 59% (total) 79% (rural), 58% (total) >90% (total) >45% (rural)	WHO (2011)

Notes: The 230 Asian cities referred to in rows 1 and 2 are from China; India; Indonesia; Thailand; Malaysia; Philippines; the Republic of Korea; and Taipei,China. See CAI (2010) for further details. PM_{10} refers to particulate matter <10 μm in diameter.

2.4. Climate Change

Asia is highly vulnerable to the effects of climate change. With a large population in low-lying and coastal areas, widespread water insecurity, and around two thirds of the world's poorest people, the region is likely to suffer extensive damages in the future (see IPCC, 2007). Whilst the full force of development impacts will not be realized for many decades, climate change adaptation is already a contemporary issue. Rising maximum temperatures and changing rainfall patterns are affecting agriculture and food security today, and the effect of these changes will escalate to 2030 (Lobell, *et al.* 2008). For example, it is estimated that yields of important crops will decline in parts of Asia by 2.5% to 10% by the 2020s (IPCC 2007). Greater intensity of extreme weather events, incidence of flooding and tropical disease, and decline of marine ecosystems are also concerns for the proximate future (see ADB, 2009, IPCC, 2007).

Climate change will worsen the ill effects of Asia's current environmental problems, such as water insecurity, but these problems also contribute to climate change. Deforestation and black carbon emissions in Asia are important drivers of global warming, both in terms of contribution and also because their mitigation could be a low-cost option with short-term benefits. Energy demand in Asia is expected to explode with ongoing economic expansion and, accordingly, so will coal use and greenhouse gas emissions (see Table 4). Asia is set to be the dominant source of expansion in global emissions. Recent projections of global emissions estimate that, under a 'business as usual' scenario, China's share of global fossil fuel emissions will be 34% by 2030, and the figure for developing Asia as a whole will be 51.9% (Garnaut, *et al.* 2008). Unsurprisingly, International Energy Agency (IEA) projections indicate that China will need to be a large source of the mitigation necessary to restrict global warming to 2°C in a cost-efficient manner (see Table 4).

Whilst the scale of climate change damages to 2030 alone may not warrant the substantial mitigation investment required in Asia over the next two decades, it will be in the longer run. At a regional level, Asia is both highly vulnerable to climate change and will play a decisive role in its limitation. Therefore, extensive climate change mitigation activities are a matter of self interest. It is clear today that the process of lifting the standard of living throughout Asia cannot follow the carbon-intensive trajectory laid out by today's high-income economies: the limits of the climate system render such repetition infeasible. Switching to a "green growth" development pathway will reduce the impact of potentially major stumbling blocks arising from climate change, such as food and water insecurity, environmental refugees and conflict, among others. Not only does avoidance of major climate damages provide a firmer base for growth beyond 2030, but there are significant economic opportunities in the short-term from leading the way in, for example, renewable energy generation, and also increasing energy security. Indeed, China and, to a lesser extent, India and ASEAN countries are moving towards exploiting these opportunities.

Table 4: Selected Climate Change Statistics for Asia

Issue/Variable	Location	Description/Value	Source
Crops estimated to decline in yield by 2030	South Asia SE Asia	wheat[1], millet[2], groundnut[2], rapeseed[2] rice[1], soybean[2]	Lobell et al. (2008)
Projected energy demand increase to 2030 (above 2008 levels)*	China India Non-OECD Asia[3]	67% 94% 70%	IEA (2010)
Proportion of global emissions reductions to reach 450ppm target from IEA modeling	China India	19% (2020), 36% (2035) 7% (2020), 8% (2035)	IEA (2010)
Projected increase in coal-based energy production to 2030 (above 2008 levels)*	China India Non-OECD Asia[3]	41% 83% 52%	IEA (2010)

Notes: [1] High statistical probability of decline (>95% confidence) and highly important crop for food security. [2] Potentially large decline (between 5 and 10%), but with low or moderate statistical probability. Millet, groundnut, and rapeseed considered highly important crops and soybean classed as important. Further details see Lobell et al. (2008). [3] Indicates all Asian countries not belonging to the OECD (i.e. all expect Japan, Australia, South Korea. This estimate includes China and India. *See IEA (2010) for assumptions underlying projections.

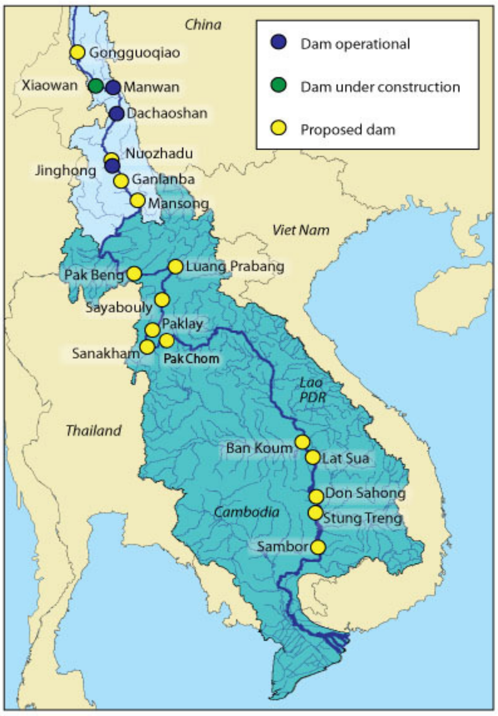
3. Case Studies of Environmental Problems in Asia

This section presents seven case studies of environmental issues affecting the economies of Asia.

3.1. Regional Management of Hydropower Development on the Mekong River

The Mekong is one of the world's few major rivers whose hydropower potential remains largely unexploited. This relative absence of dams is set to change at a rapid pace. Eleven mainstream dams are planned in the Lower Mekong Basin (LMB), an area encompassing Laos, Thailand, Cambodia, and Viet Nam (Figure 3).[7] The environmental and social impacts of the proposed dams will endure for decades, yet, due to the complex processes involved, any prior assessment of costs and benefits is riddled with great uncertainty.[8] Outcomes will be broadly and unevenly distributed across stakeholders, time, and countries. In recognition of the scale of potential transnational impacts, a regional forum, the Mekong River Commission (MRC), was created during the 1990s to facilitate collective and mutually beneficial management. However, meeting this fundamental objective, whether through the MRC or otherwise, is likely to be a major challenge during both planning and operation of these projects, should they proceed.

Figure 3: Planned Mekong River Dams - Lower Mekong Basin and Upper Mekong Basin



Source: ICEM (2010).

[7] Away from the mainstream, a further 56 tributary dams are in various stages of design or construction through the LMB, mainly in Laos (MRC, 2011b). Although tributary dams can have a major impact on the mainstream river, they are outside the auspices of the MRC.

[8] A recent study by Costanza, *et al.* (2011) demonstrates that cost-benefit analysis of Mekong mainstream dams can produce highly variable results across a credible range of values for economic and environmental parameters.

Dam construction on the Mekong addresses two important economic issues in the LMB: the need for an abundant and cheap supply of electricity to meet the burgeoning demands of the Thailand and Viet Nam economies (Middleton, *et al*. 2009); and, enduring poverty in Laos and Cambodia. Proponents claim that the dams represent a major opportunity for the host countries: the 9 mainstream projects in Laos and 2 in Cambodia are expected to increase annual state revenues by 18% and 4% above 2009 levels respectively (Grumbine and Xu 2011). In fact, the national government of Laos aims to become the "battery of ASEAN" and views hydropower as the key driver of poverty alleviation in the country (see Powering Progress, 2011). In the context of climate change, hydropower is often presented as a clean alternative to fossil-fuel intensive energy generation, and this attribute is also commonly invoked by the Laos government.[9]

On the other hand, dams also threaten major environmental degradation that would have a disproportionate impact upon low-income rural communities (ICEM 2010). Whilst benefits will be distributed between countries in the Lower Mekong Basin (LMB), the transboundary course of the river ensures that the costs will be as well. Among the most prominent of these is the barrier created for upstream migration of species belonging to what is presently the world's largest inland fishery (Sarkkula, *et al*. 2009). The MRC commissioned a strategic environmental assessment (SEA) of all mainstream proposals that estimated an annual loss of 340,000 tonnes of fish by 2030, equating to US$ 476 million per year (ICEM, 2010, p. 59). As fish account for 47–80% of animal protein consumed within the LMB (Hortle, 2007), and are a major source of rural income (Dugan, *et al*. 2010), this factor alone could have a major impact on food security and poverty (ICEM, 2010). In addition, substantial blockage of sediment transfer would cause significant downstream erosion and undermine the productivity of riverside and flood plain agriculture (Kummu, *et al*. 2010). Although prior assessment of the damages caused by LMB mainstream dams are unavoidably estimates, disastrous experiences in China (Economy, 2010) and on Mekong tributaries (see Amornsakchai, *et al*. 2000) indicate their potential scale.

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[9]Mitigation of carbon emissions through hydropower expansion is however debatable. Dam projects may involve road construction that provides access to areas previously inaccessible for logging, and dam reservoirs are significant sources of methane.

The major recommendation of the MRC commissioned SEA was a 10-year moratorium on any construction decisions, pending further scientific study into uncertainty over large environmental and social costs (ICEM, 2010). This and other MRC technical reports (see MRC, 2011c), as well as associated planning processes (see MRC 2011a, 2011d), have significantly contributed to dissemination of information on the mainstream proposals. However, the future effectiveness of the MRC as a forum for LMB countries to collectively pursue hydropower development sustainably is an open question (Grumbine and Xu, 2011). The MRC has frequently been marginalized in states' decision making (Dore and Lazarus 2009, Campbell, 2009). Despite the recommended delay, the Lao government has consistently demonstrated a determination to proceed in a much shorter timeframe (Hirsch, 2010). Although other member countries—particularly Viet Nam—have recently used the MRC framework to voice objections to progress in the first mainstream project at Xayaburi (near Luang Prabang in Laos) (see MRC, 2011d), and subsequently secured a temporary suspension on the sidelines of the ASEAN summit, the MRC remains in principal a consultative body which affords no veto power for members to prevent construction of a mainstream dam in another country. This lack of oversight was demonstrated during the MRC consultation process for the Xayaburi dam, when construction activities were already taking place (Bangkok Post, 2011), and also during the supposed suspension, when the Laos Ministry of Energy notified the dam developer that it was authorized to proceed (Reuters, 2011).

