Towards a China Environmental Performance Index

Yale Center for
Environmental Law and Policy,
Yale University

Center for International
Earth Science Information Network,
Columbia University

In collaboration with:
Chinese Academy for
Environmental Planning

City University of
Hong Kong

Additional materials available at:
www.yale.edu/envirocenter

Yale Center for Environmental Law and Policy (YCELP)
Center for International Earth Science Information Network (CIESIN), The Earth Institute at Columbia University
Chinese Academy for Environmental Planning (CAEP)
City University of Hong Kong (CityU)

Towards a China Environmental Performance Index (CEPI)

Final Report

Table of Contents

Authors and Acknowledgements

Core Team YCELP

Daniel ESTY	Director
Christine KIM	Project Manager
Jay EMERSON	Senior Statistician
Angel HSU	Researcher

Core Team CIESIN

Marc A. LEVY	Deputy Director
Alex DE SHERBININ	Senior Research Associate
Valentina MARA	Senior Research Associate

Core Team CAEP

WANG Jinnan	Vice President
CAO Dong	Director
CAO Ying	Researcher
CAO Guozhi	Researcher

Core Team CityU

Hon S. CHAN	Professor of Public Administration
SHI Han	Assistant Professor of Environmental Policy
LI Wanxin	Associate Professor of Public Administration

Other contributors

YCELP:

Ysella EDYVEAN	Program Coordinator
Bill DORNBOS	Associate Director
Jessica JIANG	Research Assistant
Elyssa GELMANN	Research Assistant
Fran MOORE	Research Assistant
Chung-En (John) LIU	Research Assistant
Lucy SORENSEN	Research Assistant
Mayanka MUGDAL	Research Assistant
MENG Ji	Research Assistant
Elizabeth CAMPBELL	Research Assistant
Jie BAI	Research Assistant
Andy BARNETT	Research Assistant
Alice SONG	Research Assistant
Jiaona ZHANG	Research Assistant
Jennifer WANG	Research Assistant
Jacob MEYER	Research Assistant
Diana CONNETT	Research Assistant
Wanting ZHANG	Research Assistant
ZHENG Yeqing	Research Associate, Yale Law School

CIESIN:

XING Xiaoshi	Information Scientist, CIESIN

Renmin University:

ZHOU Jingbo	Research Associate, Yale / Assoc. Professor, Renmin University

In addition, we would like to acknowledge contributions by participants at three expert workshops held in Beijing in September 2008 and February 2009 and in Hong Kong in May 2009:

Chonchinee AMAWATANA	Environmental Performance Assessment Coordinator, GMS Environment Operations Center, Asian Development Bank
Christian AVEROUS	Head, Environmental Directorate, Environmental Performance and Information Division, OECD
CHAI Fahe	Vice Director, Chinese Research Academy of Environmental Sciences
CHEN Ying	Research Fellow, Environment Development Center of MEP
CHEUN Richard	Associate Professor, Department of Biology and Chemistry, City University of Hong Kong
CHO Jackson	Tutor, General Education Center, Hong Kong Polytechnic University
FU Deqian	Researcher, Chinese National Environmental Monitoring Center
FU Liu Cheng	Professor, Hunnan Environmental Protection Research
GE Chazhong	Division Director, Professor, CAEP, MEP
Brendan GILLESPIE	Head, Environmental Performance and Information Division, OECD
HE Wensheng	Professor, Lanzhou University
Paul HIGGINS	Assistant Professor, Department of Public and Social Administration, City University of Hong Kong
HO Richard Yan-ki	Professor, City University of Hong Kong
Maria Fancesch HUIDOBRO	Assistant Professor, Department of Public and Social Administration, City University of Hong Kong
HU Qiansheng	Associate Professor, Sun Yat-sen University of Medical Sciences
JIANG Wenlai	Researcher, Chinese Academy of Agricultural Sciences
Michalak KYZYSZTOF	Administrator, Environmental Performance and Information, OECD
LI Linda Chelan	Associate Professor, Department of Public and Social Administration, City University of Hong Kong
LI Wuoqiang	Director, Division of Environmental Statistics, National Bureau of Statistics
LI Yunsheng	Assistant Professor, CAEP
LIANG Tan	Director, General Office Affairs, Guangxi Environmental Protection Bureau
LU Xiaotong	Researcher, Sichuan Environmental Protection Research
MA Daphne	Senior Research Fellow, Governance in Asia Research Center, City University of Hong Kong
MA Zhong	Dean and Professor, School of Environment and Natural Resources, Renmin University
MIAO Bo	Research Fellow, Department of Asian and International Studies, City University of Hong Kong
PEI Xiaofei	Research Fellow, Policy Research Center for Environment and Economy, State Environmental Protection Administration
PENG Xushu	Researcher, CASS
QI Jianguo	Senior Research Fellow, Professor, Chinese Academy of Social Science
REN Yong	Deputy Director, Policy Research Center for Environment and Economy, State Environmental Protection Administration
David ROSENBLOOM	Chair Professor of Public Management, Department of Public and Social Administration, City University of Hong Kong
WAH YEUNG King	Lecturer, Division of Commerce, City University of Hong Kong
WAI Chung Ling Jackson	Environmental Protection Department, HKSAR Government
WANG Xin	Director, Project Manager, Division 1, Foreign Economic Cooperation Office, MEP
WANG Yi	Deputy Director-General, Institute of Policy and Management of Chinese Academy of Science
WATSON Iain	EPA Task Leader, GMS Environment Operations Center, ADB
WANG Jin	Professor, Beijing University
WING KIN Benny Lam	Researcher, Environmental Protection Department, HKSAR Government
XIONG Jianhua	Ph.D, Guangxi Environmental Protection Bureau
WONG Kenneth	Head and Professor, Department of Geography, Hong Kong Baptist University
XU Jintao	Professor, Department of Environmental Sciences, Peking University

XUE Lan	Professor, Dean, School of Public Management, Tsinghua University
YE Hong	Researcher, Sichuan Research Institute of Environmental Protection
YU Fei	Director, State Environmental Protection Administration
ZHANG Bing	Professor, Environmental Studies, Nanjing University
ZHANG Ganlin	Researcher, Chinese Academy of Science
ZHANG Huiyuan	Senior Research Fellow, CAEP, MEP
ZHANG Jinhua	Deputy Regional Coordinator, Division of Early Warning and Assessment, UNEP
ZHANG Shaofeng	Director, China Program, The Nature Conservancy
ZHANG Tianzhu	Professor, Department of Environmental Science and Engineering, Tsinghua University
ZHANG Xiliang	Professor, Deputy Director, Institute of Energy, Environment, and Economy, Tsinghua University
ZHENG Chunmiao	Professor, Department of Geological Sciences, Beijing University
ZHOU Hongchun	Societal Development Researcher, Development Research Center of the State Council
ZHU Bing	Associate Professor, Department of Chemical Engineering, Tsinghua University
ZHU Xiang	Senior Researcher, Yunnan Province Environmental Protection Research

II. Executive Summary

China is confronting significant environmental challenges across the board, from air and water quality to natural resource management, waste management, toxics exposure, biodiversity conservation, and greenhouse gas emissions. All of this is occurring in the context of high population densities, rapid economic growth, and the imperative of lifting large numbers of people out of poverty. Given the challenges China faces, it is important for the government to have policy tools that are adequate for guiding and prioritizing action. Globally, the move toward a more data-driven empirical approach to environmental protection promises to better enable policymakers to spot problems, track trends, highlight policy successes and failures, identify best practices, and optimize the gains from investments in environmental protection. China, like many countries, has employed performance metrics in areas such as economic, educational, and social policy. It is natural to extend this practice to the environmental sphere.

This project was conducted by a team of researchers at Yale University, Columbia University, City University of Hong Kong and Chinese Academy for Environmental Planning. The work was carried out from late 2008 through mid-2010 and reflects the state of China environmental data availability and policy developments during that time period (Appendix 3 provides details on the most recent environmental targets from the 12th Five-Year Plan). The project explored the feasibility of constructing a provincial level Environmental Performance Index (EPI) in China. The main purpose was to describe a process and identify the elements that would be required for creating a China EPI. Although we provide a proposed framework, sample indicators, targets, and other elements of an EPI, we in no way suggest that this is the only blue print for creating a provincial EPI in China. In other words, the results are meant to be illustrative, not definitive. This was a research project; an operational EPI would need to be designed and developed by government and civil society stakeholders within China.

An EPI includes *environmental indicators* that are (1) normalized by proximity to policy targets (with 100 representing at or above the target and 0 representing farthest from the target), (2) grouped into relevant *policy categories*, and (3) aggregated into an *overall index* with or without weighting. These indicators provide a gauge at any relevant scale – nation, province, or city – of how close different jurisdictions are to established environmental policy goals. The proximity-to-target methodology facilitates comparisons between geographic entities (districts, cities, provinces, or nations) as well as analysis of how provinces and the country as a whole perform on each policy issue.

Any EPI requires the following core elements:

- A carefully constructed and theoretically grounded framework of indicators that encompasses the range of high-priority environmental issues and situates them with respect to one another in a nested manner.
- Baseline measurements for each indicator.
- Policy targets, whether based on explicit government decisions or alternative sources, against which to measure observed environmental outcomes.
- Methodological transparency with regard to indicator construction and a capacity to evaluate uncertainties in the underlying data.

- Ongoing measurement programs that provide regular, consistent updates for all data required to calculate indicators.
- A clearly spelled out basis for assigning weights to constituent indicators, to permit aggregation to the index level.

No country or international organization currently possesses all these elements to the full extent desirable. Some jurisdictions approach "best practices," while others fall far short due to competing policy priorities, insufficient technical and financial capacities, or institutional weaknesses. Interest in producing environmental performance indicators almost always rises before all the elements identified above are in place. Given the high priority put on progress toward pollution control and natural resource management goals in many countries and the increasingly recognized value of a data-driven approach to environmental policymaking, such interest can be observed to be increasing around the world.

Although there is considerable interest in the development of a provincial level EPI within China, we found that not all of the elements are yet in place for its development. The absence of clear policy targets for many indicators, the lack of suitable data for some important policy areas (fisheries and water quality), and an inability to properly evaluate data sources meant that we stopped short of producing an aggregated EPI. Instead, in this report we present the results of an in-depth study of the main environmental issues and China's policy responses for 12 environmental policy categories, current international best practices in measurement for those policy areas, and China's own measurement practices. We also chose selected indicators for these policy categories (32 in total), clearly spelling out the strengths and limitations for each one, and present ranked results by province in the form of tables and maps. We did not feel that it would be appropriate to normalize or aggregate these indicators. Instead we identify the elements of a system that would need to put in place for tracking environmental performance across the 12 policy categories.

Overall, it is our sense that China has made important inroads in environmental monitoring and policy, but that the country would benefit from greater transparency and freer access to data, especially raw data from monitoring systems and spatial data on environmental conditions. Such transparency could, in turn, stimulate the research and policy communities to develop innovations that will help the country to navigate the difficult paths of sustainability. Even in the very best scenario, however, a country the size of China with economic growth rates of close to 10%, will face significant environmental challenges. An EPI will help the government to design policies and programs that will improve environmental conditions, and provide useful information on provinces that are lagging in environmental performance so that resources can be better targeted.

III. Main Report

Project Overview and Objectives

China's environmental challenges have become the focus of considerable domestic and international attention. China has long suffered environmental problems common to low income countries – inadequate water supplies in terms of quantity and quality, high levels of ambient air pollution, and threatened biodiversity. Yet, with the advent of China as a major industrial power, a host of new problems associated with affluence are beginning to appear. Recently China passed the US as the world's largest emitter of carbon dioxide and passed Japan to become the world's second largest economy (IEA, 2010). Plumes of air pollutants and dust from desertified lands now affect many of its Asian neighbors. Agricultural and wild lands are rapidly being urbanized. Toxic wastes are accumulating.

In the face of these challenges, China's policymakers need strong analytic foundations on which to build pollution control and natural resource management programs. Provincial-scale environmental indicators can help to spot critical issues, track trends, evaluate policy success, and target funding. Better environmental data and fact-based analysis as well as commitment to transparency and vigorous policy debate can help China's transition to sustainability.

This project was conducted by a team of researchers at Yale University, Columbia University, City University of Hong Kong, and the Chinese Academy for Environmental Planning. The work was carried out from late 2008 through mid-2010, and thus, apart from Appendix 3, does not reference the 12th Five Year Plan. The project explored the feasibility of constructing a provincial level Environmental Performance Index (EPI) in China, excluding Hong Kong, Macau, and Taiwan, for which we were unable to obtain comparable data. The main purpose was to describe a process and identify the elements that would be required for creating a China EPI. Although we provide a proposed framework, sample indicators, targets, and other elements of an EPI, we in no way suggest that this is the only blue print for creating a provincial EPI in China. In other words, the results are meant to be illustrative, not definitive. This was a research project; an operational EPI would need to be designed and developed by government and civil society stakeholders within China.

The Yale Center for Environmental Law & Policy and the Center for International Earth Science Information Network (CIESIN) at Columbia University have been the world leaders in developing national-scale environmental indices since they launched the Environmental Sustainability Index in the year 2000. The most recent of these reports, the 2010 Environmental Performance Index (EPI), provides national policymakers with a scientifically accurate and easily applicable tool for data-driven environmental decision-making. The 2010 EPI ranks 163 countries by their proximity to targets for 25 indicators and allows countries to benchmark their management against that of their neighbors and peers.

The EPI, however, only addresses environmental issues at the national scale. Given China's diverse geographical landscapes and extensive environmental policy-making scope by local governments, a sub-national index is a more effective tool for the development of environmental policy. In partnership with the Chinese Academy for Environmental Planning (CAEP) of China's Ministry of Environmental Protection, City University of Hong Kong, and CIESIN at Columbia University's Earth Institute, the Yale Center for Environmental Law & Policy launched a project to assess management and performance at the provincial level across a broad range of environmental categories. The project was conceived to answer a basic question: Is it possible, given available data, to develop an environmental performance index that ranks all province-level administrative areas in China on the basis of their proximity to clearly identified policy targets? Based on extensive consultations and an exhaustive review of available data, the short answer to this question is "no." While we were able to rank provinces for 32 indicators in 12 environmental policy categories (e.g., air pollution, water quality, climate change, biodiversity, agriculture, and forestry)[1], the absence of clear policy targets for many indicators, and an inability to sufficiently evaluate the data meant that we stopped short of producing an aggregated environmental performance index. The elements that are missing for the production of a full EPI are described in more detail in the following section on Measurement Assessment.

Beyond exploring the potential for the creation of an aggregated EPI for China's provinces, this project had further objectives such as developing a framework for the assessment of China's environmental challenges and informing policymakers of best practices in measurement and performance assessment. These objectives were, we believe, fully met. The China EPI framework (see following pages), developed in consultation with many environmental experts in China and the US, provides a tailored set of issues and indicators that will be important to track for the foreseeable future. The project also serves to inform China's environmental policy-makers of data collection needs, best practices in measurement, and the importance of establishing and monitoring progress towards concrete performance targets. It is hoped that, with attention to these matters, it will be possible to develop an aggregate provincial level EPI in the future.

This project report and the accompanying China EPI data set are available on the Internet at the following sites: http://envirocenter.yale.edu/chinaepi and http://ciesin.columbia.edu/chinaepi/.

---

[1] A 13th category, fisheries, does not have any indicators because of the difficulty of attributing responsibility for impacts on coastal fisheries to any given province.

Proposed Framework for a Province Level China Environmental Performance Index

Index	Objective	Objective Code	Policy Category	Policy Category Code	Indicator	Indicator Code	Data Source	Proposed Target (Sources Listed in Indicator Profiles)
EPI	**Environmental Health**	ENVHEALTH	**Air Pollution (effects on humans)**	AIR_H	Population weighted PM10 concentrations	PM10	Ministry of Environmental Protection, 2003-2007	≤ 20 ug/m3 WHO (≤100ug/m3 China)
					Population weighted SO_2 concentrations	SO_2	Ministry of Environmental Protection, 1998-2007	≤ 40 ug/m3 WHO (≤80ug/m3 China)
					Population weighted NO_2 concentrations	NO2	Ministry of Environmental Protection, 2000-2007	≤ 60 ug/m3 China (no yearly WHO target)
			Water (effects on humans)	WATER_H	Access to tap water in rural areas	RURTAP	China Environmental Statistical Yearbook, 2004-2006	75% by 2010
					Access to tap water in urban areas	URBTAP	China Environmental Statistical Yearbook, 1996-2005	100% of population with access
			Waste and Sanitation	WASTE	Municipal waste intensity	MSW_PC	China Statistical Yearbook, 1996-2007	not available
					Industrial solid waste intensity	ISWINT	China Statistical Yearbook, 1996-2007	not available
					Municipal solid waste treated	MSW_T	China Statistical Yearbook, 2003-2007	60% by 2010
					Municipal wastewater treatment	MWW_T	China Statistical Yearbook, 2004-2006	not available
					Urban human waste disposal	SANU	China Statistical Yearbook, 2003-2007	78% by 2010
					Rural human waste disposal	SANR	China Environmental Statistical Yearbook, 2004-2005	65% by 2011

Index	Objective	Objective Code	Policy Category	Policy Category Code	Indicator	Indicator Code	Data Source	**Proposed Target** (Sources Listed in Indicator Profiles)
			Toxics	TOXIC	Heavy metals	METALS	China Environmental Statistical Yearbook, 2003-2007	not available
					Hazardous waste intensity	HAZINT	China Statistical Yearbook, 1996-2007	not available
	Ecosystem Vitality	ECOSYSTEM	**Air Pollution (effects on ecosystem)**	AIR_E	SO_2 emissions per populated land area	SO2_E	Ministry of Environmental Protection	10% reduction during the 11th Five-year Plan
					NO2 emissions per populated land area	NOx_E	Ministry of Environmental Protection	not available
			Water (effects on ecosystem)	WATER_E	Water Scarcity Index	WSI	China Statistical Yearbook, 2002-2007	0.4 (expert's judgment)
					Intensity of COD emissions	COD	China Statistical Yearbook, 2003-2007	10% reduction in total COD load during the 11th Five-year Plan
			Biodiversity & Habitat	BIODIV	Terrestrial protected areas	TPA	China Statistical Yearbook, 1997-2007	13% by 2010
					Marine protected areas	MPA	China Marine Statistical Yearbook 2006	not available
					Water quality of offshore marine areas	WATQM	Report on the Administration of the Use of Sea Areas 2006, 2007	not available
			Forestry	FOREST	Growing stock change	FORGRO	China Statistical Yearbook, 1998, 2003	ratio of growing stock in time 2 to time1 ≥1
					Forest cover change	FORCOV	China Statistical Yearbook, 1998, 2003	ratio of forest cover in time 2 to time1 ≥1
			Agriculture and Land Mgt	AGCLTR	Pesticide use intensity	PESTINT	China Statistical Yearbook, 2004-2007	3 kg/ha

Index	Objective	Objective Code	Policy Category	Policy Category Code	Indicator	Indicator Code	Data Source	**Proposed Target** (Sources Listed in Indicator Profiles)
			Agriculture and Land Management (continued)		Chemical fertilizers use intensity	FERTINT	China Statistical Yearbook, 1996-2005, 2007	250 kg/ha
					Soil erosion	SELAND	China Soil Erosion Bulletin 2000	Reduce by 34% during the 11th Five-year Plan
	Economic Sustainability	SUSTAINABILITY	**Climate Change and Energy**	CLIMATE	CO2 intensity	CO2INT	China Statistical Yearbook, 2004-2005	not available
					CO2 emissions per capita	CO2PC	China Statistical Yearbook, 2004-2005	not available
			Resource Efficiency	RESOURCE	Economic energy efficiency	EFFEC	China Statistical Yearbook, 1998-2007	varies by province, 12-30%
					Efficient use of waste	EFFWASTE	China Statistical Yearbook, 1995-2007	60% by 2010
					Efficient use of water in agriculture	EFFWATagr	China Statistical Yearbook, 2002-2007	Reduce by 30% during the 11th Five-year Plan
					Efficient use of water in industry	EFFWATind	China Statistical Yearbook, 2002-07	Reduce by 30% during the 11th Five-year Plan
			Environmental Governance	GOVERNANCE	Number of EPB employees on government payroll	GOVEMPL	China Statistical Yearbook, 1995-2002, 2006	not available
					Investment in environmental protection, as percentage of GRP	INVPOLL	China Statistical Yearbook, 1998-2007	not available

Main Overview of the Report

A. Measurement Assessment

This project explored the feasibility of constructing an Environmental Performance Index (EPI) at the provincial level in China. An EPI requires the following core elements:

- A carefully constructed and theoretically grounded framework of indicators that encompass the range of high-priority environmental issues and situates them with respect to one another in a nested manner.
- Baseline measurements for each indicator.
- Ongoing measurement programs that provide regular, consistent updates for all data required to calculate indicators.
- Methodological transparency with regard to indicator construction and a capacity to evaluate the underlying data.
- Policy targets, whether based on explicit government decisions or alternative sources, against which to measure observed environmental outcomes.
- A clearly defined basis for assigning weights to constituent indicators, to permit aggregation to the index level.

No country or international organization possesses all these elements to the full extent desirable. However, some jurisdictions approach "best practices" while others fall far short. Given the high priority put on progress toward pollution control and natural resource management goals in many countries and the increasingly recognized value of a data-driven approach to environmental policymaking, interest in producing environment performance indicators almost always emerges before all the elements identified above are in place. All countries and organizations pursuing such a goal are pioneers charting a new direction for scientifically grounded, empirically oriented environmental decision-making.

We find that some of the elements of the foundation needed to construct an analytical framework suitable for the production of an EPI in China at the provincial level are in place. Chinese environmental policy-making is sufficiently advanced across a broad range of policy issues that it is possible to identify high-priority environmental issues, to group them into meaningful categories, and to nest them within a hierarchical structure. The ability to construct the requisite framework was strongest for industrial pollution and weakest for ecosystem conservation. This imbalance is common in many countries. While there remain challenges to constructing a robust analytical framework that can serve as the basis for an operational EPI, these challenges are not overwhelming and could be addressed by the Chinese government.

We find that the existence of baseline environmental data is highly uneven. Less than half of the candidate indicators we evaluated had baseline data against which to benchmark environmental performance. Baseline data were most prevalent for economic sustainability indicators (68%) and least prevalent for ecosystem vitality indicators (20%), while environmental health indicators were in the middle (42%). This pattern reflects the priorities of Chinese environmental policy-making in the past decade, which has emphasized pollution control and resource efficiency in the industrial sector.

The recent high-level commitment to sustainable development is encouraging, but it has not yet been matched by measurement systems that are capable of monitoring performance across the appropriate range of issues.

We find that ongoing measurement systems are also highly uneven. Consistent measures, produced on a regular basis, following established methodologies, in a transparent and verifiable manner, are critical for environmental performance monitoring. In China, the measurement systems related to industrial efficiency are exemplary models. In this arena, the published data meet the foundational requirements and, as a result, permit operational use of performance indicators in the five-year plans. The other measures generally fall short. For example, methodologies for ecosystem measures tend to change over time, making comparison problematic, and the metrics used to measure air and water quality are highly transformed in ways that make tracking performance difficult.

We find that difficulties in accessing raw data hinders the kind of data evaluation that would be required for a province-level index. This report provides pilot indicators based on official statistics. We did not have the ability to independently evaluate those statistics in order to produce uncertainty estimates. Data evaluation can be accomplished in a number of ways. For example, to evaluate the uncertainties in air and water pollution metrics it would be useful to obtain raw monitoring station data so as to identify spatial and temporal anomalies. Monitoring station data can also be aggregated to different administrative levels for different time periods and compared to official statistics. This project found that official statistics for most indicators lacked detailed information on data collection methods and monitoring systems, and in no instance were we able to obtain raw data from monitoring stations. Nor were we able to obtain data from third parties that might have been used to corroborate official statistics. For all these reasons, it proved difficult to assess the validity and reliability of the official statistics. Without recourse to raw or third-party data for data validation, we did the next best thing, which is to analyze time series for outliers, and in one instance (air quality), to analyze separate sets of official statistics measuring the same phenomenon (see Appendix 1).

Policy targets for the vast majority of candidate indicators are not easily identified. Overall, we were able to establish a basis for constructing a policy target for 21 of the 33 indicators we included—8 in the environmental health objective, 7 in the ecosystem vitality objective, and 6 in the economic sustainability objective. Of the 50 additional indicators that we considered but decided against including, none of them had policy targets. The lack of properly specified policy targets is not unique to China. Similar challenges around goal setting exist in many countries, especially in the developing world. Unfortunately, the limited number of plausible policy targets makes construction of a useful EPI nearly impossible.

We find that there are no technical obstacles to the selection of indicator weights and an appropriate aggregation methodology. This conclusion is somewhat tentative because it is based on an analysis of the indicators for which we had necessary inputs. It is most uncertain concerning the highest level of aggregation that integrates environmental health, ecosystem vitality, and economic sustainability indicators into a single overarching index. Because the indicators are not spread evenly across the three areas, we have not been able to fully test their robustness with regards to weighting. Based, however, on the information at hand and our experience in other settings, we are cautiously optimistic that indicator aggregation will not be a technical problem in moving forward. Since any weighting scheme necessarily reflects value judgments about the relative importance of different environmental issues, at the political level there may be other issues that will arise.

In conclusion, we find that China has a solid foundation on which to build a cutting-edge environmental performance measurement system at the provincial level. However, key weaknesses in methodological structure, transparency, the capacity for data verification, and policy target selection need to be addressed in order to realize the potential for a full-blown EPI at the provincial scale. A growing reliance on robust environmental performance measurement is found in some sectors (such as energy efficiency and COD discharges) and regions of the country (such as the Pearl River Delta region in air quality monitoring). Likewise, there exists interest in monitoring programs and the capacity to set policy as well as to evaluate the impact of government interventions based on solid data. There is a high-level commitment toward the integration of scientific knowledge about environmental sustainability into all aspects of policy-making. This foundation can most effectively be built on to construct an EPI by directing attention toward extending measurement activities across a broader range of policy areas, by adhering more closely to established norms of indicator construction, and by engaging in assessments and deliberations that flesh out a basis for identifying policy targets.

B. Calculating an Environmental Performance Index

To develop a national-level EPI requires multiple steps. The first priority is to establish a framework that includes the most relevant objectives and policy categories for the country (see the table in this section). For the China EPI the framework was the subject of extensive discussion, and ultimately resulted in the inclusion of a third objective on Economic Sustainability that was not in the global EPI. This objective focuses largely on resource efficiency, which is a major policy priority of the Chinese government

After a framework is established, for each policy category indicators need to be identified that most closely measure the parameter of interest. For the 2010 EPI, the following criteria were used:

Relevance: The indicator tracks the environmental issue in a manner that is applicable to countries under a wide range of circumstances.

Performance orientation: The indicator provides empirical data on ambient conditions or on-the-ground results for the issue of concern, or is a “best available data” proxy for such outcome measures.

> *Transparency*: The indicator is based on peer reviewed scientific data or data from the United Nations or other institutions charged with data collection.
>
> *Data quality*: The data represent the best measure available. All potential data sets are reviewed for quality and verifiability. Those that do not meet baseline quality standards are discarded.

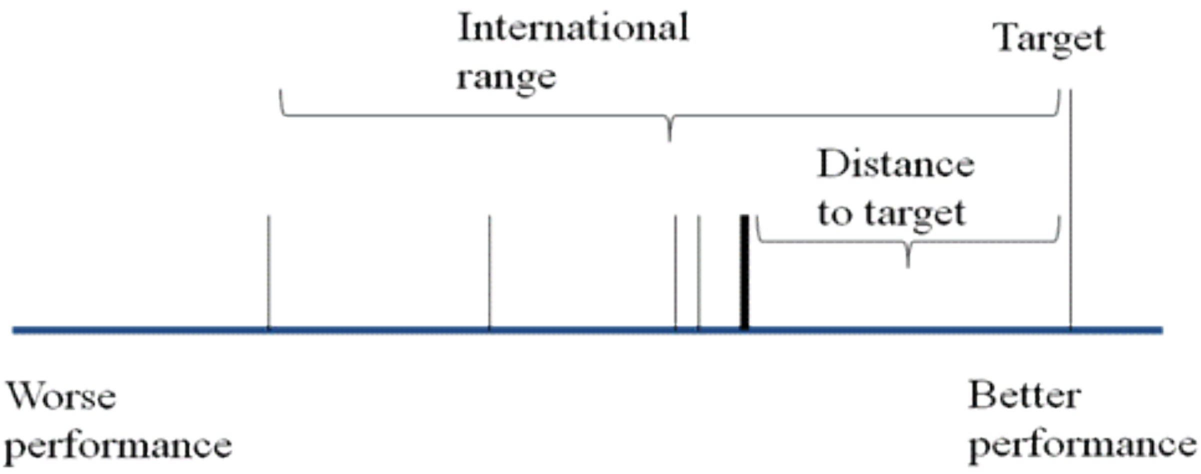
Often indicators are chosen on the basis of available data, but there may be good reasons to include indicators for which data are not yet available in order to flag important environmental issues in need of attention and to spur data collection efforts. Generally data come from government agencies, research institutes, academic institutions, or international agencies. The format of the data generally follows from how they were collected or processed. Data from water or air quality monitoring stations are point data, data from biodiversity surveys may represent point or area estimates, and data from model outputs or remote sensing represent pixels or larger areas.

If sub-national units are being used as the unit of analysis (e.g. provinces or states), then data often need to be normalized to be comparable. This is because comparing raw values (e.g. total area deforested, or total emissions) would not reflect the different territorial sizes, environmental endowments, and demographic and economic contexts of each unit. Common normalizations include percent change (e.g. rates of deforestation over some time period), units per economic output (e.g. energy use per GDP), units per area (e.g., percent territory where water extraction exceeds a certain threshold), or units per population (e.g. CO_2 emissions per capita). Note that the denominator in each case should be relevant for the environmental issue of interest. Furthermore, in other cases it may be useful to weight exposure to some harmful thing (e.g. air pollution) by the population exposed. If ambient air pollution is higher in heavily populated urban areas where 75% of the population lives, it makes sense for the ambient levels for urban areas to contribute 75% to the score for that unit and for rural areas to contribute only 25%.

It is critical to determine if the data are valid (correspond to the “real world”) and reliable (the results are consistent over time). There is no single test for validity and reliability, but an investigation into the monitoring systems and adherence to proper protocols is usually enough to establish if the data can be used for indicator construction. It is also helpful to run statistical tests for outliers, or to compare against data sets measuring the same or similar parameters. If multiple sources of data are available for a given indicator, a thorough vetting of the relative strengths and weaknesses of each data source can uncover anomalies or potential issues with regards to validity and reliability (see Appendix 1 for an evaluation of two air quality data sets for China).

To be aggregated, raw data need to be transformed into indicators. The global EPI is based on a proximity-to-target methodology whereby each country’s performance on any given indicator is measured based on its position within a range established by the lowest performing country (equivalent to 0 on a 0-100 scale) and the target (equivalent to 100).

This can be illustrated through the following diagram.



The generic formula for the proximity-to-target indicator calculation in the context of the global EPI is as follows:

$$\frac{\text{(international range)} - \text{(distance to target)}}{\text{(international range)}} \times 100$$

For example, in the 2010 EPI, China's score for the indicator Access to Sanitation (i.e., percent of population with access to adequate sanitation) is calculated as follows:

- The target is 100% access to sanitation.
- The worst performer is Eritrea, with 5% of its population with access to adequate sanitation. In the EPI terminology, Eritrea's *raw score* is 5%.
- For the 2010 EPI most of the indicators were winsorized, meaning that the tail end of the distribution was "trimmed" at either the 95th or 97th percentile.[2] In the case of Access to Sanitation, this value is 10.9%. Therefore the international range is 100-10.9 = 89.1.
- China's value is 65%, so its distance to the target is 35.
- China's *proximity-to-target score* for Access to Sanitation is calculated as follows: (89.1-35/89.1) x 100 = 60.7. By contrast, Eritrea's *proximity-to-target score* is 0.

Since targets are essential to the indicator calculation, the next step is to identify potential targets for each indicator. For national-level EPIs, these are preferably derived from government plans or policies. Failing this, international targets (e.g. from environmental treaties or global organizations

---

[2] Trimming the tail is a simple matter of examining the entire distribution, and "pulling in" outliers at the low end of the performance spectrum by establishing the low performance benchmark at the 95th or 97th percentile of the distribution. As described in this bullet, if Eritrea represents the 100th percentile (the lowest performance) at 5% coverage, then the 95th percentile of the range is 10.9% coverage.

such as the World Health Organization), scientific criteria, or expert judgment may be used. In the EPI, achieving or exceeding the target is equivalent to a score of 100 on the 0-100 scale. If a target cannot be identified for a candidate indicator based on some scientific or policy grounds, then there is good reason to question its inclusion in the overall framework. For example, for coastal water quality the benchmark for what might be considered acceptable levels of chlorophyll-a concentration will vary significantly based on the type of coastal waters – e.g. estuarine environments, eutrophic systems, and areas of coastal upwelling.

After establishing the target, it is necessary to establish the low performance benchmark, which is the low end of the EPI range (equivalent to 0 on the 0-100 scale). For EPIs based on sub-national units such as states or provinces, the low performance benchmark is usually established by the worst performing sub-national unit on that particular indicator. In the example above, in the 2010 EPI the country with the lowest percentage of its population with access to adequate sanitation is Eritrea with 5%, which is below the winsorized low performance benchmark of 10.9%, so Eritrea scores a 0 on the indicator Access to Sanitation. It is also possible to set the low performance benchmark by using time series data (e.g., the lowest performance in a 10 year time series of a given parameter) or by establishing some theoretical minimum. For example, though there is no country in which 0% of the population has access to adequate sanitation, nevertheless the lowest theoretical rate of coverage would be 0%.

If the underlying raw data are heavily skewed, it may be necessary to perform a logarithmic transformation on the data. This serves two purposes. First, and most importantly, if an indicator has a sizeable number of sub-national units very close to the target, a logarithmic scale more clearly differentiates among the best environmental performers. Using raw (untransformed) data ignores small differences among top-performing countries and only acknowledges more substantial differences between leaders and laggards. The use of the log transformation has the effect of "spreading out" leaders, allowing the EPI to reflect important differences not only between the leaders and laggards, but among best-performing leaders as well. Secondly, logarithmic transformation improves the interpretation of differences between sub-national units at opposite ends of the scale. For example, in the 2010 EPI, consider two comparisons of particulate matter (PM10): top-performers Venezuela and Grenada (having PM10 values of 10.54 and 20.54, respectively), and low performers Libya and Kuwait (87.63 and 97.31, respectively). Both comparisons involve differences of 10 units on the raw scale ($\mu g/m^3$), but they are substantively different. Venezuela is an order of magnitude better than Grenada, while Libya and Kuwait differ by a much smaller amount in percentage terms. Compared to the use of the raw measurement scale, the log scale somewhat downplays the differences between the leaders and laggards, while more accurately reflecting the nature of differences at all ranges of performance. This can encourage continued improvements by the leaders, where even small improvements can be difficult to make, but provides relatively fewer rewards for the same amount of improvement among the laggards.

Once the raw data are ready to be transformed into proximity-to-target indicators, the following specific formulas are used depending on whether larger numbers on the raw scale imply good or bad performance:

> Where high values equate to good performance (e.g. protected areas coverage):
> 100 - [(target value - winsorized value) x 100 / (target value - minimum winsorized value)]
>
> Where high values equate to bad performance (e.g. air pollution emissions):
> 100 - [(winsorized value - target value) x 100 / (maximum winsorized value - target value)]

This results in each unit of analysis being assigned a score ranging from 0-100 for each indicator.

The final step is to aggregate the indicators into policy category, objective, and overall EPI scores. Aggregation at each stage can be accomplished by a simple average of indicator proximity-to-target scores into policy categories, then of policy category scores into objectives, and then objective scores into the EPI. But often there are theoretical, scientific, or policy reasons to apply differential weighting at each stage of aggregation. At the indicator level, some indicators may be considered more robust or may more closely track the policy area of interest, and therefore be deserving of greater weight. For example, in the 2010 EPI the Environmental Burden of Disease (EBD) as an indicator is given 25% of the weight of the overall EPI score, whereas the four other indicators are each given a weight of 6.25%. This was based on a determination that the EBD more closely tracked the issues of interest to the Environmental Health objective, and in some ways represented a summation of the other indicators.

There are also valid reasons to suppose that some policy categories are worthy of greater weight in the overall aggregation. For instance, in the Pilot 2006 EPI the policy category addressing climate change was only contributed 10% to the overall EPI score within the Ecosystem Vitality objective. By 2008 the EPI team determined, owing to the potential impacts of climate change on all other ecosystem functions and its importance in international environmental discourse, that the climate change policy category deserved a greater weight within the overall EPI. As of the 2008 EPI its weight was increased to 25% of the overall score.

Choosing the proper weights is inherently subjective, yet whatever weights are chosen should be provided in the documentation so that there is transparency. Note that if an indicator is only relevant for certain regions (e.g., an indicator on marine fisheries may only relevant for coastal states or provinces), then it can be given a 0 weight for those regions where it is not relevant (equivalent to being omitted from the aggregation).

Once one has calculated the EPI, it is important to test the sensitivity of the framework and aggregation methods. This requires some statistical skills in order to test the sensitivity of results based on the framework, the weighting scheme, and other assumptions. An example of a sensitivity analysis can be found in Chapter 5 of the 2008 EPI report (Esty et al. 2008), or in Appendix G of the Pilot 2006 EPI report (Saisana and Saltelli 2006).

C. Data Analysis

In the construction of the global EPIs, the best available data sets in all categories are used to construct proximity-to-target indicators, which are then weighted according to expert judgment and combined to result in an aggregate index score for each country. On this basis, countries can then be ranked. The primary barrier to creating a comprehensive scaled aggregate index was the lack of targets for many indicators, which renders it impossible to transform the raw data to a normalized proximity-to-target indicator (with 0 representing the worst performing province and 100 representing "at target" provinces). This, in turn, means that the indicators cannot be averaged or weighted to produce an aggregate index.

While the indicators were not aggregated into a composite index, we do present official statistics for the indicators that we considered and selected as the most promising and/or useful for the China EPI. These data sets are presented as ranked tables (from the best performer to the worst performer by province) for the most recent year available for each indicator within each policy category section, as well as charts and maps (where available) showing provincial comparisons. Further information regarding the sourcing and breakdown of each indicator is available in the Indicators Metadata section. The Indicators Metadata section also shows the distribution and outliers of each data set over the available time series, often from 2002-2007.

The indicators presented in this report are not transformed into proximity-to-target scores because targets were missing for some of the indicators. Normalization was sometimes performed in order to increase the comparability of indicators across provinces. Some common normalizations include dividing emissions totals by economic output to derive emissions intensities, dividing emissions by populated land area to derive a measure of population exposure (on the assumption that most emissions occur in more populated areas), and dividing emissions by population for a per capita measure. The choice of normalization generally depends on the indicator in question.

IV. Policy Categories

Environmental Health

A. Air Quality for Human Health

1. *Introduction*

According to the World Health Organization (WHO) estimates at the global level, indoor and outdoor air pollution cause approximately two million premature deaths each year. Given its significant human health impacts, air quality is perhaps the pre-eminent environmental policy concern for developing countries. In recognition of this fact, WHO developed air quality guidelines applicable to all countries that set acceptable thresholds for exposure (WHO 2008a).

China suffers from particularly high levels of air pollution. China is dependent on coal for much of its electricity generation, and coal-fired power plants emit large quantities of particulate matter and sulfur dioxide. Motor vehicle emissions are the fastest growing new source of particulates in cities, and industry contributes many volatile organic compounds (Fang et al. 2009). China has been making efforts to improve ambient air quality and indoor air quality by means of enforcing stringent air quality standards, setting further emissions reduction targets, identifying special control zones, establishing of a national air quality monitoring network, promoting development of public transportation systems, and adopting fuel efficiency standards for light-duty passenger vehicles (OECD 2007, 59). In the 11th Five-Year Plan (2006-2010), China specified goals to reduce overall SO_2 emissions by 8.4 million tons and to reduce SO_2 emission from electricity and industry by at least 10%, and to have 75% of key cities attain a Grade II air pollution index (API) at least 292 days of the year (NDRC 2007a 12).[3] In 2010 it was determined by the government that these goals were met.

Despite these efforts, the air quality in China continues to be unsatisfactory, and the burden of disease attributable to air pollution remains high. In the 2010 EPI China scored 40.1 on a range of 0-100 for the human impact of air pollution policy category, far below the average scores for countries in its income and regional peer groups (63.4 and 58.6 respectively) (Emerson et al. 2010). High levels of air pollution can be attributed to the heavy dependence on high sulfur coal as an energy source, the expanding use of fossil fuels in China's transport sector, and the growth in the manufacture and use of chemicals. Given the projected growth in GDP, China faces many challenges in tackling air pollution.

---

[3] MEP& the National Development and Reform Commission (NDRC): National 11th Five-Year Plan Environmental Protection (《国家环境保护“十一五”规划》) enacted on Nov. 22, 2007, available at http://www.gov.cn/zwgk/2007-11/26/content_815498.htm (last visited on 30 June 2010).

2. *Ideal and International Best Practices for Measurement*

The WHO has established international guidelines for particulate matter ($PM_{2.5}$, PM_{10}), ozone (O_3), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) (WHO 2005a; 2005b) (see Table 1). As mentioned, particulate matter has particularly significant human health impacts. Though much of the existing monitoring equipment still measures coarser particles (PM_{10}), which often include a mix of anthropogenic and natural sources such as airborne dust, many countries are beginning to monitor fine particulate matter (particulates measuring less than 2.5 microns – so called $PM_{2.5}$). Indoor air pollution tends to be dominated by $PM_{2.5}$, but evidence shows that both indoor and outdoor PM have significant impacts on health (WHO 2005a).

Table 1: WHO Air Quality Guidelines

Pollutant		**Guideline**
Particulate Matter	$PM_{2.5}$	10 μg/m³ maximum annual mean
		25 μg/m³ maximum 24-hour mean
	PM_{10}	20 μg/m³ maximum annual mean
		50 μg/m³ maximum 24-hour mean
Ozone	O_3	100 μg/m³ daily maximum 8-hour mean
Nitrogen Dioxide	NO_2	40 μg/m³ maximum annual mean
		200 μg/m³ maximum 1-hour mean
Sulfur Dioxide	SO_2	20 μg/m³ maximum 24-hour mean
		500 μg/m³ maximum 10-minute mean

Source: (WHO 2005b ; 2005c)

For China, the WHO further recommends tracking air pollutants from coal-burning, such as fluoride and arsenic (WHO 2008b 18-19). To evaluate progress on reaching pollutant guidelines, especially for developing countries, the WHO has also set several gradients of interim targets (WHO 2005a). These interim target guidelines are available in the cited reference.

Other country/regional organization guidelines

The US Environmental Protection Agency (EPA) and the European Environment Agency have set targets similar to the WHO guidelines for a number of pollutants (WHO 2000 ; EPA 2009a), and the EPA has added lead (Pb) and carbon monoxide (CO). Countries often collect and report data on atmospheric concentrations for specific pollutants and communicate to the public the relative risk of outdoor activity. For example, the EPA reports an Air Quality Index (AQI) to inform the public about outdoor air quality. The AQI served as a model for China's Air Pollution Index (API), which was conceived in 1995. At the time of this report's publication, further amendments were announced to the API will result in even closer conformity to the AQI..

3. *China's Measurement Practices*

Technical Standards and Guidelines

Outdoor Air Pollution

Cities with a population of greater than three million people are required to track urban air quality with at least eight monitoring stations, and smaller cities are required to have at least one monitoring point. China first established ambient air quality standards in 1982 and then amended them in 1996 using hourly, daily, monthly, seasonal and annual average concentrations of SO_2, Total Suspended Particulate (TSP) matter, PM_{10}, NO_2, CO, O_3, Pb and P[a]B. The ambient air quality standards were then classified according to three levels: Grade I, Grade II and Grade III, with Grade I standards applying to nature reserves and other conservation areas, Grade II to residential, municipal and agricultural areas, and Grade III to industrial zones (NEPA 1996). In 2000, the grade system gave way to an Air Pollution Index (API) incorporating SO_2, NO_2, and PM_{10}. In 2007, new rules were proposed to include CO and O_3 in API calculations, and in March 2011 the MEP released a second draft of amended API specifications that include both pollutants (hourly and 8-hour average). Table 2 describes the thresholds used for assignment of API scores, and Table 3 compares the API with the US EPA's AQI scores.

Table 2: Thresholds for Calculating the Air Pollution Index

Pollution Index	**Pollutant Concentrations (mg/cubic meter)**				
API	SO_2 (daily average) *Updated 2000*	NO_2 (daily average) *Updated 2000*	PM_{10} (daily average) *Updated 2000*	CO (hourly average) *Proposed 2007*	O_3 (hourly average) *Proposed 2007*
50	0.050	0.080	0.050	5	0.120
100	0.150	0.120	0.150	10	0.200
200	0.800	0.280	0.350	60	0.400
300	1.600	0.565	0.420	90	0.800
400	2.100	0.750	0.500	120	1.000
500	2.620	0.940	0.600	150	1.200

Source: National Environment Monitoring Centre, 2007 p.267

Table 3: API (China) and AQI (US) Health Effects and Colors

API (China)	**Air Quality Description**	**AQI (US EPA)**	**Air Quality Description**	**Reported Color**
0-50	Excellent	0-50	Good	Green
51-100	Good	51-100	Moderate	Yellow
101-150	Slightly Polluted	101-150	Unhealthy for sensitive groups	Orange
151-200	Lightly polluted	151-200	Unhealthy	Red
201-250	Moderately polluted	201-250	Very Unhealthy	Purple
251-300	Moderately-heavily polluted	251-300	Very Unhealthy	Purple
>300	Heavily polluted	>300	Hazardous	Maroon

Source: Andrews et al. 2008

Indoor Air Pollution

The legislative history of indoor air quality (IAQ) in China may be divided into three stages: starting stages (late 1970s-1993), developing stage (1994-2000), and normative management stage (2001-present).[4]

Since 2000, a series of hygienic norms and national standards have been issued. The Ministry of Health (MOH) issued three hygienic norms in September 2001. "Hygienic norms of IAQ" set the standards and sanitary requirements for IAQ of residential apartments and office building, sanitary requirements for ventilation and purification, and the measurement methods of indoor air pollutants and other parameters. Furniture and indoor decoration usually contribute a lot to IAQ and China has issued several standards to regulate. For example, Wood-based Panels - Determination of Formaldehyde Release - Gas Analysis Method[5] and Hygienic Limit of Formaldehyde Emission of Wood-based Panels and Finishing Products[6], specifying both the sanitary requirements and the measurements methods, applies to wood-based panels products used in furniture manufacture and indoor decoration.

The Code for Indoor Environmental Pollution Control of Civil Building Engineering[7] was enacted in 2002 by the Ministry of Construction and the China State Quality Supervision-Inspection-Quarantine Administration (MOC and SQSIQA 2002). It is the first code for controlling indoor environmental pollution for civil buildings.

China's first regulation setting required standards for indoor air quality[8] took effect on March 1st, 2003. The regulation establishes a ceiling for 13 chemical pollutants including formaldehyde, benzene, ammonia and several harmful particulate matters (SEPA 2002b). In 2004, the State Environmental Protection Administration (SEPA) issued Technical Specifications for Monitoring of Indoor Air Quality[9] which includes sampling, monitoring items and the corresponding analytical methods, data processing, quality control and reporting (SEPA 2004).

Methodology

The latest version of ambient air quality standards[10] were issued in 1996 and amended in 2000. This standard mainly regulates the function area division of air quality, standard classification, pollutants, monitoring time, concentration limits, sampling, analytical methods and data statistics, etc. In 2006, regulations governing Manual Methods for Ambient Air Quality Monitoring[11] and Automated Methods for Ambient Air Quality Monitoring[12] took effect. In order to improve the standardization of ambient air quality monitoring, in 2007, SEPA issued the Specification for Ambient Air Quality

---

[4] Information and standards available online at China Indoor Air Quality Center: http://www.chinaiaq.org/lm6.htm

[5] GB/T 23825-2009《人造板及其制品中甲醛释放量测定-气体分析法》

[6] GB18580-2001《室内装饰装修材料人造板及其制品中甲醛释放限量》

[7] GB50325-2001《民用建筑工程室内环境污染控制规范》

[8] Indoor Air Quality Standard GB/T 18883-2002 《室内空气　量　准》

[9] HJ/T167-2004

[10] GB 3095-1996

[11] HJ/T 194-2005 (环境空气质量手工监测技术规范), promulgated by SEPA on November 9, 2005.

[12] HJ/T193-2005 (环境空气质量自动监测技术规范), promulgated by SEPA on November 9, 2005.

Monitoring (for trial use),[13] which focuses on the requirements for monitoring network design and the setup of monitoring points, the methods and technical requirements of manual and automated monitoring, and the management of air quality data.

Despite these efforts, we were unable to obtain raw data with which to evaluate the air quality measurements,. Using available data, we report preliminary province-by-province results in the next section.

Data Collection

The institution responsible for this data collection is China's National Environmental Monitoring Center (CNEMC), which measures daily average concentrations for PM_{10}, SO_2, and NO_2 for over 600 major cities.

By June 2004, 688 automatic air quality monitoring systems had been installed in 234 cities, 118 cities reported a daily API to the public, and 47 cities reported the 24-hour air quality forecast to the public (Wang et al. 2004). Information on the API, primary pollutant, grade and state of air quality of 86 cities are issued on a daily basis through the Web sites of Ministry of Environmental Protection (MEP) and the China National Environmental Monitoring Center (CNEMC).