It is important to note that regional management is not simply a case of deciding whether the mainstream projects are built or not, but also minimizing their negative impacts should they proceed. Planning tools such as those pursued by the MRC inform the need for dam design measures that incorporate environmental river flows. The latter include: variable water outlet capacity, sediment bypasses and flushing outlets, re-regulation reservoirs, and fish passages (Krchnak, *et al.* 2009). However, such measures can entail significant additional costs to dam developers across all phases of the project, including operation. What's more, their utility will always be site-specific; for example, there is no scientific evidence to suggest that fish ladders will work for most species in the Mekong mainstream (Dugan, *et al.* 2010). Minimizing environmental and social damage entails significant financial investment and a lengthy planning period to allow sufficient scientific study, yet dam developers are unlikely to meet such requirements if they impinge on short-term profits.

Outside of the MRC, other means for managing environmental risks exist, but appear limited. Where domestic environmental regulations exist on paper in Laos and Cambodia, the institutional capacity or willingness to enforce them is often deficient (Foran, et al. 2010). Similarly, the prospects for regulation through corporate social responsibility standards (such as the World Commission on Dams principles (WCD, 2000)) are constrained by the primacy of profit to private-sector financiers and developers from Thailand, Viet Nam, China, and Malaysia (Foran, *et al*. 2010; Middleton, *et al*. 2009). These sources of new finance have supplanted the prospect of direct involvement, and hence significant oversight, by multilateral institutions such as the World Bank in the mainstream projects.

The task facing LMB governments within the MRC framework is complicated by the existence of competing domestic interests. Aside from the importance of electricity imports to growth of the Thai and Viet Nam economies, dam developers and financiers from these countries stand to make large profits from mainstream dams (Foran, *et al*. 2010). However, substantial community opposition exists both in Thailand, where NGOs have effectively harnessed anti-dam sentiment from previous domestic projects, and in Viet Nam, where farming productivity and food security is likely to suffer in the Mekong Delta. From the perspective of the Cambodia and Laos governments, elite groups stand to gain personally if the dams proceed, yet the broader development impacts for many of their citizens from, for example, resettlement and lower fish catches could potentially be overwhelmingly negative, especially in the short-term. Whilst the Cambodian government seeks to mitigate the detrimental impacts from dams upstream in Laos, it does not oppose mainstream dam construction more generally due to plans within its own territory (see MRC, 2011d).

Although China has only a loose affiliation with the MRC, it is playing a major role in the mainstream projects. Dams on the upper reaches in China provide not only a moral case for Laos (i.e., dams are already having impacts in the LMB), but have changed the river's hydrology so that the run-of-river projects planned in Laos are commercially viable (Hirsch, 2011)[10]. Aside from the four mainstream projects led by China interests (ICEM, 2010), it is estimated that up to 40% of all hydropower development in the LMB (including tributary dams) will be undertaken by China companies in the coming decades (Hirsch, 2011). More broadly, China has been heavily expanding economic investment in both Cambodia and Laos, in projects such as the forthcoming high-speed rail link between China's Yunnan Province and Vientiane.

Regional governance through a purpose built institution like the MRC is essential because mainstream dams are such a multi-faceted issue with wide ranging impacts (Grumbine and Xu, 2011, Campbell, 2009). In addition to the issues discussed above, future transboundary damages have the potential to undermine long-term cooperation and security in the region (Cronin, 2009). Even if the current plans do not proceed in the near future, the prospective financial gains for some stakeholders ensure that demand for dams will always be present. If they do proceed, strong mechanisms will have to be developed within the MRC framework to ensure that they are operated to the benefit of the region's inhabitants. The perpetual yet dynamic nature of the issue, as well as the great risks involved, will require adaptive and strong regional governance in the years ahead. A crucial first step to achieving such governance will be large investments in scientific studies to inform the planning process and, in doing so, to achieve an understanding of the full range of potential impacts, some of which could be disastrous for regional development.

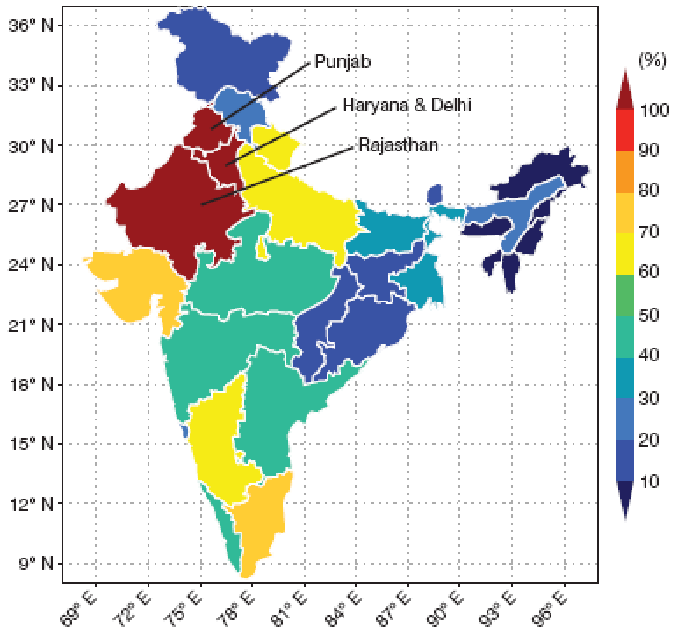
3.2. Groundwater Depletion in India

The impending water crisis in India is widely acknowledged as one of the major environmental and economic issues facing the country (see ADB, 2007, Briscoe and Malik 2005, GoI 2009). A principal component of this problem is the unsustainable depletion of the nation's groundwater aquifers (Figure 4). Groundwater is a crucial resource in India, accounting for over 65% of irrigation water and 85% of drinking water supplies (World Bank, 2010). However, on current trends it is estimated that

[10] Run-of-river dams typically have small reservoirs and require a steady flow to operate year-round. The high fluctuation of the Mekong's flow across the seasons in northern Laos, site of several proposed run-of river dams, is now regulated by the mainstream dams in China increasing flows outside of the monsoon and vice versa.

60% of groundwater sources will be in a critical state within the next twenty years (Briscoe and Malik, 2005). In the most seriously affected north-western states, the nation's centre of irrigated agriculture and site of economic hubs such as Delhi, recent satellite measurements indicate an average decline of 33 cm per year from 2002 to 2008 (Rodell, *et al*. 2009). At a more localized level, observations of annual water table decline exceeding 4 metres are common throughout India; even exceeding 10 metres in some cases (see GoI, 2010)[11].

Figure 4: Groundwater Withdrawals as a Percentage of Recharge in India



Source: Rodell, *et al.* (2009).

Groundwater depletion is driven by a diverse range of demand-side factors. Utilization of this resource facilitates irrigated agriculture in areas far from rivers; groundwater was a key component of the "green revolution" that occurred from the mid 1960s (Briscoe and Malik 2005). In regions where surface water is available but unsafe for drinking or farming—over 70% of India's surface water resources are polluted by human waste or toxic chemicals, rendering many of them unfit for consumption (GoI, 2009)—groundwater has often been seen as a safe alternative

[11] A consequence of India's monsoonal weather patterns is that groundwater levels can vary greatly between the seasons. To avoid discrepancies arising from this inter-seasonal variability, the source of these figures, the Central Ground Water Board, takes local measurements during different months of the year (see GoI, 2010).

(Chakraborti, *et al.* 2011). Water supply infrastructure in urban areas is commonly poor and unreliable, therefore rendering well drilling the most economical means of obtaining household water (World Bank, 2010); the local government estimates that 40% of the water transmitted through Delhi's mains system is lost through leakages (GoNCTD 2010, p. 58).

In rural areas, the electricity subsidies allowing farmers to pump groundwater cheaply have become entrenched in the political landscape (Shah, 2011), and are likely to become more so as energy requirements increase to extract water from greater depths (Briscoe and Malik 2005). Low cost encourages excess water withdrawal, an inefficient pattern of usage commonly exacerbated by ineffective application to crops and the wastage of agricultural produce between farm and market (Kondepati, 2011). In order to feed a growing and wealthier population, it is projected that by 2030, and under current usage patterns, agricultural water demand will double to 1,200 billion m^3, comprising 80% of total water demand (WRG, 2009, p. 54).

The state of groundwater quality in India is a major health issue from both a contemporary and long-term perspective (Chakraborti, *et al.* 2011). As wells are drilled deeper in pursuit of the falling water table, the water which is extracted frequently displays higher levels of arsenic, fluoride and other harmful chemicals. The attendant health effects have been well documented throughout India (e.g., Mandal, *et al.* 1996, Chakraborti, *et al.* 2011), particularly in poorer rural communities where there is no alternative for drinking water. Geological contamination is often compounded by the broader hydrological effects of a falling water table. Over-depletion of a freshwater aquifer can induce leakage from a contaminated external source (Konikow and Kendy 2005), such as saline water in coastal areas or surface water polluted by sewage, agricultural fertilizers, or industry (see Ramesh, *et al.* 1995, Chakraborti, *et al.* 2011 for examples in India). It follows that depletion of groundwater is not simply a case of drawing down a replenishable resource, but one of lasting and proximate degradation.

The impact of climate change in India adds a further dimension to this issue. Greater incidence of drought in some regions and an eventual reduction in dry season river flow (once glacial melt decreases) will position groundwater as a crucial buffer stock of water (World Bank, 2010). A deficiency in alternative water sources will increase the pressures for exploitation in the future, thus rendering sustainable management under present conditions even more important.