To date, ambient air quality is only measured in urban areas, but the network is to be extended to cover rural areas and also background pollution stations (CNEMC 2009). Although the location of the monitoring stations has significant influence on the level of pollution measured, the location and total number of stations included in the monitoring network remain unclear.

Instruments and Data Quality

The process of monitoring ambient air quality requires complex techniques and instruments and a high level of expertise is needed for operation, calibration and maintenance. Since the concentration data are made available as annual means, it is difficult to evaluate the impact of missing daily reports (which can be caused by equipment failure) on the annual means, or to identify changes in the level of emissions caused by the change in monitoring location of mobile stations. Since the creation of the API system and mandated daily reporting requirements, several pollutant thresholds have been shifted upwards so that scores that would have led to a higher API equivalent under the old system now lead to lower (or "healthier") scores (Andrews et al. 2008). Additionally, even though mandated daily readings are supposed to be made purely by instruments and be tamper-proof, statistical analyses in cases of concentrations reported close to the cut-off line for an API score have shown a bias towards clustering just below the cut-off line, rather than being evenly distributed just above and below the line as would be expected in a random distribution of instrument readings (ibid.).

China's Air Pollution Index (API) reporting system is calculated based on three major pollutants: particulate (PM_{10}/TSP), nitrogen oxides (NO_2, NO_x), and sulfur dioxide (SO_2) and air quality is rated

---

[13] State Environmental Protection Administration Bulletin No. 4 issued on January 19, 2007. See《 境空气 量 范》, available at http://www.mep.gov.cn/gkml/zj/gg/200910/t20091021_171691.htm (last visited on 19 July 2010).

according to daily average concentrations, based on a scale from 0-500. The index also included carbon monoxide (CO) and ozone (O_3) from 1998 to 2000.

As previously mentioned, the API composite was modeled after the EPA's Air Quality Index (AQI), yet it includes several important differences that have significant impact on the reported pollution levels:

1. The EPA's AQI is based on the *highest reading* in a city for a given parameter in each 24 hour period, whereas a city *average concentration* is used in China's API. The reported API of the day is the maximum API for daily average concentrations among the three pollutants—PM_{10}, NO_2 and SO_2—and the pollutant with the highest API is identified as the primary pollutant of the day. From 2000 to 2007, PM_{10} was the major contributor for 85% of reported APIs.
2. The grading systems used by the two countries also differ (see Table 3 above). Air that is considered "lightly polluted" in China is considered "Unhealthy" by the US standards. A "blue sky day" has been defined as a day when API does not exceed 100 – although the system is being revised as of this report's release.

CNEMC reports the daily API calculated from the worst pollutant of the day, and the capital city of each province reports the number of days that meet Grade II standards is in the annual China Environment Statistical Yearbook. China has set a nation-wide target for 75% of cities to meet Grade II standards at least 292 days of the year.

In contrast to outdoor air pollution, there is no national level strategy for measuring the levels of indoor air pollution.

Transparency

The API is widely measured, and at present 86 large cities report daily APIs. The daily API report is accessible to the public at the China National Environmental Monitoring Center's Web site.[14] As of this report's release, 113 environmental key cities have daily air quality API monitoring report available to the public through MEP's web site.[15] The API tracks three parameters (PM_{10}, NO_2 and SO_2) because these are the major concerns in Chinese urban air pollution context. However, as previously discussed, these three parameters are insufficient for measuring the health impacts for air pollution, and it would be important to report separately the levels of each pollutant and to base the API on a combination of all three. In addition, API only covers 113 of 600 cities in China. The API is a good start, but it is recommended that China expand the number of pollutants monitored and reported, expand the number of cities covered by the API, and report the location of monitoring stations. In a positive development, in early 2011 MEP reported the number of monitoring stations per province.

---

[14] The China National Environmental Monitoring Center is an institute directly under the Ministry of Environmental Protection (环保部直属事业单位). Its duties include nation-wide environmental monitoring, assessments and reports, monitoring technology research, and policy consulting. For more information, visit http://www.cnemc.cn/index.aspx.

[15] See http://www.cnemc.cn/

4. *Summary Indicator Calculations and Results*

China EPI Air Quality Indicators

The air quality (effects on human health) policy category measures human exposure to harmful air pollutants. Ideally, daily averages of hourly concentrations should be reported by monitoring station for $PM_{2.5}$, PM_{10}, SO_x, and NO_x. With the exception of Beijing, however, no daily average concentration data are currently available for monitoring stations. Furthermore, there is little public information about the monitoring network, such as the number, type (i.e., urban, industrial, background stations, or roadside sites), and location (latitude/longitude) of stations, which is needed to judge whether the network is representative of the city's air quality and to assess human exposure to certain air pollutants. Fortunately, recent developments suggest that more information is being made available.[16]

We created three performance indicators based on the available parameters:

Policy Categories	Policy Category Codes	Indicators	Indicator Codes	Data Source	Target
Air pollution (effects on humans)	AIR_H	**Population weighted PM_{10} concentrations**	PM10	Ministry of Environmental Protection, 2003-2007	≤ 20 ug/m3 WHO target (≤100ug/m3 China target)
		Population weighted SO_2 concentrations	SO2	Ministry of Environmental Protection	≤ 40 ug/m3 WHO target (≤80ug/m3 China target)
		Population weighted NO_2 concentrations	NO2	Ministry of Environmental Protection	≤ 60 ug/m3 China target (no yearly WHO target)

Province level indicators are calculated using city level air quality average annual concentration data and population data. Demographic data comes from the decennial census in the year 2000, and the emissions data are for the year 2007. The purpose of calculating a population-weighted concentration for each province based on city level data is to better reflect the relative exposure of the overall provincial population to different concentration levels. For example, if in a province with data for two cities, one with a population of 3m people and a PM10 concentration of 100 ug/m3 and another with a population of 1m people and a PM10 concentration of 50 ug/m3, the provincial concentration would be 87.5 ug/m3 ((0.75 x 100)+(0.25 x 50)=87.5).

The province level indicators of air pollution (effects on human) are calculated as follows:

- Use average annual city concentration values for PM_{10}, SO_2 and NO_2
- Weight city level pollution concentration levels by city *urban* population[17]
- Create a weighted average of the annual pollution concentrations based on the monitored cities within that province

---

[16] See http://58.68.130.147/air/air/airtestpage.html.

[17] According to the Chinese Census, cities include both urban and rural population, also referred to as agriculture and non- agriculture population. We used only the urban portion of the population.

Data Quality and Representativeness

We evaluated two ambient air quality data sets (see Appendix 1 for the full evaluation). Of the two available data sets, one is short-term (2004-2007) and the other is long-term (beginning in 1998 for SO_2, 2000 for NO_2, and 2003 for PM_{10}). Although the short-term data set has a higher number of cities overall, it also has a higher level of missing values (so-called "missingness"). Based on these findings, we considered the long-term data set as being most reliable and thus decided to use it in our analysis. Only about one-sixth of the cities included in the national air quality monitoring network are available for the three parameters in the long-term data set. Thus, the data cannot be said to be truly geographically representative of air quality at the provincial and national level.

The result of the spatial and urban coverage analysis (see Appendix 2) reveals a good national level spatial coverage, but poor coverage of the urban areas and populations. A little over 40% of the urban population from the 31 provinces is covered. Based on the two analyses, we conclude that the available city air quality data are incomplete, and thus inadequate for use in performance measures.

The following sections show the provincial ranks and analysis using the incomplete data. Considering the limitation of the data, the results should be interpreted with caution for all provinces with high levels of city missingness (identified in the indicator metadata in Section IV).

Correlations

The Pearson coefficients calculated for the three air quality indicators show that PM_{10}, SO_2 and NO2 are moderately positively correlated with one another. A study of Canadian cities found similar correlations between SO_2 and NO_2 concentrations (Burnett et al. 1998)

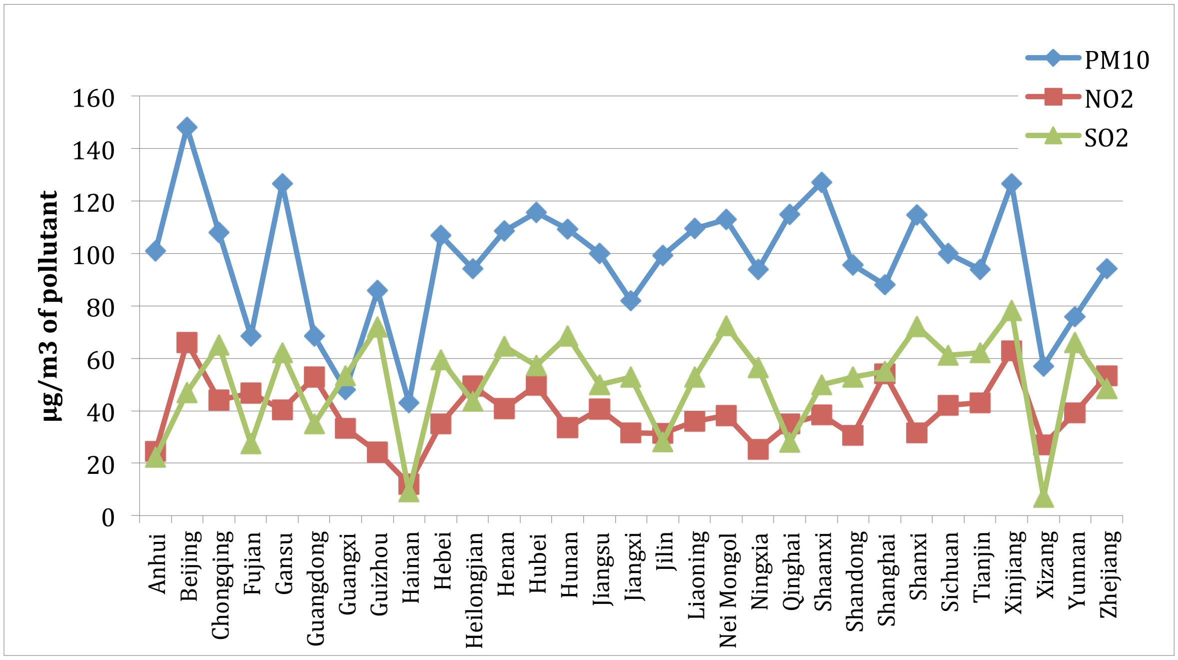
	PM10	**NO2**	**SO_2**
PM10	1		
NO2	0.45	1	
SO_2	0.48	0.30	1

Ranks and Trend Analysis

The PM10 pollution levels highly exceed the WHO targets (≤ 20 ug/m^3) for all provinces. Half of the provinces also exceed the China target, which is set at five times the value of WHO cutoff (see Appendix 1). While all provinces meet China SO_2 targets (≤ 80 ug/m^3), only 7 (22%) meet the more stringent WHO target. For NO_2 there is no clear WHO guideline, and 93% of provinces meet China's target of ≤ 60 ug/m^3.

Figure 1 below shows annual mean concentrations for the three major air pollutants monitored in China from the year 2007.

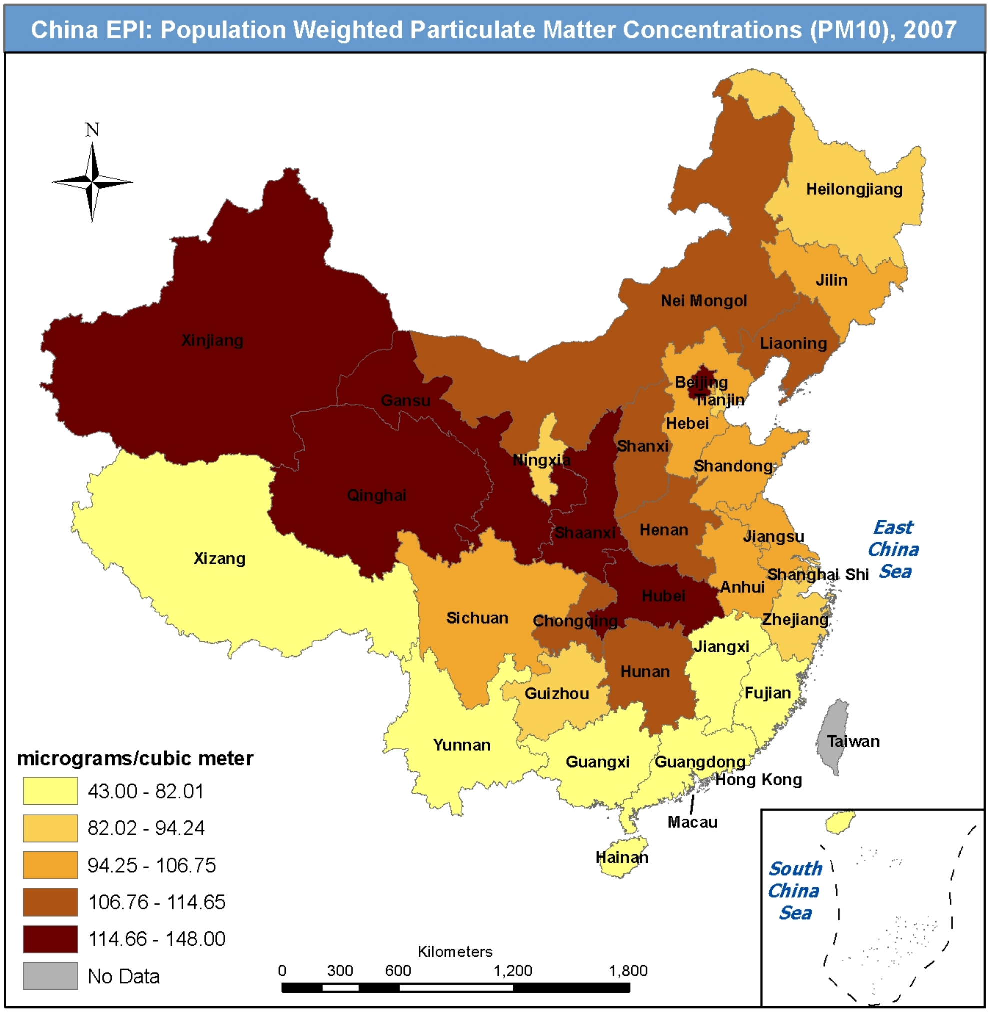
Figure 1. Air Quality for Human Health by Province



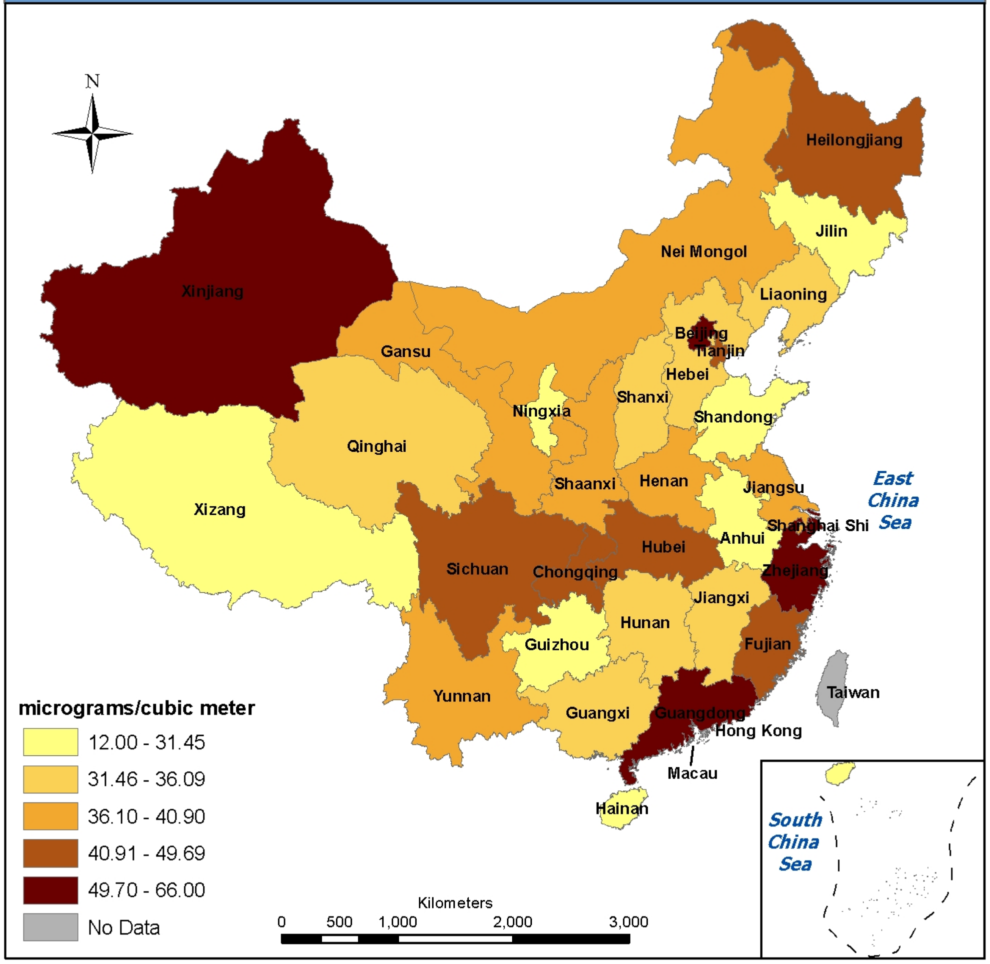
The following table lists all provinces and their 2007 annual mean concentrations of the three monitored air pollutants. Additional maps, charts, and analysis on air quality can be found in Appendices 1 and 2.

Rank	Province	PM10 (µg/m3)	Province	NO_2 (µg/m3)	Province	SO_2 (µg/m3)
1	Hainan	43.00	Hainan	12.00	Xizang	7.00
2	Guangxi	47.92	Guizhou	24.13	Hainan	9.00
3	Xizang	57.00	Anhui	24.49	Anhui	22.20
4	Guangdong	68.39	Ningxia	25.35	Fujian	27.52
5	Fujian	68.44	Xizang	27.00	Qinghai	28.00
6	Yunnan	75.79	Shandong	30.72	Jilin	28.28
7	Jiangxi	82.01	Jilin	31.45	Guangdong	34.96
8	Guizhou	85.91	Jiangxi	31.53	Heilongjiang	43.59
9	Shanghai	88.00	Shanxi	31.67	Beijing	47.00
10	Ningxia	93.76	Guangxi	33.40	Zhejiang	48.42
11	Tianjin	94.00	Hunan	33.46	Jiangsu	49.86
12	Heilongjiang	94.04	Hebei	34.99	Shaanxi	49.95
13	Zhejiang	94.24	Qinghai	35.00	Jiangxi	52.76
14	Shandong	95.50	Liaoning	36.09	Shandong	52.94
15	Jilin	99.34	Nei Mongol	38.21	Liaoning	52.96
16	Sichuan	99.90	Shaanxi	38.40	Guangxi	53.27
17	Jiangsu	100.02	Yunnan	39.05	Shanghai	55.00
18	Anhui	101.04	Gansu	40.43	Ningxia	56.39
19	Hebei	106.75	Jiangsu	40.62	Hubei	57.26
20	Chongqing	108.00	Henan	40.90	Hebei	59.35
21	Henan	108.49	Sichuan	42.18	Sichuan	61.08
22	Hunan	109.26	Tianjin	43.00	Tianjin	62.00
23	Liaoning	109.56	Chongqing	44.00	Gansu	62.09
24	Nei Mongol	112.87	Fujian	46.66	Henan	64.53
25	Shanxi	114.65	Heilongjiang	49.46	Chongqing	65.00
26	Qinghai	115.00	Hubei	49.69	Yunnan	65.96
27	Hubei	115.53	Guangdong	52.73	Hunan	68.55
28	Xinjiang	126.53	Zhejiang	53.45	Guizhou	72.00
29	Gansu	126.74	Shanghai	54.00	Shanxi	72.12
30	Shaanxi	127.22	Xinjiang	62.81	Nei Mongol	72.28
31	Beijing	148.00	Beijing	66.00	Xinjiang	78.13

The following maps depict the indicator scores by province. The maps consistently depict the best performers in yellow and the worst performers in dark brown. Natural dust from soils and crustal material may be contributing to the high concentrations of particulate matter found in the northwestern portions of China.

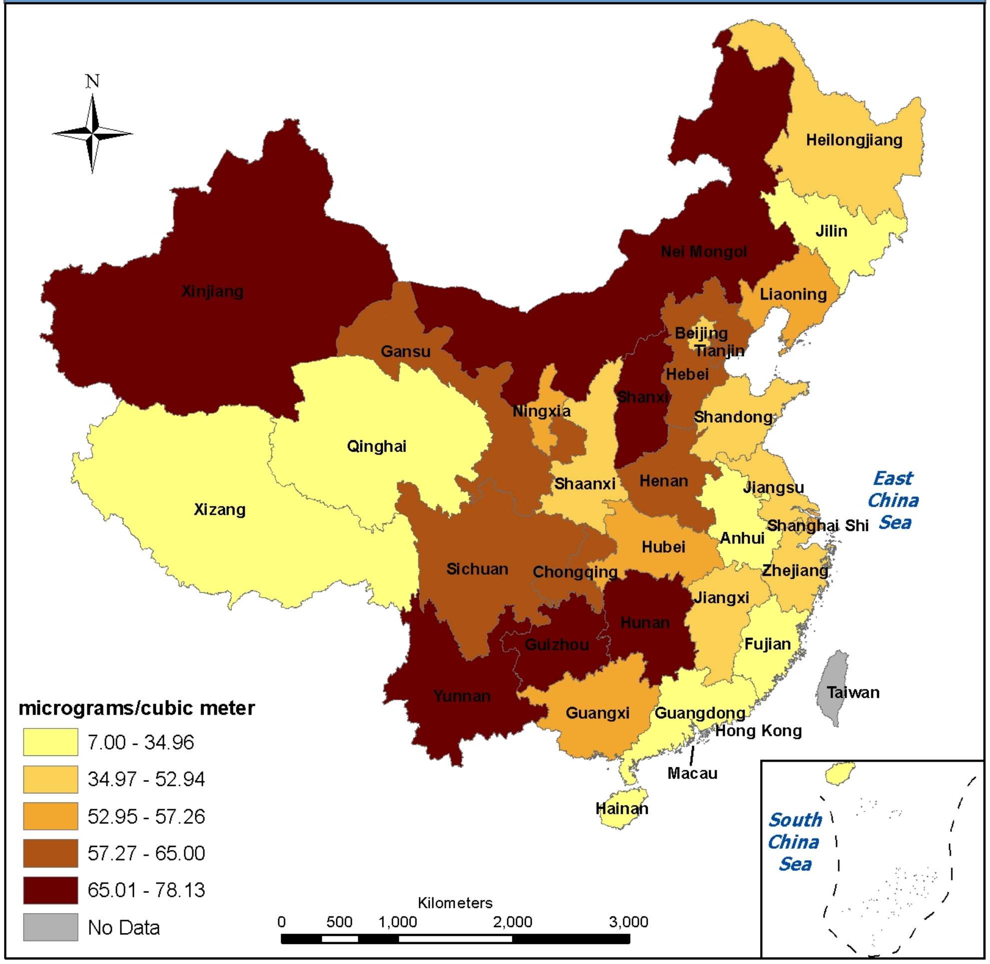


China EPI: Population Weighted Particulate Matter Concentrations (PM10), 2007



China EPI: Population Weighted Nitrogen Dioxide Concentrations (NO2), 2007

China EPI: Population Weighted Sulfur Dioxide Concentrations (SO2), 2007



B. Water Quality and Quantity for Human Health

1. Introduction

Humans require an adequate supply of water meeting minimum standards of quality for health and hygiene. Unsafe and untreated drinking water sources, in combination with lack of improved sanitation, create substantial risk to human health. WHO estimates that diseases related to unsafe drinking water and poor sanitation contribute 4% to global mortality and 5.7% to the global burden of disease (in DALYs) (Prüss, Kay et al. 2002 537). Globally, diarrhea kills 2.2 million people every year, three-quarters of whom are children under the age of five (WHO 2009).

With only one quarter of the world average freshwater per capita, China has very limited water resources. Furthermore, the wettest regions in China are in the less densely settled and less economically advanced South, whereas the urbanized northern provinces, with 42% of the population, have access to only 14% of national water supplies (UNDP 2006). The South-to-North Water project represents a massive investment to redress this imbalance.[18] Nearly half of China's 640 largest cities face water shortages, and this is compounded by a lack of investment in water supply infrastructure and problems with water management (Yu and Danqing). Beginning in 1991 the government sought to address water shortages through privatization of municipal water systems, but the resulting price increases have meant that some poor households have had to obtain water for household use from public toilet facilities (ibid).

Water quality is also of significant concern. People in China tend to avoid drinking unboiled water. According to the fourth national five-year health census, 14.7% of rural residents still lack access to safe drinking water.[19] The majority of these people use untreated water from surface water bodies like rivers, lakes, ponds or wells (WRI 1998). A survey conducted by China National Environmental Monitoring Center in 2006 reports that 32% of total drinking water tested was not suitable for drinking (Liu 2006a). Water pollution accidents amount to about a third of the total pollution accidents in China. A highly publicized explosion at a petrochemical plant on the Songhua River in 2006 resulted in the release of a toxic plume of more than 100 tons of chemicals into the river, affecting millions of people in China and even impacting Russians living downstream (UNEP 2005c).

The China Disease Prevention and Control Center found that about 90 percent of Chinese waterworks are using obsolete technologies that cannot handle chemical pollution ("Xinhua" 2006). It is estimated that only 30% of the organic substances are filtered. Research found that of all illnesses due to contaminated water, approximately 85% are caused by untreated sewage (Wu, Maurer et al. 1999).

---

[18] More information is available at the official South-to North Water Diversion Web site at http://www.nsbd.gov.cn/

[19] The methodology and major findings of the fourth national health five-year census are available at http://www.gov.cn/gzdt/2009-02/27/content_1245006.htm (last visited **5** July 2010**).**

The issue of water quality measurement is taken up in the section on Water Quality and Quantity for Ecosystem Vitality. Although as indicated above, water quality is critical to human health, here we focus primarily on water access. This is because research shows that access to water of even relatively poor quality improves personal hygiene and therefore has a significant impact on human health (Billig, Bendahmane et al. 1999).

2. *Ideal and International Best Practices for Management*

Water Access

The Millennium Development Goal target 7c is to halve the proportion of people without sustainable access to safe drinking water and basic sanitation by the year 2015 (WHO 2010). For access to improved water sources, the WHO-UNICEF Joint Monitoring Program measures the percentage of the population with access to at least 20 liters of water per person per day from an "improved" source (household connections, public standpipes, boreholes, protected dug wells, protected springs, and rainwater collection) within one kilometer of the user's dwelling (WHO 2008c). The Joint Monitoring Program considers access to an improved water source to be either a direct connection to the home or a public facility within 200 meters of the home in urban areas (WHO 2010). Neither of these access measures considers the quality of the available "improved" water source.

3. *China's Measurement Practices*

In China, the Ministry of Water Resources (MWR), MEP, the Ministry of Housing and Urban-Rural Development (MOHURD), the Ministry of Health (MOH), and the Ministry of Agriculture (MOA) are together responsible for water management. MEP is responsible for water quality monitoring, and since the 1990s has issued independently or in collaboration with other administrations, several standards such as the Quality Standard for Ground Water,[20] Sea Water Quality Standard,[21] and Standards for Irrigation Water Quality.[22] The latest standard for surface water monitoring is Environmental Quality Standard for Surface Water,[23] which was issued by SEPA in collaboration with General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ) in 2002. In 2008, SEPA initiated an Investigation and Assessment of Basic Environment of Nation-wide Drinking Water Sources, which will be completed in 2010. MWR is responsible for the monitoring and measurement of water resources and the quality of surface water. Since 2000, MWR has issued the *Annual Report for Water Resource Quality in China*, and other water resource statistics such as water quantity are published within the *China Water Resource Bulletin*. MOHURD leads in the monitoring of urban water supplies, and the *China Urban Construction Statistical Yearbook* includes some urban water

---

[20] GB/T 14848-1993

[21] GB 3097-1997

[22] GB 5084-1992

[23] GB 3838-2002

supply data such as percentage of urban population with access to tap water, and similar data sets such as percentage of rural population with access to tap water can be found in *China Health Statistic Yearbook* published by MOH. In 2007, China MOH and SAC enacted the latest version of the Standards for Drinking and Household Water Quality[24], which replaced an earlier standard enacted in 1985.[25] This is the quality standard for all tap water supplies according to the text of the regulation. This regulation requires 42 general inspection items and 64 special inspection items. The general inspection items are mandatory to include in a water quality test, while the special inspection items are given flexibility of implementation to provincial government. The regulation requires that all 106 inspection items must be implemented by July 1, 2012.

China conducts a national-wide health census every five year since 1993. Sanitation is one important part in health census. The most recent (the fourth) one was conducted in 2008 and the report was released on February 27, 2009. This census includes four components: a family health survey, a local medical institution survey, a survey to employees of medical institutions, and key issues research projects. The family health survey covers 56,400 households covering 200,000 people in 31 provinces.[26]

China has been monitoring water quality for years. Chinese water quality standards have five degrees, with one being the best and five the poorest. Different water bodies will fall under different water quality levels, depending on the water body's ecosystem function and human health impact. There are several laws, regulations and standards regarding water quality, including Water Pollution Prevention and Control Law,[27] Underground Water Quality Standards,[28] Environmental Quality Standards for Surface Water, Standards for Irrigation Water Quality, and Water Quality Standard for Fisheries.[29] Currently, water quality data are reported weekly and monthly by the China National Environmental Monitoring Center and the reports are available at its Web site, Environmental Monitoring of China.[30] The monitoring system collects data from 100 key sections of automatic monitoring stations,[31] which are located in primary water bodies nation-wide. The monitoring tests eight aspects of water quality: temperature, pH, turbidity, dissolved oxygen, conductivity, COD Mn, NH3-N, and TOC.

---

[24] GB 5749-2006

[25] GB 5749-1985, available at http://www.moh.gov.cn/open/web_edit_file/20070618123913.pdf (last visited 28 June 2010)

[26] The methodology and major findings are available at http://www.gov.cn/gzdt/2009-02/27/content_1245006.htm. (last visited 5 July 2010)

[27] 中华人民共和国水污染防治法, 2008, http://zfs.mep.gov.cn/fl/200802/t20080229_118802.htm

[28] 《地下水 境 量 准》（GB/T14848-93）, available at http://www.bjmac.gov.cn/huanwei/content/browseInfo.jsp?infoId=co0000002749 (last visited July 19, 2010)

[29] 《地表水环境质量标准》GB 3838-2002,《农田灌溉水质标准》GB 5084-2005,《渔业水质标准》GB 11607-89, http://www.mep.gov.cn/info/bgw/bbgth/200907/t20090724_156752.htm

[30] The China National Environmental Monitoring Center Web site: http://www.cnemc.cn/

[31] 重点断面水质自动监测站

4. *Summary Indicator Calculations and Results*

China EPI Water Quality Indicators

We found two data sets that are relevant to measuring the effect of water quantity and quality on human health: access to tap water in rural areas, and access to tap water in urban areas. Ideally, in a full EPI, this category would also include indicators measuring levels of bacterial and toxic contaminants in tap water as well as access to sanitation.

Policy Categories	Policy Category Codes	Indicators	Indicator Codes	Data Source	Target
Water (effects on humans)	WATER_H	**Access to tap water in rural areas**	RURTAP	China Environmental Statistical Yearbook, 2004-2006	75% by 2010
		Access to tap water in urban areas	URBTAP	China Statistical Yearbook, 1996-2008	100% of population with access

Both indicators are expressed in terms of percentage of the relevant population with access to tap water.

Data Quality and Representativeness

The data were found in the China Statistical Yearbook, but no additional information was available concerning data collection methodology or the agencies responsible for collection, nor were there data available at administrative levels below the province level.

Data is available in the Statistical Yearbook for all provinces in both categories, with the exception of access to tap water in rural areas for Xizang province. This extensive data coverage allows provinces to be easily compared with one another, as shown below. By splitting up the indicator into urban and rural components in China, we are able to compare highly urbanized provinces (such as Beijing) with more rural provinces without penalizing the rural provinces for lower overall access to tap water. Tap water coverage is greater overall in urban areas.

Correlations

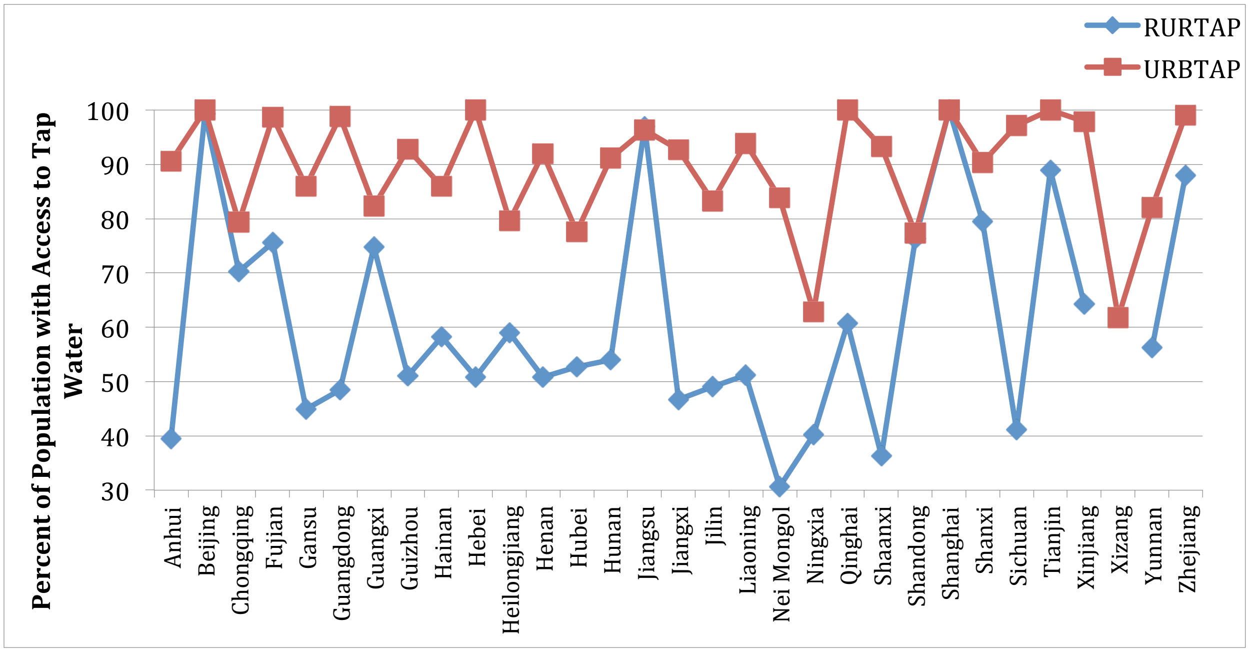
The Pearson coefficient calculated for the two water quality indicators shows that URBTAP and RURTAP are slightly positively correlated.

	URBTAP	RURTAP
URBTAP	1	
RURTAP	0.34	1

Ranks and Trend Analysis

Figure 2 shows the percent coverage of tap water access for all provinces, divided into rural and urban subcategories. Thirty-five percent of provinces come within five percentage points of meeting the government's goal of 100% tap water access in urban areas, and 32% of provinces come within five percentage points of the target for rural areas (75% access).

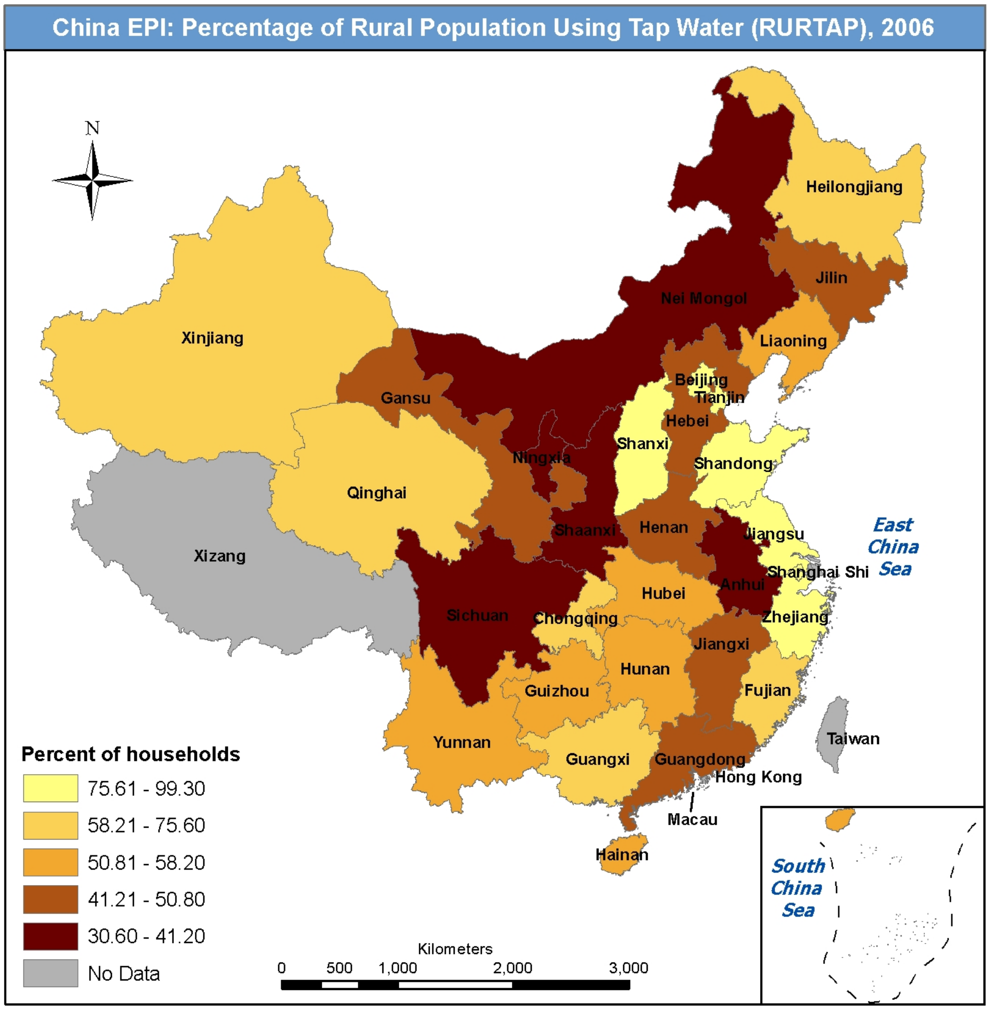
Figure 2. Water Quality and Quantity for Human Health by Province



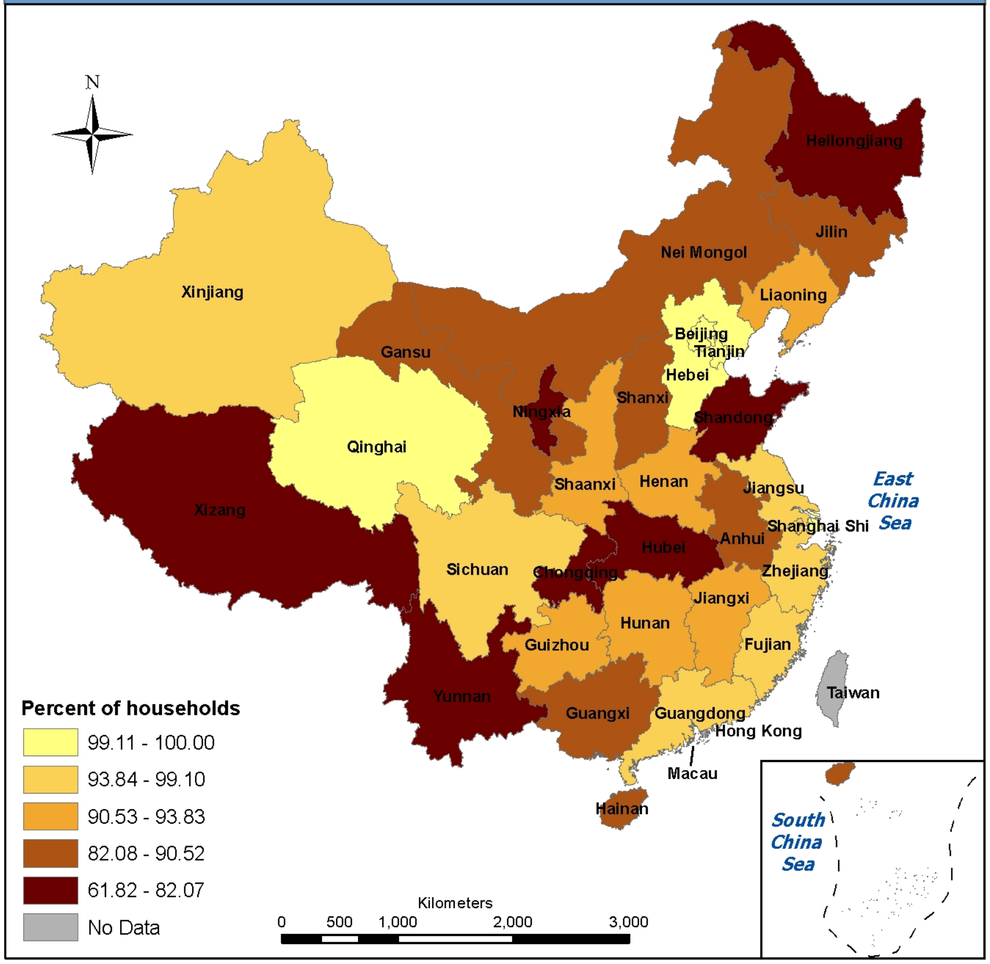
The following table lists all provinces in rank order, from best to worst performing, according to the percentage of residents with access to tap water in urban (in 2005) and rural areas (in 2006).

Rank	Province	RURTAP (%)	Province	URBTAP (%)
1	Shanghai	100.00	Beijing	100.00
2	Beijing	99.30	Qinghai	100.00
3	Jiangsu	96.90	Tianjin	100.00
4	Tianjin	88.90	Shanghai	99.98
5	Zhejiang	88.00	Hebei	99.95
6	Shanxi	79.50	Zhejiang	99.10
7	Shandong	76.30	Guangdong	98.80
8	Fujian	75.60	Fujian	98.68
9	Guangxi	74.70	Xinjiang	97.86
10	Chongqing	70.30	Sichuan	97.22
11	Xinjiang	64.30	Jiangsu	96.28
12	Qinghai	60.70	Liaoning	93.83
13	Heilongjiang	59.00	Shaanxi	93.24
14	Hainan	58.20	Guizhou	92.75
15	Yunnan	56.20	Jiangxi	92.64
16	Hunan	54.00	Henan	91.94
17	Hubei	52.70	Hunan	91.11
18	Liaoning	51.20	Anhui	90.52
19	Guizhou	51.10	Shanxi	90.32
20	Hebei	50.80	Hainan	85.97
21	Henan	50.80	Gansu	85.94
22	Jilin	49.00	Nei Mongol	83.88
23	Guangdong	48.50	Jilin	83.20
24	Jiangxi	46.70	Guangxi	82.28
25	Gansu	44.90	Yunnan	82.07
26	Sichuan	41.20	Heilongjiang	79.55
27	Ningxia	40.20	Chongqing	79.38
28	Anhui	39.50	Hubei	77.62
29	Shaanxi	36.30	Shandong	77.39
30	Nei Mongol	30.60	Ningxia	62.89
31			Xizang	61.82

The following maps depict the indicator scores by province. The maps consistently depict the best performers in yellow and the worst performers in dark brown. The more economically developed coastal provinces consistently have higher rates of water access.



China EPI: Percentage of Urban Population Using Tap Water (URBTAP), 2005



C. Waste and Sanitation

1. Introduction

While the overall quantity of solid wastes is increasing globally, the construction of new facilities and management of these waste streams are becoming increasingly difficult (UNEP 2005a). The problem is most acute in developing countries, where rapid economic growth combines with limited financial resources and institutional capacity (UNEP 2005b).

The combined effect of illicit waste disposal, insufficient waste collection services, and inadequate waste disposal facilities has serious and adverse implications for public health. Among these are the direct transmission of diseases, the spread of epidemics, the degradation of the quality of the urban and natural environments and the social reinforcement of poor hygienic habits and practices. The inclusion of hazardous waste, health care waste, and human waste in the urban waste stream poses special challenges that make it more difficult to manage waste so as not to compromise public health (UNEP 2005b).

Environmental health impacts of solid waste can occur along all stages of the waste cycle. Impacts include chemical fires (and the toxic smoke they may release), direct, poisoning by hazardous chemical waste, infections, and worm infestations. Blood borne, ophthalmologic, dermatologic, and enteric infections can all result from exposure to solid waste (UNEP 2005b). The health impacts of solid waste can be reduced by proper treatment and disposal of waste, including routing of waste to recycling streams. The collection and transfer of waste away from the source is an important first step for reducing contact with harmful waste. Proper treatment and disposal through composting, reuse, recycling, incineration, and landfilling can further reduce environmental health impacts.

China surpassed the United States as the global leader in waste generation in 2004, and annual generation of solid waste is estimated to increase by another 150% from approximately 190 million tons in 2004 to more than 480 million tons by 2030 (World Bank, 2005). While annual waste production is growing at close to 10% every year, sanitary landfills are still rare (Suocheng, Tong et al. 2001). The amount of the stockpiled and discharged wastes, especially hazardous wastes, is still very large (Wei, Herbell et al. 1997).

Two key factors are driving China's increasing waste generation, according to a World Bank (2005) study: urbanization and increasing affluence. Urban dwellers generate two to three times more waste than rural residents. While there has been substantial progress in the waste management sector in urban areas over the last decade, as cities began developing sanitary landfills, the country is still unable to keep pace with the surging demand for waste service and to meet the environmental requirements for safe disposal (ibid.).

According to the World Bank (2005), China's municipal recycling rates are much lower than that of most other economies (waste paper recovery is 30%, as compared, for instance, with Korea's 66% and Taiwan's 55%). The Bank attributes this to the negative impact of imports of low-cost secondary materials from high-income countries that are exporting (in effect, "dumping") these materials to avoid reaching landfill capacity and paying higher domestic costs of disposal. In 2002 the United States exported an estimated 1.2 billion scrap and secondary materials to China.

Electronic or E-waste exports to China are also becoming an issue of concern (World Bank 2005).

Sanitation refers to the facilities, infrastructure, and knowledge necessary to ensure the safe disposal of human excrement and waste. Safe disposal of human waste reduces the pathogen load in the ambient environment and lowers the burden of disease (Billig et al. 1999). In the policy literature, sanitation generally refers to the household-level provision of latrines and improved water supplies; however, education programs to promote knowledge of hygienic behaviors such as hand washing also fall under the heading of sanitation. Also related is the treatment of sewage after leaving the household and before being released into the environment, particularly with the water-based piped sewage systems common in urban areas (WEHAB 2002). Sanitation is a vital policy category due to its correlation with a number of diseases and the large disparities in access to basic sanitation facilities both within and among countries.

Diseases closely related to water quality, sanitation, and hygiene include diarrhea, trachoma, schistosomiasis, ascariasis, trichuriasis and hookworm (Prüss-Üstün and Corvalan 2006). Diarrhea alone kills 2.2 million people every year, of which 1.8 million are children under five. Eighty-eight percent of this disease burden can be attributed to inadequate water supply and sanitation facilities (Prüss-Üstün, Kay et al. 2004 ; WHO 2009). All of the world's 150 million current trachoma infections and 160 million current schistosomiasis infections are also attributable to poor sanitation and environmentally-transmitted disease (Bartram, Lewis et al. 2005 ; Prüss-Üstün et al. 2006). It is estimated that almost half of the population in the developing world has one or more of the main diseases or infections associated with poor sanitation facilities (Bartram et al. 2005). Currently about 2.6 billion people worldwide lack access to basic sanitation and it is thought that over half of the hospital beds in the developing world are occupied by people with diseases related to poor sanitation provision (ibid.).

China has steadily improved its provision of adequate sanitation over the last two decades, particularly in rural areas, though gaps in coverage still remain. The percentage of the population with access to improved sanitation facilities increased from 48% to 65% between 1990 and 2006 (WHO and UNICEF 2008). However, this aggregate statistic disguises the large disparities between urban and rural populations. In 2006, the urban improved sanitation coverage was 74% versus only 59% in the countryside (ibid.). Even looking only at rural areas, there are substantial differences in sanitation coverage among provinces. For example, rural sanitary latrine coverage ranges from 28% to 95% depending on the province (UNDP 2008).

Other indicators within the sanitation policy category are relatively low for China. Only 66% of urban residents and 10% of rural residents are connected to the sewer system (JMP 2006). Even with this low rate of connection, sewage treatment capacity is barely able to handle the large amount of discharge. Every year approximately 30 billion tons of urban sewage are discharged into the environment in China, of which between 2.7-10% receives no prior treatment (Beach 2001). Individual sewage treatment plants in China typically serve an average of 1.5 million people as compared to an average of only 7,000-8,000 people in Europe (ibid.).

2. *Ideal and International Best Practices for Measurement*

Waste

There are several international agreements touching on solid waste management, but the only one that addresses the issue directly is the 1992 Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal. As indicated by its name, this treaty addresses only hazardous waste. It is designed to reduce the movements of hazardous waste between nations, and specifically to prevent its transfer from developed to less developed countries (United Nations 1989). In addition to the Basel Convention, some countries have national waste plans to guide their waste management strategies. However, standardized metrics for measuring and monitoring waste are not readily available across national borders, and waste was included as an indicator in the 2010 global EPI. Some aspects of waste measurement are addressed in the Resource Efficiency category, below in this report.