The public good characteristics of groundwater aquifers in India render their governance a major challenge. Consider an agricultural area with many farmers. All users have access to the groundwater supply and, though all suffer from over-depletion, the farmers have strong incentives to unsustainably deplete the resource. More efficient usage of groundwater would likely involve some small to moderate private cost in the short term, such as installing improved infrastructure. If all users bore this moderate cost the long-term social benefit, healthy groundwater resources, would improve all users private welfare. But the actions of an individual farmer cannot prevent the water table falling. Unless all users cooperate, more efficient usage patterns merely inflict a personal burden on the individual farmer pursuing them, and there exists a strong private incentive to respond to over-depletion by simply digging a deeper well. Even if users agree to cooperate, each farmer has an incentive to “cheat” and not bear the cost of more efficient extraction, whilst still reaping the benefits of neighbor’s sustainable usage patterns.

These circumstances, an example of the “prisoner’s dilemma problem” from game theory, typically require some form of official regulation to produce beneficial social outcomes. In India however, there are very large transaction costs associated with national governance of an estimated 25 million groundwater extraction structures (Shah, 2011). This difficulty is compounded by institutional incapacity and the fragmentation of responsibility for groundwater management throughout different departments of the national government (World Bank, 2010, p. 54). What’s more, India’s state governments have primary jurisdiction over groundwater usage and, in many cases, state agencies are even more poorly equipped than their national equivalents. Both underground aquifers and rivers traverse state borders; competition over use of water is already a major source of inter-state conflict (Briscoe and Malik 2005), as well as between users at a local level (World Bank, 2010). To date, the difficulties of regulation and collective management of India’s groundwater resources have been overwhelming, and are a fundamental cause of India’s groundwater crisis (World Bank, 2010, Briscoe and Malik 2005).

The link from water to food security in India compels urgent solutions to the unsustainable levels of demand for its dwindling groundwater supplies. But given the multiple levels of the problem outlined above, this is no simple task. A comprehensive World Bank study concluded that high-level policy reform in the shape of regulatory measures, economic instruments, or tradable groundwater extraction rights is simply not a credible way forward (World Bank, 2010). Instead, this report proposes that some form of "bottom-up" community management may be the only hope. Other studies have supported this proposal (see Shah, 2011), with particular focus on community level groundwater recharge and use of communally managed alternatives to groundwater such as small dams.

3.3. Afforestation and Land Restoration in China

Although deforestation and land degradation have been common throughout China's history, the unsustainable use of the country's land-based resources has become most apparent in the last two decades of rapid economic growth. By the late 1990s, soil erosion was degrading 20% of the country's landmass, the area of cropland and forested land per person had declined to one half and one-sixth of the global average, and desertification affected 25% of China (Liu and Diamond 2005). In addition to the pressures of population growth and urban development, these problems were symptomatic of the national government's earlier willingness to pursue economic expansion at the expense of the environment. However, multiple factors prompted the government to initiate urgent action during the late 1990s, including: major flooding; dust storms affecting urban areas, particularly Beijing; and concerns over food security, as well as the future of the nation's forest resources.

The government response was to design and implement several land-based ecological restoration programs (ERPs) which have, since 2000, entailed an unprecedented financial investment in China's forestry resources of approximately US$ 100 billion (Wang, *et al*. 2008a).[12] Key focus areas include: forest conservation (including wholesale logging bans in many areas), prevention of slope erosion and desertification, afforestation of degraded land, and re-vegetation of agricultural land. The primary mechanism of these programs has been an extraordinary rise in

[12] See Wang et al. (2007, Table 2) for a detailed description of each program.

afforestation activities[13]. The official statistics are impressive to say the least. Chinese government figures indicate that forest coverage has been increasing at 1.6% per year since 2000, or approximately 3 million ha annually (FAO, 2011a). It has been estimated that within the first eight years of the ERPs: 8.8 million ha of cropland was converted to forest; soil erosion and desertification of land had been reversed, and were declining annually by 4.1% and 1283 km^2 respectively; and 98 million ha of natural forest were placed under effective protection (Wang, *et al.* 2007).

Aside from the finances dedicated to the ERPs, contributing factors to their success have included: payments to local communities, particularly for farmers through the Sloping Land Conversion Program (SLCP) (Yin and Yin 2010); ownership and tax reform at a state level that has encouraged the growth of commercial plantations (Wang, *et al.* 2007); and national government programs that have resettled or retrained workers previously engaged in logging (Wang, *et al.* 2007).

There are however a number of caveats to this success story. The term "forest" in China has changed meaning over the last decade, and can now describe scrub and grass land, as well as orchards and other types of "economic forests" (Demurger, *et al.* 2009, Si, 2011). Thus, definitional alterations may account for some of the statistical expansion. Monitoring and assessment is a major challenge; the political system ensures that regional governments and the bureaucracy at all levels have a strong incentive to state that central government targets are being met, even if that is not the case (Guan, *et al.* 2011, Yin and Yin, 2010). A field study of afforestation programs in a small township of Sichuan province demonstrated this problem, finding that local government statistics had grossly misrepresented reports of success (Trac, *et al.* 2007).

Another issue pertains to the desirability and permanence of tree plantations, particularly in the arid and semi-arid lands of China. Large-scale afforestation in these areas, particularly of non-local tree species, has frequently lowered the water table and actually advanced land degradation (see Cao, 2008, Jiao, *et al.* 2011, Sun,

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[13] Formally, afforestation refers to tree-planting on land that did not previously support forests and reforestation applies to planting that occurs on land where forests did exist but were removed or degraded. For simplicity, we use the term afforestation to describe tree-planting in both cases.

et al. 2006). As they are simply not suited to the environment in these regions, survival rates of planted trees in China's dry northern provinces have been as little as 15% in some cases (Cao, 2011). Although using revegetation of local grasses and shrubbery would produce better long-term results (Jiao, *et al*. 2011), the "top-down" nature of ERP design and implementation means that the central government has been slow to recognize that afforestation alone will not produce favorable outcomes (Cao, *et al*. 2010). Across a wider range of geographic areas, forestry management practices that encourage higher survival rates and better quality of plantation forests (such as thinning and tending of branches, as well as site selection) have been insufficiently incorporated into afforestation programs to date (Yin and Yin, 2010).

A further component of the permanence issue is the long-term maintenance of reforested land by private land-owners. Uncertainty over the duration of compensatory funding—5 to 8 year periods are typical—provides a disincentive to quality stewardship and, in the case of the SLCP, analysis of surveyed participants responses indicated that a large proportion will simply return forested land to cropping once funding ends (Bennett, 2008). Moreover, the level of support and resources available for implementation of ERPs on the ground has often been lacking (Wang, *et al*., 2007, Bennett, 2008).

A common thread to critiques of the ERPs is the inefficiency of their "top-down" design and the multiple levels of bureaucracy required for implementation (Demurger, *et al*. 2009; Cao, 2011; Yin and Yin 2010). Obviously this is not a problem specific just to forestry and environmental management, but a wider issue pertaining to governance in China as a whole. Although vast resources have been dedicated to afforestation and land degradation since the turn of the century, it would appear that the efficacy of these efforts has been hindered by China's political system. Official estimates of China's forest coverage and related statistics have improved, but they are rarely corroborated by independent evidence (Yin and Yin, 2010).

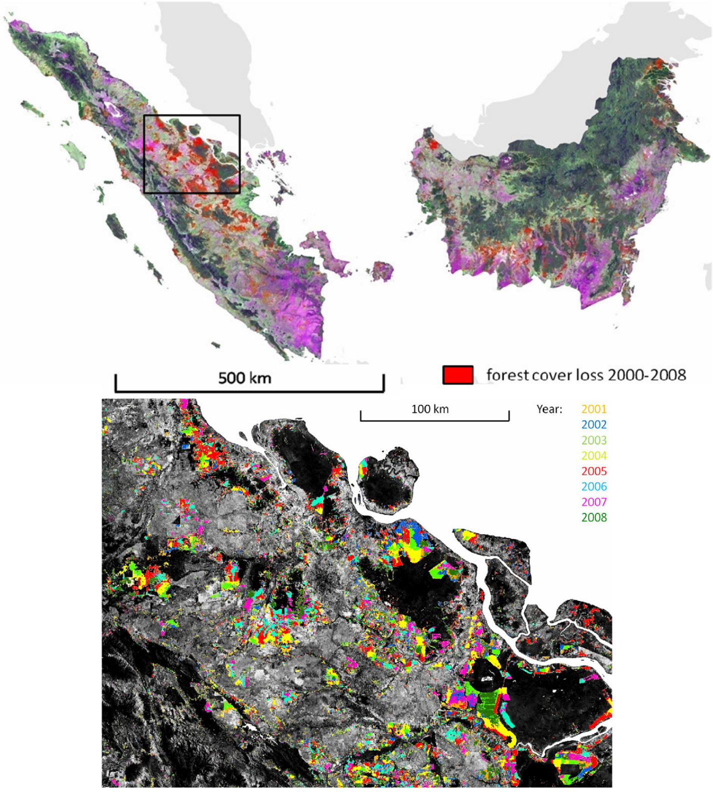
The government has stated plans to further increase official forest cover to 23% by 2020 and 26% by 2050 (up from 22% in 2011); hence, large-scale afforestation activities are set to continue. A major component of this increase will be plantations to fulfill the growing demands of China's economy, particularly the manufacture of timber products. In light of the issues outlined above, actual future increases in domestic supply are unlikely to meet burgeoning domestic demand (White, *et al*. 2006). Another pressure on China's forestry resources will be conversion to agricultural land as the population and incomes grow. However, given the central government's commitment to reversing deforestation, rather than a widespread return to unsustainable domestic practices it is more probable that the recent "exportation" of China's deforestation problems to its neighbors will escalate (Liu and Diamond, 2005, Demurger, *et al*. 2009).

3.4. Deforestation in Indonesia and transboundary haze pollution

Although estimates differ over the precise scale of deforestation in Indonesia, they all tell the same story: the country's forestry resources are being degraded at a massive rate[14]. Satellite-based observations of Indonesia's largest land-masses, Sumatra and Kalimantan, between 2000 and 2008 have revealed 5.39 million ha of deforestation, comprising 5.3% of the land area and 9.2% of forest cover in 2000 (see Figure 5). Deforestation in Indonesia is driven primarily by demand for timber and conversion of land into palm oil plantations (mostly for export overseas), as well as the expansion of subsistence farming which also plays a lesser, though still significant, role (Verchot, 2010).

[14]For example, Verchot, *et al*. (2010) quote government statistics of 1.2 million ha per year. The FAO (2011a) report 498,000 ha per year. Such discrepancies are common and arise from the difficulties of measuring such a dynamic and geographically disperse issue.

Figure 5: Deforestation in Sumatra and Kalimantan 2000–2008



Notes: Forest cover loss calculated from satellite observations. Right-hand side of the figure is the inset of the larger map showing both islands.

Source: Broich, *et al*. 2011

Central to the problem is that weak institutional capacity and corruption at a local level limit the strength of national laws aimed at reducing deforestation; illegal logging in government managed areas is common.[15]Further drivers include: the short term financial gain in regional income and employment associated with deforestation activities, particularly given that Indonesia exhibits relatively low-income levels (Tacconi, *et al*. 2008); government policies in the 1980s that encouraged land-use change (Herawati and Santoso 2011); and the move to decentralization of governance after the fall of the Suharto regime (Arnold, 2008). More broadly however, much of the demand for timber and palm oil originates from overseas, where surging economic growth and more stringent domestic regulation in countries

[15]For example, the Broich, *et al*. (2011) study found that 20% of deforestation occurred in legally protected areas.

such as China have caused Indonesia to "import" some of its deforestation problems from elsewhere (see previous section of the present study).

Whilst deforestation in itself is a major environmental issue—Indonesia's remaining forests support extensive animal and plant biodiversity, as well as providing vital ecosystem services to rural communities—the manner in which it occurs greatly accentuates its ill effects. Land-clearing for logging and agricultural purposes is commonly pursued by means of fire simply because this is the cheapest method available (Tacconi, *et al*. 2008). The smoke and air pollution associated with fire clearing is exacerbated by its frequent occurrence on Indonesia's vast expanse of tropical peat land; peat is organically rich and highly combustible, thus fire clearing, combined with the accompanying practice of draining swampy peat land, causes the land itself to burn. The consequent haze is transported by monsoonal winds over to Indonesia's neighbors, of which Malaysia and Singapore are among the worst affected. In 1997 a major incidence of regional transboundary haze pollution (THP) from forest fires in Indonesia exacted a short-term economic impact across the three countries of around US $4.5 billion, including US$1.4 billion from air pollution related health costs (EEPSEA/WWF, 2003).

Once again, THP and deforestation are not just an important issue in terms of their regional impacts, but also because of their direct link to the greatest environmental challenge at a global scale: climate change. The drainage and burning of peat land releases large volumes of carbon dioxide trapped in soil. Forest clearing eliminates a major carbon sink. The combination of these two factors, plus the scale at which they are occurring, renders deforestation in Indonesia an issue of global importance. The forest fires causing the aforementioned THP incidence in 1997 have been estimated to account for 13–40% of global carbon emissions in that year (Page, *et al*. 2002). In fact, Indonesia is considered the third highest source of carbon emissions by country, though 80% are caused by the land-use change discussed here, and not the energy and industrial production that are major emissions sources elsewhere.

From a domestic perspective, the Indonesian government has to weigh up many competing interests within the country. Deforestation represents a short-term economic opportunity locally, particularly in peatland areas where there is a high incidence of poverty (Harrison, *et al.* 2009), but it adversely affects national health and unsustainably degrades Indonesia's natural resources; 41% of remaining forest land is considered to be degraded (Verchot, *et al.* 2010). Decision-making in the interests of long-term sustainability are made more difficult by logging and palm oil companies, both domestically and foreign owned, which use their influence over regional economies to extract favorable treatment from politicians.

Within Malaysia, Singapore and other neighbors affected by THP, costs are borne from air pollution but benefits also accrue from deforestation, such as a ready supply of cheap timber to manufacture wood-based furniture. Further afield, consumers and companies in countries not affected by THP, such as China, suffer in the long-term if Indonesia's land-based resources are degraded to the point where they are no longer available.

The twin issues of deforestation and THP have been, and continue to be, the focus of potential solutions at a domestic and international level. Numerous legislation and other regulations have been devised, but largely failed due to the incapacity or unwillingness of local authorities to enforce them (Herawati and Santoso 2011); corruption has commonly exacerbated the difficulties of enforcement (Palmer, 2001). As a response to THP, a regional haze agreement was formulated under the auspices of ASEAN in 2002. However, the Indonesian parliament has not ratified it, partly as Indonesia would have to foot the majority of the cost of compliance (Tacconi, *et al.* 2008), but also because poor air quality in Singapore lies well outside the political compass of a politician representing a region where there are many pressures for land clearing.

More recently, the Norwegian and Indonesian government signed an agreement in 2010 whereby the latter would institute a two year moratorium on the issuance of new permits to log or set up palm oil plantations in government managed forest and peatland. As part of this agreement Norway will help build institutional capacity for improved forest management and, if deforestation rates decrease, Indonesia will receive up to US$ 1 billion. In May 2011 a presidential instruction (PI) to regional authorities brought the moratorium into effect. However it contained numerous exemptions as a result of lobbying by business entities. For example, projects where the application was received prior to the PI can still proceed, as can those which are up for renewal and also those related to mining (Wells and Paoli, 2011). The Norwegian funding is seen as laying the groundwork for future expansion of Reducing emissions from deforestation and forest degradation (REDD) in Indonesia as part of international climate mitigation policy. If successful, the two-year freeze in the increasing rate of deforestation will enable data collection and other activities that aid successful implementation of REDD. Despite the potentially large sums involved in future REDD based activities in Indonesia (up to US$ 5.6 billion (Clements, *et al*. 2010)), they will only be effective if they address the key impediments to previous attempts at stopping deforestation: local-level incentives and a deficient institutional capacity for effective monitoring and enforcement.

3.5. Regulation of Air Pollution in Delhi

In the 50 years to the end of the twentieth century the population of Delhi increased from just under 2 million to around 13 million people (Firdaus and Ahmad 2011). Rapid population growth, urban sprawl and rising incomes in one of India's major economic hubs have come however at a major environmental cost. By the 1990s air pollution from a burgeoning vehicular fleet—registered vehicles doubled to 4 million between 1991 and 2001 (World Bank, 2005, p. 81)—and industrial activity suffocated Delhi with the highest level of suspended particulate matter in Asia (World Bank, 2005). Unsurprisingly, the health impacts were substantial. Given that up to 25% of non-trauma deaths were associated with air pollution in the earlier 1990s, and the peak impact was on Delhi residents between the ages of 15 and 44, Cropper, *et al*. (1997) found that there would be major benefits to stronger air quality regulation.

Intervention by the Indian Supreme Court beginning in 1996 compelled the government to reform the state government's existing suite of poorly targeted and even more poorly enforced air quality regulations.[16] As vehicular emissions were the major cause of air pollution (approximately 60–70% during the 90s (Foster and Kumar 2011)), they were the primary target of the new regulations, although forced closure or relocation of polluting industries also occurred. The central component of the reform was the conversion of all commercial vehicles (including buses, taxis and

[16]See Bell, *et al.* (2004) for a comprehensive exposition of the judiciary's role in the reform process.

motorized rickshaws, or “three-wheelers”) to using compressed natural gas (CNG), a much cleaner fuel than diesel or gasoline. Other measures included: retirement of old commercial vehicles, reduction of sulfur content in diesel and gasoline fuels, emissions standards for private vehicles, and enhancement of the public transport system.[17]

Despite the challenges of broad reform involving so many road users, the program has been a major success. Statistical analyses of air quality measurement have indicated that the results of these policies have been highly beneficial, significantly reducing, or at least arresting the rapid rise, in concentrations of particulate matter, sulfur dioxide, carbon monoxide and other pollutants (Firdaus and Ahmad, 2011; Narain and Krupnik, 2007; World Bank, 2005). Similarly, the respiratory function of Delhi’s inner city residents has substantially benefited, particularly amongst low-income households (Foster and Kumar, 2011). As a direct result of the reforms, it has been estimated that nearly 4,000 deaths in Delhi have been averted each year (World Bank, 2005).

Despite the success of the government reforms, air pollution remains a major problem in Delhi (GoNCTD, 2010), and the concentration of many pollutants commonly exceeds national quality standards, particularly in the winter months[18] (Guttikunda, 2010; Firdaus and Ahmad 2011; CSE 2011). In fact, the benefits of recent regulation are being rapidly eroded as pollution levels approach record levels once again. This deterioration is being driven, quite literally, by the sheer scale of the rise in private vehicle use. Around 1100 new vehicles are added to Delhi’s roads each day, an increasing proportion of which are cars; from 2000 to 2008 the number of cars more than doubled (GoNCTD, 2010). With an extra 10 million inhabitants projected over the next decade, car volume is likely to increase further. A major concern associated with this expansion is that the market share of diesel cars is approaching 50% (CSE, 2011). This trend, caused by government subsidy of diesel, is generating substantial growth in nitrous dioxide pollution (Firdaus and Ahmad, 2011; Nahrain and Krupnik, 2007).

[17] See GoNCTD (2010, Table 2.5) for a timeline of state government air pollution reduction measures.

[18] Local weather conditions during winter months prevent the dispersion of Delhi’s air pollution. Burning of biomass fuel for heating also tends to increase the amount of particulate pollution at this time.

A further consequence of a rising population and economic boom in Delhi is urban sprawl and, coupled with the concentration of economic activity in the city centre, a greater number of commuters travelling further distances (Firdaus and Ahmad, 2011). Though improving, the present state of public transport in Delhi is insufficient to meet spiraling transport needs—buses comprise only 1% of all vehicles and much of the underground rail network is still under construction—and the local government sees expansion in this area as a major focus of air quality improvement (GoNCTD, 2010).