In the European Union (EU), there are two basic directives on final disposal of waste: the Waste Landfill Directive[32] and the Waste Incineration Directive.[33] Furthermore, the Packaging and Packaging Waste Directive[34] requires EU member states to reuse and recycle a minimum of 55% and a maximum of 80% of packaging waste by the end of 2008 (European Union 1994). This goal is still valid since about half of the member states applied for extension until 2015.

Sanitation

Although Millennium Development Goal (MDG) 7 Target 10 (improve access to safe drinking water and basic sanitation by 2015) is the most important international policy related to sanitation, other decisions are also relevant (UNDP 2010). Vision 21 on Water and Sanitation was adopted at the Second World Water Forum in 2000. It includes four action areas: building on people's energy and creativity; acknowledging hygiene, water, and sanitation as a human right; fostering committed and compassionate leadership and good governance; and creating synergy among partners (WSSCC 2000).

The World Health Organization (WHO) has set standards for drinking water quality and proposed targets for the level of fecal coliform bacteria. As an indicator of fecal contamination, the level of fecal coliform bacteria in a water sample is closely related to other harmful bacteria such as giardia, salmonella, and cryptosporidium that are derived from human or mammalian excrement. The WHO suggests that fecal coliform bacteria should be undetectable in any 100ml water sample (WHO and UNICEF 2006).

The WHO and the United Nations Children's Fund (UNICEF) are using the indicator of access to improved sanitation sources as means of evaluating progress toward the MDG water and sanitation target. WHO and UNICEF accept the following as examples of improved sanitation: a flush or

---

[32] 1999/31/EC

[33] 2000/76/EC

[34] 94/62/EC, amended by 2004/12/EC

pour-flush connection to a piped sewer system, septic tank or pit latrine, a ventilated and improved pit latrine, a pit latrine with a slab, or a composting toilet (WHO et al. 2006).

The United States Agency for International Development (USAID) has also published indicators for evaluating water and sanitation projects as part of its Food and Nutritional Technical Assistance Program (Billig et al. 1999). Indicators that might be relevant at the national or provincial level include the percentage of children less than three years of age with diarrhea, the quantity of water used per capita per day, and the percentage of households with access to sanitation facilities.

3. *China's Measurement Practices*

Waste

Chinese solid waste generation data are generally grouped into three categories: municipal, industrial, and hazardous waste. *Municipal waste* includes residential, institutional, commercial, street cleaning, and non-processed waste from industries. Construction and demolition waste is also often considered part of municipal waste. *Industrial waste* typically refers to processed waste from specific industrial processes and would include by-products such as scrap metal, slag, and mine tailings. *Hazardous waste* can refer to either industrial waste or household generated waste: industrial hazardous waste can be generated from manufacturing processes or medical treatments, while small-scale levels of hazardous waste can also be generated by households or institutions. For this policy category, municipal waste is most relevant. Paper, plastics, and multi-laminates, such as plastic-coated paper, are the fastest growing components of China's waste stream (World Bank 2005). While certain information is available from government statistics, data collection on waste management must be improved in order to be truly useful in planning (Bei et al. 2009).

Waste disposal has not been a national priority until recently, with urban communities reliant on itinerant junk buyers to collect and recycle municipal waste on small scales. Rural citizens produce much less waste per capita and in many cases continue to use informal dumping grounds. China recently surpassed the United States as the largest generator of municipal waste in the world, and sanitary landfill construction, while growing, has not kept up with the need. Garbage incineration has been promoted through the use of tax breaks and subsidies in order to dispose of urban waste without taking up excessive land area, but this has resulted in increased air pollution. (Wang 2009)

In 2003, China enacted a regulation on Municipal Solid Waste Classification Marks,[35] and later enacted the Municipal Solid Waste Classification and Evaluation Criteria[36] in 2004. According to the 11th Five-Year Plan of National Urban Sanitation[37], China is putting great effort into the improvement of non-hazardous municipal waste treatment. The goals include increased garbage treatment capacity of >200,000 tons/day, municipal solid waste treatment rate of >60%. The Five-

---

[35] 《城市生活垃圾分类标志》GB/T 19095-2003, available at http://www.bjmac.gov.cn/huanwei/content/browseInfo.jsp?infoId=co0000002779 (last visited 19 July 2010).

[36] 《城市生活垃圾分类及其评价标准》CJJ/T102-2004

[37] 《全国城镇环境卫生"十一五"规划》

Year Plan also aims to improve urban daily street sweeping service, with a goal that 25% of street sweeping will be done with machinery rather than manually.[38]

Sanitation

Urban areas

Methodological details on the data for urban sanitation are difficult to find, and one case study on wastewater quality management in Kunning had to use a great deal of estimation and imputation to arrive at a useable data set (Huang et al. 2007; Shalizi 2008). Despite the lack of publicly available methodology, the central government releases many facts and figures in the statistical yearbook (Shen 2006).

In the future, more water-saving toilets will be built with better public toilet layout; and old toilets renovated in urban areas. The quality of latrines shall be gradually improved and ideally by the end of the 11th Five-Year Plan period, 70% of urban sewage should be treated (Wang 2008).

Rural areas

Large improvements have also been made in rural sanitation. By the end of 2007, China had built 144 million sanitary toilets for rural residents,[39] accounting for 57% of total rural households, an increase of 12 % over 2000. By the end of 2007, the central government had invested a total of RMB 764 million (US$112 million) in poor and schistosomiasis-prone areas to build 3.02 million sanitary toilets with sewage treatment systems ("China News of Traditional Medicine" 2008).

Some problems remain unsolved and need further investment and improvement, including fecal contamination, poorly treated drinking water, difficulty establishing accurate billing structures for centrally supplied tap water, waste water pollution emitted by township companies (which may be insulated against enforcement), and low environmental awareness among rural residents ("China News of Traditional Medicine" 2008). In accordance with the United Nations Millennium Development Goals, China aims to provide all rural residents safe and clean drinking water and 65% sanitation coverage by 2010 (Zhang et al. 2010).

---

[38] The enaction of the 11th Five-Year Plan of National Urban Sanitation《全国城镇环境卫生“十一五”规划》颁布实施》, Oct. 31, 2006, http://www.gov.cn/gzdt/2006-10/31/content_429244.htm (last visited 19 July 2010).

[39] “According to Chinese Government Criteria, a sanitary latrine should have a water proof underground compartment, a proper roof and superstructure as no fly and maggot and obnoxious smell” {Shen, 2006 #271}.

Assessment of China's Measurement Practices

The Chinese government adopted a Circular Economy Promotion Law in August 2008 to promote the reduction, reuse, and recycling of wastes during the production, distribution, and consumption stages of the economy. For a more complete overview on solid waste management policy in China, please also review the Resource Efficiency section of this report.

The Chinese government has identified expanding improved water and sanitation coverage in the rural areas as a development priority and invested US$2.45 billion in the rural sanitation sector between 1996 and 2002 (Asian Development Bank 2006). According to the 11th Five-Year Plan, China expects to expand rural latrine coverage to 65% and to 70% by 2010 (ibid.). If government support and financing can be sustained, China will likely meet the MDG target of halving the proportion of the population without access to basic sanitation by 2015 (see below, UNDP 2008). These improvements will, however, be more effective in raising public health standards if accompanied by hygiene education programs. One study found that knowledge of core sanitary and health information of people over 15 years old was only 36 percent in rural areas (Asian Development Bank 2006).

The World Bank (2005) reports several shortcomings in China's waste data: inconsistencies in definitions and methodologies; lack of references for data collection; frequently changing parameters that complicate comparison of trends; and disconnect between national resources, guidelines and local management. Also noted is the problem with information based on "waste collected" rather than "waste generated." Waste generation data are more useful because information on recyclable secondary materials and full-cost accounting are included.

4. Summary Indicator Calculations and Results

China EPI Waste Indicators

Based on the analysis of what should be measured and what data are available regarding waste and sanitation in China, the following indicators are recommended to be included in the China EPI. Waste is not a category included on the global EPI, but it is a high priority for China and extensive data sets are available.

Policy Categories	Policy Category Codes	Indicators	Indicator Codes	Data Source	Target
Waste and Sanitation	WASTE	**Municipal waste intensity**	MSW_PC	China Statistical Yearbook, 1996-2007	not available
		Industrial solid waste intensity	ISWINT	China Statistical Yearbook, 1996-2007	not available
		Municipal solid waste treated	MSW_T	China Statistical Yearbook, 2003-2007	60% by 2010
		Municipal wastewater treatment	MWW_T	China Statistical Yearbook, 2004-2006	not available
		Urban human waste disposal	SANU	China Statistical Yearbook, 2003-2007	78% by 2010
		Rural human waste disposal	SANR	China Environmental Statistical Yearbook, 2004-2005	65% by 2011

All of the indicators in this category are sourced from the China Statistical Yearbooks referenced above. Municipal waste intensity per capita (MSW_PC) is measured in kg waste/person. Because it is difficult to determine the total quantity of domestic garbage produced, the total quantity of domestic garbage collected is used as a substitute even though this represents an under estimate of municipal waste intensity. Industrial solid waste intensity (ISWINT) is calculated by dividing the quantities of industrial solid wastes (ISW) generated to industrial value added (IVA) and is measured in kg/RMB 1,000. Municipal solid waste treated (MSW_T) is the proportion of harmless municipal waste treated in urban areas to the total amount produced and is measured in percentage terms. The target of 60% treatment by 2010 comes from China's 11th Five-year Plan. Municipal wastewater treatment (MWW_T) is the proportion of municipal treated wastewater from the total output of municipal wastewater, and is also measured in percentage terms. Urban and rural human waste disposal (SANU and SANR) are expressed as percentages and measure the ratio of human waste disposed of to all human waste collected and transported.

Data Quality and Representativeness

All seven data sets were sourced from China Statistical Yearbooks and China Environmental Statistical Yearbooks, with no supplementary information available regarding how the data is collected, methods for aggregating, and representativeness. No raw data were available for any of the indicators.

Data is available for almost all provinces in all cases, with the exception of Xizang prior to 2006 for MSW_T, Xizang any year for MWW_T and SANR, and Fujian, Qinghai, and Xizang for SANU.

Correlations

The Pearson coefficients calculated for the six waste indicators show that comparatively strong relationships exist between ISWINT and MSW_PC, between ISWINT and MWW_T, between both SANU and SANR and MSW_T, between SANU and MWW_T, and between SANR and SANU. The highest correlation is the penultimate, showing a strong link between urban human waste disposal and municipal wastewater treatment (primarily urban), indicating that cities that invest in cleaner waste disposal do so through multiple means.

	MSW_PC	**ISWINT**	**MSW_T**	**MWW_T**	**SANU**	**SANR**
MSW_PC	1					
ISWINT	-0.38	1				
MSW_T	-0.07	-0.19	1			
MWW_T	-0.02	-0.38	0.24	1		
SANU	-0.04	-0.14	0.39	0.50	1	
SANR	0.09	-0.49	0.37	0.30	0.33	1

Ranks and Trend Analysis

The following figures show each of the six indicators graphed by province.

Figure 3. Waste Intensity by Province

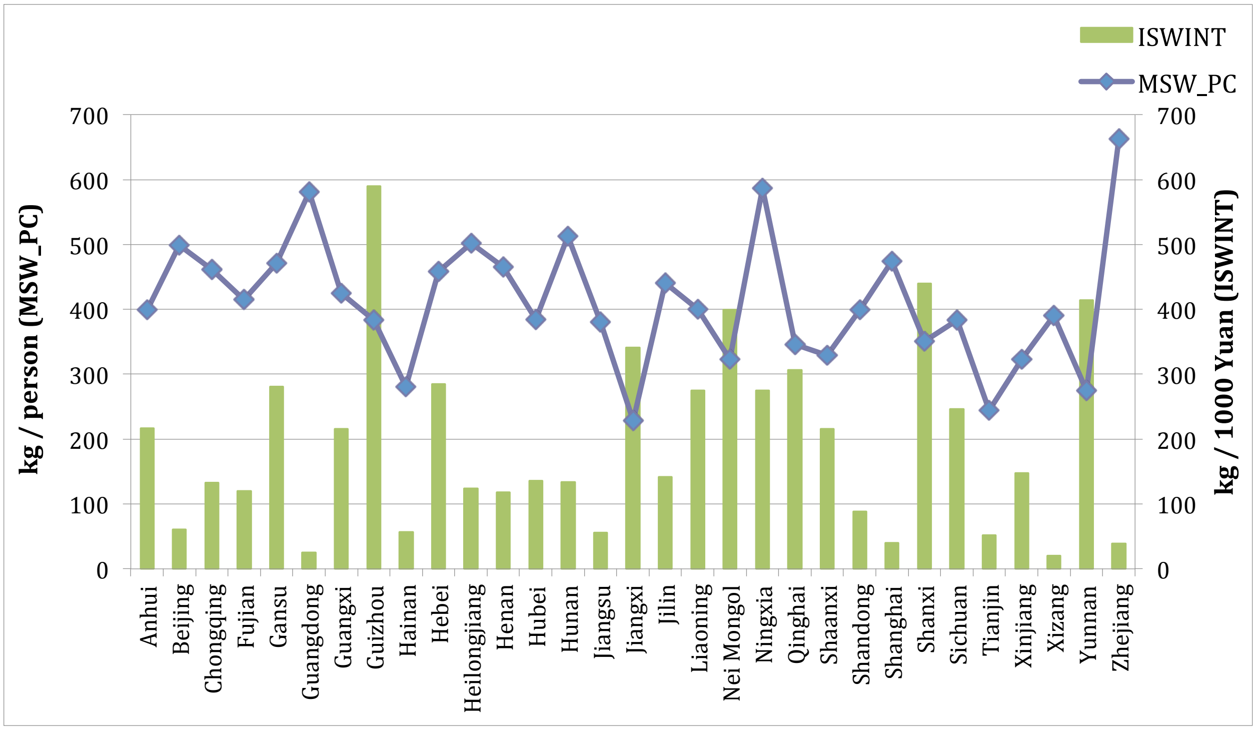


Figure 4. Waste Treatment by Province

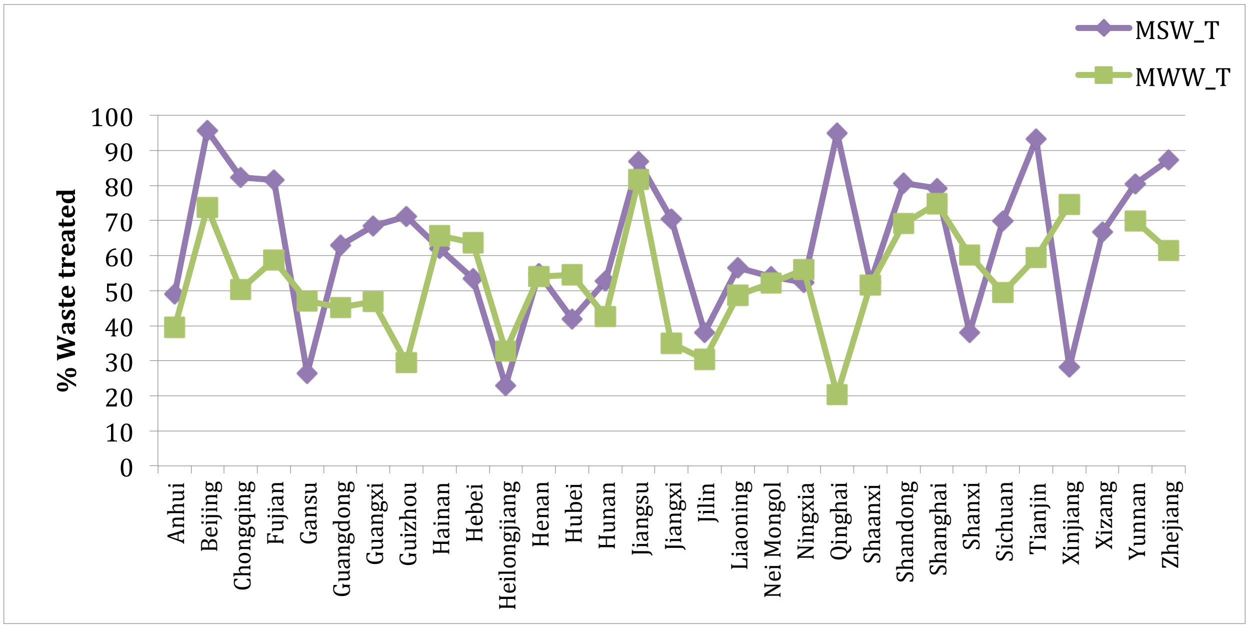
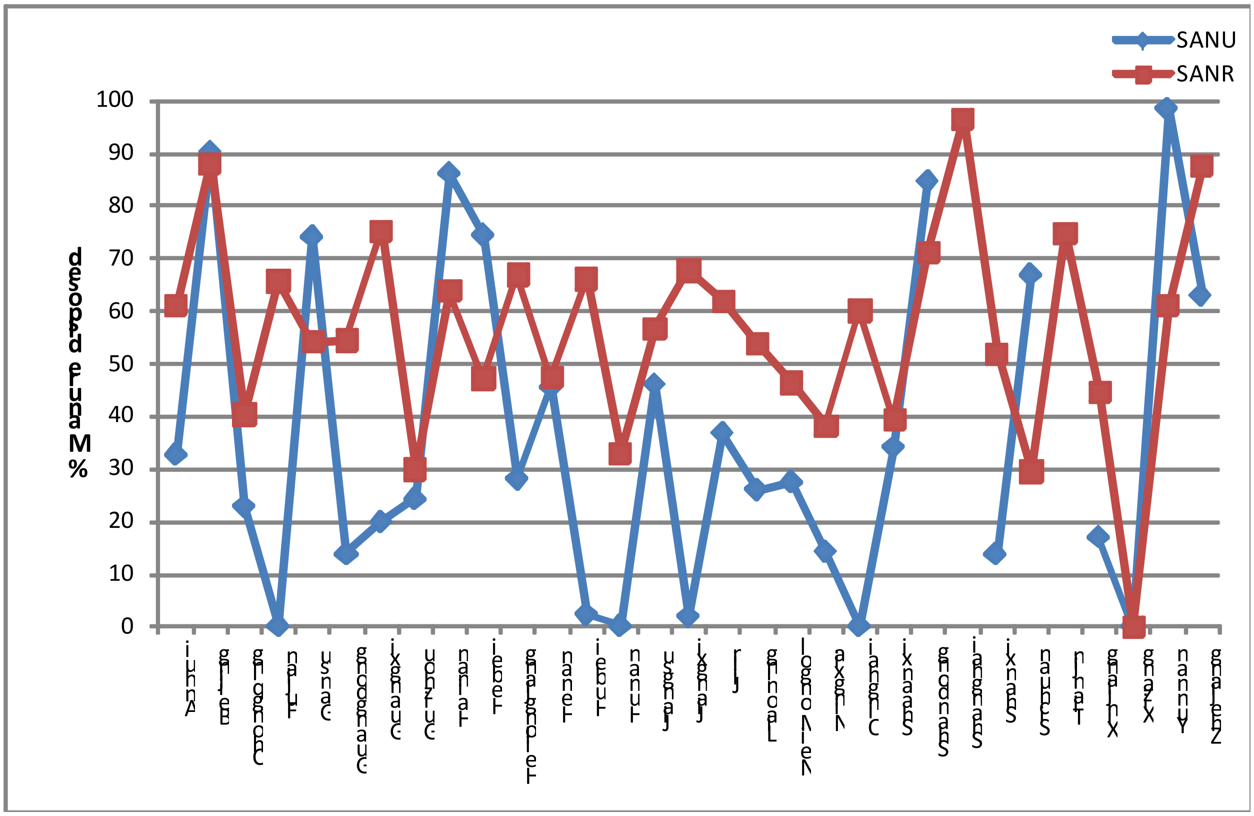


Figure 5. Human Waste Disposal by Province

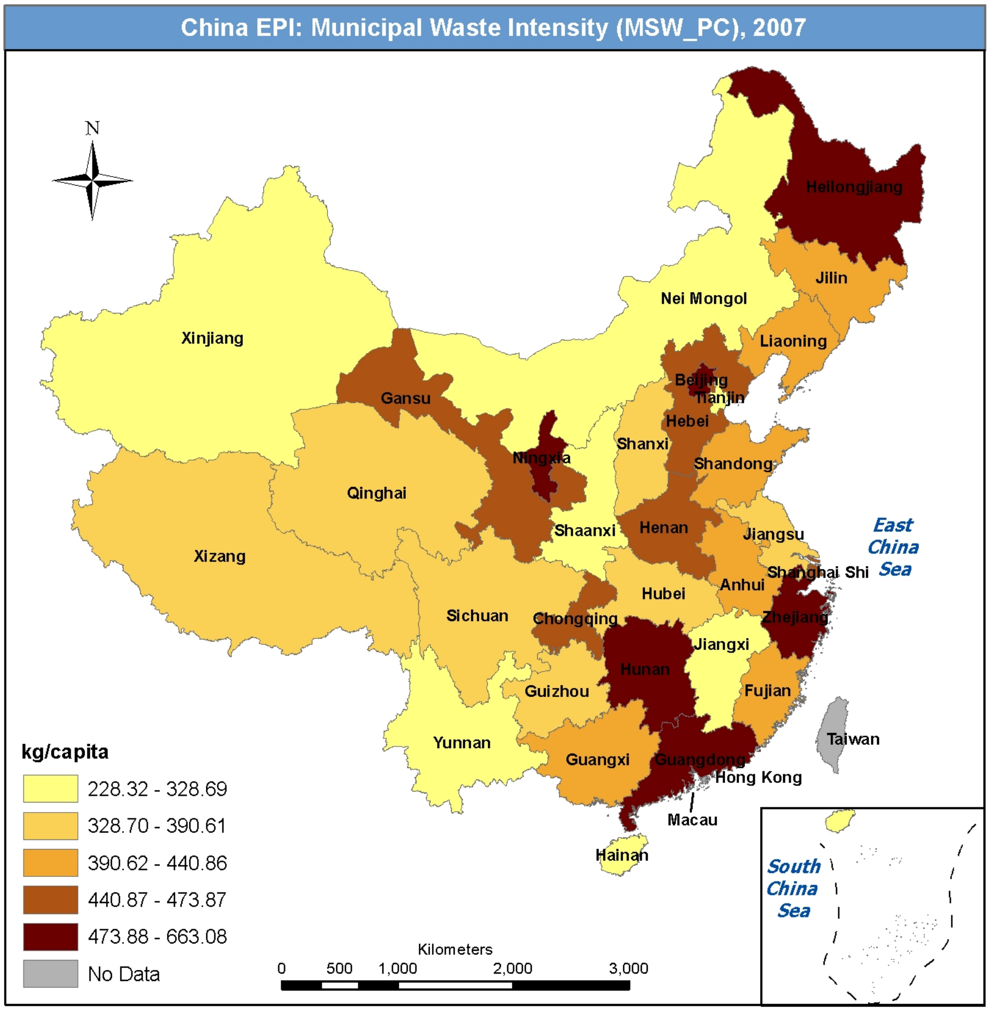


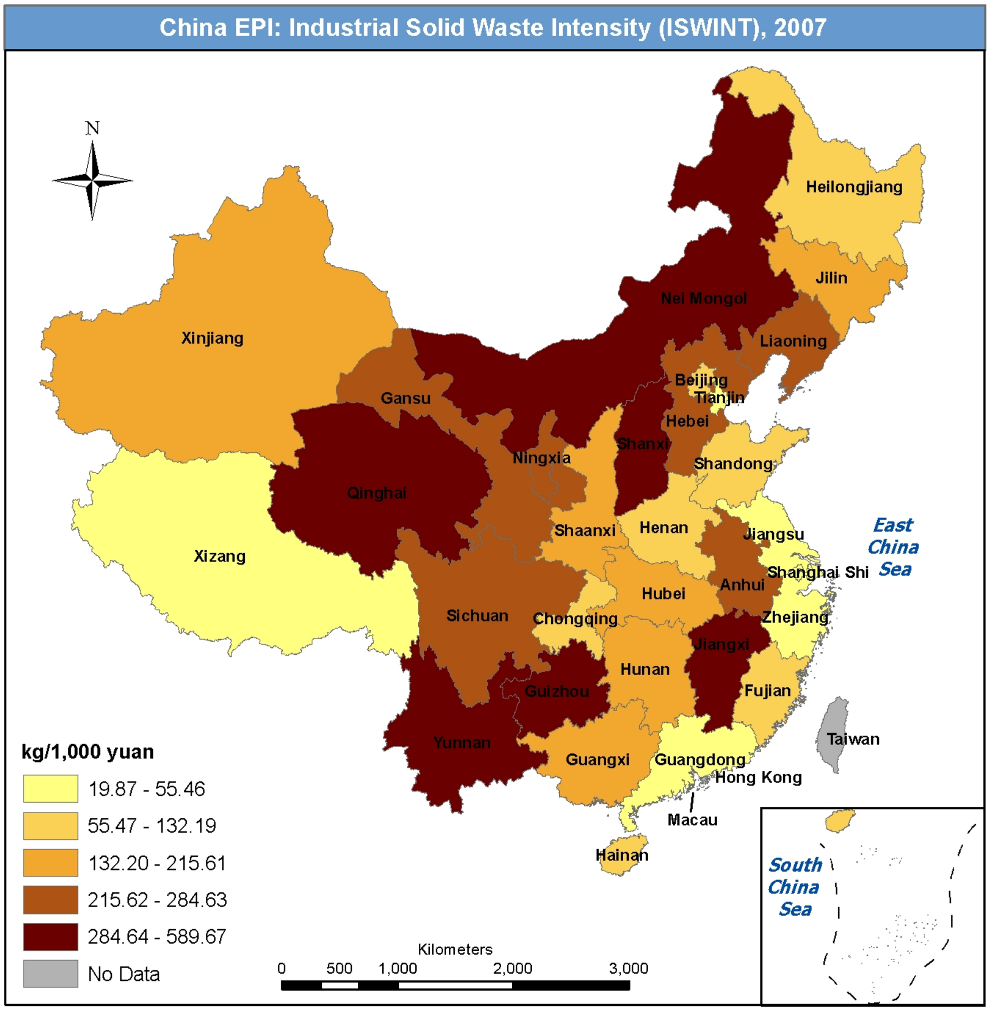
The tables below show the ranked province level aggregate data for each indicator. Data are from 2007 for municipal waste intensity (MSW_PC), industrial solid waste intensity (ISWINT), municipal solid waste treated (MSW_T), urban human waste disposal (SANU). Data for municipal wastewater treatment (MWW_T) are from 2006, and for rural human waste disposal (SANR) are from 2005.

Rank	**Province**	**MSW_PC (kg/person)**	**Province**	**ISWINT (kg/1000 ¥)**	**Province**	**MSW_T (%)**
1	Jiangxi	228.32	Xizang	19.87	Beijing	95.73
2	Tianjin	244.35	Guangdong	25.21	Qinghai	94.88
3	Yunnan	274.88	Zhejiang	39.14	Tianjin	93.31
4	Hainan	280.57	Shanghai	40.01	Zhejiang	87.35
5	Nei Mongol	322.88	Tianjin	51.99	Jiangsu	86.91
6	Xinjiang	323.23	Jiangsu	55.46	Chongqing	82.33
7	Shaanxi	328.69	Hainan	56.2	Fujian	81.62
8	Qinghai	345.78	Beijing	60.53	Shandong	80.71
9	Shanxi	350.87	Shandong	87.94	Yunnan	80.43
10	Jiangsu	380.3	Henan	117.62	Shanghai	79.16
11	Sichuan	383.4	Fujian	119.55	Guizhou	71.15
12	Guizhou	383.8	Heilongjiang	123.6	Jiangxi	70.51
13	Hubei	384.31	Chongqing	132.19	Sichuan	69.92
14	Xizang	390.61	Hunan	133.73	Guangxi	68.38
15	Anhui	399.21	Hubei	135.25	Xizang	66.7
16	Shandong	399.29	Jilin	141.09	Guangdong	63.03
17	Liaoning	400.05	Xinjiang	147.49	Hainan	62.07
18	Fujian	414.89	Shaanxi	215.06	Liaoning	56.52
19	Guangxi	424.58	Guangxi	215.61	Henan	54.9
20	Jilin	440.86	Anhui	216.39	Nei Mongol	53.98
21	Hebei	458.22	Sichuan	246.26	Hebei	53.37
22	Chongqing	461.3	Liaoning	274.62	Hunan	52.77
23	Henan	465.56	Ningxia	275	Shaanxi	52.43
24	Gansu	471.12	Gansu	281.04	Ningxia	52.41
25	Shanghai	473.87	Hebei	284.63	Anhui	49.07
26	Beijing	498.44	Qinghai	306.02	Hubei	41.88
27	Heilongjiang	501.77	Jiangxi	341.23	Jilin	38.17
28	Hunan	512.8	Nei Mongol	398.88	Shanxi	38.15
29	Guangdong	581.18	Yunnan	413.64	Xinjiang	28.16
30	Ningxia	586.59	Shanxi	439.7	Gansu	26.32
31	Zhejiang	663.08	Guizhou	589.67	Heilongjiang	22.97

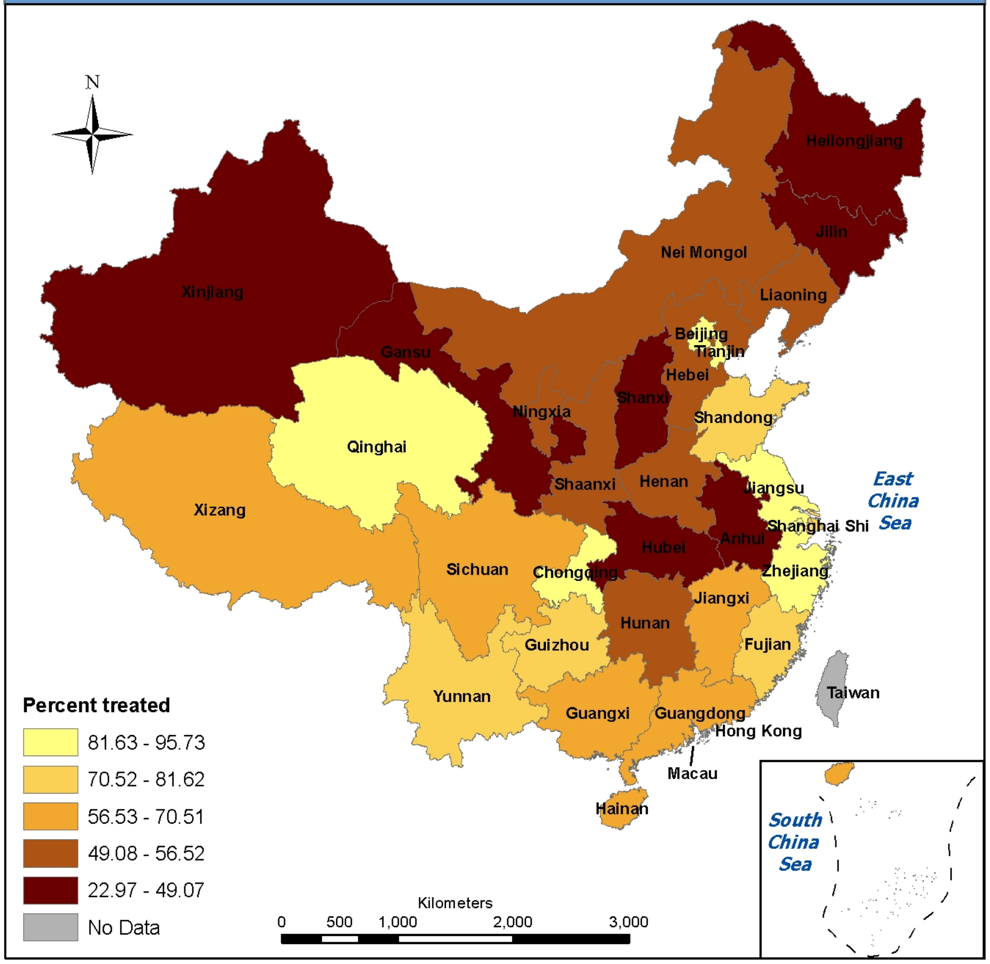
Rank	Province	MWW_T (%)	Province	SANU (%)	Province	SANR (%)
1	Jiangsu	81.82	Yunnan	98.45	Shanghai	96.5
2	Shanghai	74.92	Beijing	90.33	Beijing	88.09
3	Xinjiang	74.62	Hainan	86.08	Zhejiang	87.58
4	Beijing	73.78	Shandong	84.66	Guangxi	75.19
5	Yunnan	69.83	Hebei	74.4	Tianjin	74.81
6	Shandong	69.18	Gansu	74.01	Shandong	71.14
7	Hainan	65.74	Sichuan	66.85	Jiangxi	67.73
8	Hebei	63.63	Zhejiang	62.9	Heilongjiang	66.97
9	Zhejiang	61.53	Jiangsu	46.03	Hubei	66.17
10	Shanxi	60.22	Henan	45.56	Fujian	65.75
11	Tianjin	59.48	Jilin	36.8	Hainan	63.87
12	Fujian	58.82	Shaanxi	34.13	Jilin	61.91
13	Ningxia	55.92	Anhui	32.69	Yunnan	61
14	Hubei	54.52	Heilongjiang	27.99	Anhui	60.95
15	Henan	54.08	Nei Mongol	27.39	Qinghai	60.03
16	Nei Mongol	52.08	Liaoning	26.09	Jiangsu	56.54
17	Shaanxi	51.57	Guizhou	24.14	Guangdong	54.43
18	Chongqing	50.36	Chongqing	22.86	Gansu	54.12
19	Sichuan	49.38	Guangxi	19.88	Liaoning	53.82
20	Liaoning	48.75	Xinjiang	16.91	Shanxi	51.92
21	Gansu	46.97	Ningxia	14.29	Henan	47.37
22	Guangxi	46.82	Guangdong	13.71	Hebei	47.19
23	Guangdong	45.15	Shanxi	13.67	Nei Mongol	46.36
24	Hunan	42.72	Hubei	2.26	Xinjiang	44.66
25	Anhui	39.5	Jangxi	1.85	Chongqing	40.42
26	Jiangxi	34.93	Hunan	0.05	Shaanxi	39.48
27	Heilongjiang	32.77	Yunnan	98.45	Ningxia	38.19
28	Jilin	30.36	Beijing	90.33	Hunan	33.01
29	Guizhou	29.54			Guizhou	29.97
30	Qinghai	20.37			Sichuan	29.57

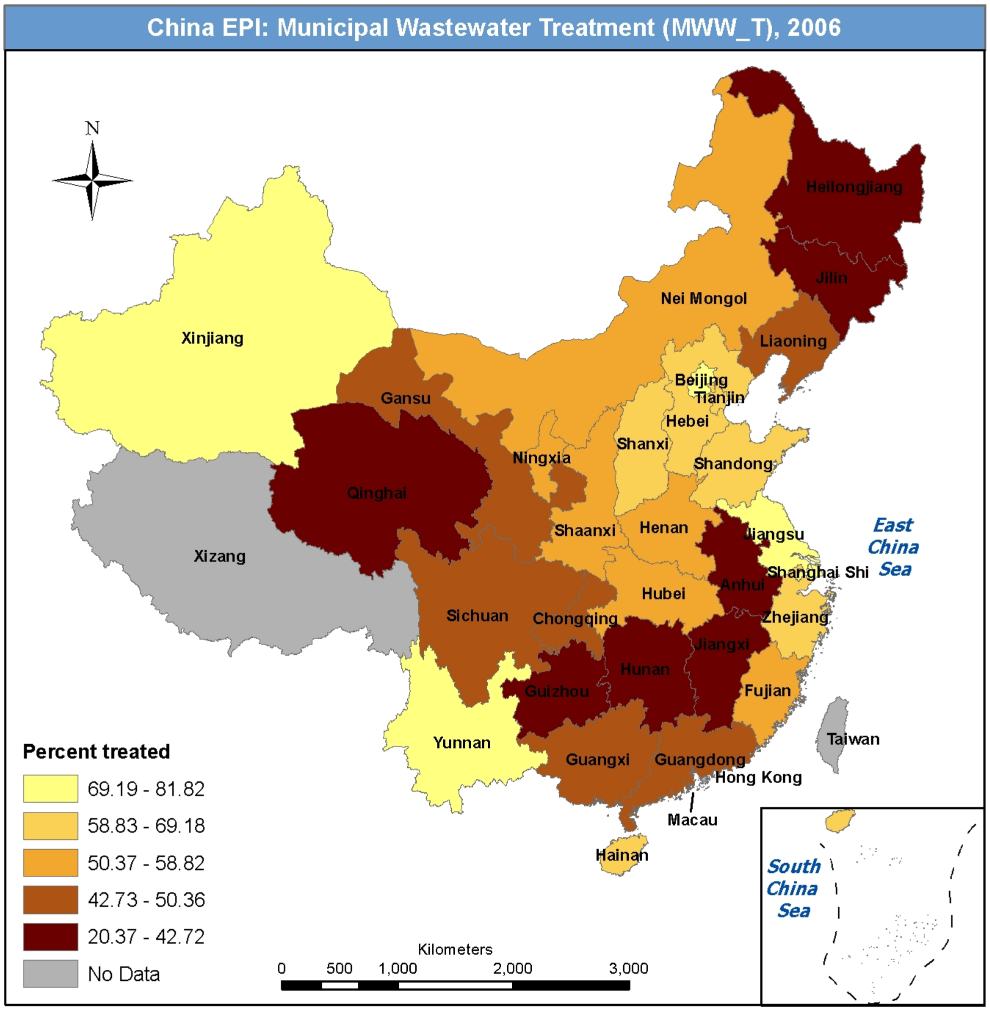
The following maps depict the indicator scores by province. The maps consistently depict the best performers in yellow and the worst performers in dark brown.


China EPI: Municipal Waste Intensity (MSW_PC), 2007


China EPI: Industrial Solid Waste Intensity (ISWINT), 2007

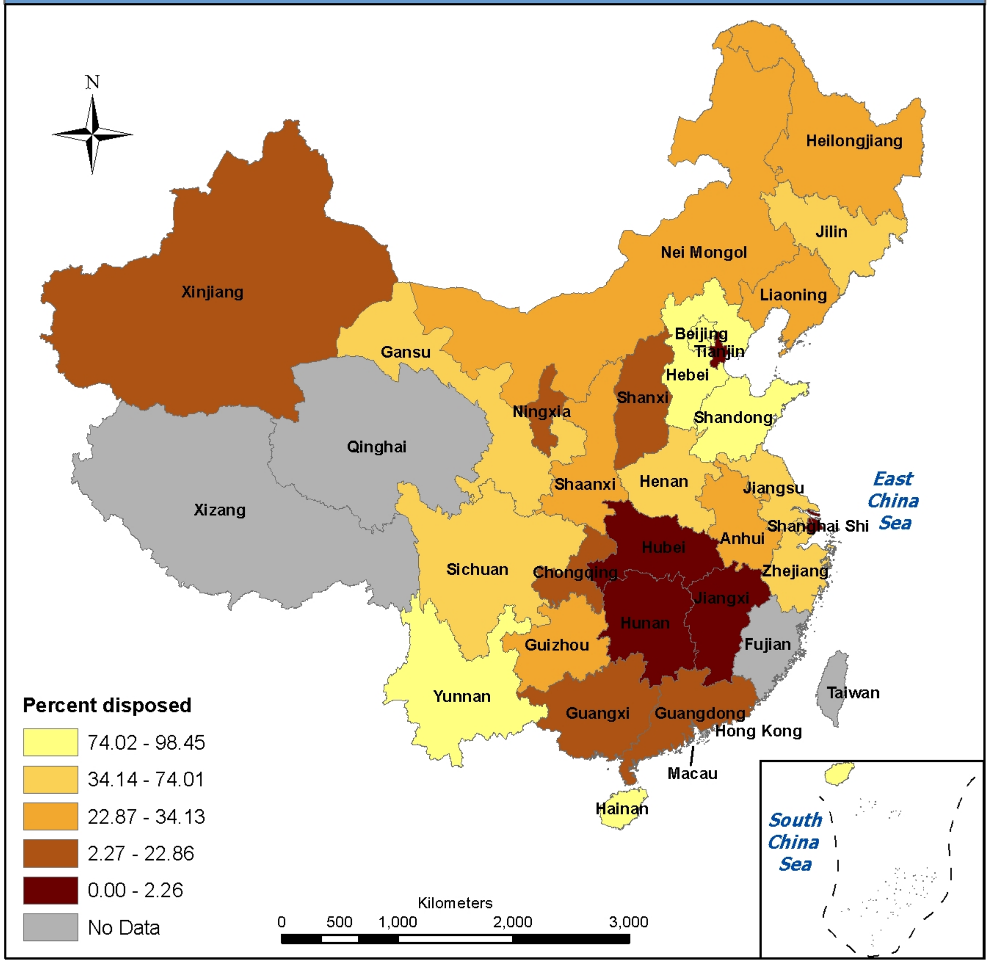
China EPI: Municipal Solid Waste Treated (MSW_T), 2007

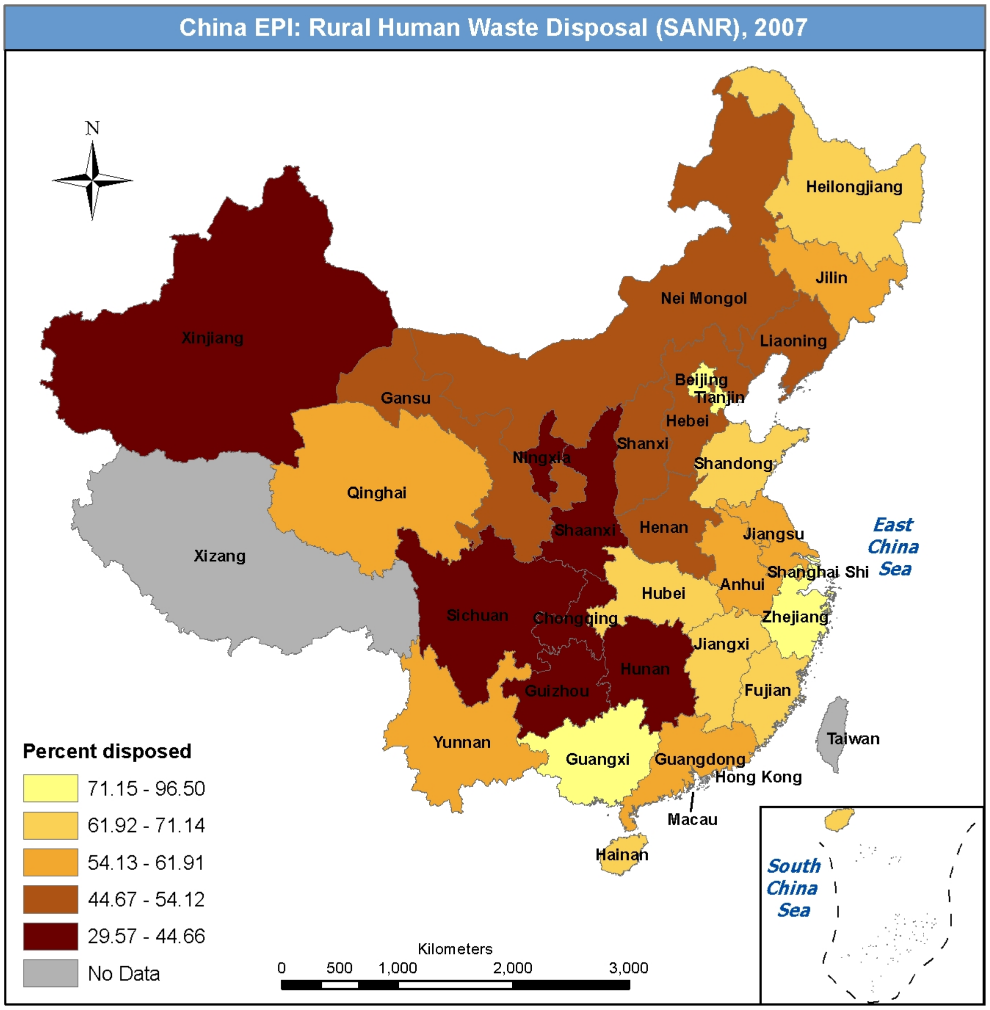




China EPI: Municipal Wastewater Treatment (MWW_T), 2006

China EPI: Urban Human Waste Disposal (SANU), 2007





China EPI: Rural Human Waste Disposal (SANR), 2007

D. Toxics

1. Introduction

The toxics category measures the critical environmental health effects of toxic substances, including heavy metals and persistent organic pollutants. Toxic substances can be released into soil, air, and water through industrial and agricultural processes as well as domestic coal combustion. These substances can accumulate at rates harmful to human health. Therefore, the concentration of toxic substances in the environment is an important measure of environmental health and overall environmental stewardship.

The uncontrolled spread of toxic substances poses a serious threat to the environment and human health. A toxic substance is defined as any chemical or mixture of chemicals that may be harmful if inhaled, ingested, or absorbed through the skin. Examples include heavy metals such as lead, arsenic, cadmium, and mercury, as well as persistent organic pollutants such as polychlorinated biphenyls, dioxins, and furans. Each year, approximately 355,000 people die worldwide from unintentional poisonings. Approximately two thirds of the deaths that occur in developing countries are due to excessive exposure to toxic chemicals (UNEP and WHO 2010). Deaths arise when toxics are emitted directly into the soil, air, and water at levels dangerous to humans. These chemicals may come from industrial processes, mining, fuel combustion, or various unsustainable forms of agriculture. Pesticides are also responsible for a particularly high percentage of unnecessary deaths (ibid.).

Many of the most dangerous toxics play important roles in industry today. Mercury, lead, and cadmium are all toxic chemicals that contribute significantly to global environmental degradation (UNEP 2009a). In China, toxic pollutants include all substances listed in the Directory of Highly Toxic Chemicals[40], all the Type I pollutants as defined in the Integrated Wastewater Discharge Standard[41], and persistent organic pollutants (POPs). Type I pollutants include many chemicals used in manufacturing and industry: total mercury, alkyl (organic) mercury, total cadmium, total chromium, hexavalent chromium, total arsenic, total lead, total nickel, benzo[a]pyrene, total beryllium, total silver, and total radiation. Persistent organic pollutants are organic substances found in agricultural pesticides, plastics, and industrial solvents that persist in the environment regardless of chemical, biological, and photolytic processes. They often have both acute and chronic toxicity to humans and the environment, and due to their persistence they bioaccumulate up the food chain.

In addition, despite being a signatory to the Basel convention and having several e-waste import regulations, a great deal of the world's high-tech waste flows into China, and unregulated e-waste management harms human health (BAN and SVTC 2002). Workers soak old electronics in hydrochloric acid to recover valuable metals like gold and copper. The process releases pollutants into the atmosphere, groundwater, and surrounding farmland.

---

[40] Available at http://www.chinasafety.gov.cn/whpcx.htm

[41] GB 8978-1996

2. *Ideal and International Best Practices for Measurement*

International Law

The international community has agreed to the terms of three conventions relating to toxic substances: the 1992 Basel Convention on the Control of Transboundary Movements of Hazardous Waste and their Disposal, the 2004 Stockholm Convention on Persistent Organic Pollutants (POPs), and the 2004 Rotterdam Convention on Prior Informed Consent Procedure for Certain Hazardous Chemicals in International Trade.

The Basel Convention on the Control of Transboundary Movements of Hazardous Waste and their Disposal was opened for signature in 1989 and went into effect in 1992. The convention governs the practice of exporting hazardous waste from developed countries to less developed countries in an effort to eliminate toxic waste "dumping" (United Nations 1989).

The Stockholm Convention on POPs aimed to reduce or eliminate the use of POPs internationally. Countries that agreed to the Stockholm Convention promised to outlaw nine of the so-called "dirty dozen" toxic chemicals identified by the Forum on Chemical Safety and the International Programme for Chemical Safety. The chemicals that had to be outlawed were a subset of POPs: aldrin, chlordane, dieldrin, endrin, heptachlor, hexachlorobenzene (HCB), mirex and toxaphene. DDT was restricted, and dioxins and furans were marked as unintentional production (United Nations 2001). Nine additional POPs were added to the convention in 2009, with more under consideration (UNEP 2008c).

The Rotterdam Convention on Prior Informed Consent Procedure for Certain Hazardous Chemicals in International Trade called for mutual responsibility in monitoring the movement of hazardous toxics. The convention resulted in an international agreement to use proper labeling in the exportation of hazardous materials, as well as allowing countries the decision of whether or not to ban these chemicals (United Nations 1998b).

United States Law

The United States has multiple main federal statutes addressing toxic substances and hazardous waste:

- The 1976 Toxic Substances Control Act (TSCA)
- The 1976 Resource Conservation and Recovery Act (RCRA)
- The 1980 Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, also known as Superfund Act)
- The 1986 Emergency Planning and Community Right-to-Know Act (EPCRA)
- The 1990 Pollution Prevention Act (PPA).

TSCA regulates toxic chemicals including polychlorinated biphenyls (PCBs), asbestos, radon and lead-based paint. However, chemical substances from food, drugs, cosmetics and pesticides are excluded from TSCA and governed by other laws and/or regulations (EPA 2010c). RCRA creates a full life-cycle management framework for both hazardous and non-hazardous solid wastes (EPA 2010b). CERCLA regulates hazardous waste sites (also known as brownfields) and clean up programs, and imposes joint and strict legal and financial liability upon broad classes of parties potentially responsible for hazardous waste sites, allowing many cleanups to go forward without undue taxpayer funding (EPA 2010a). EPCRA requires the communities and citizens to be informed of chemical hazards around them by setting up the Toxics Release Inventory (TRI) to provide toxic chemicals data and waste management to the public (EPA 2009b). PPA amends EPCRA with the creation of voluntary community education programs by emitting facilities (Knudsen Unknown).