Despite their achievement, the major reforms did however suffer from a lack of planning in certain areas. Although the CNG program was a success overall, poor technology used in the conversion of Delhi's three-wheelers reduced its effectiveness (Nahrain and Krupnik, 2007). Also, regulations within the city simply shifted many polluting vehicles and industry just outside the city boundaries, thus dispersing the problem to areas that will become more populated as the city grows (Firdaus and Ahmad, 2011).

It is clear that the present trajectory of the air pollution issue in Delhi is unsustainable. Rising incomes and more people are a toxic cocktail for more and more cars to be added to Delhi's roads. It would appear that the reforms initiated in the 1990s may have only picked the "low-hanging fruit", and have just delayed the worst of the problems. Today, Delhi ranks globally amongst the cities most affected by poor air quality (Guttikunda, 2010). Certain measures present as potential solutions, such as removing diesel subsidies and continued investment in public transport, but their implementation are likely to be complex challenges in themselves, and, in any event, are unlikely to provide long-lasting solutions on their own.

3.6. Indoor Air Pollution, Black Carbon, and Improved Cookstoves

In the developing countries of Asia more than 1.9 billion people rely on biomass fuel (e.g., wood or dung) for cooking (IEA 2010).[19] The use of these fuels on inefficient

[19] The term "biomass fuel" is not analogous to solid fuels as the latter also includes coal. The International Energy Agency (2010) points out that around 400 million people, mostly in China, use coal as a fuel for traditional stoves, also producing major health damage, air pollution, and carbon emissions.

traditional cooking stoves causes heavy indoor air pollution which commonly exceeds safe limits by a factor of ten, or even hundreds. The resulting health effects include respiratory infections, lung cancer and eye diseases, among others (Rehfeuss, *et al*., 2011). As noted earlier, the World Health Organization estimates that 1.15 million deaths in China, India, and ASEAN each year are directly attributable to indoor air pollution (WHO, 2009), almost all those fatally affected are children and women. Aside from the direct welfare impact of disease, indoor air pollution impairs labor productivity, educational opportunities and, more generally, the prospects for poor households to emerge from poverty. Moreover, inefficient cookstoves that produce large volumes of smoke also require large quantities of fuel, and the burden of collecting it largely falls on women. Despite rising incomes, the IEA predicts that 1.77 billion people in developing Asia will still be using traditional biomass stoves in 2030 under existing policies (IEA, 2010).

A broader consequence of indoor air pollution is its role in a major cause of climate change, namely black carbon emissions.[20] Black carbon, or soot, is a form of particulate air pollution arising from fossil fuel combustion and biomass burning[21]. It contributes to climate change in both global and regional dimensions.[22] At the global scale, warming of glaciers and ice cover at high altitudes (the part of the atmosphere where black carbon accumulates and traps solar radiation), reduces the overall reflectivity of the earth's surface. Deposition of soot on these same surfaces at all altitudes accelerates ice and snow melt, further reducing reflectivity. Regionally, black carbon combines with other aerosols in atmospheric brown clouds (ABCs) to dim the amount of light reaching the Earth's surface, altering the temperature gradient from surface to top of atmosphere and, consequently, breaking down regional weather patterns. These ABCs are prominent throughout Asia, and have been shown to cause weakening of the Indian monsoon and shifting rainfall patterns in China (Ramanathan and Carmichael, 2008).

Although its precise contribution is subject to uncertainty[23], black carbon is considered to be a significant cause of present and future climate change (Ramanathan and Carmichael 2008; Levy, i. 2008). As it has a large effect across a much shorter time span than

[20] In addition to black carbon, burning of solid and biomass fuels contributes to climate change in other ways, such as deforestation (for wood fuels) and emissions of carbon dioxide and nitrous oxide.

[21] Gustafson, *et al*. (2009) estimate that biomass burning is responsible for two-thirds of black carbon emissions in South Asia.

[22] See Ramanathan &Carmichael, (2008) for an exposition of the influence of black carbon on climate.

[23] This is due to the sheer complexity of the processes involved. For example, black carbon can also encourage cloud formation, thus partially increasing the earth's overall reflectivity to solar radiation.

greenhouse gases, black carbon offers rapid returns on investments in its mitigation (Grieshop, *et al*. 2009). Moreover, approximately half of black carbon emissions in Asia arise from the household usage patterns responsible for indoor air pollution (World Bank, 2011a) and, consequently, there are substantial co-benefits associated with their mitigation. For these reasons, reducing black carbon is gaining increasing prominence as a strategy to address near-term climate change (for example see UNEP/WMO, 2011).

There are many options to concurrently reduce indoor air pollution and black carbon emissions, such as increasing access to electricity and modern fuels. In the context of poor households in Asia however, more expensive measures, such as universal electricity access, are longer-term solutions requiring higher incomes and significant infrastructure to achieve sufficient coverage on their own. Hence, the IEA's most recent survey of global energy focuses on the adoption of three technologies to increase access to clean cooking facilities by 2030: improved biomass cookstoves, biogas digesters[24], and liquid petroleum gas cookstoves (IEA, 2010). Whilst the others will surely play a significant role, particularly expansion of biogas facilities in China[25], improved biomass stoves are likely to be a major focus in the future because they are less expensive to deploy (UNEP/WMO, 2011; IEA, 2010), and have been the subject of ongoing efforts in this area for several decades.

Traditional biomass stoves range from very basic "three stone" open fires to more sophisticated set-ups with a chimney, or made of brick. Past and present generations of improved cookstoves have come in a variety of forms to reduce users' exposure to smoke and improve fuel efficiency. The large numbers of different models include various features to alter the combustion of wood and other fuels, such as fans to increase air flow into the stove and improved chimneys. As the type and moisture content of fuel, household setting, construction materials, and practices of users vary, there is no single design of improved cookstove that is universally applicable (World Bank, 2011a).[26]

The need for setting-specific designs is just one of the issues that has hindered previous efforts to disseminate improved cookstoves. Slaski and Thurber (2009) identify three broad problems. First, consumers must be motivated to adopt the new technology because they value it above their existing stoves. Education concerning health benefits has been largely ineffective. Secondly, affordability is a major barrier because improved stoves generally

[24] Biogas is a technology where cow dung, crop wastes, or food scraps are placed into an airtight compartment (or digester) containing water and methane producing bacteria. The resulting gas is extracted as a cooking fuel for households. Large-scale operations exist in developed countries adjacent to farms and waste treatment plants.

[25] China government has set a target of 80 million households using biogas as their main fuel and 3GW of industrial energy generation from biogas by 2020 (NDRC, 2007).

[26] See McCarty, *et al*. (2010) for an overview of different cookstoves' performance under testing.

involve a significant upfront cost beyond the means of the poorest households. However, subsidized provision can undercut the local manufacturers required to sustain widespread dissemination. Thirdly, cooking is a traditional practice and changing it involves a major disruption to daily routine. Where motivation is not strong, the requirement of significant behavioral change diminishes acceptance further. In addition to these problems involving household participation, insufficient support services for ongoing maintenance, under-development of local supply-chains, and poor quality stove construction have obstructed previous efforts (World Bank, 2011a).

Given these difficulties, it is unsurprising that earlier activities to disseminate improved cookstoves have had mixed success. The National Improved Stove Program (NISP) was introduced in rural areas of China during the 1980s, initially to encourage more efficient use of wood fuel and prevent deforestation. Despite initial setbacks, the NISP became extremely successful, largely as a result of targeting locations where demand for improved stoves was high (Smith, *et al.* 1993). In fact, China today has around two-thirds of the world's improved cookstoves, or 115 million (IEA, 2010), due to the success of this program. However, Chinese households typically use a mix of fuels and the initial benefits of the NISP have been eroded over time as portable coal stoves have become more widely used indoors (Sinton, et al. *2004*). Consequently, China currently has the largest population of any country afflicted by disease from indoor air pollution (WHO, 2009).

In India, where nearly 90% of the rural population rely on biomass fuels (WHO, 2010), a national program was abandoned in 2002. Although up to 35 million improved stoves were disseminated, they were often poorly designed or installed and had short life-spans (Kishore and Ramana, 2002). Underdevelopment of maintenance services and local manufacturing, as well as program monitoring and evaluation, saw most households simply revert back to traditional stoves once "improved" versions failed (Aggrawal and Chandel, 2004; Chengappa, *et al.*, 2007). With the lessons from previous experience in mind, the Indian government launched a new initiative in 2009 which has a stronger emphasis on stove quality and testing (see IIT/ERI ,2010 and Venkataraman, *et al.* 2010).

Primary impetuses for the new Indian program are design and technology advances over recent years and the increasingly strong prospects for their commercialization (Adler, 2010). New varieties of advanced cookstoves are now becoming available in markets across the world, and this process is being facilitated by major manufacturing companies such as Phillips, as well as non-government organizations (NGOs) and research centers (see World Bank, 2011a, Appendices 3–4 for an overview of some commercial programs). Global efforts to increase commercial distribution are becoming more coordinated as well. The recently formed Global Alliance for Clean Cookstoves (GACC) is one such example (see GACC, 2011). This United Nations-led partnership of governments, multilaterals, NGOs, and private companies aims to facilitate the uptake of improved cookstoves by 100 million households to 2020.

One of the principal issues motivating the GACC is the opportunity arising from the linkage between indoor air pollution, health, household poverty, climate change, and empowerment of women (GACC, 2011). As improved cookstoves have large benefits across a range of development topics, many sources are available to support an expansion in their usage. These opportunities are especially pronounced in the broader context of climate change policy. International finance for mitigation activities is scheduled to expand significantly, and “win-win” situations involving mitigation and development are desirable targets for funding. As mentioned above, black carbon mitigation involves short term returns that could buy some time, particularly with regards to glacier melt in the Himalayas, if progress continues to be slow in other aspects of global action (Grieshop, *et al*. 2009). Aside from black carbon, the link between greater fuel efficiency and reduced deforestation provides a basis for improved cookstoves to be a part of REDD activities (World Bank, 2011a).

A recent World Bank report on the prospects for proliferation of improved cookstoves states that “the building blocks are falling into place” (World Bank, 2011a, p. 35). The technology, finances, and impetus are clearly accumulating. From a global perspective, it is in the developing economies of Asia that indoor air pollution exerts the greatest health burden, the largest number of people lives in poverty, and the greatest action will have to be taken to avert major climate change. Improved biomass cookstoves positively address all three of these issues. Therefore, it would appear that Asia is the region where the greatest opportunity and the greatest need exist for these building blocks to develop further.

3.7. Climate Change Mitigation in China[27]

China is now the largest emitter of CO_2 (from fossil fuels), with 25% of the global total in 2009, considerably ahead of the second largest annual emitter, the US with 17% (PBL, 2010). China has been responsible for 72% of the world’s growth in CO_2 emissions (from fossil fuels) between 2000 and 2009, a period during which China’s emissions grew at an annual average rate of 9.4%, and the rest of the world’s at 0.8% (PBL, 2010).

[27] This section draws on World Bank (2011b).

Of course, in per capita or cumulative terms, China's emissions still greatly lag those of the United States. However, one can safely say that there can be no satisfactory global response to climate change without the active participation of China.

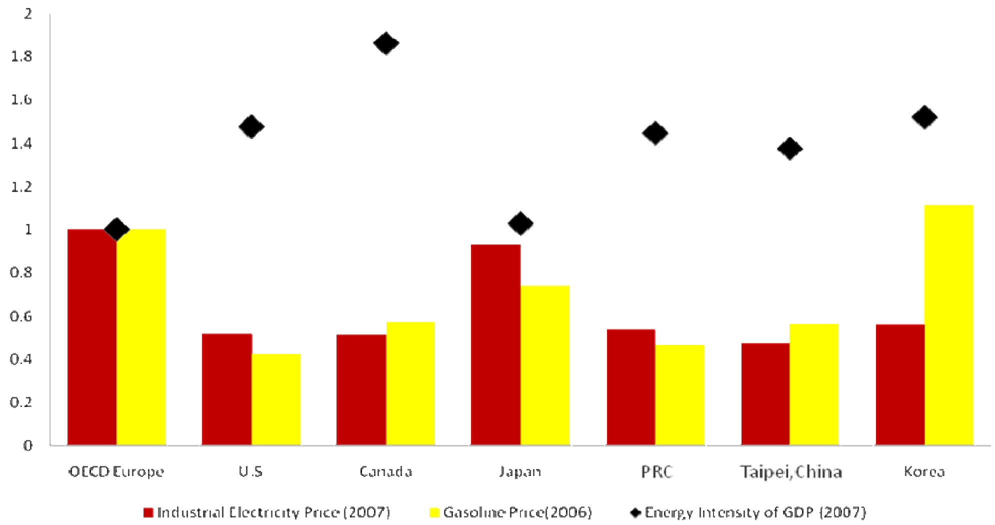
In 2009, China announced that it would, for the first time, subject itself to an emissions constraint. Its aim is to reduce CO_2 emissions intensity in 2020 by 40–45% compared to 2005. This is an ambitious target which will not be met without considerable policy effort.

China already has a large range of instruments in place to achieve its new emissions target. There are already a number of policies to improve energy efficiency (see Zhou, *et al*. 2010; Price, *et al*. 2011).Then there are a number of feed-in tariffs and special tax and tariff concessions to promote renewable energy. UNDP (2010, p. 82) summarizes the situation as follows: "There are few, if any, developing economies that have promulgated as many laws, policies and other measures to support low carbon development as China." This is probably true not only in relation to developing economies.

What we have not seen so far in China is the introduction of a nationwide carbon price. However, the Twelfth Five Year Plan for 2011–2015 commits to "start a pilot carbon emissions trading project, and gradually set up a carbon emissions market" (Xinhua, 2011). In fact, pilot projects have already been initiated in seven provinces and cities, including major centers such as Beijing and Shanghai (see Han, *et al.* 2012).

Carbon pricing would certainly seem to be a critical part of the mitigation challenge. Figure 6 compares China (and Taiwan, province of China; and Korea) to two sets of developed economies: the US and Canada on the one hand, and the EU and Japan on the other. The US and Canada have cheap energy (low electricity and petroleum prices) and a high energy/GDP ratio. By comparison, the EU and Japan have expensive energy and a low energy/GDP ratio. China, with relatively low energy prices and high energy intensity, currently looks much more similar to the US and Canada than it does Europe and Japan. But China's mitigation objective requires that it ends up looking more like the Europe and Japan in terms of its energy to GDP ratio. It will not get there without higher energy prices.

Figure 6: China's Future: Low Energy Prices or High Energy Efficiency? Cross-Country Comparison of Electricity Prices, Gasoline Prices, and Energy Intensity (ratio of energy use to GDP)



PRC = The People's Republic of China; Korea = The Republic of Korea.
Notes: Energy prices measured in current USD, using market exchange rates. Energy intensity is the ratio of energy consumption to GDP measured using PPPs. All OECD Europe values are normalized to one.
Sources: IEA (2009, 2010).

Introducing an effective system of carbon pricing into China would, however, be a major and difficult economic reform. Suppose that China did introduce a carbon price. What impact would it have? Would it actually lead to higher energy prices and lower emissions? Clearly, a carbon price would send a signal, the strength of which would depend on the level of carbon price, to commercial consumers of coal, such as steel manufacturers that they should use coal less and more efficiently. But much of the energy sector in China is regulated, and here matters are more complex.

One key problem is that cost pass-through mechanisms in the electricity and petroleum fuel sectors need further strengthening. Coal is the dominant fuel for electricity in China. In recent years, the price of coal in China has risen sharply. Through a series of electricity tariff increases, China greatly reduced electricity subsidies over the 1990s. However, China has found it difficult to pass on the increase in coal costs it has recently experienced. China has a formula in place for adjusting the electricity price every six months if the coal price changes by more than 5%. However, since the end of 2004, when the formula was introduced, although this condition has been met 10 out of 12 times (in relation to coal market prices), the price of electricity has only been changed thrice, and by much less than the formula mandated. In nominal terms, coal prices rose 40% between the first half of 2006 and 2010, but electricity prices only by about 15%. In fact, over the last few years, electricity selling prices have not even kept pace with inflation.

A good illustration that effective carbon pricing requires pricing reform comes from attempts already made to try to influence the fuel mix, or dispatch order, in the electricity sector. Under the Energy Saving and Emissions Reduction in Power Generation or ESERD pilot introduced into 5 provinces, provinces have been instructed to dispatch generators, not on an across-the-board basis as in the past, but rather according to a mix of economic and environmental criteria. To simplify, the dispatch order is: renewable, nuclear, gas, and then coal, with coal plants ordered by their thermal efficiency, from highest to lowest. Note that this is roughly the order that one would expect with a high-enough carbon price, and, indeed, simulations show implementing ESERD would cut emissions by 10%. However, the pilot provinces have only been able to partially implement this reform, because of the negative financial implications full implementation would have for less-efficient coal-fired units. These units are still valuable as reserve capacity, but, under China on-grid tariff system, plants only receive a payment if they are dispatched, and so have no incentive to provide stand-by capacity. Instead, if not regularly dispatched, they would simply shut down, thereby depriving the system of valuable spare capacity, in case of an emergency or a spike in demand. Or, put differently, the policy-induced lack of flexibility in dispatch has undermined the impact of the introduction of a carbon price (or, in this case, a carbon price equivalent).

Carrying out the reforms needed in the power sector in China to make carbon pricing effective will not be easy. Power sector reforms in developing economies are generally difficult. While there are some success stories, a World Bank (Besant-Jones, 2006) review of power sector reforms concludes that overall “political forces are difficult to align for reform” (*ibid*, p.14), that interest groups “constitute a major impediment to reform” (*ibid*, p. 16), and that “successful reform requires sustained political commitment” (*ibid*, p. 2). Not surprisingly therefore, “Power market reforms in developing economies are generally tentative and incomplete, and are still works in progress” (*ibid*, p. 4).

China is no exception to this generalization. It has made slow progress with electricity reform. In 2002, China split its single, vertically integrated utility into two grid companies (a large one covering most of the country, and a small one in the south) and a number of generation companies (including five large ones). It experimented with wholesale electricity markets in 2002, but that was short-lived and generators no longer bid for dispatch, but sell at centrally-fixed prices. China also established in 2002 a State Electricity Regulatory Commission, but it focuses on technical rather than economic regulation. Prices are still set by government (though the SERC can offer its advice) and, as noted earlier, mechanisms for cost pass-through have been established but are not used. The IEA's conclusion that in the energy sector "China is caught between the old planning mechanisms and a new approach" (2006, p.16) is probably as relevant today as when it was written.

It also has to be admitted that the direct impact of power sector reforms might be to increase emissions. Though it is often claimed that such reforms are "win-win" (IEG of the World Bank, 2009), in fact this will vary from country to country. China's elimination of subsidies in the 1990s laid the groundwork for its rapid electricity growth over the last decade. If China does allow for greater cost pass-through in the electricity sector, this will put upward pressure on electricity prices. But it will also remove one of the underlying forces which is current leading to electricity shortages, namely the unwillingness of coal producers to supply the electricity sector.

Reforms to support mitigation need to go beyond the energy sector to the economy as a whole. It is not cheap energy that is driving China's massive expansion of its energy-intensive sectors. Energy prices are low in China compared to Europe and Japan but not compared to the US (Figure 6). The search for what Rosen and Houser call "the root causes of (China's) structural over-allocation into energy-intensive industry" (2007, p. 37) must extend beyond the energy sector. As they argue: "the pervasive revealed comparative advantage of heavy industry manufactured goods from China is generally rooted in distortions other than energy inputs" (p. 38).