Other relevant statutes include the 1938 Federal Food, Drug and Cosmetic Act, which regulates toxic substances in food additives; the 1970 Occupational Safety and Health Act, which regulates exposure to toxic substances in the workplace; and the 1972 Federal Environmental Pesticide Control Act, which requires registration, certification, and premarket testing of pesticides. While these laws provide a basic framework for registering and regulating toxic substances, American law places the burden of proof to show harm upon the regulator (EPA in most cases), resulting in criticism that toxic substances are allowed to stay on the market too long and that regulators are unable to control many hazards.

European Union Law

The Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) Regulation entered force in 2007 as the strictest law controlling chemical substances in Europe. REACH has the combined goals of improving the protection of human health and protecting the environment. The most significant component of the regulation is Registration, which requires all industries manufacturing or importing a minimum of one tonne of chemicals per year to register with the European Chemicals Agency database. Other aspects of REACH include promoting alternatives to animal testing, and addressing the use of Substances of Very High Concern[42]. Unlike TSCA, REACH covers chemicals that are not already adequately regulated, especially if they are widely dispersed or used in large quantities. Also unlike US law, REACH relies upon manufacturers to submit some proof of safety before their products may be brought to market or produced in large quantities.

Directive 91/689/EEC describes the process for handling hazardous waste in the European Union. Implemented in 1991 and amended in 1994 by Directive 94/31/EC, this law affects the record keeping, monitoring, and control obligations of industries producing hazardous waste from "cradle to grave." According to this law, waste must be properly packaged and labeled to control its management. Particular attention is paid to the mixing of hazardous waste with nonhazardous wastes. Domestic waste is exempted. Waste is classified as hazardous depending on its concentrations of toxic, corrosive, irritant, carcinogenic, toxic for reproduction, and mutagenic substances (Europa 2010).[43]

---

[42] These substances include those that are: carcinogenic, mutagenic, or toxic to reproduction; persistent, bioaccumulative and toxic; very persistent and very bioaccumulative; or identified on a case-by-case basis as "causing probable serious effects" (European Union 2008).

[43] These properties are specifically explained in Directive 91/689/EEC, Decision 200/532/EC, and Decision 2001/573/E.

Japanese Law

The Chemical Substances Control Law (officially the Law Concerning the Examination and Regulation of Manufacture, etc. of Chemical Substances[44], also known as Kashin-ho) was enacted in 1973 as the world's first chemical pre-examination system. A 1986 amendment allowed the inclusion of chemical substances that are not highly accumulative but are persistently toxic, known as Class II Chemical Substances. A later 2003 amendment created an assessment and regulation program specifically focused on impact of chemical substances on flora and fauna. In 2009, an additional amendment was added to make Kashin-ho more like REACH and ensure that Japan was moving towards international goals.[45] Japan also has a Law Concerning Special Measures against Dioxins,[46] known as the Dioxins Law, which establishes basic environmental standards for dioxin effluents and contamination in air, water, and soil (JME 2005). Hazardous waste in Japan is governed by the 1991 Waste Disposal and Public Cleansing Law, which aims to promote and strengthen institutional capacities in hazardous waste management.

3. *China's Measurement Practices*

Technical standards and guidelines

The Chinese government has taken several steps to combat the level of toxic chemicals in the environment. In recent years, the Regulations on Safe Management of Hazardous Chemicals have become the core of the government's efforts to establish a management system and formulate relevant policies on hazardous chemicals. China promulgated the Law on the Prevention and Control of Environmental Pollution by Solid Waste in 1995 and amended the law in 2004. This law forbids other countries from dumping, stockpiling, and disposing of solid waste in China, and imposes criminal penalties on the illegal import of solid wastes. It is also prohibited dumping or discharging toxic substances into water bodies.[47]

China has established specialized oversight agencies for the safe and environmentally sound management of hazardous chemicals at the national and local levels. At the national level, these include the MEP, State Administration of Work Safety (SAWS), Ministry of Health, State Food and Drug Administration, Ministry of Agriculture, State General Administration for Quality Supervision and Inspection and Quarantine, Ministry of Communications, Ministry of Railways, and Ministry of Public Security. The management of persistent organic pollutants is additionally overseen by the Ministries of Foreign Affairs, Science and Technology, Civil Administration, Finance, Construction, Commerce, the General Administration of Customs, General Administration of Civil Aviation, State

---

[44] Act No. 117 of 1973

[45] The amendment summary (English version) is available at http://www.jetoc.or.jp/informationICR.htm, last visited on July 19, 2010

[46] Law No. 105 of 1999

[47] Article 31 of the "Law of the People's Republic of China on Prevention and Control of Water Pollution": "It is forbidden to discharge or dump into any water body or directly bury deadly toxic soluble slag, tailings, etc. containing such substances as mercury, cadmium, arsenic, chromium, lead, cyanide and yellow phosphorus" (PRC 1984)

Electricity Regulatory Commission, and the National Development and Reform Commission (NDRC).

China has also participated in a variety of international treaties to prevent the spread of hazardous chemicals. On March 22, 1990, the Chinese government signed the Basel Convention, which came into effect in China in 1992. Similarly, in 1999, the Chinese government signed the Rotterdam Convention, which came into effect in 2005 (An, Shinsuke et al. 2007 166). Since then, the Chinese government has acted to implement the agreements made, including enacting non-mandatory restrictions on the hazardous materials covered in the Rotterdam Convention. In addition, the Chinese government signed the Stockholm Convention in 2001 and ratified it in 2004. The Stockholm Convention was also applied to Special Administrative Regions of Hong Kong and Macao (UNIDO 2007).

In January 2004, SEPA and NDRC jointly promulgated the National Construction Plan for Hazardous Waste and Medical Waste Disposal Facilities.[48] The plan stipulates that 31 comprehensive hazardous waste disposal centers will be built in China, which will add up to an annual incremental hazardous waste disposal capacity of 2.8 million tons. Meanwhile, industry will construct and expand a total of 3.5 million ton annual capacity in terms of industrial hazardous waste recycling and disposal, which can handle all the newly generated hazardous waste, as well as part of previously accumulated hazardous waste.

Environmental statistics associated with toxics are currently inadequate. The toxics indicators only cover the heavy metal releases from industrial wastewater discharges, but do not included the heavy metal releases from industrial gaseous emissions and solid wastes. In particular, the significant heavy metal emissions (particularly mercury) associated with coal combustion have not been monitored or reported. There has been no existing environmental law and regulation to mandate industry to disclose their releases of toxic pollutants to the environment.

With China's active involvement in the Stockholm Convention, it is foreseen that China will gradually enhance its capacity to monitor and regulate persistent organic pollutants emissions.

4. *Summary Indicator Calculations and Results*

China EPI Toxics Indicators

One of the biggest sources of toxic substances in China's environment is domestic coal combustion. Domestic coal combustion in China has resulted in arsenic poisoning, dental and skeletal fluorosis, high incidence of esophageal and lung cancers caused by polycyclic aromatic hydrocarbons, selenium poisoning, and mercury poisoning. In China, millions of people burn raw coal in stoves without any ventilation system, allowing toxic vapors and hazardous organic compounds to permeate their homes. At least 3,000 people in Southwest China have arsenic poisoning, and more than 10 million people suffer from dental and skeletal fluorosis (Finkelman, Belkin et al. 1999).

---

[48] State Council Notice (2003) No. 128, available at http://www.gov.cn/zwgk/2005-08/26/content_26260.htm.

As the only liquid metal, mercury has many unique properties that make it valuable in industry. It is used as a catalyst for chlor-alkali production, and can be found in manometers, thermometers, electrical and electronic switches, fluorescent lamps, and dental amalgam fillings. Mercury is also widely used as a dioxide in batteries, as a pesticide, and as biocides in the paper industry. It is found naturally in coal at a concentration of 0.22 mg/kg in China, and coal combustion has led to solid and gaseous emissions averaging about 140 tons/year from 1978-1995 (Wang, Q, Shen et al. 2000). However, mercury can cause both chronic and acute poisoning, resulting in damage to the brain, kidneys, and lungs. Although the global demand for mercury is decreasing, many of its uses are still common in certain parts of the world (UNEP 2002). China is the single largest emitter of mercury worldwide. One estimate suggests that China was responsible for 635 tons of mercury emissions by 2005, or 40% of the global mercury by-product emissions (Pacyna, Pacyna et al. 2009).

Lead is a highly toxic metal that is used and traded globally in lead compounds, sheets, ammunition, and paint. The major use of lead in recent years is in batteries, accounting for 78% of reported global consumption in 2003 (UNEP 2008b). Between 1970 and 2003, global consumption of lead increased from 4.5 to 6.8 million tons. China is the world's leading producer and user of lead, exporting lead-based products worldwide. Existing data suggest that childhood lead poisoning may be widely pervasive as a result of rapid industrialization and the use of leaded gasoline. Childhood lead exposure causes deficits in IQ, attention span, neurobehavioral development, and physical growth, as well as comas, convulsions, or even death (Shen, Rosen et al. 1996). Lead is found in the environment in China due to industrial emissions, leaded gasoline, poor quality lead ore, and inefficient management of lead scrap (Shen et al. 1996 ; Mao, Lu et al. 2006)

Cadmium is a non-essential element that is mainly produced during the mining of zinc. The majority of refined cadmium is used in nickel-cadmium batteries, but it is also used in pigments for plastics, ceramics and enamels, stabilizers for plastics, and plating. Although global rates of consumption have stayed constant since 1990, the production in Asia has significantly increased during this time (UNEP 2008a). Through accumulation in waste materials found in landfills, cadmium can pose a substantial danger to the environment. Cadmium is toxic to plants, animals, and people. It has been shown to have carcinogenic and mutagenic effects on human health, often leading to lung and prostate cancer, kidney damage and bone disease (Ostrowksa 2008; OSHA 2009; Jin, Nordberg et al. 2002).

Chromium is a metal mainly used to manufacture stainless steel. Production of dyes and pigments, leather tanning, wood preservation, and production of refractory materials are common uses of chromium compounds (EPA 2007). The two main states of chromium found in the environment are trivalent chromium (Cr(III)) and hexavalent chromium (Cr(VI)). Although trivalent chromium is generally harmless, hexavalent chromium is toxic and carcinogenic. Hexavalent chromium causes damage to the respiratory tract and poses a significant reproductive risk in humans (ibid.). China's use of both chromium compounds has increased significantly in the past few years with the expansion of its role as a stainless steel producer (Papp 2010).

Urban exposure to benzene, toluene, ethylbenzene and xylenes (*BTEX*) poses other environmental risks. BTEX compounds are naturally occurring components of petroleum, and are found in gasoline. Frequently, BTEX chemicals are found in the environment near petroleum industries, or underground storage tanks. In China, BTEX exposure results primarily from vehicle emissions. BTEX chemicals are dangerous by ingestion or inhalation and can cause kidney or liver damage, as well as being a human carcinogen. The exposure levels in China are higher than those measured in North America or Europe (Wang, Xin-ming, Sheng et al. 2002).

Policy Categories	Policy Category Codes	Indicators	Indicator Codes	Data Source	Target
Toxics	**TOXIC**	**Heavy metals**	METALS	China Environmental Statistical Yearbook, 2004-2006	not available
		Hazard waste intensity	HAZINT	China Statistical Yearbook, 1996-2007	not available

To build the heavy metals (METALS) indicator, we combined data on concentrations of the above metals into building blocks or "pollution units" and then calculated a z-score.[49] The hazardous waste intensity (HAZINT) indicator is calculated by dividing the quantities of dangerous or hazardous wastes generated (impounded, disposed of, or released) by industrial value added (IVA).

Data Quality and Representativeness

All metals data sets were sourced from China Statistical and China Environmental Statistical Yearbooks, with no supplementary information available regarding how the data is collected, methods for aggregating, and representativeness. No raw data was available on any indicator. Data were available for all provinces, with the exception of Xizang.

Correlations

The Pearson coefficient calculated for the two toxics indicators shows that METALS and HAZINT are only very slightly positively correlated.

	METALS	HAZINT
METALS	1	
HAZINT	0.10	1

---

[49] z-score = (value – mean) / standard deviation

Ranks and Trend Analysis

Figure 6 shows toxic metals pollution in standardized z-score units (above and below the mean) by province. Figure 7 shows hazardous waste intensity.

Figure 6. Toxic Metals Pollution Equivalents (high scores are bad)

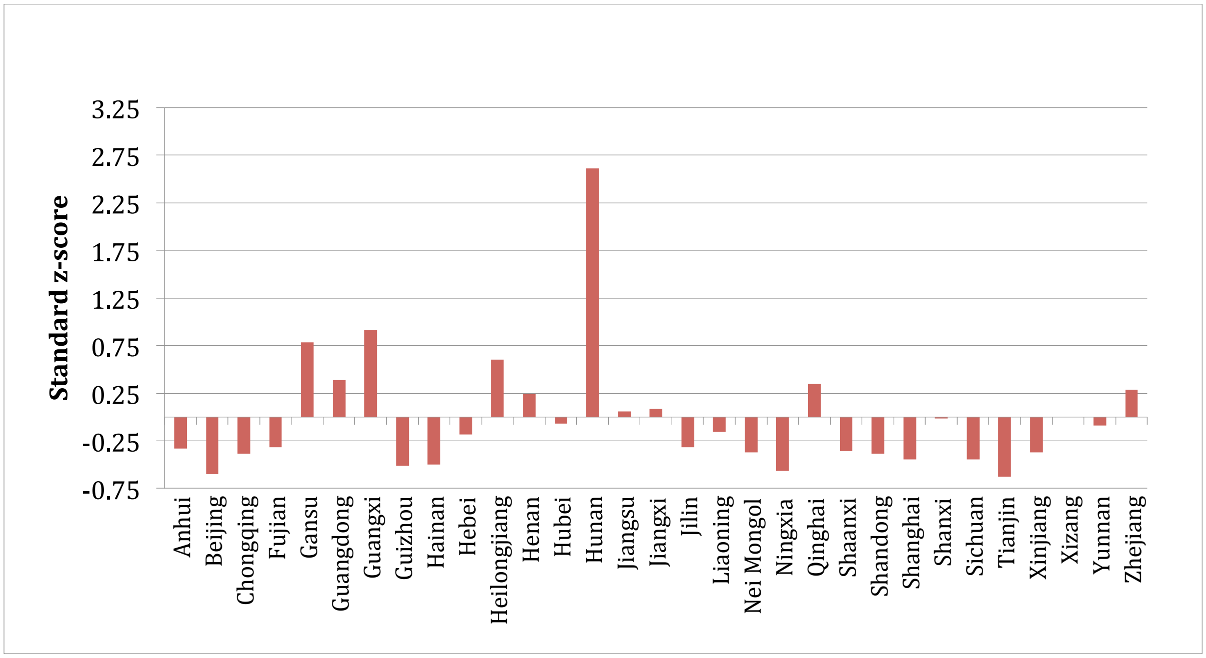
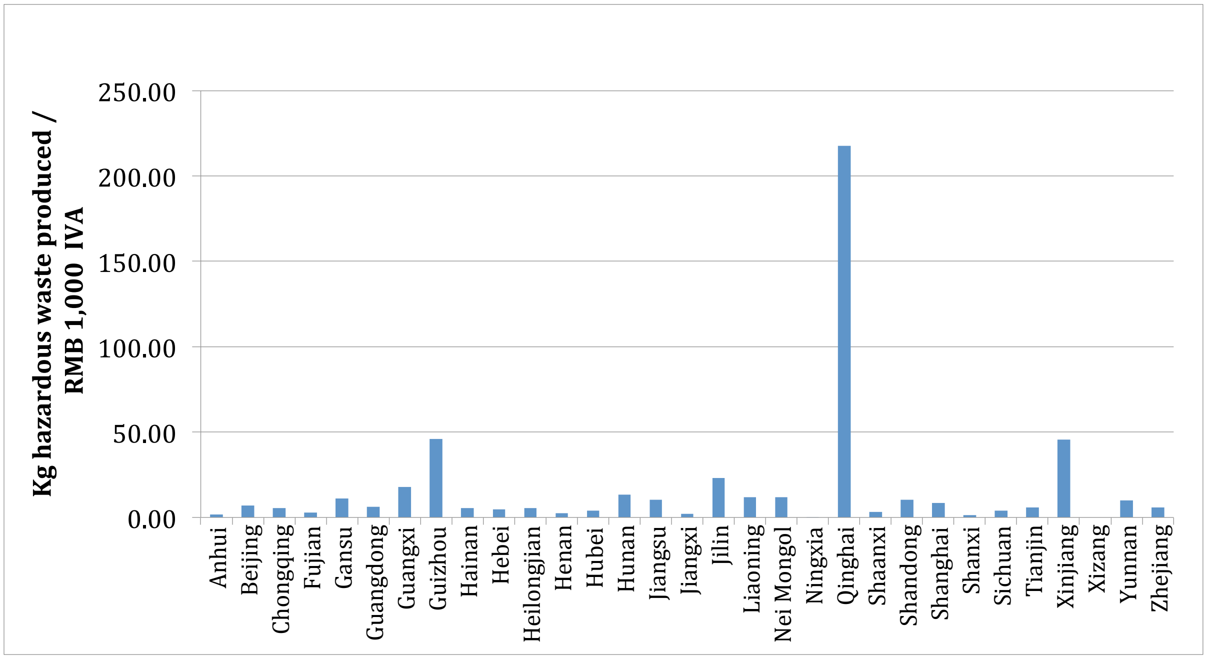


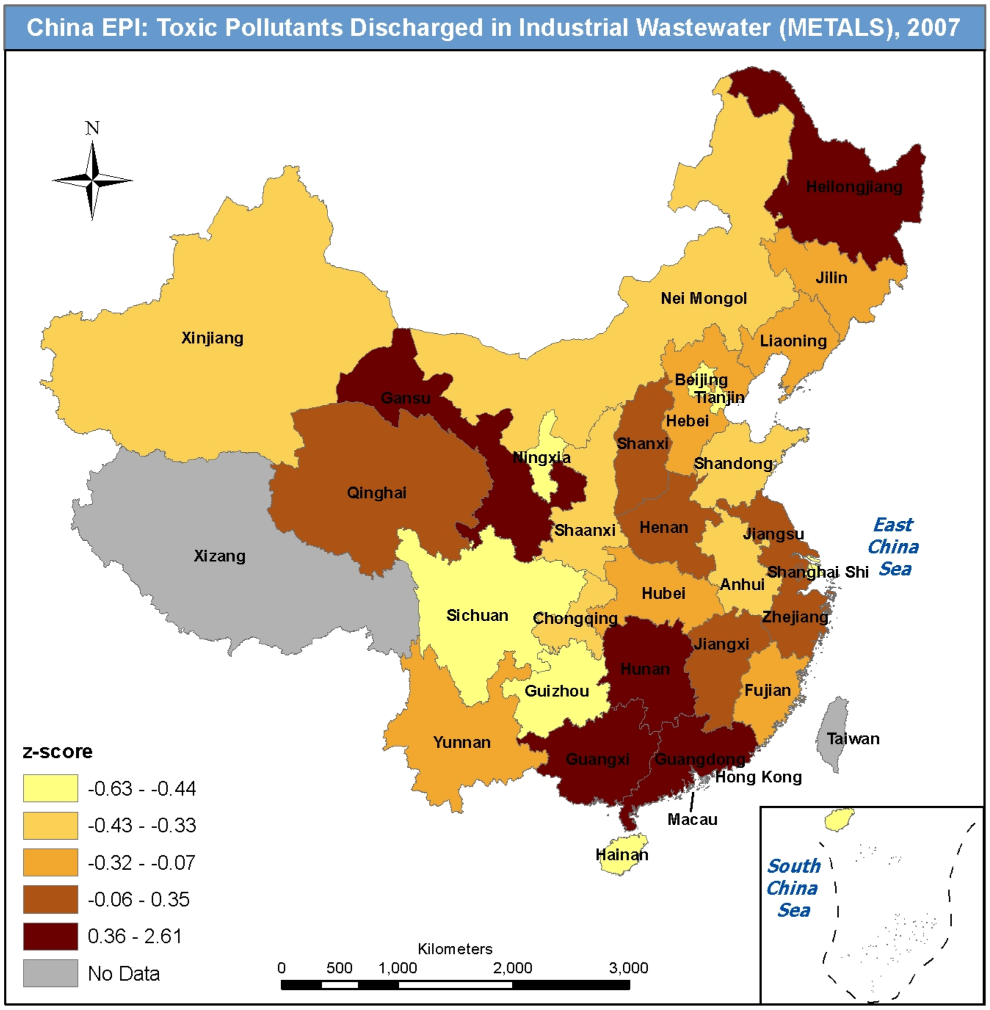
Figure 7. Hazardous Waste Intensity



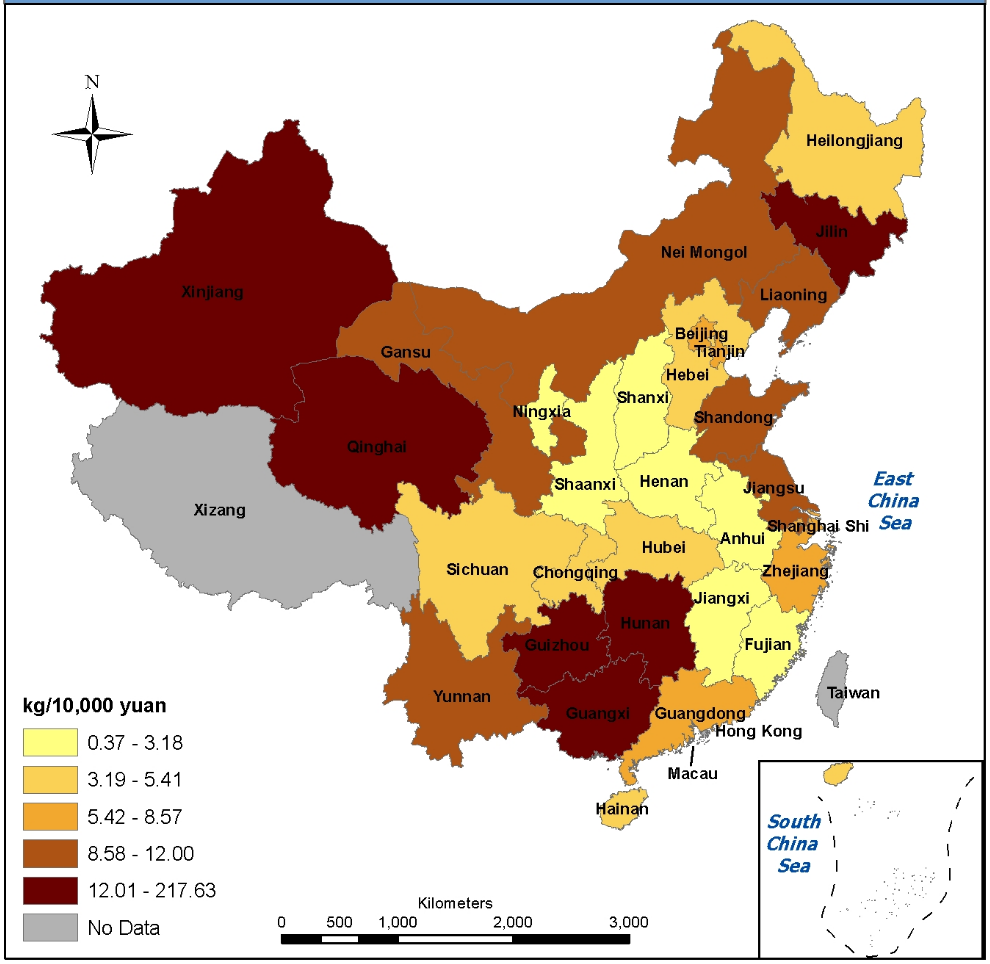
The Following table shows both ranked indicators. For heavy metals (METALS), the best performing provinces have negative z-scores, which can be understood as standard deviations from the mean. Both data sets are from 2007.

Rank	Province	METALS (z-score)	Province	HAZINT (kg/1000 ¥)
1	Tianjin	-0.63	Ningxia	0.37
2	Beijing	-0.60	Shanxi	1.40
3	Ningxia	-0.57	Anhui	1.88
4	Guizhou	-0.51	Jiangxi	2.25
5	Hainan	-0.50	Henan	2.60
6	Sichuan	-0.44	Fujian	2.70
7	Shanghai	-0.44	Shaanxi	3.18
8	Chongqing	-0.38	Sichuan	3.92
9	Shandong	-0.38	Hubei	4.13
10	Nei Mongol	-0.37	Hebei	4.62
11	Xinjiang	-0.37	Hainan	5.32
12	Shaanxi	-0.36	Heilongjiang	5.39
13	Anhui	-0.33	Chongqing	5.41
14	Jilin	-0.32	Tianjin	5.79
15	Fujian	-0.31	Zhejiang	5.82
16	Hebei	-0.18	Guangdong	6.29
17	Liaoning	-0.16	Beijing	6.82
18	Yunnan	-0.09	Shanghai	8.57
19	Hubei	-0.07	Yunnan	9.85
20	Shanxi	-0.01	Jiangsu	10.37
21	Jiangsu	0.06	Shandong	10.43
22	Jiangxi	0.09	Gansu	10.94
23	Henan	0.24	Liaoning	11.92
24	Zhejiang	0.29	Nei Mongol	12.00
25	Qinghai	0.35	Hunan	13.39
26	Guangdong	0.39	Guangxi	17.75
27	Heilongjiang	0.60	Jilin	23.01
28	Gansu	0.79	Xinjiang	45.74
29	Guangxi	0.91	Guizhou	45.84
30	Hunan	2.61	Qinghai	217.63

The following maps depict the indicator scores by province. The maps consistently depict the best performers in yellow and the worst performers in dark brown. The South and Northeast are particularly hard hit by toxics.


China EPI: Toxic Pollutants Discharged in Industrial Wastewater (METALS), 2007

China EPI: Hazardous Waste Intensity (HAZINT), 2007



Ecosystem Vitality

A. Air Quality for Ecosystem Vitality

1. *Introduction*

Air pollutants, in addition to harming human health, may adversely impact ecosystem capacity and services. For example, ground-level O_3 oxidizes and degrades plant cuticles, thereby inhibiting vegetation and crop growth. SO_2 and NO_x are oxidized in the atmosphere to form acid rain, which harms fisheries, creates imbalances in acid-sensitive aquatic ecosystems, leaches nutrients from the soil, and reduces agricultural and forest productivity.

Acid rain falls on approximately 30% of Chinese territory, reaching or passing critical loads in East, Southwest, South, and Central China (OECD 2007). In 2004, acid rain was recorded in 215 out of 526 Chinese cities, and 10.3% of cities suffer from highly acid rain. China's heavy use of coal is a major source of acid rain in Northern Asia (ibid.). Monitoring shows that the concentration of sulfuric and nitric ions in rain is also high, causing damage to forests, crops, water supply, and buildings. Additionally, excess nitrogen in the waterways (which can be deposited from air pollution) leads to eutrophication. In general, the aspects of air pollution that are harmful to human health are harmful to the environment as well (Emerson, Esty et al. 2010).

2. *Ideal and International Best Practices for Measurement*

Ideal performance measures for air pollution's effect on ecosystem health and vitality address how air pollution may affect forests, bodies of water and waterways, and vegetation and crops. Ecosystem impacts are generally measured through critical loads—deposition thresholds under which ecosystem structure and function are not harmed (Bull 1991). While the critical load concept seems simple, in practice it is more difficult to use than the straightforward monitoring of airborne pollutant levels used to assess air quality for human health. This is because the critical load approach requires defining an environmental "receptor" of concern and setting load targets relevant to that receptor, a complicated scientific process that also makes comparisons difficult across ecoregions (ibid.).

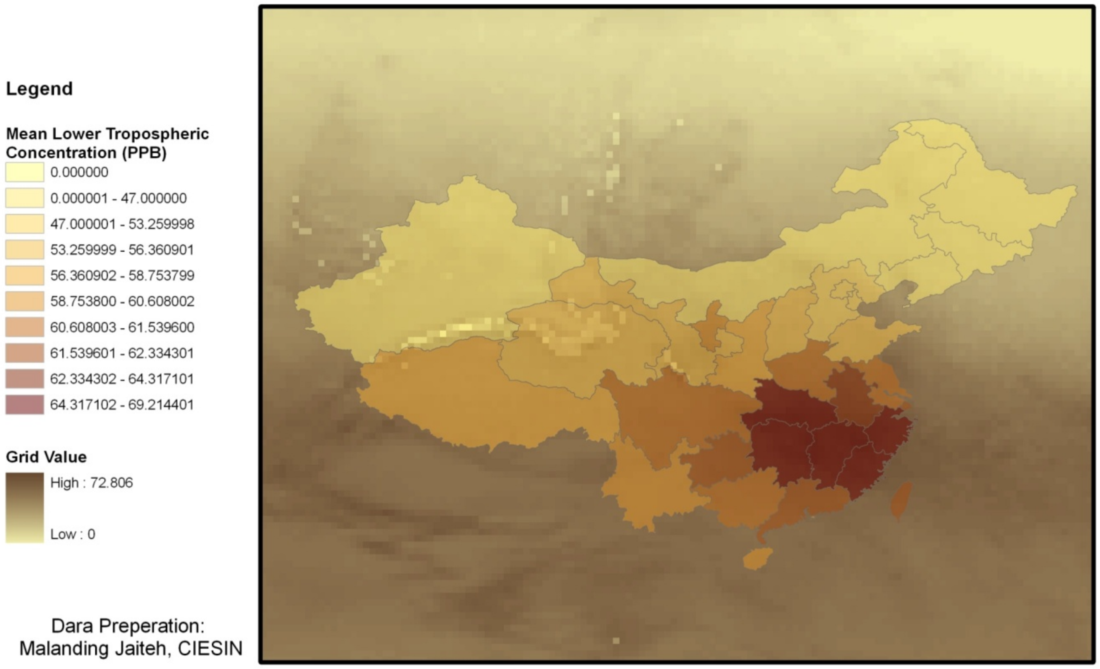
A great deal of the research and policy related to air quality is specific to impacts on human health. To manage air quality for vegetation health, governments need to focus on SO_2, NOx, ground-level ozone, and non-methane volatile organic compounds (NMVOCs) (Emerson et al. 2010). Because these pollutants can be transported long distances and across provincial and national borders, it can be difficult to assign responsibility for ecosystem impacts to local jurisdictions. In addition, for the reasons stated above, there is not a "one size fits all" target for concentrations or deposition levels.

Box: Measuring Ozone Using Remote Sensing

Remote sensing represents a promising approach to measuring pollutant concentrations. The main advantages are that it provides wall-to-wall coverage of different pollutants such as particulate matter, ozone, and nitrogen dioxide. The main disadvantage is that because the sensor is measuring the entire air column, it is difficult to measure ground-level concentrations high a high degree of precision.

Working with data from the Ozone Monitoring Instrument (OMI) and with technical assistance from colleagues at the Harvard-Smithsonian Center for Astrophysics and Goddard Earth Sciences and Technology Center of University of Maryland, CIESIN processed daily retrievals over East Asia from May 1-September 24, 2006. The readings were for the atmospheric boundary layer (0-3km altitude), the lower troposphere (0-6km), and the trophosphere (0-12km). The figure below depicts the mean lower troposphere ozone concentration in parts per billion (PPB) in its native grid format (background) and aggregated (averaged) to provincial level. The values range from 0 to almost 70 PPB. WHO has set thresholds for health effects (not ecosystem impacts) of 50 PPB (100 ug/m^3) over an eight hour period. Concentrations above this threshold are considered damaging to human health. The fact that the figure below represents an average of readings over almost five months suggests that there are very high and potentially health-threatening concentrations over the industrial belt in southeastern China. However, these data need to be calibrated against ground measurements and therefore should be treated with caution.

Mean Lower Troposphere Ozone Concentration (Parts Per Billion (PPB))



Dara Preperation:
Malanding Jaiteh, CIESIN

Different ways to track these impacts include averaging ground-level ozone concentrations over the growing season, summing hourly mean concentrations above a certain threshold, or creating a weighted average that gives greater weight to larger hourly concentrations (Fuhrer, Skärby et al. 1997 93). The European Union has developed Air Quality Index (AQI) guidelines that recommend choosing a limit value, target value, alert threshold, and guide value for each of the pollutants measured (Kassomenos, Skouloudis et al. 1999). The United States also uses an AQI, but while there are international standards on the basic principles for constructing such an index, there are no standards for metrics or targets. There is also continued scientific controversy over whether it makes sense to aggregate multiple pollutants together in this way, and how to account for the differences between short-and long- term impacts and the synergistic effects of multiple pollutants (Shooter and Brimblecombe 2009). Furthermore, few if any countries set separate standards for ecosystem impacts and human health, preferring to subsume all goals into one easily-digestible synthetic index (Bruno and Cocchi 2007). While simpler from a policy and public awareness perspective, this type of indexing makes it difficult to identify best practices in the specific realm of protecting air quality for environmental as distinct from human health.

3. China's Measurement Practices

Data on air pollution concentrations are collected at the city level in China, but are not typically collected or reported for rural areas (e.g., agricultural regions or protected areas). This means that it is difficult to infer from the urban data what the impacts are on ecosystems of concern. In addition, to our knowledge there has been no calculation of critical loads for ecosystems in China, and hence there is no way to assess whether or not there have been exceedences of those loads. Acid deposition monitoring work in China was started in the late 1970s, and in 1989 China established the national acid rain monitoring network (Ding Xu, et al. 2004). By the end of 2005, there were over 1,200 monitoring sites carrying out regular monitoring of acid rain in over 600 cities (including districts and counties) (Zheng, Xu et al. 2008). Of these monitoring sites, 75% of them are located in urban area and 25% of them are located in suburbs. It is thought that there are not enough suburban and rural sites (ibid). In 2004, SEPA issued Technical Specifications for Acid Deposition Monitoring (HJ/T 165-2004.), specifying the acid deposition monitoring point sets, sampling methods, monitoring frequency, sample analysis and the corresponding analysis of the project, monitoring of quality assurance, and monitoring, data processing and reporting.

As an air pollution management strategy for ecosystem vitality, China has concentrated on lowering emissions, particularly of SO_2 and NO_x. The 11th FYP (2006-2010) sets a target of reducing total SO_2 emissions by 10 percent from 2005 levels by 2010. The 10th FYP (2001-2005) set the target of reducing total SO_2 emissions by 10 percent from 2000 levels. Instead of meeting that target, by 2006 China exceeded the goal by over 40 percent (Cao, Garbaccio et al. 2009 235). MEP departments held a seminar on implementing total NO_x emissions control in the 12th FYP (2011-2015) in April of 2009.

China has been collecting some key emissions data since the early 1990s. The length of time allows for the possibility of trend analysis. To better monitor exposure to air pollution, it is recommended that authorities collect and analyze concentration data for the pollutants of greatest concern to ecosystem health.

4. *Summary Indicator Calculations and Results*

China EPI Air Quality for Ecosystems Indicator

Of the indicators considered, the following two were chosen to assess the impact of air quality on the environment.

Policy Categories	Policy Category Codes	Indicators	Indicator Codes	Data Source	Target
Air Pollution (effects on ecosystem)	**AIR_E**	**SO_2 emissions per populated land area**	SO2_E	Ministry of Environmental Protection	not available
		NO_x emissions per populated land area	NOX_E	Ministry of Environmental Protection	not available

Both emissions measures were divided by the province's land area populated by more than five persons per square kilometer. This avoided favoring provinces with extensive unpopulated lands, and recognizes that most emissions and exposure to air pollution occurs in areas that are populated. SO2_E was available from 2003 to 2007, and NOx_E from 2006 to 2007. Both are measured in units of tons/square km of populated land area.

Data Quality and Representativeness

In both cases, data came from the Ministry for Environmental Protection. Data was available for all provinces except for NOX_E for Xizang.

Correlations

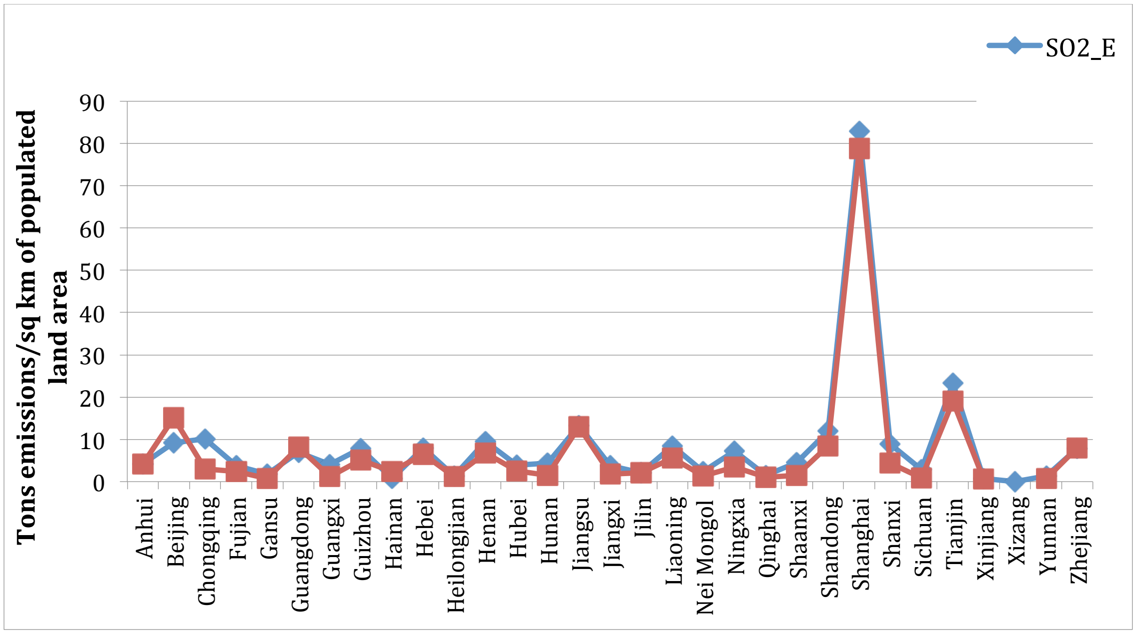
The Pearson coefficient calculated for the air quality indicators shows that SO2_E and NOX_E are extremely highly correlated, as we would expect with most measures of these two gases produced from fossil fuel combustion.

	SO2_E	**NO2_E**
SO2_E	1	
NOX_E	0.99	1

Ranks and Trend Analysis

The chart below shows both SO_2 and NOx emissions normalized by populated land area for all provinces. The populated land area was derived by using CIESIN's Global-Rural Urban Mapping Project (GRUMP) data (CIESIN 2004), and calculating the area of each province that is populated above a threshold of 2 persons per square km. The two indicators visually correlate very well with one another, with a dramatic spike for Shanghai owing to its limited populated land area (6,015 sq.km as opposed to 10,554 in Tianjin and 16,482 in Beijing).

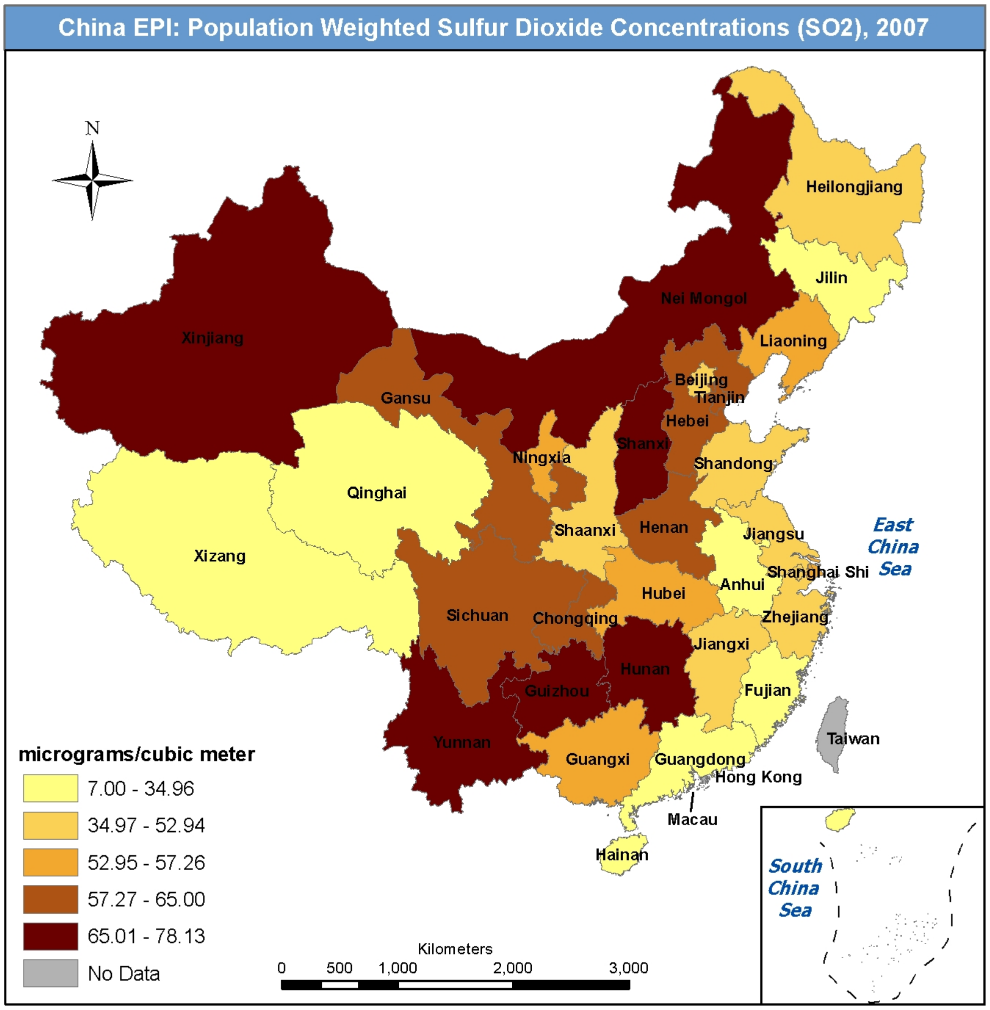
Figure 8. Air Quality for the Environment by Province.



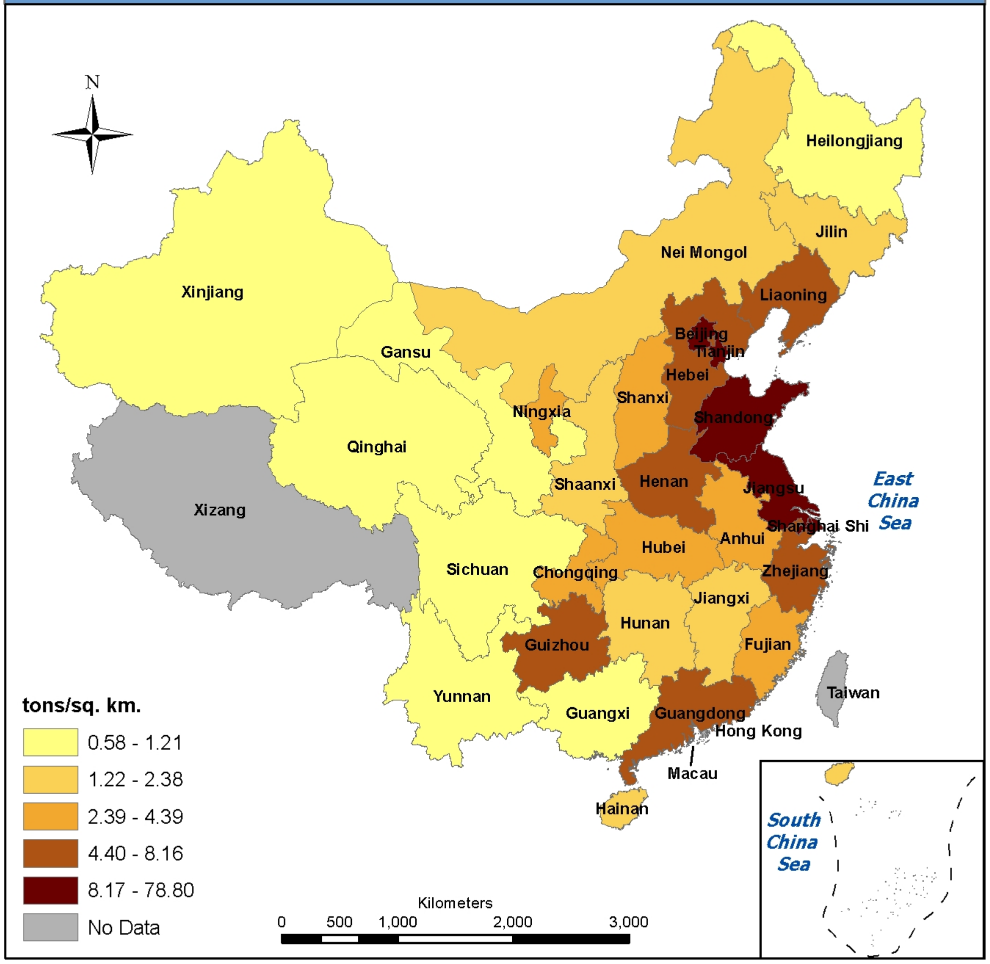
The following table shows ranked data for the two variables, from the best performer to the worst performer. Both data sets are from 2007.

Rank	Province	SO2_E (tons/km2)	Province	NOX_E (tons/km2)
1	Xizang	0.01	Xinjiang	0.58
2	Xinjiang	0.80	Yunnan	0.76
3	Hainan	0.80	Gansu	0.76
4	Heilongjiang	1.30	Sichuan	0.81
5	Yunnan	1.40	Qinghai	1.01
6	Qinghai	1.50	Guangxi	1.15
7	Gansu	1.80	Heilongjiang	1.21
8	Jilin	2.10	Nei Mongol	1.37
9	Nei Mongol	2.40	Shaanxi	1.47
10	Sichuan	2.90	Hunan	1.48
11	Fujian	3.70	Jiangxi	1.77
12	Jiangxi	3.80	Jilin	2.02
13	Hubei	3.90	Hainan	2.38
14	Guangxi	4.10	Fujian	2.46
15	Anhui	4.20	Hubei	2.56
16	Hunan	4.30	Chongqing	2.94
17	Shaanxi	4.50	Ningxia	3.49
18	Guangdong	6.90	Anhui	4.20
19	Ningxia	7.20	Shanxi	4.39
20	Guizhou	7.80	Guizhou	5.06
21	Zhejiang	7.90	Liaoning	5.62
22	Hebei	8.00	Hebei	6.52
23	Liaoning	8.50	Henan	6.73
24	Shanxi	8.90	Zhejiang	8.06
25	Beijing	9.20	Guangdong	8.16
26	Henan	9.50	Shandong	8.51
27	Chongqing	10.10	Jiangsu	13.05
28	Shandong	11.90	Beijing	15.05
29	Jiangsu	13.30	Tianjin	19.05
30	Tianjin	23.20	Shanghai	78.80
31	Shanghai	82.80		

The following maps depict the indicator scores by province. The maps consistently depict the best performers in yellow and the worst performers in dark brown. These maps clearly depict the concentration of emissions in eastern China.



China EPI: Nitrogen Oxides Emissions (NOX_E), 2007



B. Water Quality and Quantity for Ecosystem Vitality

1. Introduction

The section on water quality and quantity for human health addressed water resources for human needs, touching on aspects of water quality. Here the primary focus is on water quantity and quality for ecosystem services. Over many parts of the planet, the amount of water left over after human uses and the quality of that water is not sufficient to maintain ecosystem services. As a result of pressures on aquatic ecosystems, 20 percent of freshwater species have become extinct, threatened or endangered in the last two decades (Dudgeon, Arthington et al. 2005 ; WRI 2007). Hydrologic flow modification, along with pollution and invasive species, has been identified as one of the most important factors in the decline of freshwater ecosystems (Richter, Mathews et al. 2003). Given the importance of natural flow regimes in maintaining freshwater ecosystems and the growing human pressure on water resources, the concept of a minimum ecological flow (including magnitude, duration, timing, and frequency components) required to protect ecosystems has been developed (Suen and Eheart 2006).

The quality of fresh water is impacted most in countries with extensive cultivated and urban systems (high use, high pollution sources) and dryland systems (high demand for flow regulation, absence of dilution potential). China is characterized by all three, albeit in different regions. This has contributed to the fact that one-third of water courses are severely polluted (OECD 2007). Pollutant emissions are particularly high in the agricultural and industrial sectors. Agro-chemicals are widely used for pest management, and these may be dispersed into water bodies via non-point source runoff. Industries such as pharmaceutical plants, paper-making, smelting and chemical manufacturers often illegally discharge sewage into reserves. Toxic chemicals from e-waste processing often finds its way into underground aquifers.