China is characterized by both an exceptionally high investment rate (some 45% of GDP) and an exceptionally high share of industry in value added (about 50%): see

He and Kuijs (2007). The reasons for this are complex, but include, as argued by Huang (2010), limited liberalization of China's factor markets. Low interest rates, high re-investment rates by state-owned enterprises and low land prices in particular have all encouraged capital-intensive industrial production.

Rebalancing the economy should not only lift economic welfare, but also reduce emissions. Table 5 illustrates this point by comparing the share of GDP for China's different sectors with their share of energy use. Industry (the secondary sector) is responsible for 49% of China's GDP, but 84% of its energy use. Rebalancing implies, among other things, faster growth in services than industry. A ten percentage point switch in GDP composition away from industry towards services (the tertiary sector) would, everything else being equal, result in a 14% reduction in energy intensity.

Table 5: A Switch from Industry to Services Would Help Reduce China's Energy Intensity.

Sector	Share of GDP	Share of energy	Energy intensity index
Primary (agriculture)	11%	3%	0.3
Secondary (industry, construction)	49%	84%	1.5
Tertiary (services)	40%	14%	0.3
Total	100%	100%	1

Notes: The year is 2007. Construction is included with industry in the secondary sector. Household energy use (about 11% of the total) is included in the secondary share of energy use.
Source: NBS (2010)

Slower economic growth would also of course help reduce the growth in China's emissions. Its average economic growth between 2005 and 2010 was 11.2%. This is not only well above the 7.5% target embodied in the 2006–2010 Eleventh Five Year Plan, it was also China's highest 5-year average growth since the reforms began. This is a remarkable result considering that the period encompasses the global financial crisis. It seems heretical to suggest that China would do better by growing more slowly, but it is possible that slower growth would actually improve welfare. For example, a switch in government spending from infrastructure to health could reduce growth but still be welfare-enhancing as well as emissions-reducing. Whether China will be able to slow growth to the 7% target announced in the new Twelfth Five Year Plan remains to see seen.

As with energy reform, rebalancing will not be undertaken to reduce emissions. Its primary motivation will be economic. But emission reduction efforts will be more successful if rebalancing occurs.

Of course, the measures already in place, such as support for research and development, and other regulatory and technology-specific-promotion measures, are also important. But these are already at the heart of China's mitigation efforts. What is now needed is a broader response to the mitigation challenge, one which embraces pricing reform, energy sector reform, and structural economy-wide reforms. Neither the importance nor the difficulty of the path ahead should be underestimated.

4. Managing Asia's Environmental Problems

A fundamental characteristic of human society has been the ability to adapt over time to complex problems that undermine economic and social systems. The environmental issues facing Asia are examples of such major challenges. They are examples of 'wicked problems' which are complex, multidimensional, hard to solve, and often harder to define. Rittel and Webber (1973, p. 160) contrasted such challenges to "tame problems", for which the task is more straightforward, even though the impacts may be considerable. For example, consider the contrast between dealing with air pollution in an entire city and preventing the discharge of harmful air pollutants by a single factory.

There are various characterizations of wicked problems.[28] Table 6 summarizes the characteristics of wicked problems in contrast to tame problems. By and large, all of the case studies presented in the previous section and many of their counterparts within the broader issues can be classified as wicked problems. They evade precise definition, are ever-changing, and present a moving target for policy. Often there is no final resolution. Many stakeholders are involved in a dense web of competing interests and interdependencies. Solutions are neither right nor wrong, but better or

[28] Rittel and Webber (1973) considered eleven defining characteristics of wicked problems. Subsequent studies have either followed this original specification directly (see Levin, *et al*. 2010), presented a subset of the eleven characteristics (see Kreuter, *et al*. 2004),or reformulated the initial definitions (see APS 2007, Batie, 2008). The present study belongs in the final category.

worse depending on how one weights (or measures) the welfare of particular groups, and their potential outcomes are difficult to estimate ex ante.

Howes and Wrywoll (2012) provide a detailed analysis showing that Asia's environmental problems are indeed wicked ones. For the purposes of this paper, an illustrative approach will suffice. Consider groundwater exploitation in India. There are millions of stakeholders, largely small farmers, but also urban households, and some businesses. The problem can be defined as an agricultural one, or an environmental one, or an energy sector one. Various solutions have been proposed, but none are obviously dominant. Increasingly electricity prices is very problematic; defining water rights seems a formidable task; and community management, while promising, would have to be introduced on an unprecedented scale to be effective.

Table 6: Wicked and Tame Problems Compared

Characteristic	Tame Problem	Wicked Problem
Problem formulation	A clear and objective definition is readily available. The sources and underlying processes are simple and widely understood.	No definitive formulation due to extreme complexity. The problem is perceived through personal judgement and/or preconceived notion of solution.
	The nature of the problem does not change significantly over time. Problem is terminated by applying solution(s).	The problem is constantly evolving and is never completely resolved. Any solution(s) may only be temporary.
Interdependency	The problem is composed of a small number of constituent parts without extensive linkages between them.	The problem is composed of and related to many different problems. All of these different elements affect each other through a network of linkages.
	A narrow range of stakeholders is involved all of whom view the problem in a similar manner.	Many, diverse groups and stakeholders with competing interests are affected by the problem and solution.
Solution set	The effects of solutions are isolated to specific targets.	Any solution causes feedback effects. The linkage between constituent elements means that the total effect is difficult to ascertain.
	A clear and finite solution set exists. Solutions are developed from objective analysis.	A potentially infinite solution set exists. The merits of different solutions are determined by the judgement of different stakeholders.
	Outcomes are "true-or-false"	Outcomes are "better-or-worse".

Sources: Kreuter, *et al.* (2004) provides a similar presentation of the difference between tame and wicked problems using four of the characteristics formulated by Rittel and Webber (1973)., Batie (2008) adapts this approach, although using a broader set of characteristics.

If Asia's environmental problems are wicked, they will defy simplistic, pre-packaged solutions. "Green growth" and "rebalancing" might serve as useful slogans for overall change, but themselves give little idea of what is needed to give environmental considerations greater weight and, more importantly, how this will be brought about. To help take the debate forward, we propose below a set of policy objectives that might serve as a platform from which to better address Asia's environmental problems. We offer below seven areas of strategic focus, engagement with which will facilitate management of Asia's environmental problems to 2030, and beyond. For the purposes of illustration, we refer directly to the earlier case studies, in addition to the broader environmental issues discussed in previous sections.

4.1. Co-benefits and Issue Linkage

One of the principal characteristics of wicked problems is that they are composed of and related to many problems. This presents complexity but also opportunity. The links between Asia's environmental problems, as well as to development and other issues, allows a single measure to address more than one negative outcome, or achieve co-benefits. Such a situation has many advantages. The value for money in terms of welfare and economic benefits from finance dedicated to attempted solutions is likely to be higher. "No-regrets" policies may be available; even if one goal is not achieved satisfactorily by a multi-objective solution, another is likely to be. Finance and resources available for one issue can be used to address another where the wherewithal is less prevalent. Regional policymakers should divert some resources towards identifying where these opportunities may exist and how they can be best exploited.

Opportunities to realize these co-benefits are most conspicuous where climate change is involved. For example, future REDD arrangements may enable the Singapore and Malay governments to prevent the health impacts of THP in their countries. Similarly, the distribution of improved cookstoves in the interest of climate change mitigation also addresses the health impacts of indoor air pollution on low-income communities. Energy sector reform and a shift to renewable technology can be pursued in the joint interest of energy security, sustainable economic growth, and climate change mitigation. Indeed, the development co-benefits of climate change mitigation have been a principal focus for climate policy in Asia and developing countries more generally. To 2030, the international architecture is likely to present many more opportunities similar to the Clean Development Mechanism and REDD. These should be embraced by the governments of Asia's emerging economies, even where there are up-front costs, such as imposition of outside oversight or structural reform.

Away from climate change, a fundamental issue for Asia's policymakers is that environmental problems are also problems of development and economic growth. Environmental sustainability is not an end in itself, but a key determinant of future prosperity. Certainly, some trade-offs will still occur in the short-term, but not later or even in the proximate future. China's shift towards greater environmental protection reflects the economic downside of the "development first-environment later" mindset, even over just a decade or so of major expansion. Other economies in the region have the opportunity to avoid undergoing this correction. This is why problems such as water and air pollution, farmland degradation, deforestation, and the like are economic issues first and foremost. Hence, their engagement by definition produces "win-win" situations.

A further relevant point here is that the economist adage of "one problem, one instrument" is unlikely to work for these wicked problems. More complex responses operating across multiple issues will be required. In the energy-environment space, for example, a mix of policies will be required to reduce emissions, improve energy security, tackle air pollution, and extend energy access.

4.2. "Bottom-up" Management Processes and Stakeholder Participation

Many of Asia's environmental issues involve diffuse groups whose actions are difficult to control by centralized, one-size fits all regulation. The nature of an environmental problem is likely to differ across locations in the same country, state, or even neighboring communities. Without the participation of local level stakeholders in their formulation, attempted solutions will not be effective, especially where the incentive structure to change behavior is not addressed. Where possible, participation of stakeholders in both the decision-making process and adaptive management should be encouraged. Stakeholders will generally have the best idea of how problems and their solutions work and affect them. Even where broad-scale strategies are required, the design of centralized measures should be place a heavy emphasis on information gleaned from “bottom-up” consultative processes.

The advantages of this approach are apparent from our earlier examples. The short-term financial incentives for communities to be engaged in logging would need to be overcome to achieve a lasting halt to deforestation in Indonesia. Similarly, improved groundwater management in rural India would require some form of cooperation between groundwater users, perhaps through community management. Rural households are unlikely to adopt improved cookstoves unless they consider them to be viable and improved alternatives to traditional methods. Impacts of dams on riparian communities in the Mekong, the management of groundwater in India, and the choice of afforestation activities in the arid regions of China are all issues that will have improved environmental outcomes by the direct engagement of local stakeholders.