Low water flows owing to climatic fluctuations combined with overuse for agriculture and industry deprives aquatic ecosystems of adequate water for maintenance of aquatic biodiversity and other essential ecosystem functions and services (Smits and Chen 2004). In the Yellow River basin, it is estimated that a minimum of 25% of natural flow is required to sustain the estuarine environment, but human withdrawal currently leaves less than 10% and frequently leaves the river running dry (Shalizi 2006). Intensive water use in northern China has led to the unsustainable mining of the aquifer under the North China Plain. In the Hai basin, the deep aquifer water table has dropped by 90 meters while around Beijing it has dropped by 100-300 meters (Xie 2008). In 1997, over 221,000 new wells were dug on the North China Plain, while over 100,000 were abandoned (World Bank and SEPA 2007). Because the deep North China aquifer recharges only slowly, this consumption represents the depletion of a non-renewable resource. The World Bank estimates the cost of groundwater depletion in China at RMB 92 million (US$13m) a year (ibid.). In terms of water quality, China has serious nutrient water pollution, partly because of intensive agriculture; fertilizer application is estimated at 379 kg/ha, more than 2.5 times the world average (Koo-Oshima 2005). One study of 50 lakes found that 60% were eutrophic or hypertrophic, including the five largest freshwater lakes in the country (Xiangcan 2003).

OECD (2007 91) finds that "the 2002 Water Law opens the way for integrated river basin management, stakeholder participation and the use of market mechanisms in water management, in other words for a *major reform* of the water sector." Institutions are also in place for river basin management. Yet the demand for water resources and the growth in industrial activities are placing a significant strain on aquatic ecosystems.

2. Ideal and International Best Practices for Measurement

Internationally, two measures are commonly used to compare countries or jurisdictions on water availability for human uses. The Falkenmark Water Stress Index, a commonly used indicator of water quantity, relates existing water resources to minimum per capita requirements. Currently 17 countries are categorized as water stressed (with between 1,700 and 1,000 m^3 per capita renewable water resources per year) and 29 countries are water scarce (< 1,000 m^3 per capita per year) (WRI 2009). The United Nations uses a water scarcity and sustainable development indicator developed by Raskin. The indicator calculates the ratio of withdrawals to available renewable resources. Because the Raskin metric compares actual withdrawals to theoretically available resources, it is more closely related to environmental performance than the Falkenmark indicator.

The WHO has established an exhaustive list of guidelines for the various chemicals, radioactive elements, biologically and chemically derived contaminants, and microbes that affect drinking water quality. For example, the guidelines specify standards for chemical contaminants, including cadmium, cyanide, mercury, benzene, EDTA, and various PCBs that are toxic to humans or animals (WHO 2008c). There are important chemical indicators of water quality including dissolved oxygen levels (EPA 1995 ; Grossman and Krueger 1995), biological oxygen demand (Delzer and McKenzie 2003), nitrogen and phosphorous levels (Carpenter, Caraco et al. 2008), and pH (Schindler 1988 ; Feng, Huang et al. 2001).

Though chemical indicators like those described above have a long history in water quality monitoring, biological indicators are beginning to be used more frequently. Yoder and Rankin (1998) have argued that chemical proxies give information on only one aspect of water quality while in fact the ecosystem effects of pollution can interact in non-linear ways and are integral across many components. They suggest that only using chemical indicators for tracking water quality underestimates the area of degraded freshwater habitat. This problem can be addressed by using standard biological indicators of ecosystem health.

The Index of Biotic Integrity (IBI) is the original and most widely used biological index of water quality (Karr 1991). The original formulation included 12 metrics measuring fish species richness and abundance and was developed for use in small warm-water streams in the mid-West of the United States. Each metric was scored between 1 and 5 based on comparison with a system undisturbed by human activity. Since originally formulated it has been widely used and adapted for different regions and ecosystems. For example, Zhu and Chang (2008) applied the IBI to study the upper Yangtze River. The IBI is now routinely used in several states in the U.S. as well as in France and Mexico.

3. *China's Measurement Practices*

Data is available on industrial toxic pollutant discharges. It is unclear if these discharges are directly measured by industries or government agencies, or if they are estimated based on industrial composition and economic output statistics.

For the agricultural sector, according to the first environmental pollution census of 2007, non-point source agricultural runoff contributes significantly to water pollution. At the national level, 43.7% of Chemical Oxygen Demand (13 million tons), 57.2% of nitrogen emissions (2704.6 thousand tons), and 67.3% of total phosphorous emissions (284.7 thousand tons) are from agriculture.[50] These data are not available on the provincial level.

4. *Summary Indicator Calculations and Results*

China EPI Water Quality for Ecosystems Indicator

A full EPI should include indicators for water stress and water quality. We were unable to obtain raw data on water quality such as nitrogen and phosphorus concentrations, dissolved oxygen, pH, or electrical conductivity.[51] Water quality data are reported based on the amount of surface water that meets standard grades I through V, where Grade I indicates better water quality and Grade V indicates worse. Table 4 shows the requirements for each grade of water. The table shows that with 24 factors, disentangling the factors contributing to why a water body failed to meet the grade requirements becomes nearly impossible. For example, the grading scheme does not allow one to ascertain if pollutant levels for only or for many pollutants decreased in the case of a water body that improved from Grade IV to III. As with the API, the grading scheme makes it difficult to assess which pollutants are at the root of water quality problems.

Data for 400 surface water quality monitoring stations are collected annually. However, members of the China EPI team could not obtain the data from the China National Environmental Monitoring Center, and instead were referred to the grading scheme. Results are generally termed as percentages of surface water sections below or above a certain grade. Even though there is time-series data, the indicators are difficult to interpret since this approach tends to mask the specific pollutants and concentration levels found in each water body. This, in turn, also limits remediation efforts, since in the absence of this information it is difficult to target interventions.

---

[50] MEP: First National Pollution Source Census Press Conference (transcript) 《第一次全国污染源普查情况和成果新闻发布会文字实录》, March 11, 2010.

[51] These data are available for a small number of stations through UNEP-GEMS Water, but the stations are not sufficiently representative geographically to be able to calculate provincial level indicators in the same way that the 2010 EPI has developed the Water Quality Index (Emerson et al. 2010).

Table 4. China's Water Quality Grading Rubric

		Grade I	Grade II	Grade III	Grade IV	Grade V
Water temperature		The standard is that weekly average of human waste-caused water temperature increase is less than 1°C and decrease is less than 2°C				
pH		6-9				
Dissolved oxygen (mg/L)	≥	7.5	6	5	3	2
Permanganate Index (mg/L)	≤	2	4	6	10	15
COD (mg/L)	≤	15	15	20	30	40
BOD_5 (mg/L)	≤	3	3	4	6	10
NH_3-N (mg/L)	≤	0.15	0.5	1.0	1.5	2.0
Phosphorus (mg/L)	≤	0.02	0.1	0.2	0.3	0.4
Nitrogen (mg/L)	≤	0.2	0.5	1.0	1.5	2.0
Bronze (mg/L)	≤	0.01	1.0	1.0	1.0	1.0
Zinc (mg/L)	≤	0.05	1.0	1.0	2.0	2.0
Fluoride (mg/L)	≤	1.0	1.0	1.0	1.5	1.5
Selenium (mg/L)	≤	0.01	0.01	0.01	0.02	0.02
Arsenic (mg/L)	≤	0.05	0.05	0.05	0.1	0.1
Mercury (mg/L)	≤	0.00005	0.00005	0.0001	0.001	0.001
Cadmium (mg/L)	≤	0.001	0.005	0.005	0.005	0.01
Chromium (mg/L)	≤	0.01	0.05	0.05	0.05	0.1
Lead (mg/L)	≤	0.01	0.01	0.05	0.05	0.01
Cyanide (mg/L)	≤	0.005	0.05	0.2	0.2	0.2
Volatile phenols (mg/L)	≤	0.002	0.002	0.005	0.01	0.01
Petroleum (mg/L)	≤	0.05	0.05	0.05	0.5	1.0
Anion Surfactant (mg/L)	≤	0.2	0.2	0.2	0.3	0.3
Sulfide (mg/L)	≤	0.05	0.1	0.2	0.5	1.0
Fecal Coliforms (total/L)	≤	200	2000	10000	20000	40000

Source: (SEPA 2002a 2)

As a result, the only indicators we are able to include are the Water Scarcity Index (WSI) and the Intensity of Chemical Oxygen Demand (COD) emissions. WSI is the ratio of total consumption of water (for agriculture, industry, and households) to the total water resources. The Intensity of COD emissions are measured as metric tons of emissions divided by provincial GDP.[52] Data came from the China Statistical Yearbook.

Policy Categories	Policy Category Codes	Indicators	Indicator Codes	Data Source	Target
Water (effects on ecosystem)	**WATER_E**	**Water Scarcity Index**	WSI	China Statistical Yearbook	0.4
		Intensity of COD emissions	COD	China Statistical Yearbook	10% reduction of total COD emissions during the 11th five-year plan

---

[52] Note that the new 12th Five-year Plan has targets for total COD emissions that are not normalized by GDP.

Data Quality and Representativeness

Besides the lack of adequate data for calculating a full index for the Water Quality and Quantity for the Environment category, the available WSI data had the same drawbacks as other data sets, as detailed above—no information on the methodology or monitoring approach. Data were available for all provinces.

Correlations

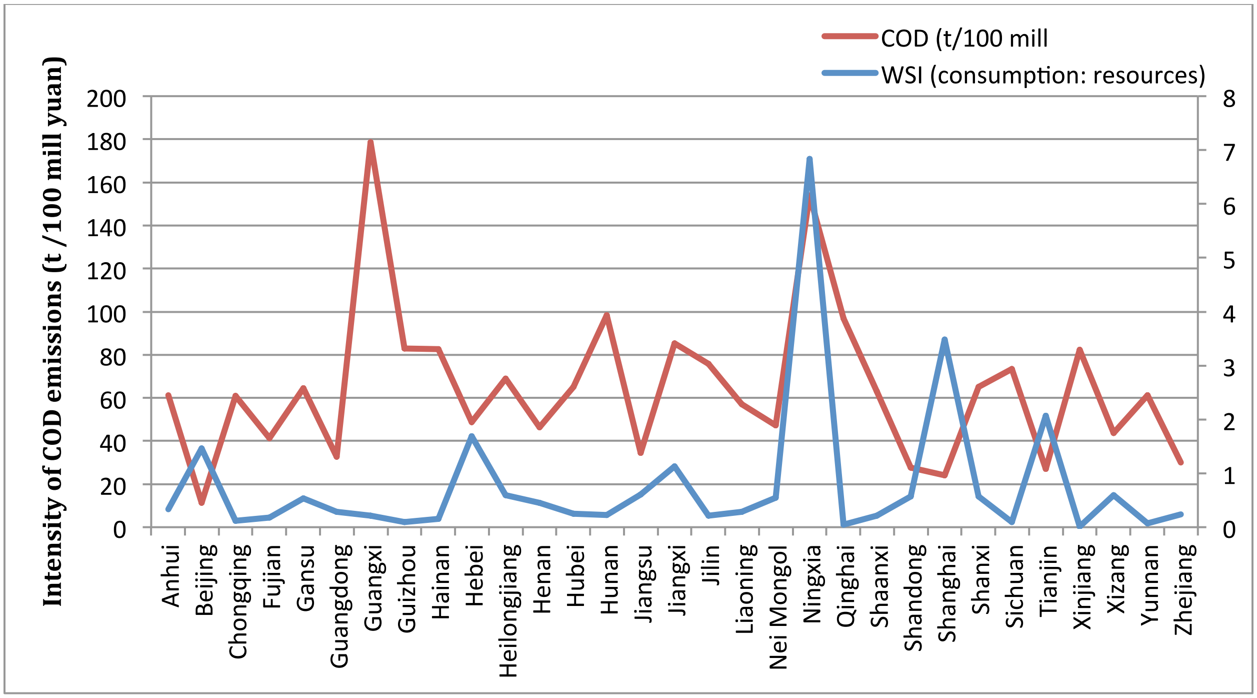
No correlation calculations are possible due to the use of only one indicator.

Ranks and Trend Analysis

Figure 9 shows the calculated Water Scarcity Index and the Intensity of COD emissions for all provinces. For the Water Scarcity Index, any ratio higher than one should be considered unsustainable, as water is being depleted at a rate greater than it is naturally available in the province. Note in this chart and the following table that six provinces are above a ratio of one, and Ningxia, in northwestern China, is withdrawing water at a rate nearly seven times greater than that which could be sustainable. Most of the over-subscribed provinces are heavily urbanized.

Ningxia province is also one of the highest in intensity of COD emissions, very close to the worst performer, Guangxi.

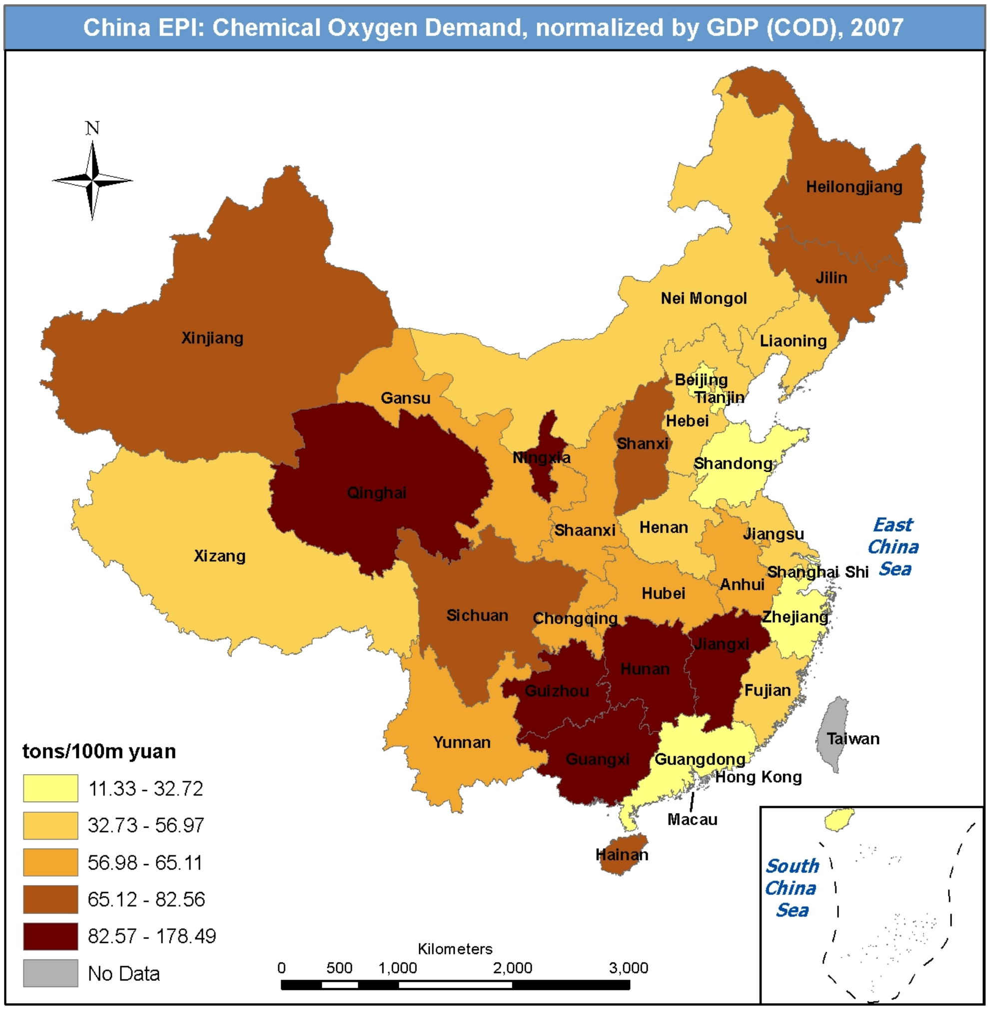
Figure 9. **Water Quality and Quantity for the Environment by Province.**

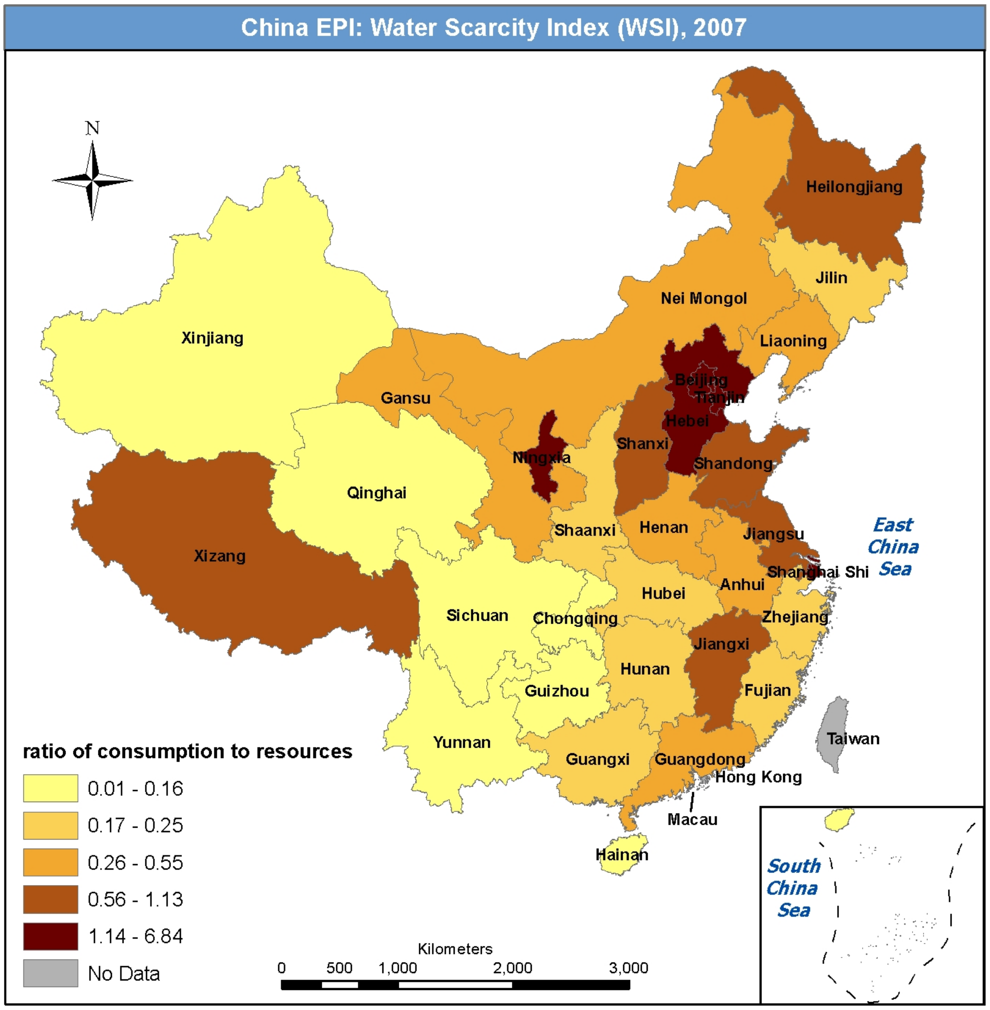


The following table shows all provinces, ranked from best performance to worst performance (lowest to highest Water Scarcity Index and Intensity of COD Emissions).

Rank	Province	WSI (consumption: resources)	Province	COD (t/100 mill)
1	Xinjiang	0.01	Beijing	11.33
2	Qinghai	0.05	Shanghai	24.12
3	Yunnan	0.07	Tianjin	27.13
4	Guizhou	0.09	Shandong	27.73
5	Sichuan	0.09	Zhejiang	30.03
6	Chongqing	0.12	Guangdong	32.72
7	Hainan	0.16	Jiangsu	34.61
8	Fujian	0.18	Fujian	41.41
9	Jilin	0.21	Xizang	43.84
10	Guangxi	0.22	Henan	46.23
11	Shaanxi	0.22	Nei Mongol	47.28
12	Hunan	0.23	Hebei	48.65
13	Zhejiang	0.24	Liaoning	56.97
14	Hubei	0.25	Chongqing	60.89
15	Guangdong	0.29	Yunnan	61.16
16	Liaoning	0.29	Anhui	61.24
17	Anhui	0.33	Shaanxi	63.12
18	Henan	0.45	Gansu	64.39
19	Gansu	0.54	Hubei	65.11
20	Nei Mongol	0.55	Shanxi	65.23
21	Shandong	0.57	Heilongjiang	69.07
22	Shanxi	0.57	Sichuan	73.39
23	Heilongjiang	0.59	Jilin	75.69
24	Xizang	0.6	Xinjiang	82.31
25	Jiangsu	0.61	Hainan	82.56
26	Jiangxi	1.13	Guizhou	82.79
27	Beijing	1.46	Jiangxi	85.27
28	Hebei	1.69	Qinghai	96.99
29	Tianjin	2.07	Hunan	98.26
30	Shanghai	3.48	Ningxia	154.07
31	Ningxia	6.84	Guangxi	178.49

The maps below depict the indicator scores by province. The maps depict the best performers in yellow and the worst performers in dark brown.





China EPI: Water Scarcity Index (WSI), 2007

C. Habitat and Biodiversity

1. Introduction

Biodiversity provides a large number of goods and services that sustain our lives. Ecosystem services and products support such diverse industries as agriculture, cosmetics, pharmaceuticals, pulp and paper, horticulture, construction and waste treatment. The Millennium Ecosystem Assessment identified four types of ecosystem services: provisioning (e.g., food and water), regulating (e.g., regulation of climate, water, and disease), cultural (e.g., spiritual, recreational, and educational), and supporting (e.g. soil maintenance, pollination, and nutrient cycles) (Millenium Ecosystem Assessment 2005: 39). Thus, loss of biodiversity threatens food supplies, opportunities for recreation and tourism, and sources of wood, medicines and energy.

Owing to its size and diversity of landforms and climate zones, China is a country rich in biological diversity, with more than 30,000 species of higher plants, 6,000 species of vertebrates, and nearly 600 types of terrestrial ecosystems (Xu, H., Wang et al. 1999). Up to half of China's species are endemic to the country (Liu, J., Ouyang et al. 2003). Economic development and resource exploitation, however, currently threatens this diversity. Around 15-20% of China's fauna and flora species are endangered (UNEP 1999: 82). Over the past half-century, significant numbers of animals and plants in China have become endangered, with some going extinct. Over-harvesting, habitat conversion, and pollution have all contributed to this decline in species diversity. Because of China's size and the diversity of its habitats, efforts within its borders to protect habitats and biodiversity will not only benefit China, but will also make feasible the protection of Earth's most vital ecosystems and endangered species on a global scale.

To protect its biodiversity, China has created 2,067 national and local nature reserves covering about 17 percent of the nation's territory (UNEP-WCMC 2011). Although this exceeds the recommended coverage by the Convention on Biological Diversity, Liu et al. (2003) state that local governments manage most national level reserves with only limited support from the central government, and that as of around the year2000 many protected areas had poorly defined boundaries, limited management teams and limited funding levels. The situation has improved since then.

Protected areas are a necessary but insufficient condition for biodiversity conservation. Other measures include incorporating biodiversity assessments in environmental impact assessments (EIAs), landscape conservation, and *ex situ* conservation. According to Xu & Li (2006), biodiversity is generally neglected in EIAs for major construction projects.

2. Ideal and International Best Practices for Measurement

At the 1992 Earth Summit in Rio de Janeiro, global leaders agreed on a comprehensive strategy for sustainable development. The conference resulted in the Convention on Biological Diversity (CBD), which makes commitments for maintaining the world's ecological underpinnings while still pursuing economic development. Three main goals have been established in the convention: the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits from the use of genetic resources (UNEP 2009b). The overarching goal of CBD and countless other international conservation organizations is to halt the loss of biodiversity.

In 2001, the European Union (EU) adopted its Strategy for Sustainable Development, which included the target of halting biodiversity loss by 2010 (EEA 2007). CBD subsequently adopted this target, and in 2003 the CBD released both technical and technological advice on designing indicators for biological diversity analysis (UNEP 2003). The following table summarizes the 2010 Target indicators.

Table 3: Provisional Indicators for Assessing Progress towards the 2010 Biodiversity Target

Focal Area	Indicators
Status and trends of the components of biological diversity	Trends in extent of selected biomes, ecosystems, and habitats
	Trends in abundance and distribution of selected species
	Coverage of protected areas
	Change in status of threatened species
	Trends in genetic diversity of domesticated animals, cultivated plants, and fish species of major socioeconomic importance
Sustainable use	Area of forest, agricultural and aquaculture ecosystems under sustainable management
	Proportion of products derived from sustainable sources
	Ecological footprint and related concepts
Threats to biodiversity	Nitrogen deposition
	Trends in invasive alien species
Ecosystem integrity and ecosystem goods and services	Marine Trophic Index
	Water quality of freshwater ecosystems
	Trophic integrity of other ecosystems
	Connectivity / fragmentation of ecosystems
	Incidence of human-induced ecosystem failure
	Health and well-being of communities who depend directly on local ecosystem goods and services
	Biodiversity for food and medicine
Status of traditional knowledge, innovations and Practices	Status and trends of linguistic diversity and numbers of speakers of indigenous languages
	Other indicator of the status of indigenous and traditional knowledge
Status of access and benefit-sharing	Indicator of access and benefit-sharing
Status of resource transfers	Official development assistance provided in support of the Convention
	Indicator of technology transfer

Table Source: (UNEP 2003)

CBD encourages biodiversity protection on a national level, and provides a framework of indicators and targets as a flexible guideline for each nation to implement accordingly. Currently, the main challenge to achieving the 2010 Target lies in implementation, especially in the food, agriculture, and trade sectors. Although global-scale measures to fully assess progress are lacking, available indicators show that biodiversity is still in decline at all levels and geographical scales. However, with the potential for the Biodiversity 2010 Targets to be incorporated into the Millennium Development Goals, protecting biodiversity still retains its position as an important, if not crucial, international environmental goal (UNEP 2010). Currently, the legal and policy instruments are, for the most part, in place. Implementation and assessment, however, still leave room for improvement.

Measurement of biodiversity and habitat varies considerably by ecosystem type. Habitat measures typically look at the size and intactness of habitat types. Forest ecosystems can have both small-scale and landscape diversity, and so multi-scale monitoring techniques (for example, landscape-scale remote sensing combined with stand-level monitoring in inventory plots) are appropriate for assessing diversity (Noss 1999). For species inventories, standard statistically representative field survey techniques have been developed (Yoccoz, Nichols et al. 2001). In addition, annual wildlife population surveys using consistent methods are considered vital for gauging population trends (ibid.).

In an early article on biodiversity monitoring, Noss (1990) wrote, "Intensive research and monitoring can be directed to high-risk ecosystems and elements of biodiversity, while less intensive monitoring is directed to the total landscape (or samples thereon)…[P]articular attention should be paid to specifying the questions that monitoring is intended to answer and validating the relationships between indicators and the components of biodiversity they represent" (p.355). Noss added that "monitoring will be most successful when it is perceived (and actually qualifies) as scientific research and is designed to test specific hypotheses that are relevant to policy and management questions" (p.361). Unfortunately, despite a high level of policy focus and research into measuring biodiversity, it has been exceedingly difficult to develop scientifically valid and politically useful global indicators for measuring actual biodiversity, and many indicators currently in use are by necessity proxies (Orians and Policansky 2009; Emerson et al. 2010).

3. *China's Measurement Practices*

Technical standards and guidelines[53]

China was one of the first countries to ratify the Convention of Biological Diversity (CBD) in 1993. Since then, it has become a signatory to several other international conventions and agreements related to biodiversity, and has also established an internal legislative framework for biodiversity conservation. To date, China has issued four national reports on implementation of the Convention on Biological Diversity, the latest one published in 2008. Since 1993, China has promulgated and implemented a number of plans and programs related to biodiversity conservation. Relevant departments have also developed special conservation action plans to integrate biodiversity conservation into national action plans.

At the national level, the following three should be mentioned:

- China Biodiversity Conservation Action Plan[54] (NEPA 1994). Officially released by the State Council in June 1994, the Action Plan defines the overall target for China's biodiversity conservation as "[to] set in place as soon as possible measures for avoiding further damage,

---

[53] Clearinghouse Web sites for information on biodiversity protection in China can be found at: http://www.cbd.int/countries/?country=cn and http://english.biodiv.gov.cn.

[54] http://bpsp-neca.brim.ac.cn/books/actpln_cn/index.html

and, over the long term, for mitigating or reversing the damage already done". The overall goal includes 7 concrete objectives: "(1) strengthen fundamental studies on biodiversity… (2) improve the network of national nature reserves and other protected areas… (3) protect wild species significant to biodiversity… (4) protect the genetic resources of crops and domesticated animals… (5) In-situ Conservation Outside Nature Reserves… (6) establish the national network of biodiversity information and monitoring… (7) coordinate biodiversity conservation with sustainable development." Under these objectives, 26 actions and 18 key projects have been identified.

- China's Agenda 21. Adopted by the State Council in March 1994, the Agenda identified the following objectives concerning biodiversity conservation: "(1) Establish a national nature reserve network with a full range of categories and levels, reasonable distribution, and appropriate coverage by the year 2000; (2) Protect special habitats and ecosystems, such as wetlands, coral reefs, mangroves, estuaries, Tibetan Plateau and lake ecosystems, as well as those important for migrating wildlife; (3) Protect habitats and species outside nature reserves; (4) Establish and perfect an ex-situ conservation network for rare and endangered wild animals and plants; and (5) Protect fresh water and marine biodiversity" (Xu, H. et al. 1999 824). Approximately 60% of the priority projects in China's Agenda 21 were implemented or started by 1999 (ibid.).
- National Program for Nature Reserves (1996-2010). In 1996 China set short- and long-term goals for the conservation of various habitats, culminating in 2010. By 2010, the country was meant to have 1,200 nature reserves spread across forest, grassland, desert, wetland, and coastal habitats—more than 10% of the country's land area. See table 3 below for land area goals in 2000 and 2010 (Xu, H. et al. 1999).

During the 11th FYP, several other plans and programs related to biodiversity conservation have been released, such as the National Program for Conservation and Use of Biological Resources.

The Ministry of Environmental Protection (MEP) coordinates these domestic efforts, and has established a Leading Group of agencies with significant biodiversity responsibilities to provide overall supervision, direction and coordination under the Biodiversity Conservation Action Plan (NEPA 1994).

Table 3. Nature Reserve Development planning in China

Types of habitat	Area of nature reserves by year 2000 (million hm^2)	Percent area of this type habitat in China (%)	Area of nature reserves by year 2010 (million hm^2)	Percent area of this type habitat in China (%)
Forest	22.37-23.45	22.4-23.5	26	26.0
Grassland	11.40-12.00	6.6-6.9	16	9.2
Desert	39.30-39.95	20.5-20.8	45	23.4
Terrestrial Wetland and Fresh waters	8.77-9.07	23.1-23.9	11	28.9
Ocean and coast	4.50-4.80	1.0	12	2.5

Source: (Xu, H. et al. 1999)

More specifically, the government report Outline for National Ecological Conservation[55] has stipulated many short, intermediate, and long-term objectives, including increasing forest coverage, protecting land areas from desertification, increasing the area of forest parks and wildlife nature reserves, and instituting conservation projects for endangered plants and animals (Xu, H. et al. 1999).

However, despite the wealth of initiatives, there are many problems with the current government endeavors and legislative framework. First, protection mechanisms remain very weak, and financing for conservation methods is not sufficient. Also, besides the China Biological Diversity Protection Action Plan drafted in 1994, there is no comprehensive law on nature conservation. Thus, with little coordinated and coherent action, China has seen only inefficient and fragmented responses to the problem of conservation. Mentions of biodiversity are scattered within various natural resource laws and regulations, and they often go unenforced. Ambiguous responsibility and unreasonable penalization of violators further undermine the effectiveness and practicability of laws and regulations (ibid.). There do not seem to be sufficient legal and policy structures available to achieve the stated goals of the Outline for National Ecological Conservation.

China's biodiversity protection would benefit from more institutional coordination and monitoring. China also needs to assess the viability of its conservation plans, because most goals (as above) are in terms of amount or percent of land area protected, not actual species-related outcome measurements. While large amounts of land area are technically speaking protected, as indicated the effective protection is often low, and the planning of the protected area system as a whole does not take into account factors such as critical habitat, connectivity corridors, marine sanctuaries, and core endangered species habitat (OECD 2007 147). Finally, many protected areas are inadequately funded for personnel and enforcement, and many of these protected areas serve a dual function as tourist destinations, a role that often leads to significant negative impacts on the very habitat the reserve was designed to protect (Xu, H. et al. 1999 836).

Globally, it is common for biodiversity monitoring to be highly localized (and therefore spotty), and to be driven by research interests of biologists in given locations. There is a move, however, to be

---

[55] State Council Notice (2000) No. 38, see http://www.mep.gov.cn/ztbd/rdzl/2010sdn/zcfg/201001/t20100113_184239.htm

more systematic about species monitoring. In China, for selected endangered species such as pandas, the government has reliable numbers. However, for avian species, a key indicator of ecosystem integrity, there are no nationally representative periodic population surveys.

4. Summary Indicator Calculations and Results

China EPI Habitat and Biodiversity Indicators

Developing indicators for biodiversity and habitat conservation has proved difficult, and many organizations have tried but not achieved consensus on input criteria (Orians et al. 2009). The global EPI relied heavily upon protected area status to calculate this category, and following that precedent, China's available data sets are sufficient in scope for the calculation of an EPI.

Policy Categories	Policy Category Codes	Indicators	Indicator Codes	Data Source	Target
Biodiversity & Habitat	BIODIV	**Terrestrial protected areas**	TPA	China Statistical Yearbook, 1997-2007	13% by 2010
		Marine protected areas	MPA	China Marine Statistical Yearbook 2007	not available
		Water quality of offshore marine areas	WATQM	Report on the Administration of the Use of Sea Areas 2006, 2007	not available

Terrestrial protected area (TPA) is the percentage of the provincial territory under protected status. Marine protected area (MPA) is measured as the percentage of total offshore marine areas that are under marine natural reserves. Finally, water quality of offshore marine areas (WATQM) represents the ratio of marine monitoring points whose water quality meets grade IV and below grade V on China's 5-class water quality scale (see Water Quality and Quantity for the Environment section for details on the water grading scale).

Data Quality and Representativeness

There is no available information on sources or methods for producing the numbers behind the indicators TPA and MPA, and no information on aggregation for WATQM. It is not known whether coastal lands (as well as oceans) are included as part of marine protected areas. However, the criteria for assigning a territory under protective status (TPA) are included in the document Principle for Categories and Grades of Nature Reserves[56], and the standards and methodology for monitoring marine water quality are publicly available online (see indicator metadata for Web sites). Data is available for all relevant provinces for the three indicators. Among coastal provinces, Hebei is missing data for MPA.

---

[56] GB/T 14529-93

Correlations

The Pearson coefficients calculated for the biodiversity and habitat indicators show that TPA and MPA are very highly correlated (0.89), indicating that provinces that invest in habitat protection are likely to invest in both terrestrial and marine biomes if they have both available. WATQM is not strongly correlated with TPA but is moderately correlated with MPA, showing that provinces with larger areas under marine protected areas are more likely to have better marine water quality than those with fewer protected zones.

	TPA	**MPA**	**WATQM**
TPA	1		
MPA	0.89	1	
WATQM	0.31	0.47	1

Ranks and Trend Analysis

Figure 10 below shows the percent of land area of each province under protected status. Thirteen provinces have at least 10% of land area protected (the goal is 13%), which leaves 58% of provinces well short of the goal.

Figure 10. Terrestrial Habitat Protection by Province

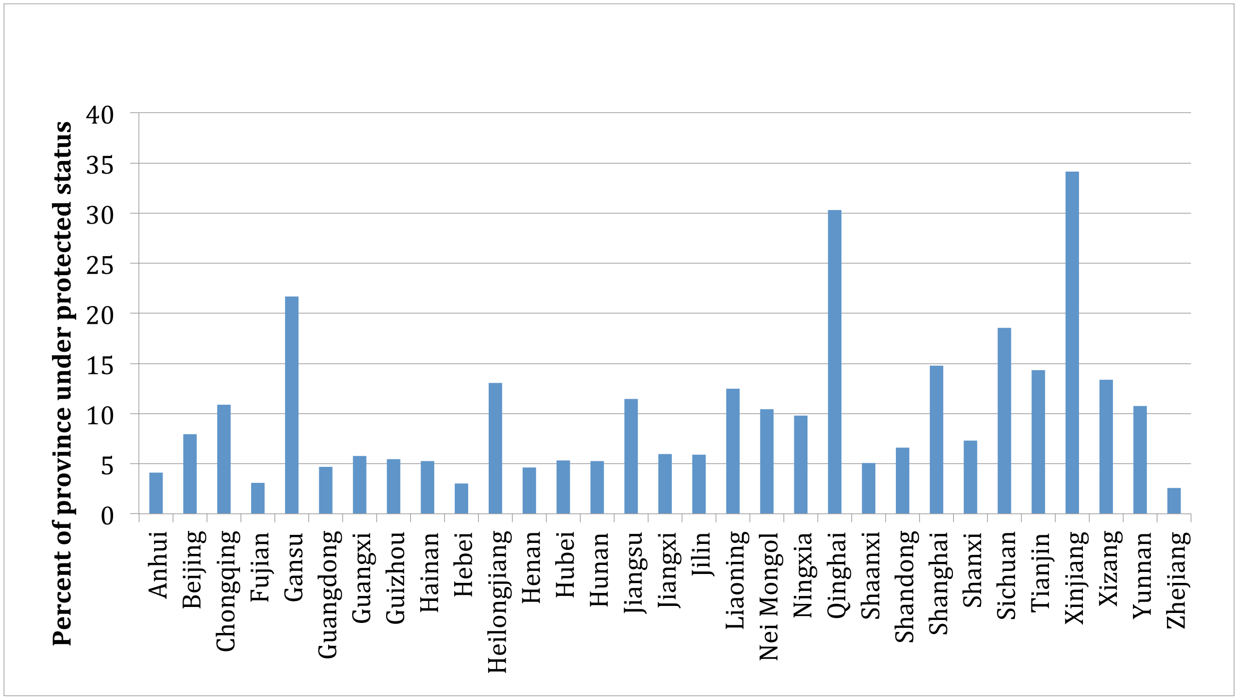
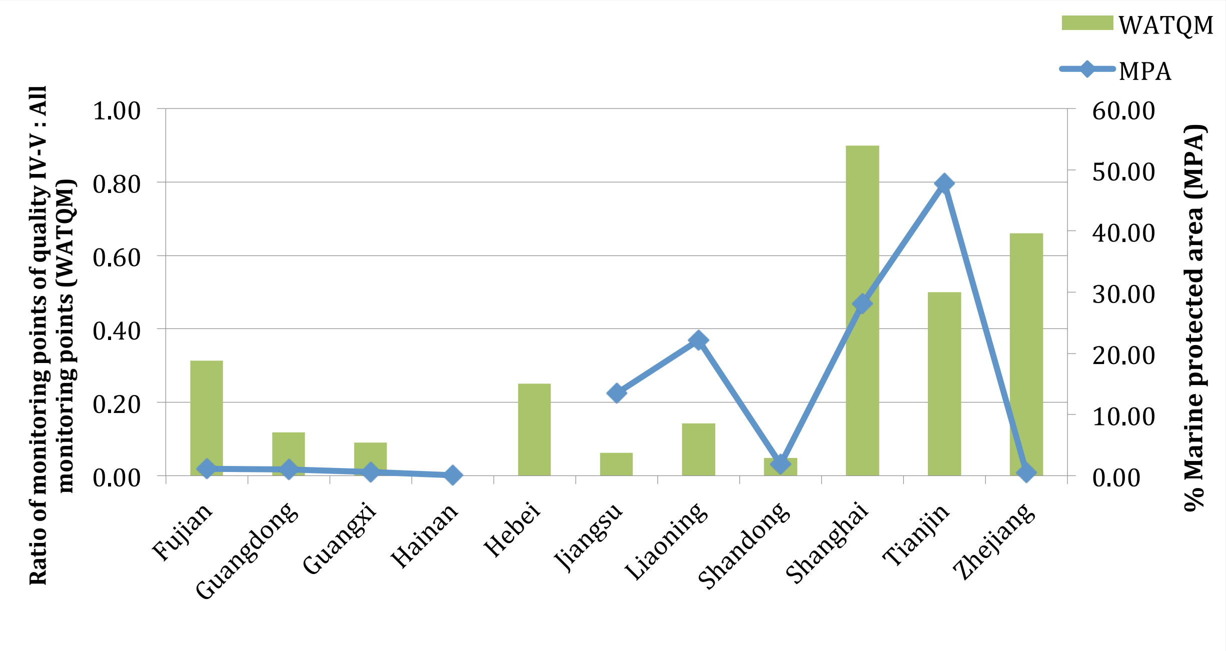


Figure 11 on marine habitat protection, is limited to coastal provinces and shows a large range in both variation of marine protected area (the blue line, axis on the right) and marine water quality (green bars, axis on the left). For WATQM, since it is calculated as a ratio of monitoring stations with high water quality to all monitoring stations, an ideal goal would be as close to 1 as possible.

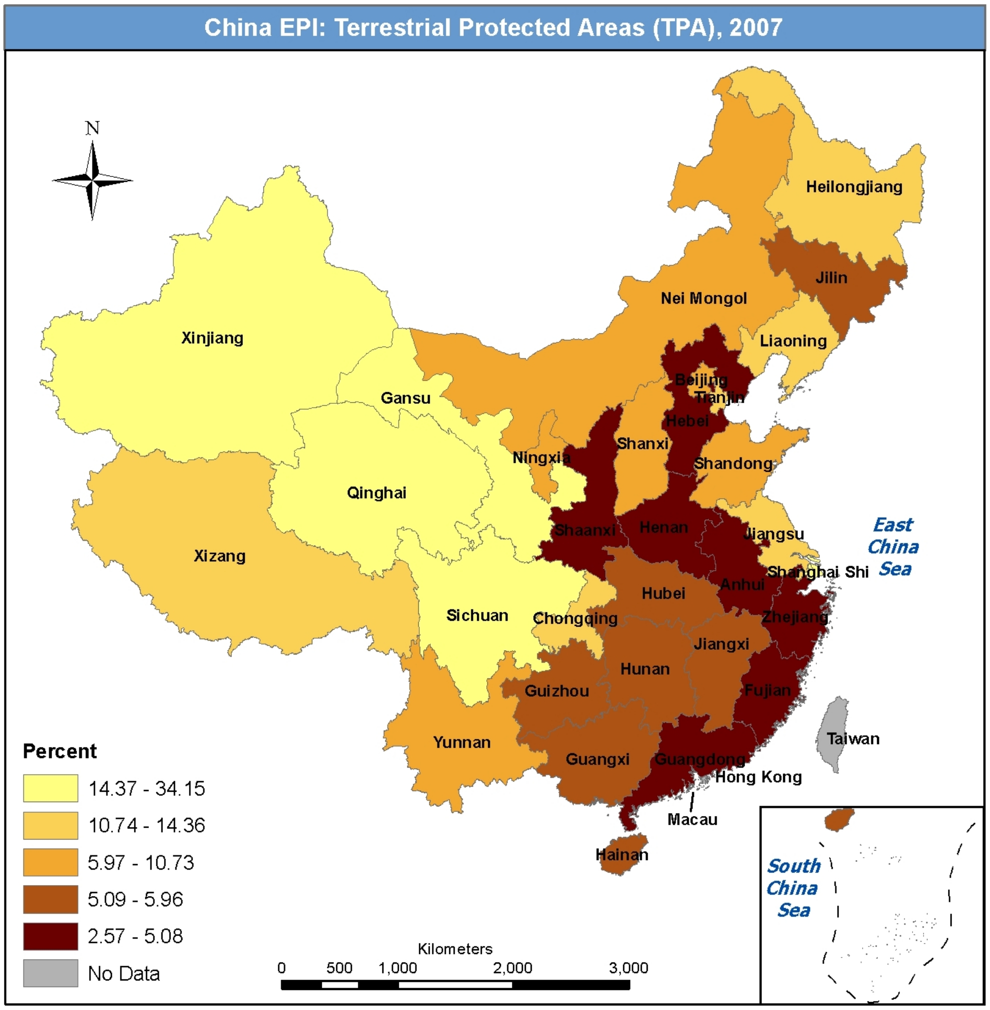
Figure 11. Marine Habitat Protection and Water Quality of Offshore Marine Areas by Province

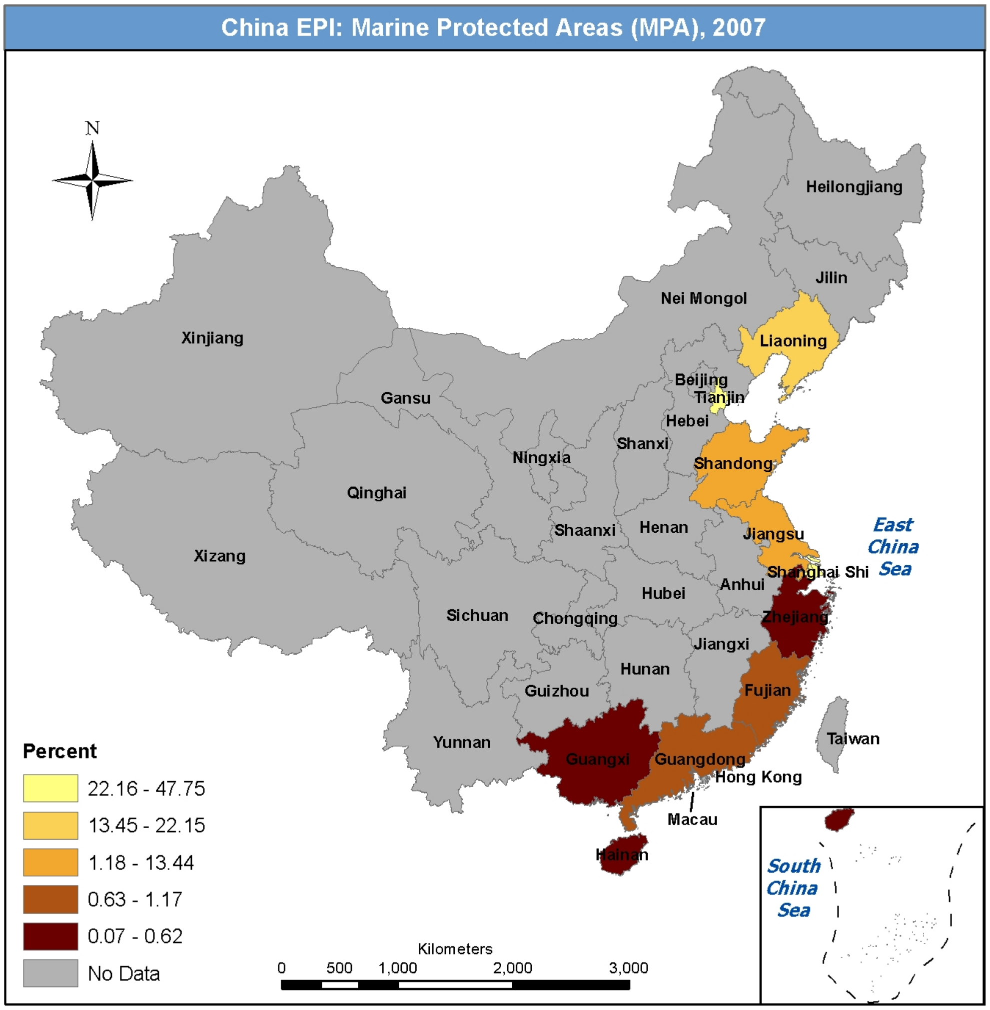


The following table shows all provinces, ranked from highest to lowest percent of terrestrial area under protection. Data for terrestrial protected areas (TPA) and water quality of offshore marine areas (WATQM) are from 2007, and marine protected areas (MPA) are from 2006.

Rank	Province	TPA (%)	Province	MPA (%)	Province	WATQM (Points @ IV-V : All points)
1	Xinjiang	34.15	Tianjin	47.75	Shanghai	0.9
2	Qinghai	30.28	Shanghai	28.08	Zhejiang	0.66
3	Gansu	21.67	Liaoning	22.15	Tianjin	0.5
4	Sichuan	18.56	Jiangsu	13.44	Fujian	0.31
5	Shanghai	14.79	Shandong	1.89	Hebei	0.25
6	Tianjin	14.36	Fujian	1.17	Liaoning	0.14
7	Xizang	13.39	Guangdong	0.98	Guangdong	0.12
8	Heilongjiang	13.06	Guangxi	0.62	Guangxi	0.09
9	Liaoning	12.5	Zhejiang	0.52	Jiangsu	0.06
10	Jiangsu	11.47	Hainan	0.07	Shandong	0.05
11	Chongqing	10.91			Hainan	0
12	Yunnan	10.73				
13	Nei Mongol	10.41				
14	Ningxia	9.78				
15	Beijing	7.96				
16	Shanxi	7.29				
17	Shandong	6.63				
18	Jiangxi	5.96				
19	Jilin	5.92				
20	Guangxi	5.78				
21	Guizhou	5.44				
22	Hubei	5.34				
23	Hainan	5.28				
24	Hunan	5.24				
25	Shaanxi	5.08				
26	Guangdong	4.68				
27	Henan	4.61				
28	Anhui	4.09				
29	Fujian	3.09				
30	Hebei	3.02				
31	Zhejiang	2.57				

The following maps depict the indicator scores by province. The maps consistently depict the best performers in yellow and the worst performers in dark brown. Less densely settled provinces in the West tend to have higher proportions of their land area protected.


China EPI: Terrestrial Protected Areas (TPA), 2007


China EPI: Marine Protected Areas (MPA), 2007

D. Sustainable Forestry

1. *Introduction*

Forests cover almost 30% of the Earth's terrestrial surface (FAO 2006). They harbor much of the world's biodiversity, provide invaluable ecosystem services (e.g., oxygen supply and flood control), and are a major source of traditional medicines, food products, biomass energy, wood for construction, and pulp for paper. Deforestation rates are particularly high in the tropical regions of Southeast Asia, South America, and Africa. Forest planting, the natural expansion of forests, and landscape restoration are only partially offsetting these losses.

In China, agricultural expansion and the demand for construction materials have put pressure on natural forests. In the upper Yangtze region, for example, the forest cover was reduced from roughly 35% in the 1950s to only 10% by 1998 because of heavy forest product extraction (UNDP 2002). Although natural forest cover has declined, the area of planted secondary forests and forest plantations has increased in recent years owing largely to governmental afforestation initiatives (Wenhua 2004 ; OECD 2007). According to the Seventh National Forest Inventory, at the country level total forest area increased from 5.2% in 1950 to 20.36% in 2008.

Although the forest coverage has increased, the quality of China's forests has continued to decline. The age-distribution of China's forests is heavily skewed to young and middle age-groups, with very little old-growth forest cover remaining (Wang et al. 2004). The proportion of natural forest has continued to shrink, resulting in habitat loss, and the extinction of many species (Wenhua 2004). Less than 3% of the country's forest area has been designated for biodiversity conservation (OECD 2007). Additionally, China's large-scale reforestation projects largely ignore biodiversity. The new forests may not provide ecological services as comprehensively as natural forests, and they are much more sensitive to natural disturbances such as fire and pest infestations (UNDP 2002).

2. *Ideal and International Best Practices for Measurement*

In the UN Food and Agriculture Organization's *2010 Global Forest Resources Assessment* (FAO 2010), seven thematic elements are recommended for use in evaluating the progress towards sustainable forest management:

1. Forest biological diversity, measured as the area of forest where "conservation of biological diversity" is the primary designated function. These are usually in protected areas.
2. Forest health and vitality, measured in the percent of forest area significantly affected by burning and in the area damaged by pests, diseases, disasters, and invasive species.
3. Productive functions of forest resources, measured in amount of wood removal and percent of forest area with production of wood and non-timber forest products as the primary management objective.
4. Protective functions of forest resources, measured in the percent of forest area with soil and water conservation or other ecological goals (such as desertification control) as the primary management objective.

5. Socio-economic functions of forests, measured in the proportion of forests designated for the provision of social services such as recreation, tourism, and education. Also measured in number of forest-related jobs, amount of forest-related income, and government spending on and revenue collection from forests.
6. Legal, policy, and institutional framework, measured in forest area covered by a national forest policy or program.
7. Ownership and management of forests, measured in area of forest under a management plan and, more importantly, area under nationally-designated sustainable management (a new measurement criteria).

A review of forest monitoring practices in North America and Europe by Hickey *et al.* (2005) found a generally high level of formal monitoring and information reporting being conducted at the local-level on indicators relating to planning, records and inventory, wildlife management, conservation and most of the issue areas related to forestry operations, harvesting and inspection. Relatively less effort is given to monitoring and reporting on water quality in the forest, forest fires, forest health, forest ecosystem contributions to global cycles, the nature and level of environmental pollution and the socio-economic characteristics of the local population. The FAO Assessment acknowledges these data collection difficulties, especially in the realm of socio-economic functions of forests.

3. China's Measurement Practices

China conducts a National Forest Inventory (NFI) approximately every five years. Seven have been conducted to date, with the first from 1973-1976, the second from 1977-1981, the third from 1984-1988, the fourth from 1989-1993, the fifth from 1994-1998, the sixth from 1999-2003, and the seventh from 2004-2008. The inventory is conducted on a sample of field plots, and over time the sample has grown from 160,000 to 415,000. For the fourth NFI, 106,300 remote sensing plots (RSPs) were added, and this number increased to 2,844,400 for the sixth NFI (Lei, Tang et al. 2009).

Until the seventh inventory, the NFI mainly focused on area and volume metrics, with biodiversity and ecological metrics being considered relatively less important. As of the seventh NFI, a number of measurements related to forest health, ecosystem diversity, forest disturbances, and forest functions have been added (Lei et al. 2009), increasing the total number of variables from 35 to 70. The addition of forest health and biodiversity measures are welcome, since an important function of forests is to provide wildlife habitat, and more diverse forests generally support a wider range of plant and animal life. Data at the provincial level from the seventh inventory were made available only recently, so we relied on the sixth inventory for this report.

Canopy cover thresholds for designating a land area as forest were reduced from 30% to 20% as of the sixth NFI. While this is closer to international practice (the FAO uses an even lower 10% threshold), the change affects the ability to calculate time series statistics since the numbers prior to and following the sixth NFI are no longer comparable.

In addition to the NFIs, every 10 years China conducts a Forest Management Planning Inventory (FMPI) that focuses on management and spatial and functional patterns at the Forest Management

Unit (FMU) level. Thirty-three parameters are measured, with slightly greater emphasis on tree growth, yields, and harvest for commercial forest plots and more emphasis on forest structure, diversity, and ecological factors in ecological forests, which are mostly in nature reserves and parks (Lei et al. 2009). Because the government pays forest managers for ecological services, there has been a growth in demand for data on ecological factors such as species diversity.

Although China has developed an impressive inventory system, some challenges remain. In 2002 China issued criteria and indicators for sustainable forest management with a greater focus on soil and water conservation, biodiversity, forest health, and carbon fixing. According to Lei *et al.* (2009 59), "The current forest inventory system cannot fully satisfy the new information requirements, particularly on ecological states and processes." Furthermore, they suggest that much data are collected for the sake of data collection, and not enough effort is put into analysis and translation of that data into improved management practices.

4. Summary Indicator Calculations and Results

China EPI Forestry Indicators

Currently, published data in annual statistical compendiums only report on forest area and growing stock volume. Ideally, data from the NFI and the FMPI could be used to assess the proportion of total forest area that is under sustainable management so as to better assess the sustainability of practices at the provincial level, as recommended by FAO. In addition, forest biodiversity inventories and ecological function assessments, also recommended by FAO, could be used to assess species loss and the health of critical ecosystems such as alpine forests. However, the two measures available for use as indicators in China, growing stock change and forest cover change, are the two most available internationally and comprised the entirety of the Forestry category for the global EPI.

Policy Categories	Policy Category Codes	Indicators	Indicator Codes	Data Source	Target
Forestry	FOREST	**Growing stock change**	FORGRO	China Statistical Yearbook, 1998, 2003	ratio of growing stock in time2 to time1 ≥1
		Forest cover change	FORCOV	China Statistical Yearbook, 1998, 2003	ratio of forest cover in time2 to time1 ≥1

Forest cover and growing stock changes are calculated as the ratio between the forest cover or growing stock from the most recent survey (1999-2003) to the cover or stock from the previous survey (1994-1998). In both cases, of ratio of ≥1 signifies afforestation, while a fractional ratio indicates deforestation. Data are from the China Statistical Yearbook.

Data Quality and Representativeness

Techniques and regulations for these measurements are publicly available online (see indicator metadata for links). Growing stock change data is missing for Chongqing and Sichuan, and forest cover change is missing for Chongqing, Sichuan and Xizang.

Correlations

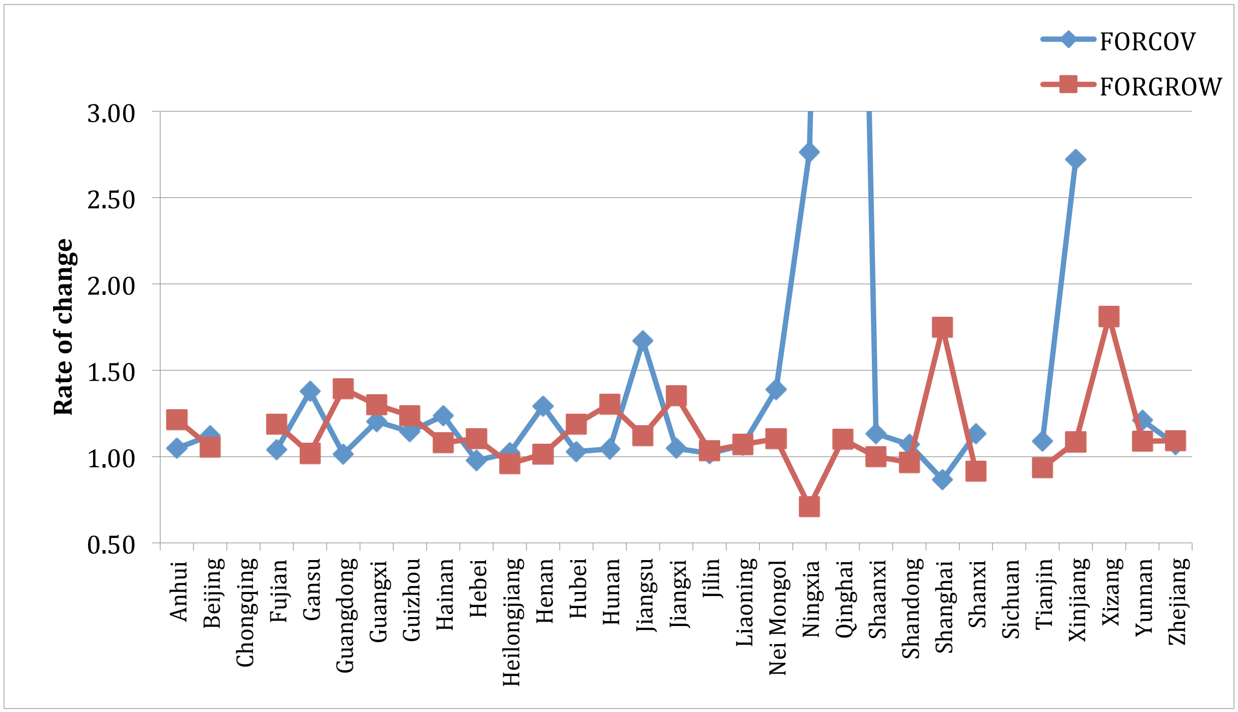
	FORCOV	FORGROW
FORCOV	1	
FORGROW	-0.13	1

The Pearson coefficient calculated for the forestry indicators shows that FORCOV and FORGROW are slightly negatively correlated. The correlation is weak, but the negative relationship may be due to active afforestation in parts of some provinces (thereby increasing forest extent) while increasing timber logging occurs in others (thereby decreasing the volume of wood).

Ranks and Trend Analysis

Figure 12 shows the rate of change of forest cover and forest growth over the monitored period. Many provinces show rates of change ≥1, which signifies increases in forest coverage and growing stocks. One province, Qinghai, has a rate of forest cover change greater than 10—completely off the chart as compared to the other provinces. The high rates of afforestation are the result of China's active policy attention to this issue, especially in the wake of devastating floods in 1998.

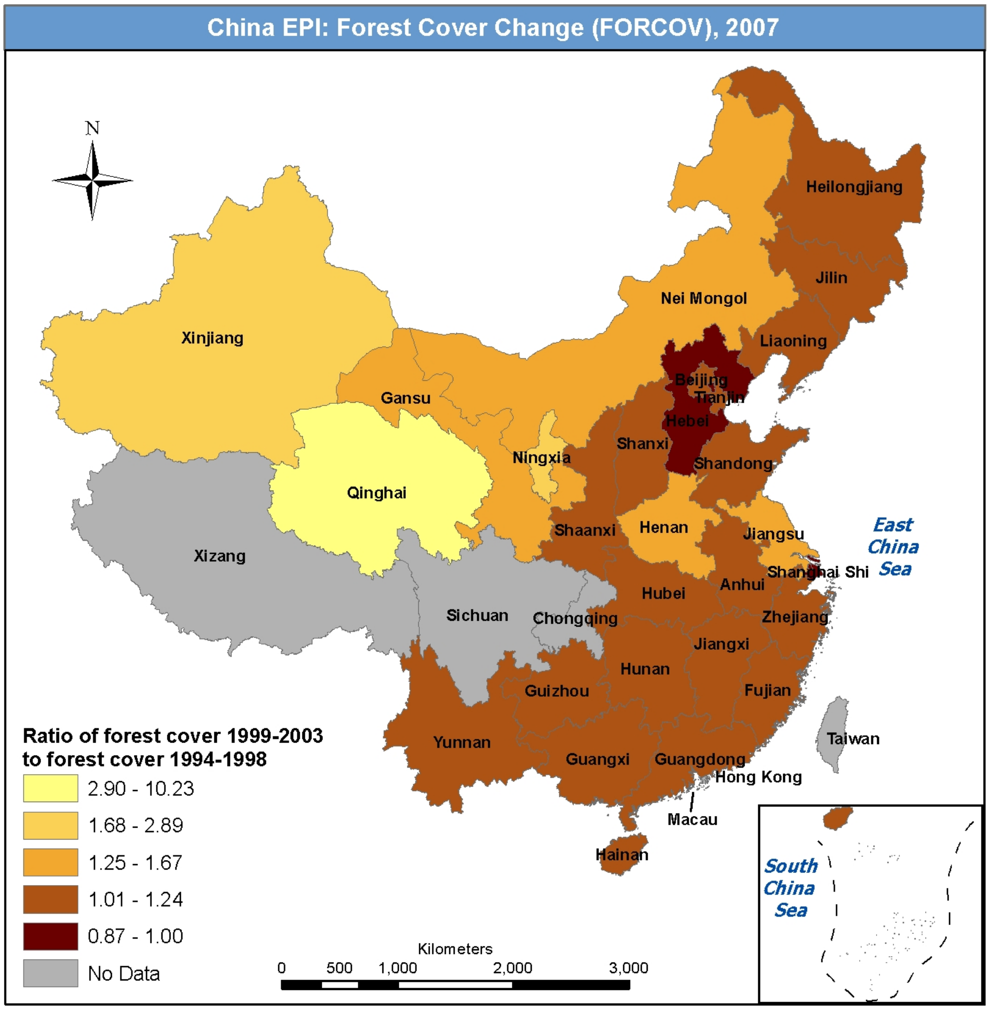
Figure 12. Forestry by Province

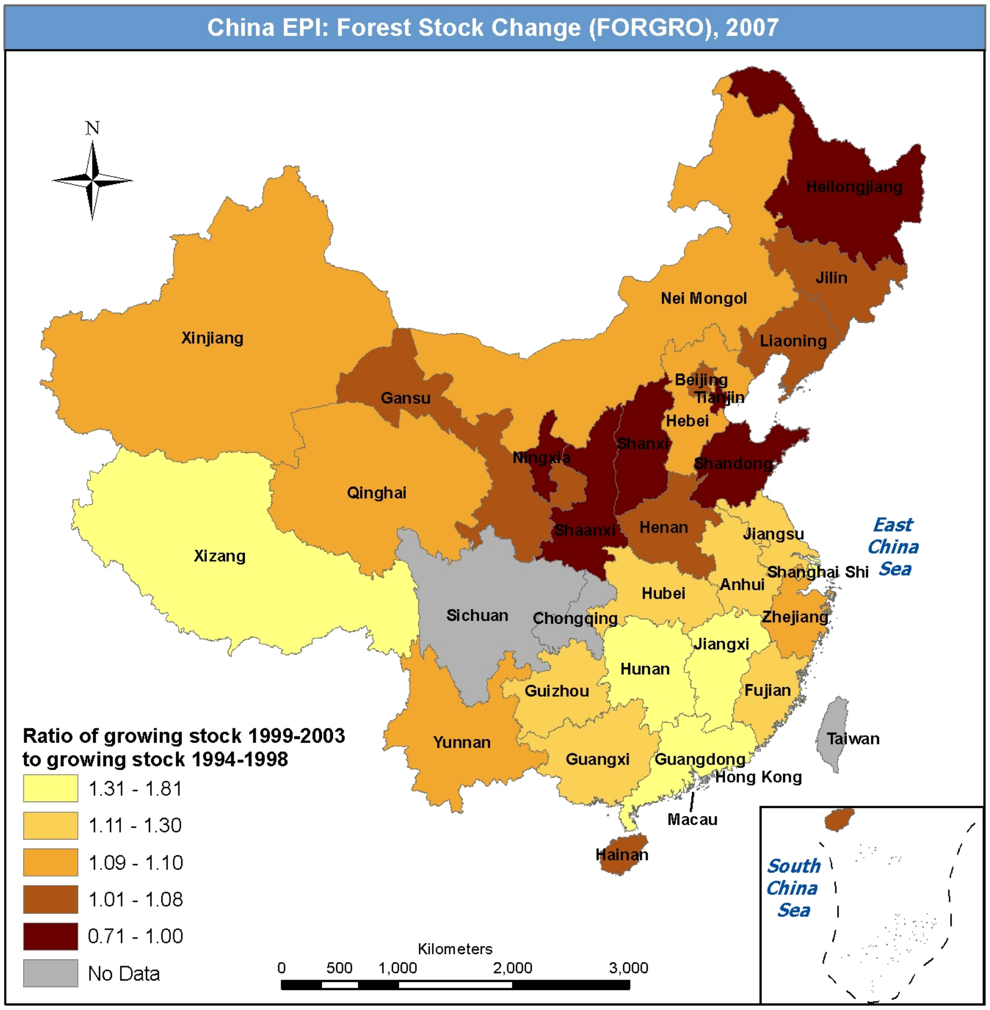


The following table shows ranked data for both forestry indicators, with provinces ranked from highest to lowest performance. An average close to 1 indicates little change in forest area and indeed, most of the provinces' averages come in at 1 or just above. The most recent forest inventory was not available at the time of data collection, so we calculated 1998-2003 change instead.

Rank	**Province**	**FORCOV (5 year rate of change)**	**Province**	**FORGROW (5 year rate of change)**
1	Qinghai	10.23	Xizang	1.81
2	Ningxia	2.76	Shanghai	1.75
3	Xinjiang	2.72	Guangdong	1.39
4	Jiangsu	1.67	Jiangxi	1.35
5	Nei Mongol	1.39	Hunan	1.31
6	Gansu	1.38	Guangxi	1.3
7	Henan	1.29	Guizhou	1.23
8	Hainan	1.24	Anhui	1.21
9	Yunnan	1.21	Fujian	1.19
10	Guangxi	1.2	Hubei	1.19
11	Guizhou	1.15	Jiangsu	1.12
12	Shaanxi	1.13	Hebei	1.1
13	Shanxi	1.13	Nei Mongol	1.1
14	Beijing	1.12	Qinghai	1.1
15	Tianjin	1.09	Yunnan	1.09
16	Liaoning	1.07	Zhejiang	1.09
17	Shandong	1.07	Hainan	1.08
18	Zhejiang	1.07	Xinjiang	1.08
19	Anhui	1.05	Liaoning	1.07
20	Jiangxi	1.05	Beijing	1.05
21	Fujian	1.04	Jilin	1.03
22	Hunan	1.04	Gansu	1.02
23	Hubei	1.03	Henan	1.02
24	Heilongjiang	1.02	Shaanxi	1
25	Jilin	1.02	Shandong	0.97
26	Guangdong	1.01	Heilongjiang	0.96
27	Hebei	0.98	Tianjin	0.93
28	Shanghai	0.87	Shanxi	0.91
29			Ningxia	0.71

The following maps depict the indicator scores by province. The maps depict the best performers in yellow and the worst performers in dark brown.


China EPI: Forest Cover Change (FORCOV), 2007



E. <u>Agriculture and Land Management</u>

1. Introduction

Agriculture and land management practices are challenging in the context of ecosystem and environmental protection. Given increasing populations and changing food preferences, agricultural production is on a trend of expansion and intensification, which, if done unsustainably, could have a damaging impact on the land, water, and natural environment.

Expansion implies bringing new lands under cultivation, which typically entails encroachment on "natural" land cover types such as forests and wetlands. In addition, land transformation is also a driving force of habitat loss, with a substantial impact on biodiversity.

Modern forms of *intensification* imply some combination of improved seeds, the use of inputs such as organic and chemical fertilizers and pesticides, and, in some cases, irrigation. Agro-chemicals and irrigation systems have had, in some instances, serious environmental consequences such as pesticide residues infiltrating food chains, waterlogging, soil salinization, and nutrient runoff, which contributes to increased eutrophication of water bodies.

Currently China has greater challenges from the expansion of urban areas than with the expansion of agricultural areas. In fact, in recent decades the country has actually been losing agricultural land to transport infrastructure and urbanization (Liu 2006b). The country's history of moving from a feudal to a modern society traces the path of land reforms, beginning with transferring feudal land ownership to peasants and later collectivizing those peasants into cooperatives and, in 1958, into very large communes "covering several townships or even a county" (Zhou 2000 90). Multiple waves of land reform have occurred since then, leading to the current model of "efficient, large-scale farming…in a mixed collective-individual economy" under the dual land system (Ibid., 91). More recently, poor agricultural practices and pressure from urbanization have led to increased erosion and desertification as agriculture is pushed to expand to more marginal lands (Lohmar and Gale 2008).

Intensification generally consists of multiple cropping, which is to say, the growing of two or more crops on the same field in one year. This occurs on roughly half the cropland in China (particularly in south China). Land and water scarcity contribute to the drive towards intensification. Only 10 percent of China's land is arable and water resources per capita are a quarter of the world average (OECD 2005b). With an abundance of labor and tiny farms spread out over a relatively low proportion of arable land, Chinese farming is largely non-mechanized (ibid.).

China's fertilizer use at 280 kilograms per hectare is among the highest in the world (ibid.). Approximately 1.2 million tons of pesticides are applied annually (Yang 2007), while the utilization rate is only 30 percent (Cao and Xie et al. 2010). This low utilization of chemical fertilizers and pesticides, combined with multiple cropping, has not only led to soil pollution (especially heavy metals (Yang 2007)) of farmland but agricultural run-off also leads to eutrophication, groundwater pollution, and air pollution.

China is facing a serious land degradation problem with topsoil erosion losses totaling nearly 40 tons per hectare of cultivated land per year (Pimental and Wilson 2004). Research shows that in the 1990s, soil erosion affected over 160,000 thousand hectares of agricultural land per year – almost every drainage area and every province faces soil erosion, in some cases over very large areas (Datong 1997). Additionally, China is confronting a serious desertification problem, caused by both climate change and human influence (Wang, Chen et al. 2008) that has threatened the nation's ecological and economic sustainability (Shili 2006).

Agricultural output has grown dramatically since 1990, but the relative stability of water consumption over that time (OECD 2007) may be an indicator that yields have grown mostly via the use of fertilizer and pesticide applications. Water consumption by agriculture still accounted for 69% of China's total water consumption in 1998 (after dropping from 97% in 1949, before the country industrialized) (Lohmar, Wang et al. 2003) and irrigation practices are relatively inefficient when compared with OECD countries. The country is undertaking pilot projects to increase the efficiency of agricultural output, from laser leveling of fields to the use of greenhouses (OECD 2007).

With continued population growth and improving living standards, the need for livestock products is also growing in China. In the last 5-20 years pork, beef, sheep, poultry, egg, and milk production have grown by 200-500%, with much of the increase accounted for not by expanding pasture acreage but by converting to intensive penned livestock production (OECD 2007). The dramatic increase is accompanied by an increased demand for feedstuff and water and issues such as animal waste disposal.

2. *Ideal and International Best Practices for Measurement*

Agriculture has an enormous effect on the global ecosystem, utilizing soil and water resources while often contributing pesticides, greenhouse gas emissions, and nutrient-heavy runoff to the environment. Internationally, a number of the most significant pesticides are regulated as persistent organic pollutants (POPs) under a treaty agreed to in 2000 (see Toxics section for more details). In 1994, 117 nations signed an agreement produced by the Uruguay round of global trade negotiations conducted under the General Agreement on Tariffs and Trade (GATT). This agreement obliged signatory countries to recognize some of the policies that make today's agriculture unsustainable (WRI 1997). The 2001 International Treaty on Plant Genetic Resources for Food and Agriculture committed the contracting parties to develop and maintain appropriate policy and legal measures that promote the sustainable use of plant genetic resources for food and agriculture. In short, international agreements have brought the world closer to recognizing and adopting sustainable agricultural practices, but individual country or province performance does not always match up with global environmental targets.

This disconnect from targets is partly caused by many nations' reliance upon subsidies. Agricultural subsidies for production and chemical inputs "exacerbate environmental pressures by encouraging intense chemical use, the expansion of agriculture to sensitive areas, and overexploitation of resources" (Emerson et al. 2010). While the best practice in environmental terms is to reduce or eliminate subsidies and support, many countries face great pressure to maintain these trade barriers to support their farmers and ensure food security. For instance, in 2004 China reversed a long-standing policy of taxing agriculture and began directly subsidizing farmers with the dual goals of boosting grain production and increasing farmers' income (Gale et al. 2005).

Agronomists and soil scientists generally recommend a fertilizer ratio of nitrogen to phosphorus to potassium (N:P:K) of 100:60:40, with nitrogen being the most limiting nutrient (Williams 2005). Nutrient inputs above this ratio, or applied in excessive quantities, lead to non-point source pollution to water bodies that contribute to eutrophication and poor water quality. Water quality and availability are also impacted by excessive water withdrawals, driven in part by inefficiencies in irrigation and water transport systems. The UN Food and Agriculture Organization considers a water requirement ratio (the percentage of available water resources used for irrigation) of greater than 40% to be an indicator of critical water stress (Khan and Hanjra 2009).

3. China's Measurement Practices

Technical standards and guidelines

Chapter VIII of the Agriculture Law on the Protection of Agricultural Environment, together with State Council Decree No. 81 (2003), specify that arable land should be kept well-maintained, chemical fertilizers, and pesticides and agricultural plastic films should be used rationally. They also mandate an increase in organic fertilizers and use of advanced techniques in order to protect and improve soil fertility and prevent pollution, soil erosion, and soil fertility declines. The administrative departments at or above county level are responsible for monitoring regularly the quality of the land. In regard to grassland, the law stipulates that the number of animals fed should be kept under control and introduces a system of rotational grazing to prevent the grassland from degeneration, encroachment by sand and salinization.

The Water Law of 1988 was China's first comprehensive law to manage water resources, and is seen as a direct response to the decrease in irrigated land area and the rise in food prices in the post-reform era. The decline in irrigated land areas was the result of poor water management, declining government investment in irrigation infrastructure, and deteriorating water supply systems. Recognition of the tight linkage between water supplies and agricultural production led to the sharing of water policy between the Ministry of Water Resources (created after passage of the 1988 Law) and the Ministry of Agriculture in rural areas (Lohmar, Wang et al. 2003).

As for horticulture, the government's Environmental Quality Evaluation Standard for Greenhouse Vegetables Production[57] specifies the concentration thresholds as well as monitoring and evaluation methods for parameters related to soil environmental quality, irrigation water quality, and ambient air quality in soil-based greenhouses. The Farmland Environmental Quality Evaluation Standards for Edible Agricultural Products[58] are similar to those for greenhouse vegetables.

Methodology: data collection, instruments and data quality

Generally, monitoring agricultural statistics based upon environmental outcomes is a joint responsibility of the Ministry of Agriculture, the National Bureau of Statistics, The Ministry of Environmental Protection, the Ministry of Water Resources, and the Ministry of Land and Resources. Important agricultural statistics are published annually in the China Environmental Statistical Yearbook, the China Rural Statistical Yearbook, the China Agriculture Statistical Yearbook, and the Yearbook of China Water Resources.

Agriculture monitoring in China started at a regional level in 1983, and extended to a national level system in 1998. Currently, three institutions provide country agriculture monitoring:

- Starting in 1999 the Remote Sensing Application Center of the Ministry of Agriculture began monitoring acreage change, growth, yield and productivity, grassland degradation, and grass-

---

[57] HJ 333-2006, February, 2007

[58] HJ 332-2006, February, 2007

livestock balance, among other things. Five main crops, including wheat, rice, maize are monitored every year. The remote sensing data are supplemented by in situ monitoring investigations, and ground truthing. The in situ investigation included about 3,549 stratified samples in 2006, and the ground truthing covered 440 counties and 870 plots for winter wheat.

- In 1998 the Institute of Remote Sensing Analysis from the Chinese Academy of Sciences began monitoring for crop condition, acreage, yield and production, multi-cropping index, crop structure and grain supply-demand balance analysis soybean, and cotton production. In addition, the Crop Watch System[59] monitors wheat, rice, soybean and maize.
- China Meteorological Agency (CMA), based on agro-meteorological in-situ sites, monitors crop condition and crop yield. There are 756 Agro-meteorological Observation Stations in China's Network, which studies the relationship between weather, climate, crops and vegetation dynamics, and specialized in crop yield modeling.

Crop-specific information is collected mainly through surveys of standing crops in agricultural research stations and agro-meteorological stations (methods used by the Ministry of Agriculture and CMA). The method mainly consists of on-the-spot visual assessment. However, the number of such stations is limited because of the high cost of maintaining them. Also, spatial variation in physico-chemical properties of soil and farming practices makes it difficult to extrapolate the data from one station to represent a larger area; this is where the remote sensing data become necessary (data available from CAS and Ministry of Agriculture).

Fertilizer and pesticide use data are collected through surveys conducted by the National Bureau of Statistics. There is no information regarding the representativeness of the country surveys.

In the use of agricultural water, the Ministry of Water Resources collaborates with the Ministry of Agriculture. In 2006, the Ministry of Water Resources (MWR) launched countrywide measurements of irrigation water use rates. This work was undertaken in two phases: from July to December of 2006, analysis of provincial and national actual use rate of agricultural irrigation water would be conducted. From January 2007 to September of 2010, an analytical network of measurement, tracking and analysis of the change of irrigation water use efficiency was created. An analytical report of the irrigation water use rate for provinces and the whole country during 2006-2010 was also completed. There are no available province level data for this indicator.

For soil erosion, the MWR launched the national monitoring network and information system for soil erosion in 2001. There are two phases of this project. The first phase focused on monitoring China's West, including the drainage area of the Changjiang River and 100 stations in 13 provinces such as Shanxi and Inner Mongolia. The second phase was started in 2009 and will concentrate on the establishment of monitoring network for Central and East China.

Due to soil degradation**,** the government has begun to attach importance to soil pollution. In its Decision of the State Council on Implementing Scientific Outlook on Development and

---

[59] http://www.cropwatch.com.cn/en/index.html

Strengthening Environmental Protection[60] and Outline of the 11th Five-Years Plan for National economic and Social Development, which were both issued by the State Council, soil pollution related issues are emphasized. In 2006, SEPA and MLR launched the Special Work on Status Survey and Pollution Prevention of Nationwide Soil, to be completed in 2009.

Grassland monitoring is conducted by the Grassland Monitoring and Supervision Center of the Ministry of Agriculture. Since 2005, they have published four national reports on grassland monitoring. In 2006, a technical manual on national grassland monitoring was issued by the Grassland Monitoring and Supervision Center, and it was amended in 2007. Besides specifications on surveys of the characteristic of sample land, sample surveys such as herbage, semi-shrub, livestock and the ecological status of grassland are also include in the manual.

Transparency

The Chinese government measures indicators of agriculture at the provincial level annually. Agricultural statistics can be found in the China Agriculture Statistical Yearbook, the China Statistical Yearbook, the China Environmental Statistical Yearbook, and the Annual Statistical Report on Environment in China. Indicators at the provincial level include: area of cultivated land, irrigated area with saved water, chemical fertilizer use, diesel oil use, agricultural chemical insecticide use, effective irrigated area, plastic film use, number of livestock, area of increased cultivated land, area of reduced cultivated land, area of desertification land and sandy land, area of soil erosion under control, total area in which it is prohibited to burn straw, quantity of straw generated in those areas, and rate of straw utilized in those areas.

The China Environmental Statistical Yearbook includes data on desertification and sandy land area at the provincial level from 2004 to 2007. The China Environmental Statistical Yearbook includes data on chemical fertilizer and pesticide use for 2004, 2005 and 2007. Based on the Second National Remote Sensing Investigation on Soil Erosion, some data are available on the land area affected by soil erosion. In the China Statistical Yearbook, there are data on the number and output of livestock by province from 1996 to 2007.

Other indicators that would be desirable but which are not available include soil quality and the percent of irrigation water lost to leakage and evaporation. Although China has begun the monitoring and measurement work, data are not yet available and such indicators cannot be included in this indicator framework.

---

[60] issued by State Council, No.39, 2005

4. *Summary Indicator Calculations and Results*

China EPI Agriculture and Land Management Indicators

Of the available indicators for China, we chose the three found below.

Policy Categories	Policy Category Codes	Indicators	Indicator Codes	Data Source	Target
Agriculture and Land Management	**AGCLTR**	**Pesticide use intensity**	PESTINT	China Statistical Yearbook, 2004-2006	3 kg/ha
		Chemical fertilizers use intensity	FERTINT	China Statistical Yearbook, 1996-2005, 2007	250 kg/ha
		Soil erosion	SELAND	China Soil Erosion Bulletin 2000	Reduce by 34% during the 11th five-year plan

Pesticide use intensity is the amount of pesticide consumed for agriculture per hectare of temporary and permanent cropland. Fertilizer use intensity is the amount of fertilizer consumed for agriculture per hectare of temporary and permanent cropland. The soil erosion indicator is calculated as a percentage of land area affected by soil erosion.

Data Quality and Representativeness

The pesticides included in pesticide use intensity are insecticides, herbicides, fungicides, acaricides, plant growth regulators, rodenticides, nematocides, molluscacides and fumigants. Of the major types of pesticides used, the most prevalent in China is insecticide, which counts for 50% of the total use. The fertilizers included in chemical fertilizers use intensity are the nutrients nitrogen (N), potash (K_2O), and phosphate (P_2O_5). No information is available for the use pesticide and fertilizer use intensity indicators regarding data collection methodology. No information is available regarding how soil erosion is measured, the methodology of aggregation at the provincial level, and representativeness. Pesticide intensity data is missing for Guangdong province. The other two data sets are complete.

Correlations

The Pearson coefficients calculated for the agriculture indicators show that pesticide and fertilizer intensity are highly positively correlated with one another, while soil erosion is moderately negatively correlated with both pesticide and fertilizer intensity.

	FERTINT	PESTINT	SELAND
FERTINT	1		
PESTINT	0.76	1	
SELAND	-0.51	-0.49	1

Ranks and Trend Analysis

The following figures show the three indicators for all provinces. The pesticide and fertilizer use intensity are shown on the same chart with different scales to convey visually their correlation by province. Note that policy goals appear to be particularly difficult to achieve in this category—only seven provinces (23%) meet the target for fertilizer intensity, only five (16%) meet the target for pesticide intensity, and while the target for eroded soil area is as close to zero as possible, only seven of provinces have less than 10% of their soil area eroded. More worrisome, another seven provinces have more than 50% of their soil area eroded, and five provinces use more than an order of magnitude more pesticide per hectare than the policy goal calls for—including one, Fujian, that uses almost 43 kg/ha.

Figure 13. Pesticide and Fertilizer Use by Province

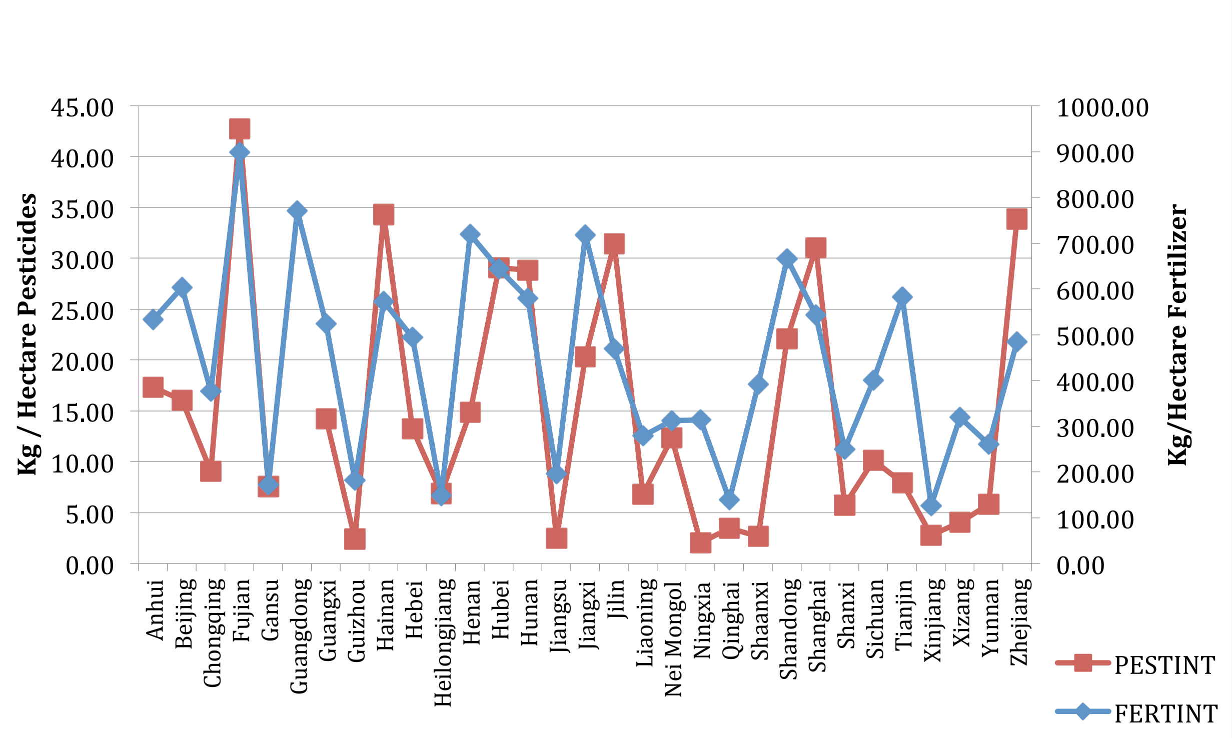
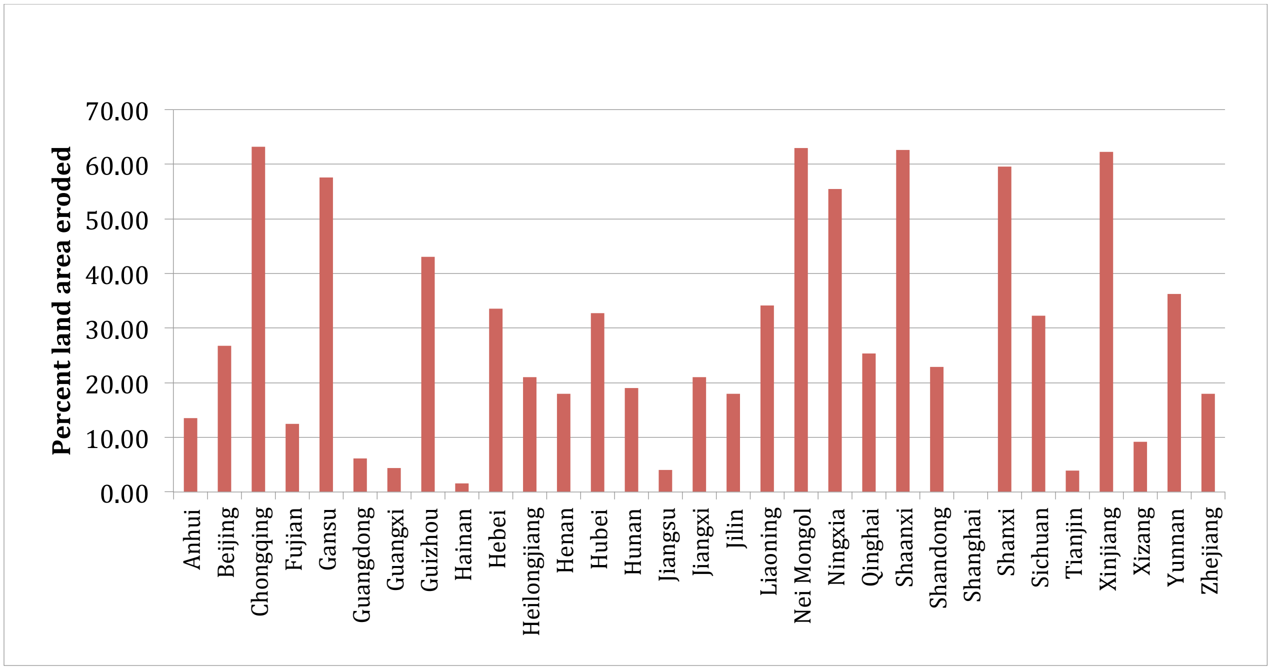


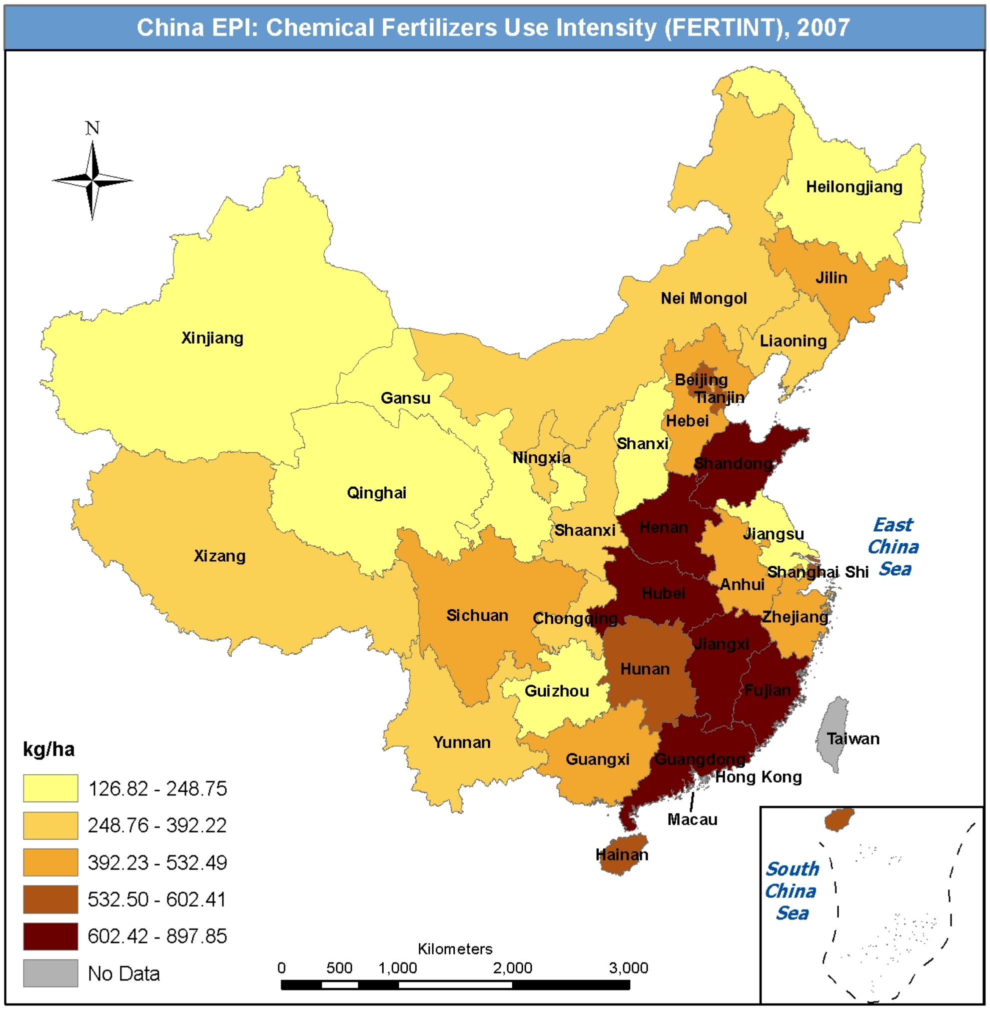
Figure 14. Percent of Provincial Land Area Experiencing Soil Erosion



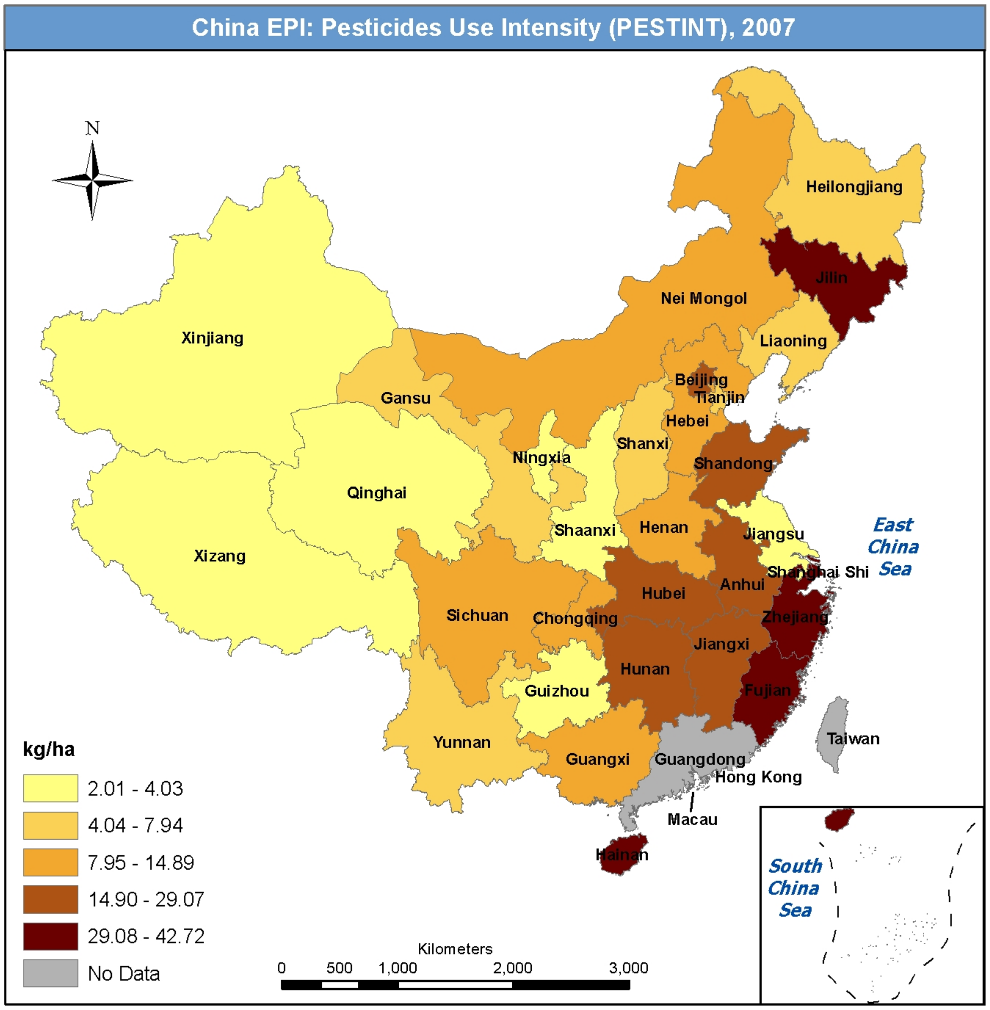
The tables below shows ranked data on all three agriculture indicators for each province, ranked from the best performer to the worst performer. Fertilizer and pesticide use intensity (FERTINT and PESTINT) data are from 2007, and soil erosion (SELAND) is from 2000.