4.3. Scientific Research

Comprehension of the dynamics and impacts of problems and potential solutions are essential inputs into effective management of environmental issues. The process of prioritizing certain measures from within an infinite solution set has to be informed by the best possible information. For example, a critical determinant of the welfare impacts of Mekong dams will be the effectiveness of fish ladders for migratory species. Without prior research into this issue, informed decisions on construction are impossible. Likewise, scientific assessment prior to the establishment of large-scale plantations in the drylands of northern China would have avoided the negative impacts on soil hydrology that have since occurred. Ongoing support of scientific research facilitates adaptive management as problems evolve and solutions are attempted. Increased linkages between research institutions across Asia will support knowledge dissemination on related issues.

4.4. Planning

As indicated at the start of this section, planning rather than reaction will be crucial to effective management. For example, measures addressing air pollution in major cities must account for continuing urban sprawl and a richer population in the future and, consequently, rising demand for vehicles. Planning for rising water demand will also be crucial over the next two decades. Policies that address only the current state of an environmental issue will likely be ineffective if and when the problem expands in the future.

The importance of planning is particularly significant to climate change. Steps taken today towards a low-carbon economy in Asia to 2030 will have a great bearing on the future extent of climate change globally. Measures in the near-term, such as energy pricing reform, will reduce the level of restructuring required once these economies have grown much larger. Moreover, climate change will render water security a much bigger challenge in the future, particularly in India and China. Planning for such events ahead of time and addressing issues before they get worse will avoid the full-scale of negative impacts.

4.5. Pricing and Economic Reform

Most environmental problems are an example of “market failure”. This failure usually pertains to environmental costs being unrepresented in the price of goods, services, and access to resources. Raise the price to reflect these costs and invariably there will be less “demand” for environmental degradation. Examples abound throughout Asia of large discrepancies between prices, or private costs, and social cost. In our case-studies, the link was particularly clear in the case of excessive ground-water degradation in India, and climate change mitigation in China. Indeed, when it comes to energy and water, prices often fail to reflect economic let alone environmental costs. Of course, one reason Asia’s environmental problems are wicked is precisely because the pricing reforms they need to solve them are so very difficult to implement. Energy pricing reform can be one of the most sensitive reforms a government can attempt to undertake. Nevertheless, if one is looking for solutions, opportunities to rectify major discrepancies between private and social cost need to be taken.

The flipside of this argument is that environmentally beneficial activities should be supported through subsidies and other price-based mechanisms. Governments throughout the region are already investing heavily in renewable energy, both development and deployment. In other areas, such as deforestation, ecosystem services are beginning to be valued and economic mechanisms developed to sustain them. Such activities should broaden. The prospects for this happening will increase with international and regional support in the provision of funds, expertise, technology, and other resources.

The link from economic reform to environmental benefit goes well beyond the internalization of economic externalities. This is well illustrated by China. China, if it wants to reduce emissions, needs to put a price on carbon. But, for this to influence behavior, price setting in the energy sector needs to be reformed to allow full cost pass-through, so that carbon prices can be passed on to consumers. As we have seen in recent years, this is not always the case, and consumers have often been protected from coal price increases, for example see (World Bank, 2011b). Going beyond pricing altogether, as argued earlier (see Section 3.7 and World Bank, 2011b) rebalancing of the economy is needed to slow down the rate of economic growth, and to make that growth less energy intensive, and more welfare-enhancing. Thus, environmental challenges in China and other countries are linked to fundamental questions of economic reform.

4.6. Tackling Corruption and Improving Institutional Capacity

A key determinant of effective environmental regulation is, of course, the quality of the regulator. Corruption remains a pervasive hindrance to improved environmental protection. Whether it be high-level sanction of forest “land-grabs”, misreporting of environmental statistics, or bribes for local officials not to enforce national laws, corruption involving public officials facilitates unsustainable resource use across many parts of Asia. Tackling corruption is a wicked problem in itself, but attention to this single issue will strengthen the effectiveness of all the other management strategies outlined here. Establishment of independent regulators, cooperation with an unrestricted NGO sector, greater transparency, and institutional democratization at all levels are important objectives.

Corruption is just one part, albeit an important one, of the wider issue of institutional capacity. Uncorrupted regulatory bodies can still be under-resourced or have poorly trained staff. Allocating central budget resources to environmental regulation should increasingly be viewed as part of the economic growth and development agenda.

4.7. Cooperative Management, Regional Institutions, and International Cooperation

Cooperative management mechanisms will be important to avoid any conflict over use of shared resources, particularly between states. Forums such as the Mekong River Commission and others like it in the region must serve as important meeting places for states to share information and negotiate. The creation of shared institutions or agreements prior to the full materialization of potential flashpoints, such as the changing hydrology of rivers originating in Tibet and the Himalayas, will assist adaptive and mutually beneficial management. At a community level, cooperative management of a shared resource, such as groundwater, could help to break "public good" characteristics wherein individual users have no self-interest in personally pursuing sustainable usage patterns. Cooperative management between government departments or national governments in the pursuit of the co-benefits mentioned above will be critical to the results of a multi-objective approach.

An important component of cooperative management will be a central role for regional institutions. Batie (2008) emphasizes the importance of "boundary institutions" in addressing wicked problems. Such institutions act as a conduit between knowledge providers (e.g. scientific researchers) and knowledge users (e.g., policymakers, resource managers, and the public). In the Asian Development Bank (ADB), the region already has a major institution that fulfils this role. As Asia's environmental problems grow, the ADB should expand its activities to further engage with the management strategies outlined here. Political and economic institutions such as ASEAN and APEC will increasingly have to incorporate environmental issues within their agenda, not just in words but in actions that reflect the significance of these problems to regional growth and stability.

Looking beyond the region, international cooperation has a critical role to play. This coming century may belong to Asia, but, at this particular juncture, Asia will need considerable assistance if it is to find the resources and expertise required to address its environmental problems. This is particularly true for the poorer countries of Asia in per capita terms, such as India. More broadly, the developed countries of the world also have a crucial leadership role to play on global issues such as climate change. Without effective action to reduce emissions being taken by OECD countries, one can hardly expect tough decisions to be made in Asia.

5. Conclusion

It is clear that the current trajectory of environmental degradation in Asia is unsustainable. Policymakers around the region acknowledge the importance of environmentally sustainable growth and are already acting, but much more will need to be done. A prosperous, growing, and safe Asia needs water, clean air, forests, and arable land. Under current trends, these components of the natural resource base threaten to decline substantially as population and per capita incomes rise. Food security, human health, and regional cooperation are all likely to weaken if natural resources are not protected. Action on climate change mitigation in the region over the next two decades will, by and large, shape the scale of damages from global warming. Both the region and the globe cannot afford for Asia as a whole to retain any vestiges of a "development first-environment later" mindset.

We have argued that Asia's diverse environmental problems share the characteristic of being "wicked". That is, they are dynamic and complex, they encompass many issues and stakeholders, and they evade straightforward, lasting solutions. Specifically, tackling environmental problems in Asia requires sustained regional cooperation, strong implementation capacity, and the ability to tackle domestic vested interests and compensate affected parties. All of these present serious challenges to even the best-intentioned government.

The six case studies presented here serve both to illustrate the breadth of problems Asia is facing on the environmental front, and the complexities involved in addressing them. These are not problems that will be solved by growth alone. Growth will help make resources available to direct towards solutions, and will reduce exposure to natural vulnerabilities. But growth will also deepen the impact of the divergence between social and private cost which underlies so many of these problems (leading to more water extraction, land degradation, and so on).

Nor can reliance be placed on technological progress to solve these wicked problems. Again, technological change can help, whether by boosting agricultural productivity or helping make cleaner energy cheaper. But there is no guarantee of a technological solution, and some technological change will make environmental problems more severe: consider the problems of water shortage faced by the Indian state which pioneered the Green Revolution.

Not only are growth and technology not the answer; the more general point is that prescriptive, simplistic solutions to Asia's environmental problems simply do not exist. There is increasing interest around Asia, and indeed worldwide, in 'green growth'. Green growth is certainly what Asia needs. As the recent UN Global Sustainability Report notes: "Green growth, pioneered in the Republic of Korea and other countries, aims to foster economic growth and development while ensuring that natural assets and environmental services are protected and maintained" (UN, 2012). But, as this articulation makes clear, green growth (like "rebalancing") is an aspiration, not a strategy. Achieving green growth means tackling the very difficult problems outlined in this paper, to which, we have argued, there are no easy solutions.

Talk of changing Asia's development model falls into the same category. Asia indeed needs a new development model, one which gives more attention to environmental sustainability. But again, this is an aspiration not a strategy. Progress can be made, but, as our examples show, it is not guaranteed, it takes time, and is not unidirectional.

Going beyond the aspirations of green growth and a new development model, the best one can hope to articulate at a general level is a set of principles that may be useful in dealing with a wide range of environmental problems. We have suggested seven: a focus on co-benefits; an emphasis on stakeholder participation; a commitment to scientific research; an emphasis on long-term planning; pricing and broader economic reform; an attack on corruption, and a bolstering of institutional capacity in environmental areas; and a strengthening of regional approaches and international support.

The above list of strategies is certainly not exhaustive and the relative importance of each will vary across different settings and problems: large investments in scientific research will not substitute for an inherently corrupt bureaucracy. But they are a starting point, helping to explain what a green growth or rebalancing agenda might mean for the environment, while emphasizing all along that there are no easy solutions.

It is unquestionable that Asia's environmental challenge is vast and the urgency mounting. Though Asia's environmental challenges are complex and difficult to solve, this does not mean that they will not be or that they cannot be addressed. Environmental resources are a critical component of human welfare and economic activity, and, consequently, their degradation will compel responses at some stage. Pre-emptive measures avoid the far greater economic burden associated with reactive or emergency responses, such as migration from areas of extreme water scarcity or government imports of food due to failed harvests. Prior mitigation necessarily avoids some of the costs from adaptation and damages. Therefore, the degree to which these problems act as a brake on regional economic development will depend in large part upon the pre-emptive steps taken towards controlling them.

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