Rank	Province	FERTINT (kg/ha)	Province	PESTINT (kg/ha)	Province	SELAND (% eroded)
1	Xinjiang	126.82	Ningxia	2.01	Shanghai	0.00
2	Qinghai	139.25	Guizhou	2.39	Hainan	1.55
3	Heilongjiang	147.99	Jiangsu	2.45	Tianjin	3.88
4	Gansu	171.98	Shaanxi	2.64	Jiangsu	4.00
5	Guizhou	182.85	Xinjiang	2.77	Guangxi	4.38
6	Jiangsu	196.31	Qinghai	3.49	Guangdong	6.12
7	Shanxi	248.75	Xizang	4.03	Xizang	9.23
8	Yunnan	260.64	Shanxi	5.73	Fujian	12.43
9	Liaoning	278.93	Yunnan	5.80	Anhui	13.47
10	Nei Mongol	312.03	Liaoning	6.81	Jilin	17.95
11	Ningxia	313.01	Heilongjiang	6.90	Zhejiang	18.00
12	Xizang	319.67	Gansu	7.58	Henan	18.01
13	Chongqing	376.58	Tianjin	7.94	Hunan	19.07
14	Shaanxi	392.22	Chongqing	9.10	Heilongjiang	21.02
15	Sichuan	400.27	Sichuan	10.14	Jiangxi	21.07
16	Jilin	469.27	Nei Mongol	12.32	Shandong	22.90
17	Zhejiang	484.06	Hebei	13.23	Qinghai	25.38
18	Hebei	493.84	Guangxi	14.24	Beijing	26.71
19	Guangxi	523.97	Henan	14.89	Sichuan	32.27
20	Anhui	532.49	Beijing	16.09	Hubei	32.73
21	Shanghai	542.30	Anhui	17.31	Hebei	33.54
22	Hainan	572.78	Jiangxi	20.32	Liaoning	34.16
23	Hunan	579.52	Shandong	22.08	Yunnan	36.18
24	Tianjin	581.96	Hunan	28.81	Guizhou	43.05
25	Beijing	602.41	Hubei	29.07	Ningxia	55.50
26	Hubei	643.10	Shanghai	31.06	Gansu	57.51
27	Shandong	666.49	Jilin	31.43	Shanxi	59.53
28	Jiangxi	717.98	Zhejiang	33.86	Xinjiang	62.24
29	Henan	718.75	Hainan	34.28	Shaanxi	62.59
30	Guangdong	771.29	Fujian	42.72	Nei Mongol	62.96
31	Fujian	897.85			Chongqing	63.16

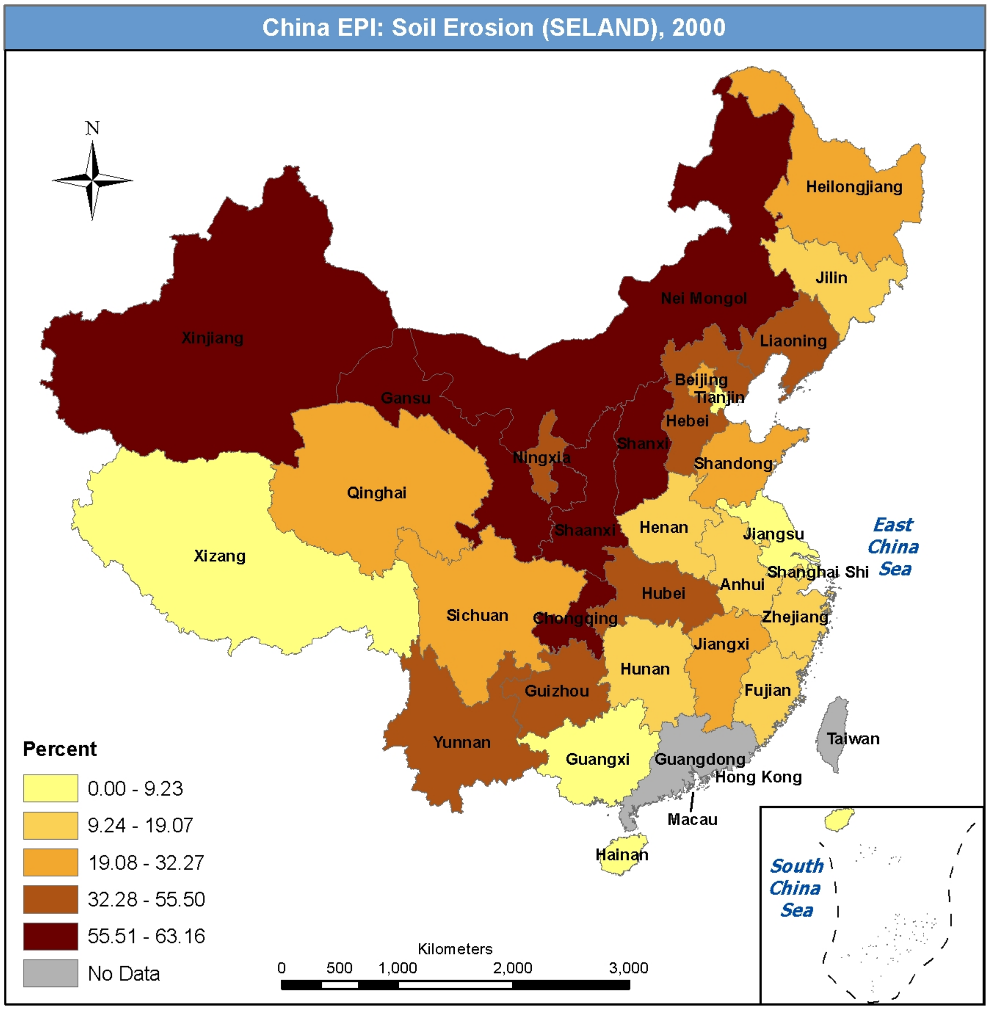
The following maps depict the indicator scores by province. The maps depict the best performers in yellow and the worst performers in dark brown. From the maps it is clear that chemical and fertilizer usage is highest in southeastern China, and soil erosion is a major problem of the Northwest.



China EPI: Chemical Fertilizers Use Intensity (FERTINT), 2007



China EPI: Pesticides Use Intensity (PESTINT), 2007



Economic Sustainability

A. Climate Change

1. *Introduction*

With global effects that will span centuries, climate change stands out among the world's most critical environmental problems. Research suggests that climate disturbances will intensify, and are very likely to include increased occurrences of heat waves, heavy precipitation, droughts, and flooding, and are likely to include an increase in tropical cyclone intensity (IPCC 2007 46). The IPCC Fourth Assessment Report (AR4) concludes with high confidence that changing climatic conditions due to anthropogenic emissions of greenhouse gases will strongly affect terrestrial and marine biological and physical systems. Climate change will negatively impact human health, ecosystem vitality, food production, water systems, and coastal populations in most if not all countries.

Abnormally high temperatures, climate variation, and climate extremes (droughts, floods) will affect agricultural production and may lead to food shortages. The droughts and floods in China in 2010 and 2011 are a case in point. Temperature anomalies may also cause water-borne epidemics, heat exhaustion, and increases in morbidity and mortality rates from cardiovascular diseases, hypothermia, and other health problems. Extreme weather events, such as hurricanes, extreme heat, floods, droughts, earthquakes, and cyclones destroy residential houses and shelters and cause water contamination, famine, infectious disease epidemics, and damage to health infrastructure (Campbell-Lendrum, Ebi et al. 2003:10-11). Natural systems and biodiversity are also affected, leading to biodiversity loss.

Climate change should be of particular concern to China. Recent data show that China's average surface temperature has increased by 1.1°C over the last 100 years (1908-2007), 48% higher than the global average of 0.74°C. The distribution of precipitation in the past 50 years has changed substantially. Heavy precipitation has increased in southern China, while precipitation has decreased in most parts of northern and northeastern China. Snow disasters have also become more frequent in western China. Other extreme events, such as heat waves, severe floods, and droughts, have become more frequent and intense. Across Chinese coastal areas, the sea surface temperature has increased by 0.9°C, and sea level has risen by 90mm in the last 30 years. Scientific research suggests that the impacts of climate change in China will further intensify. (China State Council 2008 4)

China's large coastal populations, fresh water supply, and agriculture are all vulnerable to the adverse effects of climate change. In 2007, for example, drought affected 14.9 million hectares of Chinese farmland and 89,700 people suffered severe water shortages (SEPA 2007). In July-August 2010 heavy rains devastated many parts of the country, triggering flooding and landslides that have caused thousands of deaths and billions of dollars in damages. Climate change will hurt China more than most other countries because 1.31 billion citizens rely on an at-risk food and water systems, and sea level rise threatens the increasing populations near port cities like Shanghai (IPCC 2007).

Although adaption to these changes will need to be an increasing focus of Chinese government efforts, it is still vitally important to reduce greenhouse gas emissions. Policy-makers need to track trends in greenhouse gas (GHG) emissions, energy production, consumption, and renewable energy generation. China has made increasing energy efficiency a priority. In the 11th Five-Year Plan (2006-2010), China set a target to reduce CO_2 equivalent GHGs by 0.36 billion tons per year during the 11th FYP period, reduce energy intensity (energy consumed per unit GDP) by 20% by 2010, and increase renewable energy to 10% of the overall supply (NDRC 2007a) (targets for the recently released 12th FYP can be found in Appendix 3). China strives to reduce GDP carbon intensity by 3% every year, reaching a 40% reduction between 2000 and 2020 (Committee of China's National Assessment Report on Climate Change 2009, 418). These policies address climate change while fulfilling other national goals such as energy security and air pollution control (OECD 2007 296).

While focusing on and reaching energy efficiency targets, China's overall energy use may still increase. Decoupling energy use from economic growth can be achieved to some degree, but given China's high economic growth rates, in itself it may not allow China to reach the ultimate goal of decreasing GHG emissions and minimizing the effects of climate change. Furthermore, China is heavily dependent on high sulfur coal for energy production, which is one of the most carbon-intensive energy sources. Therefore, there are still significant challenges to reducing GHG emissions.

2. *Ideal and International Best Practices for Measurement*

Research on the anthropogenic drivers of climate change suggests that policy-makers should monitor land-use changes, greenhouse gas emissions, and atmospheric greenhouse gas concentrations. The IPCC has focused on four long-lived greenhouse gases: CO_2, CH_4, N_2O, and halocarbons in the AR4. The United Nations Framework Convention on Climate Change (UNFCCC) requires Parties to the convention to submit estimates for the following GHGs: CO_2, CH_4, N_2O, perfluorocarbons, hydrofluorocarbons, and sulfur hexafluoride (United Nations 1992 6-9, 15). Additionally, countries must submit inventories on the following indirect GHGs (for which climate forcing factors are not calculated): carbon monoxide (CO), nitrogen oxides (NO_x), non-methane volatile organic compounds, and sulfur oxides (SO_x). The UNFCCC also requires reporting on emissions due to land-use change, because deforestation accounts for roughly 20% of global greenhouse gas emissions (United Nations 2004 7-8, 21).

In October 2008, the United Nations Division for Sustainable Development (UNDSD) created a preliminary set of climate change indicators for sustainable development. These indicators were grouped into three themes: mitigation, adaptation, and financing and technology.

<u>Mitigation Indicators</u>

- GHG emissions (GHG emissions per capita, GHG intensity)
- Energy (intensity of total energy use, intensity of industrial energy use, intensity of transport, intensity of household energy use, share of renewable energy sources of total)
- Industry and product use
- Agriculture, forestry and other land use (proportion of land covered by forests, land use change, land degradation)

<u>Adaptation Indicators</u>

- Temperature and precipitation changes
- Natural hazards (percentage of population living in hazard prone areas, human and economic loss due to natural disasters)
- Fresh water (water use intensity)
- Agriculture (land productivity, agriculture diversification)
- Health (morbidity of vector-borne diseases, areas in which vector-borne diseases are endemic)
- Coastal zones and marine environments
- Biodiversity and terrestrial ecosystems
- Economic development (proportion of population living under poverty line, economic diversification indicator)
- Adaptive capacity (infrastructure investment in areas vulnerable to climate change)

Financing and Technology

- Public or publicly guaranteed transfers
- Investment
- Trade
- Technology development

The current best practices are based on the UNFCCC requirements for Parties of the Convention. The binding target for most parties to the 1997 Kyoto Protocol to the Convention is to cut GHG emissions by 5% below 1990 levels, averaged over the period from 2008-2012 (United Nations 1998a). Mechanisms to achieve these cuts include a carbon market for emissions trading, the Clean Development Mechanism (CDM, described below), and Join Implementation of emissions reductions in partner countries. The Protocol requires strict monitoring and reporting of actual emissions and of carbon trades.

The more recent Copenhagen accord provides a global consensus on the need to limit the rise in global average temperatures to no more than 2° Celsius. Consequently, there will likely be a long-term global emissions target set to 40-60% reductions in emissions from 1990 levels by 2050 (Emerson et al. 2010). In the global 2010 Environmental Performance Index, the authors used a median target value of 50% reductions below 1990 levels by 2050 (ibid.). Countries that performed best on the three measures of climate change performance tend to have invested in low-carbon and more efficient growth in industrial sectors, use renewable energy sources, are not experiencing significant land use change, and have small populations. China has been quite successfully emphasizing energy efficiency in industrial production, but its tremendous rates of economic growth and development and high rates of coal consumption have led to large net increases in GHG emissions (ibid.).

3. *China's Measurement Practices*

The impacts of climate change already affect the health of the Chinese people and environment. According to the report on China's National Climate Change Programme, the National Development and Reform Commission (NDRC) listed observed impacts of climate change in China and predicted that the effects will worsen (NDRC 2007b 6, 14-18).

These observed effects have catalyzed China's domestic and global efforts to reduce emissions. Internationally, China ratified both the Kyoto Protocol (1998a) and the UNFCCC (1992). As a non-Annex I country under the Kyoto protocol, China has no binding emissions limits and participates in Clean Development Mechanisms (CDM). Under this program, developed countries fund projects that reduce emissions in developing countries. CDM proposals must prove emissions reductions from a baseline scenario to earn certified emission reduction credits, which Annex I countries may use as offsets to meet their emissions reduction targets. China actively participates in the clean development mechanisms and accounts for 42% of all the certified emission reductions issued (United Nations Unknown).

China has also enacted national policies to regulate climate change. Led by the NDRC, the central government established the National Coordination Committee on Climate Change to coordinate climate policy. Subsequently, China's National Climate Change Program was formulated in 2007 and outlined current national challenges, and policy measures to address climate change (NDRC 2007b 2). According to *China's National Assessment Report on Climate Change*, China has taken three actions to mitigate climate change: (1) Raise energy efficiency; (2) Develop renewable energy; and (3) Plant trees (Committee of China's National Assessment Report on Climate Change 2009, 341-345).

At the time of this report's publication, the most up to date publicly available GHG inventory data were from 1994, as reported in the People's Republic of China Initial National Communication on Climate Change to the UNFCCC (NCCC 2004). Categories of GHG emissions in the inventory include: energy sector, industrial processes, agriculture, land-use change and forestry, and waste. The inventory includes CO_2, CH_4, and nitrous oxide (N_2O). The provincial sectoral energy use data and China-specific combustion and emission factors are available in the annual Energy Statistical Yearbook. Data from more recent years (as well as the calculations made in this report) may be calculated using the IEA's Reference Approach, China-specific emission factors, 1994 energy use statistics by province and sector, and combustion factors.

China plans to support sustainable economic and social development with clean energy development and increased efficiency. China enacted regulations in 2005 to raise car fuel efficiency and to increase taxes on fuel and large vehicles. In the 11th Five-Year Plan (2006-2010), China set a target to reduce energy intensity by 20%, and to increase renewable energy to 10% of the overall supply (OECD 2007 298-299). The plan sets targets to reduce SO_2 emissions in each province. In the long term, China strives to reduce GDP carbon intensity by 3% every year, reaching a 40% reduction between 2000 and 2020 (Committee of China's National Assessment Report on Climate Change 2009, 418). These policies address climate change while fulfilling other national goals such as energy security and pollution control (OECD 2007 294).

Beijing has announced goals for climate change mitigation. For example, the 11th Five-Year Plan, ratified in 2006, aims to reduce energy consumption 20% per unit GDP by 2010. In the year 2006, however, it fell by only 1.23% – well below the annual goal of 4% (CSEP 2008). The 2007 General Work Plan for Energy Conservation and Pollutant Discharge Reduction[61] aims to reduce major pollutant discharge by 10% and cut energy consumption 20% per unit GDP by 2010. All companies and local governments have been asked to submit detailed plans for compliance. To implement this plan, the Chinese government will increase renewable energy generation, revise energy prices, create tax incentives for pollution-reduction projects, and revise export regulations on high-pollution products (NDRC 2007b).

China's sustainable economic growth depends on renewable energy and energy efficiency. China plans to develop 120,000 megawatts of renewable energy by the year 2020, which would require an investment of approximately RMB 800 billion (US$118 billion) (Aruvian Research 2009). This

---

[61] State Council Issuance No.15 (2007).

investment, heavily focused on hydropower, would account for 12% of China's total installed energy producing capacity.

4. *Summary Indicator Calculations and Results*

Although full GHG emissions data are available for 1994, for more recent metrics we were limited to carbon dioxide intensity and carbon dioxide emissions per capita. These are the only two up-to-date and systematically monitored parameters to measure climate change in China.

China EPI Climate Change Indicators

Policy Categories	Policy Category Codes	Indicators	Indicator Codes	Data Source	Target
Climate Change and Energy	CLIMATE	CO_2 Intensity	CO2INT	China Statistical Yearbook, 2004-2005	not available
		CO_2 emissions per capita	CO2PC	China Statistical Yearbook, 2004-2005	not available

CO2 emissions equivalents for both indicators are calculated using IPCC's sectoral approach methodology. For CO_2 intensity, CO_2 emissions equivalent is divided by the gross provincial product and is expressed in units of tons CO_2 equivalent/RMB 10,000. CO_2 is measured in tons CO_2 equivalent per person.

Data Quality and Representativeness

No information is available regarding collection methodology or aggregation. Data is available for all provinces for both indicators except Xi Zang. The most recent year available is 2005 for both indicators.

Correlations

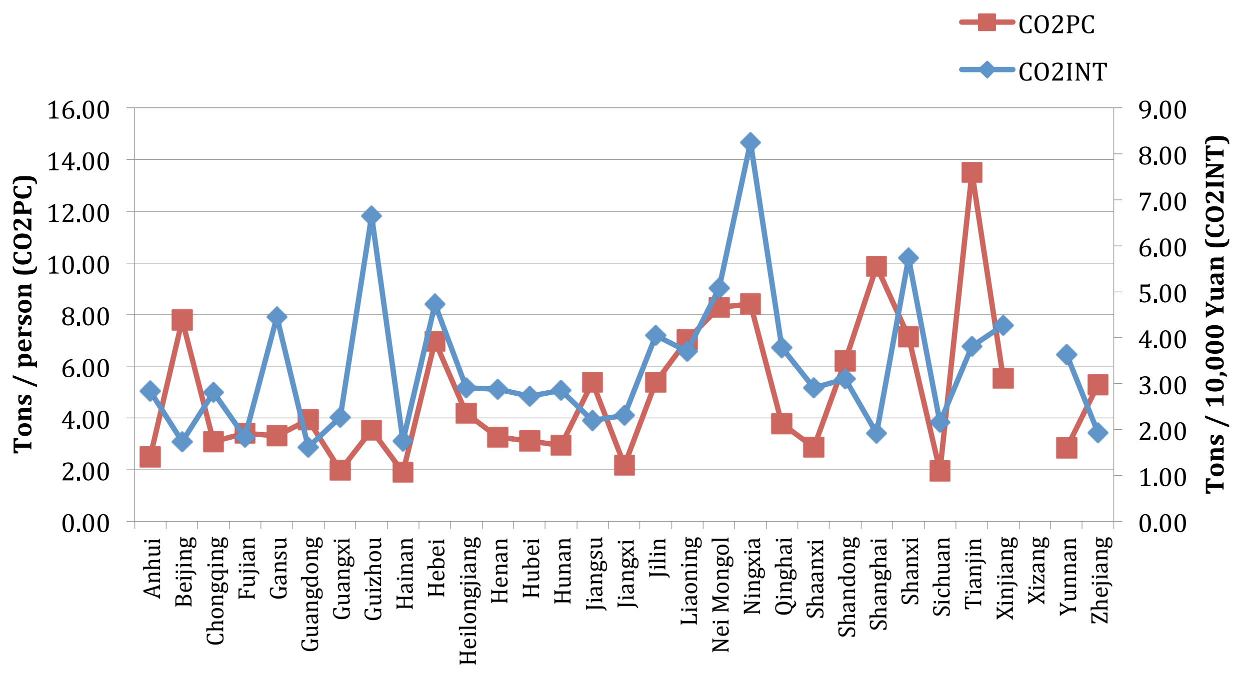
The Pearson coefficient calculated for the two climate change indicators show that CO2INT and CO2PC are moderately positively correlated (0.35).

	CO2INT	CO2PC
CO2INT	1	
CO2PC	0.35	1

Ranks and Trend Analysis

Figure 15 shows the CO2 emission. Left axis and right axis show the emissions per capita and per unit GDP, respectively.

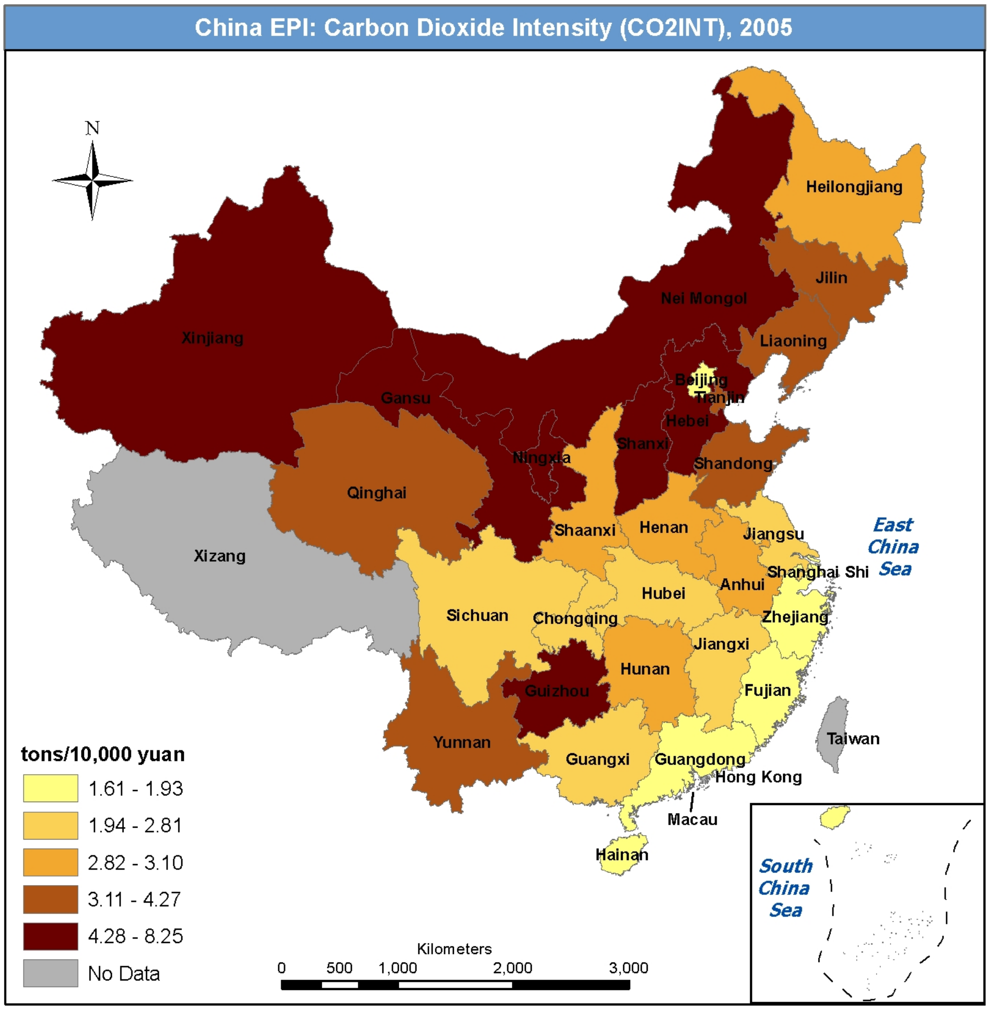
Figure 15. Carbon Dioxide Emissions

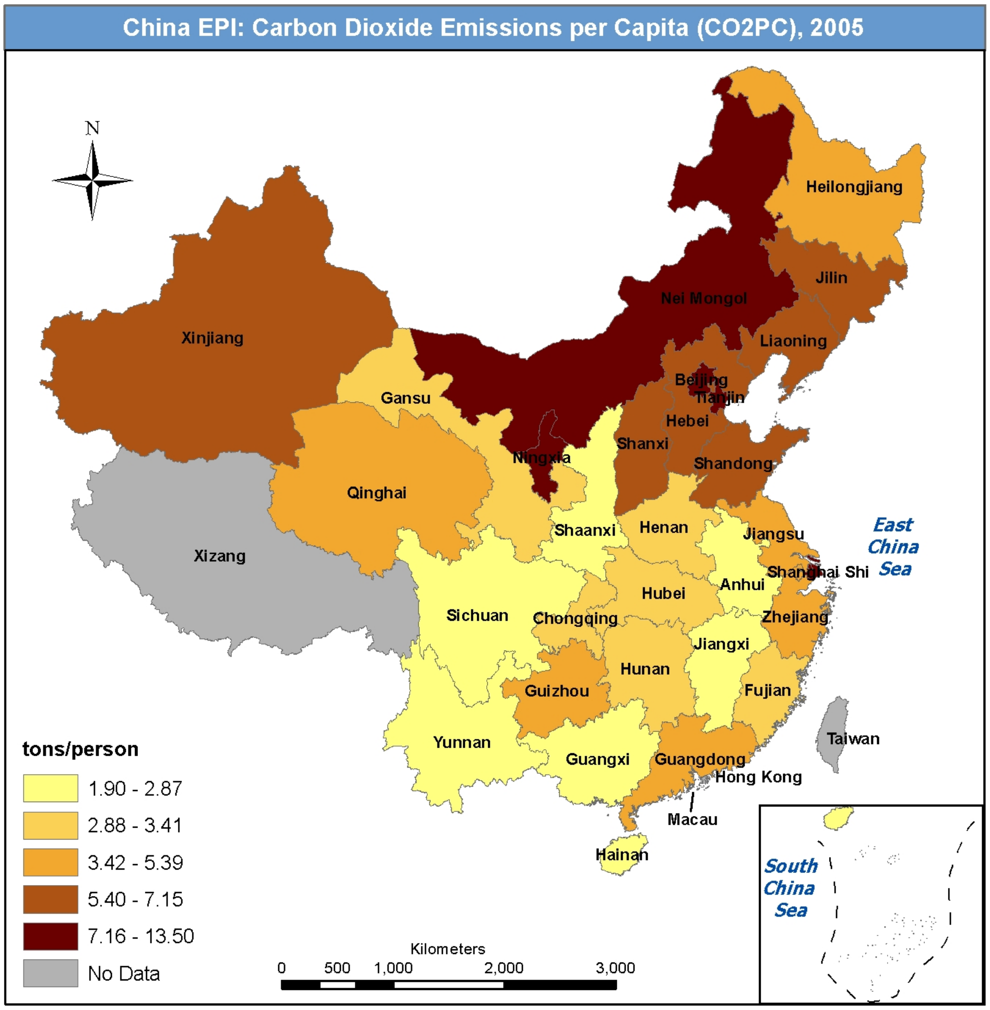


The following table shows all provinces ranked from the best to worst performer for each indicator. Both data are from 2005.

Rank	Province	CO2INT	Province	CO2PC
1	Guangdong	1.62	Hainan	1.90
2	Beijing	1.74	Sichuan	1.94
3	Hainan	1.75	Guangxi	1.98
4	Fujian	1.83	Jiangxi	2.18
5	Shanghai	1.92	Anhui	2.50
6	Zhejiang	1.93	Yunnan	2.84
7	Sichuan	2.16	Shaanxi	2.87
8	Jiangsu	2.20	Hunan	2.93
9	Guangxi	2.27	Chongqing	3.08
10	Jiangxi	2.31	Hubei	3.11
11	Hubei	2.72	Henan	3.25
12	Chongqing	2.81	Gansu	3.32
13	Anhui	2.84	Fujian	3.41
14	Hunan	2.84	Guizhou	3.53
15	Henan	2.88	Qinghai	3.79
16	Shaanxi	2.90	Guangdong	3.93
17	Heilongjiang	2.90	Heilongjiang	4.19
18	Shandong	3.10	Zhejiang	5.29
19	Yunnan	3.63	Jiangsu	5.39
20	Liaoning	3.70	Jilin	5.39
21	Qinghai	3.78	Xinjiang	5.54
22	Tianjin	3.81	Shandong	6.22
23	Jilin	4.04	Hebei	6.98
24	Xinjiang	4.27	Liaoning	7.01
25	Gansu	4.45	Shanxi	7.15
26	Hebei	4.73	Beijing	7.78
27	Nei Mongol	5.08	Nei Mongol	8.29
28	Shanxi	5.73	Ningxia	8.40
29	Guizhou	6.65	Shanghai	9.87
30	Ningxia	8.25	Tianjin	13.50

The following maps depict the indicator scores by province. The maps depict the best performers in yellow and the worst performers in dark brown. Northern provinces tend to have higher emissions per unit GDP and per capita, perhaps owing to colder climates and more antiquated industries.


China EPI: Carbon Dioxide Intensity (CO2INT), 2005


China EPI: Carbon Dioxide Emissions per Capita (CO2PC), 2005

B. Resource Efficiency

1. Introduction

Natural resources – metals, minerals, energy, food, water, wood, and land – are fundamental ingredients of economic development. Natural resource use has risen worldwide due to demands from industrialized and rapidly industrializing economies. This has led to calls for more efficient resource use in industrial processes and among consumers, where the three Rs of "reduce, reuse, and recycle" have been widely promoted.

Efficient resource use implies reducing waste, and this benefits the economy, society and environment in several ways:

- By reducing the rate of exploitation and the productivity of natural resource stocks;
- By reducing the environmental pressures associated with the extraction, processing, use, and disposal of natural resources;
- By reducing costs and stabilizing the market prices of raw materials and manufactured goods;
- By stimulating recycling of valuable materials and reducing the volume of waste material and the area required for disposal;
- By reducing dependence on foreign sources of raw materials;
- By providing employment opportunities and environmental quality for host communities; and
- By increasing the productivity and competitiveness of the national economy.

Many resources in China are scarce and are not utilized efficiently. For example, China's sustainable development has been constrained by scarce water resources per capita, uneven distribution of water resources, and low water-use efficiency. In 2005 the agricultural sector accounted for a large but declining proportion of total use (65%), while industrial and domestic use account for 23% and 12%, respectively (FAO 2010). The water infrastructure in rural China is antiquated, and irrigation technology lags behind modern techniques. Irrigation efficiency, the percentage of water consumed by crops on irrigated land, is only about 45% in China (ibid.). These rates are typical of a traditional gravity-driven irrigation systems. Yet efficiency rates of around 70% are possible with sprinkler irrigation systems and up to 90% with drip irrigation systems (Seckler 1996). There is tremendous potential for increasing irrigation efficiency in China. According to the 11th Five-Year Plan (2006-2010), the country aims to raise the effective irrigation coefficient (i.e., the amount of irrigated water consumed by crops relative to the total amount of irrigated water in the irrigation system) to 0.5 (Lu 2006). With China's growing population and its increasing demand for meat, vegetables, and other non-cereal crops, the country will need to produce more food while still meeting efficiency and use reduction targets (Hubacek and Sun 2005).

Industry is the second largest water-use sector, and the volume of water-use is increasing rapidly (ibid.). In the 11th Five-Year Plan (2006-2010), China introduced more stringent regulation for new projects that will put high demands on water resources, especially in water-scarce regions (NDRC 2009). Additionally, the government instituted a fixed maximum amount of water withdrawal so as not to out-strip supplies.

Solid waste refers to the solid or semi-solid materials that are discharged during production, construction, daily life, and other activities. Solid waste sometimes also refers to liquid waste (not including wastewater discharged into a water body) and gaseous waste (not including those discharged into the atmosphere), both of which are regulated by China's Solid Waste Pollution Prevention Law. Although solid waste disposal sites occupy large amounts of land and pollute the environment, the so-called "waste" may also contain useful materials. China's generation of solid waste has grown with its economy. However, waste discharge in China has fallen, and there have been improvements in comprehensive utilization,[62] where usable materials are extracted from solid wastes and reclaimed, processed, recycled, and exchanged (NDRC 2009). In 2006, the national industrial solid waste production was 1.52 billion tons, a 13.1% increase from the previous year (ibid). In contrast, over the same time period industrial solid waste discharge decreased 21.3% from 2005 to 2006, to 13.03 million tons (ibid). The overall amount of industrial solid waste comprehensive utilization was 0.926 billion tons (ibid).

Recycling and safely reusing industrial waste will aid China's sustainable development. The Circular Economy Promotion Law[63] took effect on January 1, 2009. "Reduce, reuse, and recycle" represent the main components of the circular economy, and the Law was designed accordingly. It seeks to promote a circular (sustainable) economy, raise China's resources utilization rate, protect the environment and realize sustained development. In recent years, all levels of governments have made progress in developing a circular economy by adjusting economic structures, changing development paths, and achieving energy savings and emissions reductions. In 2006, the recycling rate for industrial solid waste was 56%, but leaders would like to increase it to 60% by the end of 2010 (Lu 2006).

2. *Ideal and International Best Practices for Measurement*

The United Nations (UN) Commission on Sustainable Development published the third edition of "Indicators of Sustainable Development" in 2007. The framework is used for national level assessment and contains a core set of 50 indicators, out of a larger set of 96 sustainable development indicators. The core set contains 14 themes in economic, social, and environmental dimensions. One theme related to sustainable resource utilization focuses on consumption and production patterns. The UN divides this theme into four sub-themes, including material consumption, energy use, waste generation and management, and transportation. The themes and indicators are shown in Table 5 (United Nations 2007).

Table 5. Subthemes and Indicators in the Consumption and Production Patterns Theme

Theme	Sub theme	Core Indicator	Other Indicators
Consumption and production patterns	Material Consumption	Material intensity of the economy	Domestic material consumption
	Energy Use	Annual energy consumption, total and by main user category	Share of renewable energy sources in total energy use
		Intensity of energy use, total and by economic activity	
	Waste generation and management	Generation of hazardous waste	Generation of waste
		Waste treatment and disposal	Management of radioactive waste
	Transportation	Modal split of passenger transportation	Modal split of freight transport
			Energy intensity of transport

Source: (United Nations 2007)

---

[62] Rate of Comprehensive Utilization of Industrial Solid Wastes refers to the percentage of industrial solid wastes utilized over industrial solid wastes produced (including stocks of the previous years).

[63] Circular Economy Promotion Law (循环经济促进法), adopted by the Standing Committee of the 11th National People's Congress on August 29, 2008.

Among the 12 indicators suggested in the Consumption and Production Patterns theme, four are eco-efficiency indicators.

- Material intensity of the economy

This indicator is defined as the ratio of Domestic Material Consumption (DMC) to Gross Domestic Product (GDP) at constant prices. DMC is the total weight of materials directly used in the economy (domestic extraction plus imports) minus the materials that are exported. Material intensity data help to guide policymakers in decoupling the growth of the economy from the use of natural resources and in reducing environmental degradation from primary production, material processing, manufacturing, and waste disposal.

- Intensity of energy use, total and by economic activity

This indicator is defined as energy use of the economy (in total and of main sectors) divided by GDP (or value added when measuring a specific sector). Declining trends in overall energy use relative to GDP (or value added) indicate that the economy is able to improve its energy efficiency and, hence, to decouple economic growth from energy consumption.

- Waste treatment and disposal

This indicator is defined as percentage of waste that is recycled, composted, incinerated, and placed in landfills on a controlled site. It indicates the environmental impact of waste management. When more waste is recycled and composted, the demand for raw materials—and thus for resource extraction—is reduced.

- Energy intensity of transport

This indicator is defined as fuel used per unit of freight-kilometer (km) hauled and per unit of passenger-km traveled by mode. It measures how much energy is used to move both goods and people.

European Union

The European parliament and council adopted the Sixth Environmental Action Programme (EAP) in 2002, which addresses resource use policy (European Union 2005a). The EAP established an environmental protection plan for 2002 to 2012 and identified four priority areas: climate change, nature and biodiversity, environmental health, and natural resources and waste. Promoting an integrated approach, the European Commission further proposed seven thematic strategies to strengthen environmental policymaking in 2005. Natural resources and waste prevention and recycling are the two strategies that emphasize sustainable resource utilization.

The natural resources strategy stresses the important role of natural resources in human economies, and it aims to reduce negative environmental impacts from natural resource use in growing economies. The EU created new initiatives to achieve these policy goals. The first step is to gather information about resource use and its environmental impact by building a data center that provides quantitative knowledge to decision-makers. The strategy recommends developing a set of indicators to measure resource efficiency and productivity. To implement relevant policies, the strategy proposes that each EU member state develop national measures and programs for sustainable resource use. Further, the strategy suggests forming an international panel on the sustainable use of natural resources, in cooperation with UNEP and other international organizations (European Union 2005a).

Following publication of the resource strategy, the EU released a "basket" of four recommended indicators that combine to monitor resource use in 2008: Ecological Footprint (EF), Environmentally Weighted Material Consumption (EMC), Human Appropriation of Net Primary Production (HANPP), and Land and Ecosystem Accounts (LEAC). EF and EMC were found to be the most applicable to resource consumption, with EF examining resource use compared to a country's biocapacity and EMC comparing the long-term energy and resource costs of various materials using Lifecycle Analysis (LCA). While these indicators have no specific targets, the structure of EF allows a country to set a target whereby resource use (Footprint) is held within the bounds determined by national biocapacity. For the other indicators, policymakers must set relevant targets. The study notes that these indicators should be applied with other sustainability indicators, particularly the EU's Sustainable Development Indicators (SDIs) (Best et al. 2008).

A strategy to prevent and recycle waste, put forward in 2005, also addresses the negative environmental impact of resource use. The strategy focuses on simplification and modernization of the existing legal framework to improve regulation and promotes LCA to manage waste policy (European Union 2005b).

United States

In the United States, government agencies have given little attention to research regarding material flows and resource efficiency. Although some preliminary material accounts have been established, there is no initiative to perform systematic data collection and policy analysis on material flow accounting. Lacking these data, the US has not set up any significant material use policies or national targets for improving resource efficiency (Rogich, Cassara et al. 2008).

The World Resource Institute (WRI), however, has performed a series of material flow accounting (MFA) studies. In its latest report, focusing on US material flow from 1975 to 2000, the WRI defines the process of material flow accounting for a national economy and uses it to trace US extraction, production, use, recycling, and disposal of major commodities. The results show that the total material consumption increased 57% between 1975 and 2000, while per capita consumption increased by 23%. Despite the increase in total consumption, the U.S.'s resource efficiency per GDP continues to rise due to its general dematerialization trend (Ibid). Compared to that of other countries, the U.S.'s per capita materials consumption is still high—about 50% higher than the EU average (ibid). EU countries, unlike the U.S., have shown an absolute reduction in long-term per capita consumption (ibid).

Japan

Japan is the third largest economy in the world, despite its limited land and material resources. To overcome these limitations, Japan has promoted sustainable development and the establishment of a Sound Material-Cycle (SMC) society since the late 1990s. The Fundamental Law for Establishing a SMC Society was enacted in 2000, and its revised version, known as the Second Fundamental Plan, was approved by the Cabinet in 2008 (Takiguchi and Takemoto 2008).

To quantitatively evaluate progress in the development of a SMC Society, the Second Fundamental Plan sets targets for three material flow indicators: resource productivity (GDP/ natural resources input), cyclical use rate (amount of reuse and recycled material/total material input), and final disposal amount (amount of final waste disposed). These indicators are referred to as the "inlet," "cycle," and "outlet" aspects, respectively, of Japan's nationwide material flow. The targets are legally binding, based on the legal framework of the Fundamental Law and the Fundamental Plan. However, so far the Japanese government has not instituted penalties for noncompliance. Targets call for significant improvements in inlet, cycle, and outlet by 2015 (60% above, 80% above, and 80% below 1990 levels, respectively) (ibid.)

In addition to the above three indicators, Japan added two supplementary indicators. The input of non-metallic mineral resources has a large impact on the total natural resources input; thus, Japan began tracking resource productivity excluding the input of earth and rock resources. The target for this new indicator is about ￥770,000 per ton in FY 2015, a 30% decrease from the approximately ￥590,000 per ton FY 2000 rate. Japan also added an indicator for CO_2 emissions in coordination with climate change mitigation. The CO_2 target is a 7.8 million ton reduction in waste sector CO_2 emissions by FY 2010 (ibid.).

3. China's Measurement Practices

Technical standards and guidelines

Energy use efficiency

China has made increasing energy efficiency a priority. In the 11th Five-Year Plan (2006-2010), China set a target to reduce energy intensity by 20%, and to increase renewable energy to 10% of the overall supply (OECD 2007 298-299). Energy is discussed in the climate change policy category in the China EPI framework and not included in Resource Efficiency.

Water use efficiency

China has enacted a series of water laws and regulations, including the Water Law of the People's Republic of China, the Water Pollution Prevention and Control Law, the Soil and Water Conservation Law, the Flood Prevention Law, and the Water Abstraction Licensing measures, in order to establish a water management system. In 2007, the National Development and Reform

Commission (NDRC), Ministry of Water Resources, and Ministry of Housing and Rural-Urban Development (MOHURD) jointly promulgated the 11th Five-Year Plan (FYP) for Constructing a Water-saving Society to establish goals for the 11th FYP period (2006-2010). Chen Lei, the Minister of Water Resources, recently announced that China will implement the "most stringent" water resource management system, which will control watersheds and regions, rural and urban development, and conservation (Chen 2009).

Solid Waste

China has established laws and regulations for solid waste management. For example, the national-level Law on the Prevention and Control of Environmental Pollution by Solid Waste was enacted in October 1995 (and amended in 2004) to manage the cradle-to-grave system of waste prevention and treatment. This law assigns the responsibility of handling hazardous waste disposal to the original producer of the material. Additionally, there are numerous national laws regulating the import of solid and hazardous waste to support China's signatory status on the Basel Convention. China also employs a registration, declaration, and manifest tracking system (similar to RCRA in the United States) for producers and disposers of hazardous waste, regulated under a variety of national laws and standards. Tight design and construction standards exist for hazardous waste disposal facilities (Jialing 2007).

Many provinces and cities have enacted local regulations and standards complementary to the national laws. For example, Guangdong Province monitors hazardous waste and sets up detailed procedures for waste processing.[64] Zhejiang Province has established concrete environmental standards for electronic waste, from production and collection to dismantling and recycling, which fills a gap in solid waste management.[65]

4. Summary Indicator Calculations and Results

China EPI Resource Efficiency Indicators

Although the Global EPI does not assign a specific policy category for "resource efficiency" (or sustainable resource use), this category has special policy importance to China due to its limited resources. Rapid economic growth will only serve to increase tension between socioeconomic development and the sustainable use of resources. Consequently, China has put greater emphasis on resource efficiency, an important tool to achieve China's goal of a "conservation society." Moreover, the 11th Five-Year Plan has made resource efficiency one of the major goals in socioeconomic development. The importance of Resource Efficiency to China's environmental policy warrants its inclusion in the China EPI.

In terms of water resources, China confronts not only water scarcity but also low water-use efficiency. The 11th Five-Year Plan for a Water-saving Society establishes goals to lower water use per GDP by 20% between 2005 and 2010, and to reduce water use per RMB 10,000 of industrial

---

[64] Solid Waste Pollution Prevention Standard of Guangdong

[65] Provisions on Environmental Pollution Prevention for Solid Waste in Zhejiang

value-added to 115 cubic meter, a 30% decrease from 2005. In addition, the 11th FYP aims to improve the effective irrigation coefficient, urban water distribution system leaking rate, and urban water recycling rate. The FYP proposed eight safeguard measures to meet these goals (NDRC, MWR et al. 2007).

The 11th FYP for environmental protection promoted solid waste pollution control, particularly recycling and proper disposal of industrial waste. It encouraged comprehensive use of major industrial solid waste, aiming at a 60% comprehensive utilization rate by 2010 (MEP 2006).

Resources normally include energy, materials, and water. Energy efficiency, however, is included in the Climate Change and Energy category, so we include only one energy related indicator here. There are no statistics regarding the material throughputs in the Chinese economy. We include two indicators on water efficiency, and one indicator on the efficient use of industrial waste, which is a measure of recycling. An allied measure, quantity of industrial waste impounded, disposed of, and discharged per IVA was included in the Waste and Sanitation.

According to China's current resource use and our analysis of relevant policies and goals, the China EPI proposes the following ideal indicators:

- Water resource: water use per GDP, water use per industrial value-added, industrial water recycling rate, urban water recycling rate, effective irrigation rate
- Solid Waste: industrial solid waste comprehensive utilization rate, recycling rate for renewable resources (steel, nonferrous metals, paper, glass, plastics, rubber)

Given the data availability and environmental policymaking needs, the China EPI includes the following indicators.

Policy Categories	Policy Category Codes	Indicators	Indicator Codes	Data Source	Target
Resource Efficiency	RESOURCE	Economic energy efficiency	EFFEC	China Statistical Yearbook, 2002-2007	Varies by province, 12-30%
		Efficient use of waste	EFFFWASTE	China Statistical Yearbook, 1995-2007	60% by 2010
		Efficient use of water in agriculture	EFFWATag	China Statistical Yearbook, 2002-2007	30% year reduction
		Efficient use of water in industry	EFFWATind	China Statistical Yearbook, 2002-2007	30% year reduction

Economic energy efficiency (EFFEC) is the ratio of total domestic energy consumption to provincial GDP. Total domestic energy consumption refers to the total consumption of energy of various kinds by material production sectors, non material production sectors and households in the country in a given period of time. It is a comprehensive indicator to show the scale, composition and development of energy consumption (see indicator profile sheet for more details) (NBS 2002). Efficient use of waste (EFFWASTE) is measured as a percentage of industrial solid wastes that are recycled (or otherwise utilized). All of the water efficiency indicators (EFFWATxx) are measured in units of cubic meters/RMB 10,000 and consist of the ratio of water used in that sector to the gross regional product.

Data Quality and Representativeness

Resource Efficiency has become one of the policy priorities in recent years. For economic energy efficiency (EFFEC), extensive information is available on how the indicator is calculated but not on how the numerator (energy consumption) is measured, although it is clear which categories of energy consumption are measured. It is unclear if the measurement is in kWh or some other unit or if it includes only official, metered energy sources or contains estimates for informal uses of energy. No information is available regarding measurement, aggregation, or local representativeness for efficient use of waste (EFFWASTE) and the two efficient use of water (EFFWATag and EFWATind) indicators. The most recent year available for all indicators is 2007 and there is good coverage at the provincial level. Data for EFFWATag and EFFWATind are available for all provinces. For EFFEC, the only missing data is for Xinjiang. For EFFWASTE, the only missing data is for Xizang.

Correlations

	EFFEC	EFFWASTE	EFFWATag	EFFWATind
EFFEC	1			
EFFWASTE	-0.67	1		
EFFWATag	0.65	-0.39	1	
EFFWATind	-0.06	-0.04	-0.15	1

The four Resource Efficiency indicators have relatively strong correlations with each other, except EFFWATind, which only slightly correlated with the other four indicators. It is also interesting to note that EFFEC has strong correlation with EFFWASTE and EFFWATag..

Ranks and Trend Analysis

Figure 16 below shows the economic energy efficiency and the percentage of industrial solid waste recycled or utilized for all provinces.

Figure 16. Waste and Energy Efficiency

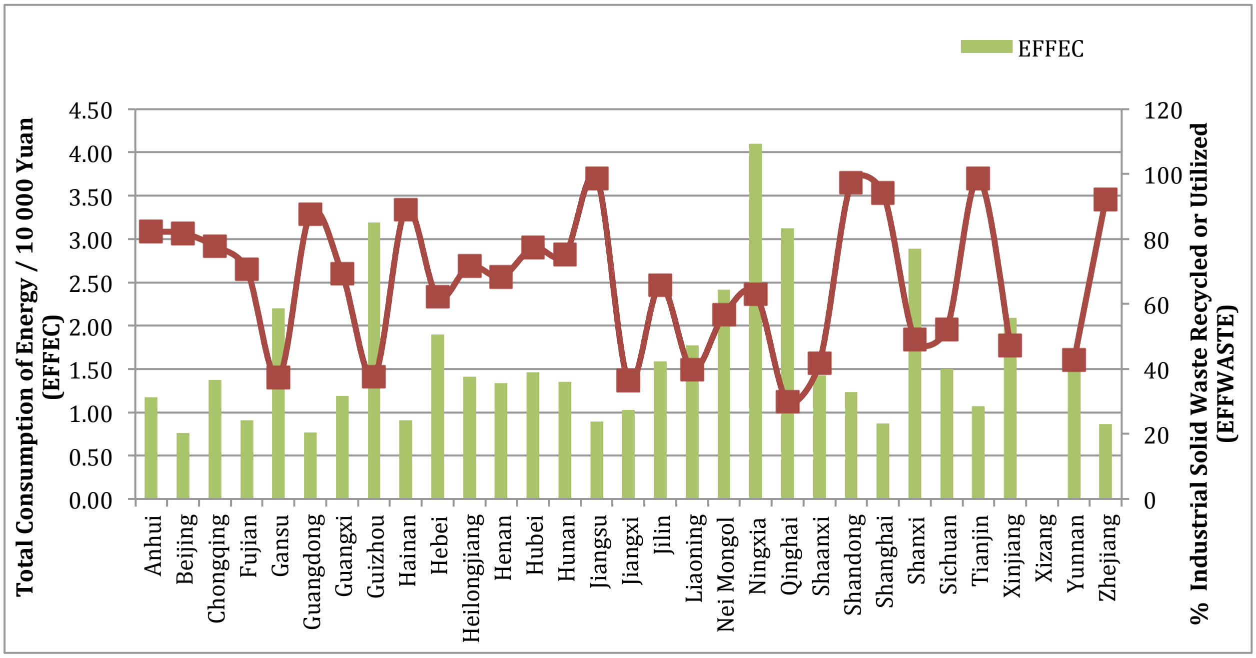
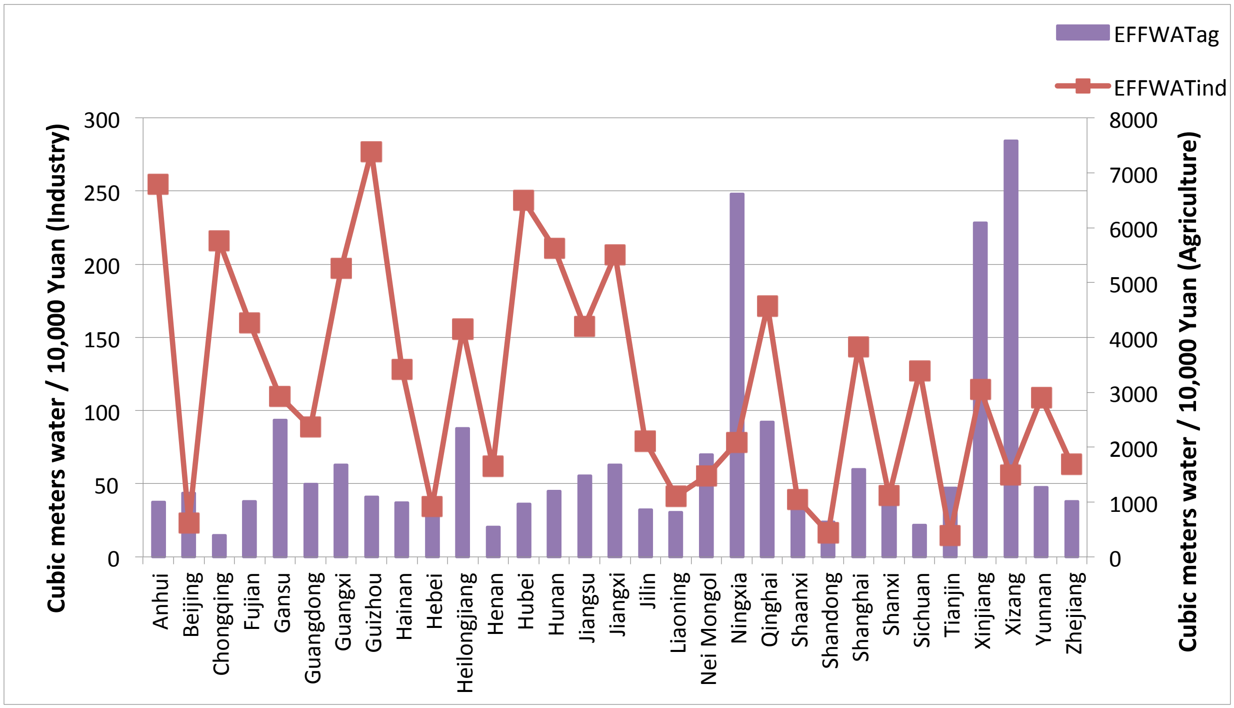


Figure 17 show all provinces water use efficiency, divided by industrial use and agricultural use.

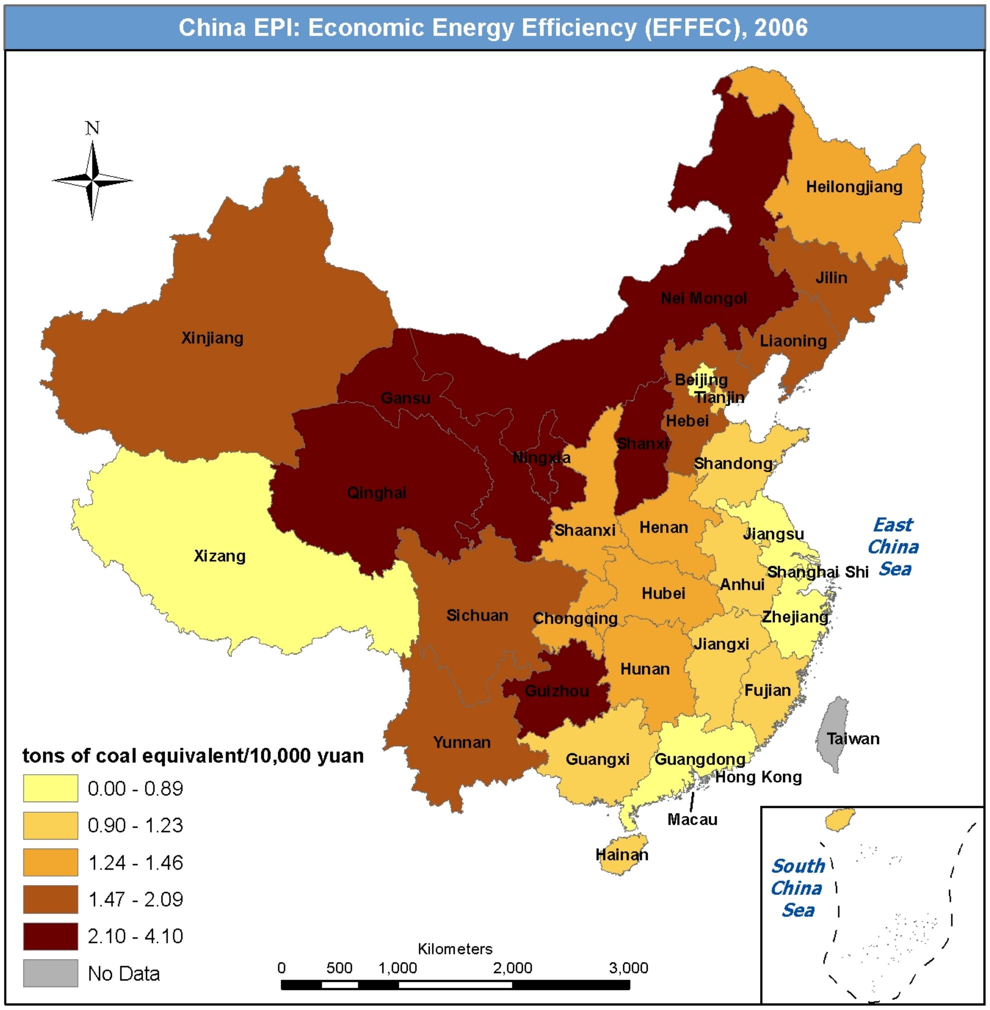
Figure 17. Water Use Efficiency



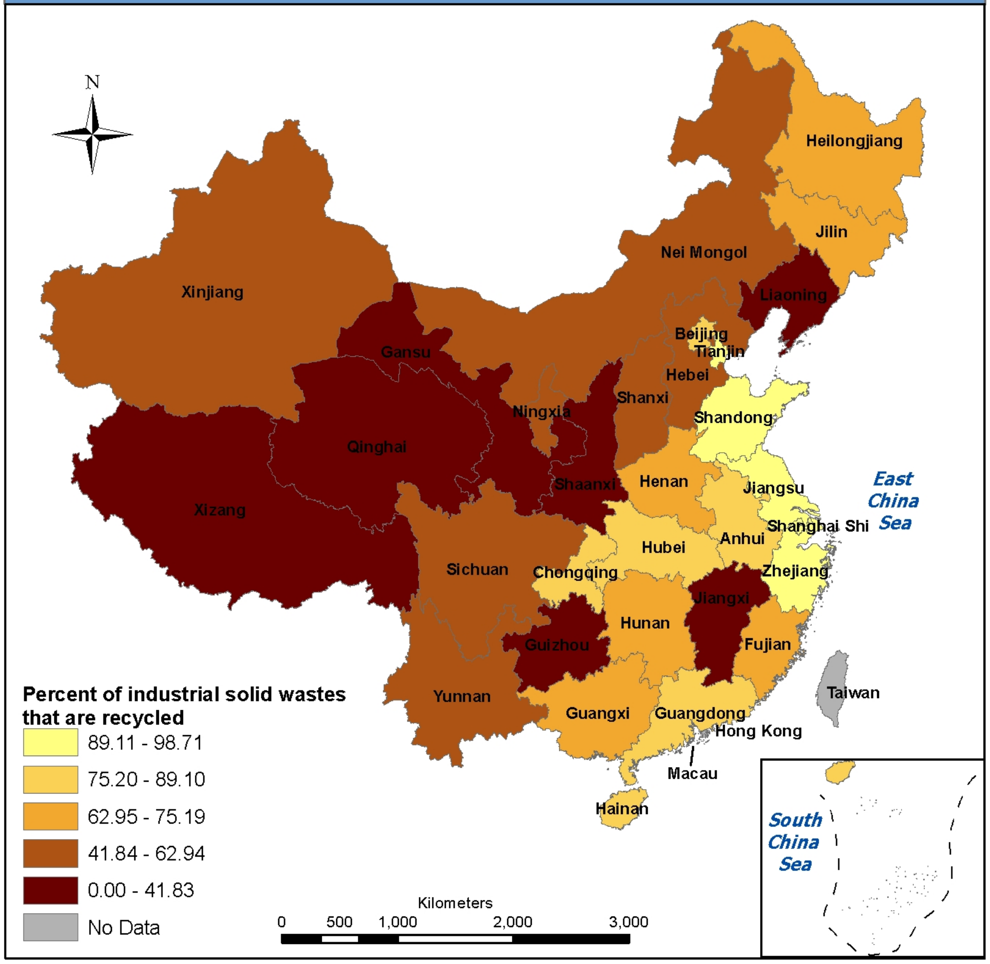
The following table shows all waste utilization indicators. Economic energy efficiency (EFFEC) data are from 2006, the other data sets are from 2007. Provinces are ranked from best to worst performing.

Rank	Province	EFFEC	Province	EFFWASTE	Province	EFFWATag	Province	EFFWATind
1	Beijing	0.76	Jiangsu	98.71	Chongqing	388.68	Tianjin	14.52
2	Guangdong	0.77	Tianjin	98.63	Henan	541.42	Shandong	16.32
3	Zhejiang	0.86	Shandong	97.32	Sichuan	584.20	Beijing	22.90
4	Shanghai	0.87	Shanghai	94.21	Shandong	636.52	Hebei	34.48
5	Jiangsu	0.89	Zhejiang	92.26	Liaoning	808.81	Shaanxi	39.37
6	Fujian	0.91	Hainan	89.10	Hebei	839.96	Liaoning	41.60
7	Hainan	0.91	Guangdong	87.70	Jilin	861.57	Shanxi	41.99
8	Jiangxi	1.02	Anhui	82.35	Shaanxi	936.61	Nei Mongol	55.31
9	Tianjin	1.07	Beijing	81.74	Hubei	962.59	Xizang	56.02
10	Anhui	1.17	Chongqing	77.79	Hainan	992.65	Henan	61.93
11	Guangxi	1.19	Hubei	77.31	Anhui	1004.52	Zhejiang	63.23
12	Shandong	1.23	Hunan	75.19	Fujian	1007.27	Ningxia	77.97
13	Henan	1.34	Heilongjiang	71.71	Zhejiang	1016.41	Jilin	78.85
14	Hunan	1.35	Fujian	70.64	Guizhou	1091.55	Guangdong	88.51
15	Chongqing	1.37	Guangxi	69.38	Beijing	1158.80	Yunnan	108.86
16	Heilongjiang	1.41	Henan	68.34	Hunan	1192.08	Gansu	109.64
17	Shaanxi	1.43	Jilin	65.75	Tianjin	1256.01	Xinjiang	114.36
18	Hubei	1.46	Ningxia	62.94	Yunnan	1265.24	Sichuan	127.08
19	Sichuan	1.50	Hebei	62.21	Shanxi	1272.57	Hainan	128.15
20	Jilin	1.59	Nei Mongol	56.73	Guangdong	1326.04	Shanghai	143.25
21	Yunnan	1.71	Sichuan	52.29	Jiangsu	1478.40	Heilongjiang	155.70
22	Liaoning	1.78	Shanxi	49.09	Shanghai	1591.92	Jiangsu	157.45
23	Hebei	1.90	Xinjiang	47.29	Jiangxi	1670.97	Fujian	159.95
24	Xinjiang	2.09	Yunnan	42.78	Guangxi	1678.78	Qinghai	171.56
25	Gansu	2.20	Shaanxi	41.83	Nei Mongol	1860.27	Guangxi	197.09
26	Nei Mongol	2.41	Liaoning	39.82	Heilongjiang	2346.02	Jiangxi	206.28
27	Shanxi	2.89	Guizhou	37.60	Qinghai	2454.35	Hunan	210.76
28	Qinghai	3.12	Gansu	37.36	Gansu	2488.66	Chongqing	216.24
29	Guizhou	3.19	Jiangxi	36.40	Xinjiang	6090.00	Hubei	243.58
30	Ningxia	4.10	Qinghai	29.88	Ningxia	6614.98	Anhui	254.81
31					Xizang	7583.18	Guizhou	276.87

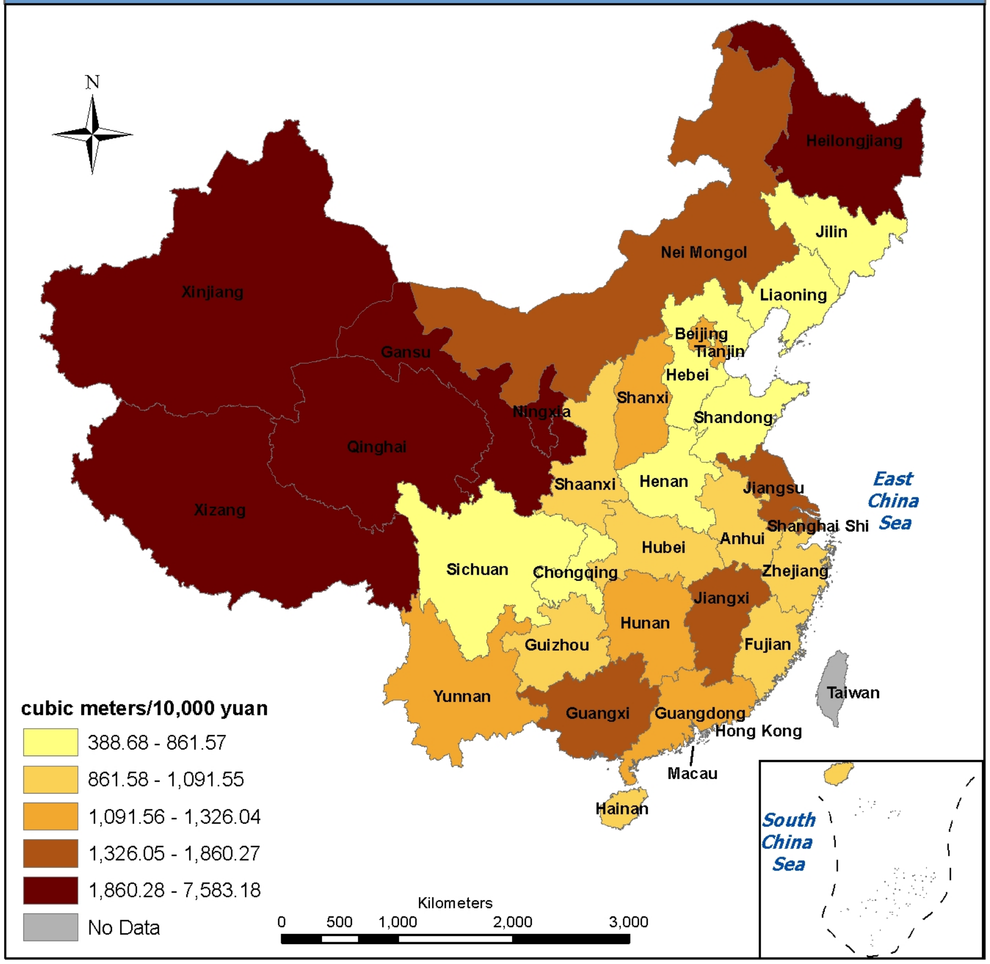
The following maps depict the indicator scores by province. The maps depict the best performers in yellow and the worst performers in dark brown.



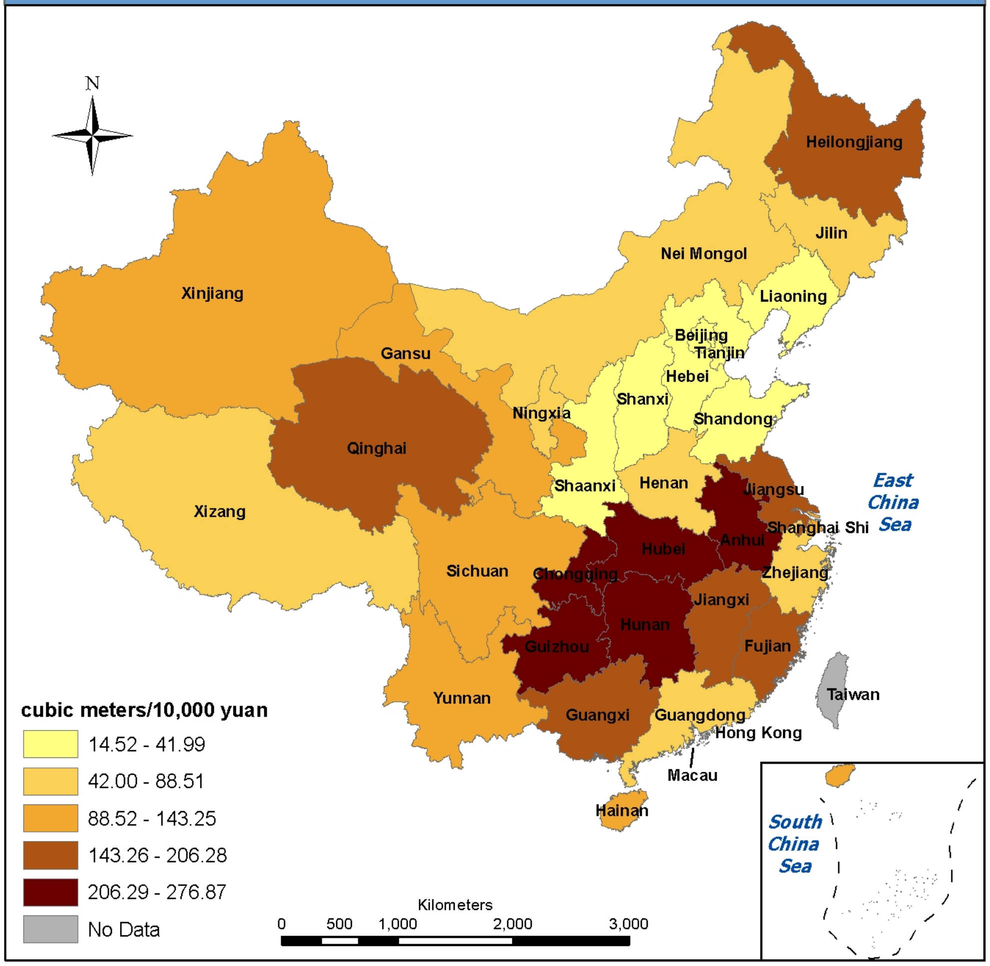
China EPI: Efficient Use of Waste (EFFWASTE), 2007



China EPI: Efficient Use of Water in Agriculture (EFFWATag), 2007



China EPI: Efficient Use of Water in Industry (EFFWATind), 2007



Environmental Governance

1. Introduction

Environmental governance is the process nations use to control pollution, conserve nature, and manage natural resources (Xue et al. 2006). Policymakers employ federal regulation, market incentives, voluntary programs, grants, and education to achieve these goals (Kato 2000). In China, government mandates have driven environmental regulation for the past few decades. But today's complex and global environmental issues overwhelm even the best-prepared agencies. Adequate response to these challenges requires governments to embrace transparent policies, access to environmental monitoring data, and global partnerships on an unprecedented scale.

Often when the policy process involves public input, regulations are stronger, implementation is more successful, and people understand policy goals more clearly (López and Mitra 2000). Reflecting this view of environmental governance, ideal indicators would measure government performance and the interactions between government and society. Unfortunately, there are insufficient data in China to monitor this relationship. Given data limitations, this pilot study attempts to measure the outcome-based environmental performance of provincial governments.

2. Ideal and International Best Practices for Measurement

While it may seem as though a strong central government will have the most ability to affect environmental protection by dictating legislation from above, research has shown that top-down legislation is not sufficient to meet environmental goals. Successful environmental governance includes stringent legislation, a regular process to evaluate and improve policy, consistent long-term funding, and public involvement (Xue et al. 2006). Environmental governance does need strong leadership from heads of state and central environmental agencies because these people can advance legislation, lift bureaucratic roadblocks, and generate political support. However, sound governance also involves major civic sectors, government, markets, and civilians because each sector engages actors who operate under unique rules and incentives (ibid.).

Recent cross-country studies suggest that corrupt governments often preside over nations with poor environmental health (López et al. 2000 ; Welsch 2004 ; Dasgupta, Hamilton et al. 2006). These studies use Transparency International's Aggregated Governance Index to measure the degree to which countries exploit public power for personal gain (ibid.). While the index measures governance in a general sense, the authors establish a strong correlation between corruption and pollution. They are quick to acknowledge that corrupt governments harm many aspects of society beyond the environment. While these studies, together with the global 2010 Environmental Performance Index, show a strong negative relationship between levels of corruption and environmental results, among governments with strong institutions and responsive governments, the relationship between governance and the environment is less strong.

Some recent studies have examined the impact of treaties on environmental outcomes. For example, Schofer and Hironaka (2005) studied the effects of global environmental governance on carbon dioxide (CO_2) and chlorofluorocarbon (CFC) emissions. They suggest that effective international treaties engage national, provincial, and local governments for at least five years. By contrast, ineffective agreements often involve some degree of "decoupling" of rhetoric and action whereby national commitments are made and some governance structures put in place but actions and motivations at lower administrative levels remain weak, with the result that goals are not achieved. The influence of general societal pressure at all levels of government and institutions (from international to individual) brings about a gradual "drift" of change in the direction of greater environmental protection. This desirable drift will happen fastest in those nations that are "highly penetrated by the world environmental regime" (p.32). The authors found that the Montreal Protocol, which regulates CFC emissions, successfully met emission reductions targets in most nations due to the multi-level engagement of stakeholders: industry found substitutes for CFCs, consumers refused to purchase CFC aerosol cans, governments signed on to a strict treaty and enforced sanctions for noncompliance, and the media displayed scientific data and imagery of the ozone hole (ibid.).

In China, the national government tends to impose laws and policies at the local level. Regarding environmental protection, evidence suggests that local governments prioritize development over environment, decoupled from environmental mandates from Beijing (Esty, Levy et al. 2008). Since the 1972 United Nations Conference on the Human Environment first provided impetus for environmental management in China, the Chinese government has gradually adopted legal, institutional, and administrative measures to advance environmental governance.

3. China's Measurement Practices

Technical standards and guidelines

China's environmental governance structure changed several times between 1970 and 2008. The preparations for the 1972 United Nations Conference on the Human Environment gave the first impetus for environmental management within the Chinese government. The first national conversation on environmental protection began in 1973 at the National Conference on Human Environment, as a follow-up to the UN meeting. Subsequently, officials in the State Council analyzed the environmental consequences of economic development. This work resulted in a 1974 report, *Key Points in Environmental Protection* which took nearly 20 years to implement (OECD 2005a 40-51).

China enacted its first Environmental Protection Law (for Trial Implementation) in 1979. The "trial" status changed in 1989 when China introduced the Environmental Protection Law[66] providing critical legislative basis for environmental enforcement.

In addition to these legislative efforts, the State Council established the Environmental Protection Bureau in 1974, with a 20-person staff. As the first environmental body in the central government, the Bureau concentrated on national environmental planning and had no authority over provincial

---

[66] Environmental Protection Law (环境保护法), adopted by the Standing Committee of the 7th National People's Congress on December 26, 1989

management. In 1982, three years after the trial environmental law came into effect, the State Council incorporated the Environmental Protection Bureau into the Ministry of Urban and Rural Construction and Environmental Protection. The Bureau gradually increased the number of staff during this period (OECD 2005a).

Subsequent reorganizations in 1984 and 1988 elevated the status of the environmental bureau to a separate office. Its staff size doubled from 60 to 120 persons, and it had dual subordination: to the Ministry of Construction and the State Council's Environmental Protection Commission. The new structure enhanced coordination among China's environmental regulatory bodies. Eventually, the Bureau emerged from the Ministry of Construction and became the National Environmental Protection Agency. With this change, the State Council increased the administration's authority, added 200 staff-members (from 120 to 320), and identified environmental protection as an emerging priority. As a mainline ministry, the National Environmental Protection Agency had direct links to the State Council (ibid.).

Environmental issues received increased attention during the early 1990s. In March 1991, then-Premier of the State Council Li Peng told the National People's Congress that environmental protection was a basic policy for China. The Eighth Five-Year Plan (1991-1996) cited environmental protection as one of the "major tasks and important targets for the following five to 10 years."[67]

In 1998, China's environmental administration received another promotion. It was renamed the State Environmental Protection Administration (SEPA) and upgraded to a ministerial rank, though it lacked a permanent seat in the State Council. This new agency absorbed work, staff, and leadership from the Ministries of Forestry, Geology, Mineral Resources, and Chemical Industry. This new structure gave the State Environmental Protection Administration a better position to influence other government bodies because the agency reported directly to the Vice Premier for environmental protection. Even after these changes, SEPA remained less powerful than other key ministries in China.

As environmental pressure mounted, the government began to incorporate sustainable development into its economic strategy. In his April 2006 speech to the Sixth National Environmental Conference, Premier Wen Jiabao called for "Three Transitions." He sought to move the country:

(1) from a singular focus on economic growth toward a strategy of sustainable development;

(2) from a mindset where economy trumps environment toward analysis where they receive equal priority; and

(3) from a management style that leans on government mandates toward a system that combines legal and market tools.

In 2008, SEPA was elevated to a full ministry, the Ministry of Environmental Protection (MEP), with a permanent seat in the State Council. The reform reflected the government's political will to

---

[67] The Eighth Five-Year Plan, available at http://news.xinhuanet.com/ziliao/2005-02/18/content_2590430.htm (last visited on July 19, 2010).

address environmental issues, and strengthened the ministry's administrative stability, decision-making power, and access to resources (Qiu 2009).

Environmental Protection Bureaus (EPBs) play a major role in provincial environmental management. In each province, these bureaus oversee compliance with pollution laws. The bureaus receive funding from provincial administrations, and the Ministry of Environmental Protection provides them with regulatory guidance and limited resources.

Environmental Protection Bureaus work within a local bureaucracy and face stiff competition from policymakers advocating economic growth. These bureaus must coordinate their work with development and reform commissions, economic and trade commissions, finance bureaus, agricultural bureaus, construction bureaus, and transportation bureaus. In the face of competing demands and scarce resources, economic growth often trumps environmental protection in China. While these multiple bureaus would ideally partner on environmental protection and sustainable development, projects that maximize revenue consistently take precedence over environmental protection at the provincial level (Li and Chan 2009).

Since the 1990s, non-governmental organizations (NGOs), internet access, and television coverage have stimulated public involvement in environmental governance. In 2008, China had more than 508 environment NGOs, nearly twice the 2005 figure (Yao 2008). These NGOs worked with the media to cover environmental affairs, publicize NGO activities, and influence government policies. Recent events such as the protest over the Xiamen PX project and Shanghai Maglev trains reflect the public's ability to influence policy debates. The 2008 Olympic Games brought international pressure on Beijing to improve urban air quality. Strong public pressure influences the Chinese government, and many observers expect political engagement to increase as internet access expands (Norris 2001).

4. Summary Indicator Calculations and Results

China EPI Environmental Governance Indicators

This ideal indicator framework would evaluate provincial governments in terms of structure, penetration, and persistence, using these definitions:

- Structure: organizational strength at the provincial level
- Penetration: industrial and civic participation in environmental policymaking
- Persistence: duration and rate of policy implementation

Potential indicators for each of these are provided in the following tables, though it must be acknowledged that some facets are not strictly amenable to quantification, and that a number of these indicators are proxies at best for more qualitative elements.

Table 6. Structure - Organizational Strength at the Provincial Level

Indicator	**Data Availability**
Number of local policies whose stringency surpasses national rules for environmental health.	Data not readily available
Average number of federal employees at provincial Environmental Protection Bureaus.	Data available in Environmental Yearbooks
Investment in environmental protection as percentage of provincial GDP	Data available in National Statistical Yearbooks

Table 7. Penetration - Industrial and Civic Participation in Environmental Policymaking

Indicator	**Data Availability**
Number of proposals submitted by local People's Congress members	Data available in Environmental Yearbooks
Number of proposals submitted by local People's Political Consultation Committee members	Data available in Environmental Yearbooks

Table 8. Persistence - Duration and Rate of Policy Implementation

Indicator	**Data Availability**
EIA implementation rate	Data available in Environmental Yearbooks
"Three Simultaneities" implementation rate	Data available in Environmental Yearbooks

The environmental governance sections of the China Statistical Yearbook and China Environmental Statistical Yearbook contain a series of parameters covering various areas including governmental expenditure, employees, legislations, law enforcement, and environmental pollution accidents. These parameters are helpful to better evaluate and understand Chinese efforts and development in environmental governance. However, not every parameter is complete or qualifies as an indicator for the purposes of this report. Transparency in methodology is important when examining indicators of governance, and we did not have access to the raw data or methodology for most of the available indicators. We carefully examined every parameter's definition, collection and calculation methodology, policy foundation, and data across the provinces. Finally we selected two indicators for their detailed description and their connection to policy implementation at the provincial level. The two indicators are number of Environmental Protection Bureau (EPB) employees on government payroll per RMB 10,000 GRP (GOVEMPL) and investment in environment protection as a percentage of GRP (INVPOLL).

Policy Categories	Policy Category Codes	Indicators	Indicator Codes	Data Source	Target
Environmental Governance	GOVERNANCE	Number of EPB employees on government payroll	GOVEMPL	China Statistical Yearbook, 1995-2002, 2006	not available
		Investment in environmental protection, as percentage of GRP	INVPOLL	China Statistical Yearbook, 1998-2007	not available

Data Quality and Representativeness

Both data sets are drawn from China Statistical Yearbook. The most recent year available for number of Environmental Protection Bureau (EPB) employees on government payroll per RMB 10,000 GRP (GOVEMPL) is 2006, while for investment in environment protection as a percentage of GRP (INVPOLL) it is 2007. No information is available regarding methodology, aggregation, or data availability. For these two indicators, the data is available for all provinces.

Correlations

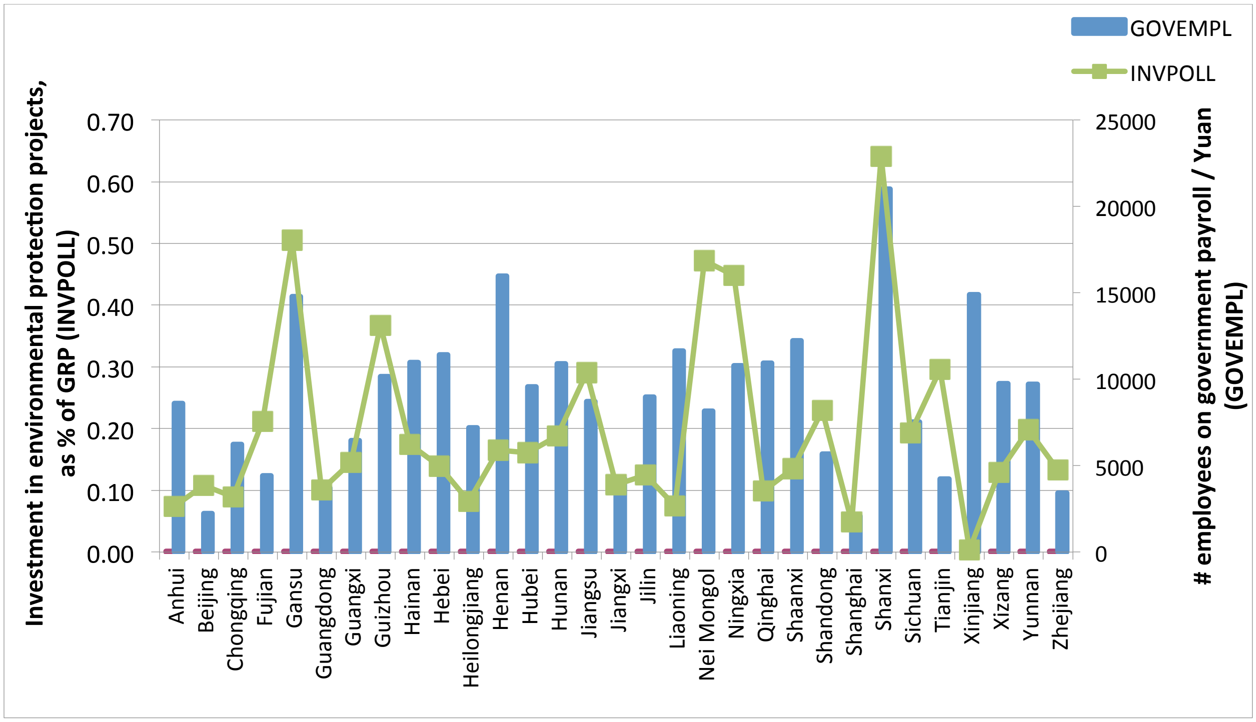
Pearson coefficients calculation shows that the two environmental governance indicators are moderately positively correlated (0.43).

	GOVEMPL	**INVPOLL**
GOVEMPL	1	
INVPOLL	0.43	1

Ranks and Trend Analysis

Figure 18 shows the two environmental governance indicators in all provinces.

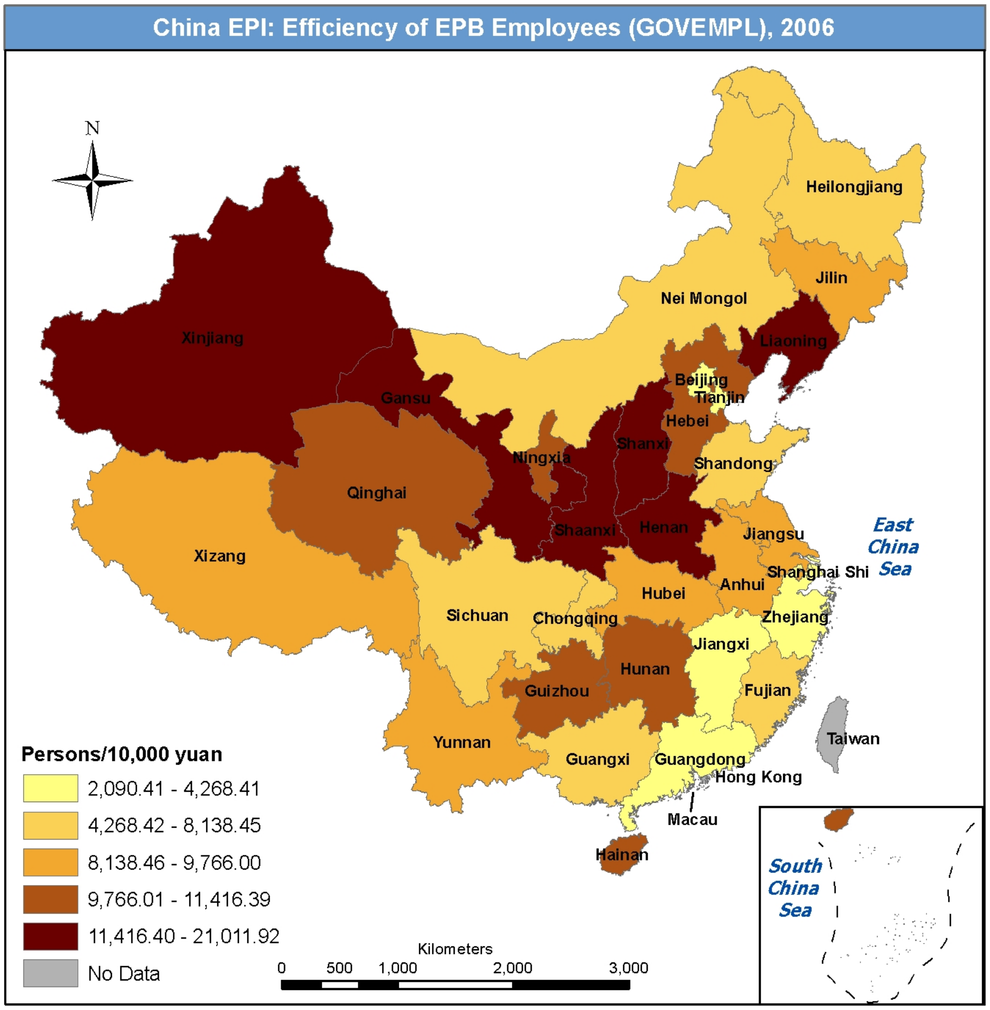
Figure 18. Environmental Governance



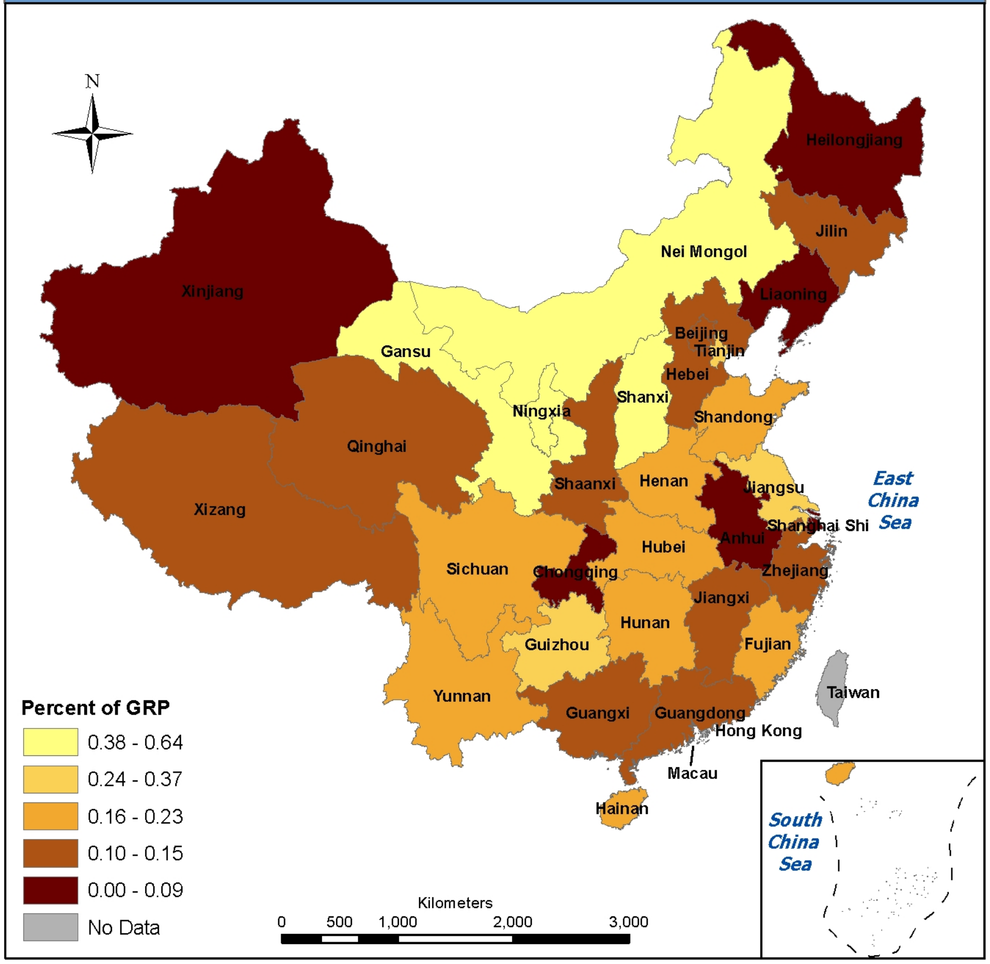
The following table shows the provincial ranking, from the best performer to the worst performer, for each indicator. Data for number of Environmental Protection Bureau (EPB) employees on government payroll (GOVEMPL) are from 2006, and data for investment in environment protection (INVPOLL) are from 2007.

Rank	Province	GOVEMPL	Province	INVPOLL
1	Shanxi	21011.92	Shanxi	0.64
2	Henan	15958.75	Gansu	0.50
3	Xinjiang	14913.58	Nei Mongol	0.47
4	Gansu	14797.73	Ningxia	0.45
5	Shaanxi	12233.24	Guizhou	0.37
6	Liaoning	11618.39	Tianjin	0.30
7	Hebei	11416.39	Jiangsu	0.29
8	Hainan	10979.72	Shandong	0.23
9	Qinghai	10941.74	Fujian	0.21
10	Hunan	10891.95	Yunnan	0.20
11	Ningxia	10777.20	Sichuan	0.19
12	Guizhou	10140.23	Hunan	0.19
13	Xizang	9766.00	Hainan	0.17
14	Yunnan	9698.71	Henan	0.16
15	Hubei	9555.06	Hubei	0.16
16	Jilin	8973.29	Guangxi	0.15
17	Jiangsu	8696.69	Hebei	0.14
18	Anhui	8596.90	Shaanxi	0.13
19	Nei Mongol	8138.45	Zhejiang	0.13
20	Sichuan	7516.95	Xizang	0.13
21	Heilongjiang	7185.44	Jilin	0.12
22	Guangxi	6436.77	Jiangxi	0.11
23	Chongqing	6223.56	Beijing	0.11
24	Shandong	5684.56	Guangdong	0.10
25	Fujian	4425.74	Qinghai	0.10
26	Jiangxi	4268.41	Chongqing	0.09
27	Tianjin	4246.24	Heilongjiang	0.08
28	Guangdong	3694.79	Liaoning	0.08
29	Zhejiang	3427.66	Anhui	0.07
30	Beijing	2218.47	Shanghai	0.05
31	Shanghai	2090.41	Xinjiang	0.00

The following maps depict the indicator scores by province. The maps depict the best performers in yellow and the worst performers in dark brown.



China EPI: Investments in Environmental Protection (INVPOLL), 2007



V. Conclusions and recommendations

In the preceding sections we have presented an in depth study of the main environmental issues confronting China in 12 environmental policy categories together with a description of China's policy response to those issues. We have also described current international best practices in measurement for those policy areas and compared it to China's own measurement practices. For illustrative purposes, we chose selected indicators for each policy category, clearly spelling out the strengths and limitations for each one, and presented ranked results by province in the form of tables and maps. Although in certain sections of the report we underscore environmental challenges and make limited recommendations, our main purpose was not to propose policies for pollution control or sustainable development. Rather, our goal was to examine the potential for creating a provincial-level EPI and to propose a framework and system for tracking performance by measuring the outcomes of those policies that already exist.

As mentioned throughout this report, though China has a great volume of official statistics available via the Internet, many analysts have questioned their validity and reliability. In the context of this report we could not make any definitive declarations regarding data quality or accuracy because independent sources of data were not available to us so as to be able to develop uncertainty estimates. Over the course of the China EPI project we became aware of many data sets that exist but which are not publicly available. This is particularly true of raw monitoring station data for pollutant concentrations and geospatial data for ecosystems and biodiversity. Primary data are vital in any effort to evaluate data quality. Although potentially useful for public communication, aggregated indices such as the Air Pollution Index (API) or the Percentage of Water Sampling Points Below Grade IV Water Quality Standard are difficult to interpret, and from a scientific perspective they conceal important information related to specific pollutants. Thus, they do not provide a sufficient basis for tracking performance measurement over time or for remediation efforts.

In our view, it will be important for environmental management and remediation in China for there to be greater access to unprocessed environmental data. The UN Economic Commission for Europe's Aarhus Convention (1998)[68] and the US Freedom of Information Act (1968) grant the public certain rights to environmental data and information held by government agencies. These laws reflect evolving norms concerning public access to information, and are based on a recognition that broader access to environmental data and information promotes environmental protection by engaging a wider range of non-state actors such as the private sector, non-government organizations, and citizen's groups. China's Regulation on Environmental Information Disclosure, which took effect in May 2008, represents a major step forward for information transparency, but

---

[68] Officially known as the UNECE Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters.

implementation is still at early stages and much remains to be accomplished to tap the full power of public participation in environmental protection.[69]

Although significant environmental challenges remain as China seeks to balance economic growth, poverty alleviation, and environmental protection, the Chinese government is making great strides in improving the stringency of environmental regulations (see Appendix 3 for a discussion of the most recent targets of the 12th Five Year Plan). It is our hope that this report provides the impetus for creating a system for environmental performance measurement over time and that in five to ten year's time the components will be in place for a full provincial-level EPI. In the mean time, this report can help decision-makers to identify the elements of the performance measurement system that will need to be put into place to make that a reality. This would include identifying "measurement gaps" (gaps in existing monitoring and data collection systems) so as to move Chinese measurement practices into closer conformity with international best practices and as an aid in target-setting.

---

[69] See "Pollution Index is Up and Running" at http://www.china.org.cn/environment/report_review/2009-06/04/content_17887468.htm.

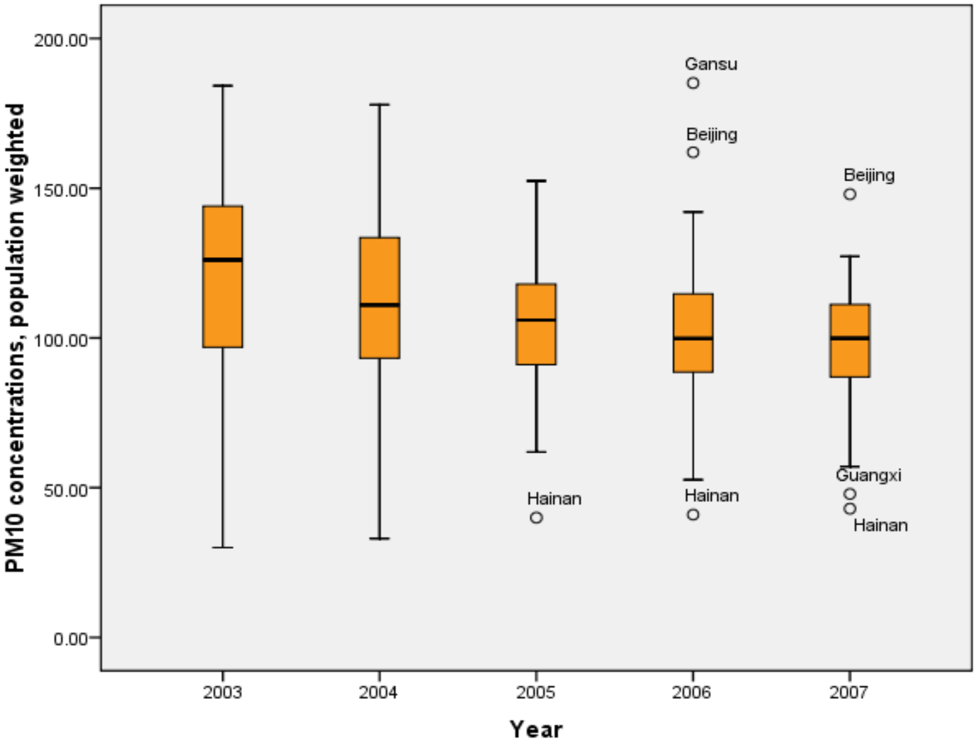
VI. Indicator Profiles

Indicator: PM10

Policy category: Environmental Health
Indicator name: Population weighted PM10 concentrations
Unit of measurement: μg/m^3
Data source: Ministry of Environmental Protection
Time period: 2003-2007
Data coverage and transparency: Varies by province; 2/3 of the provinces have less than 50% coverage of urban population in the PM10 concentration data. Only a small fraction of the 600 cities with air quality monitoring have data publicly available on the MEP Web site.
Methodology: City level mean concentrations of PM10 are weighted by city population, to generate the province level mean concentrations.
Target: 20; 100
Target source: WHO; China Ministry of Environmental Protection
Summary statistics:

Minimum: 43	Maximum: 148	Mean: 97.32	Standard Deviation: 23.57

Time series distribution: outliers and extreme values

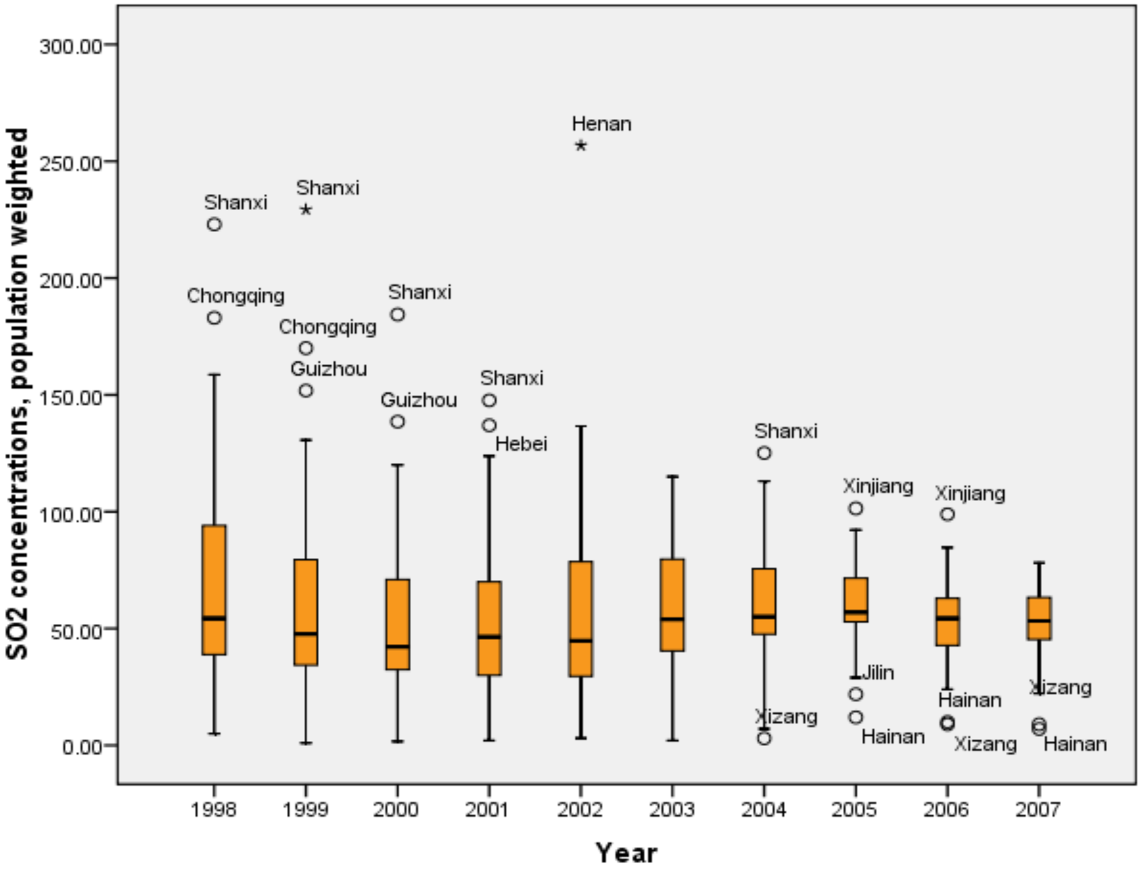


Indicator: SO2

Policy category: Environmental Health
Indicator name: Population weighted SO_2 concentrations
Unit of measurement: μg/m^3
Data source: Ministry of Environmental Protection
Time period: 1998-2007
Data coverage and transparency: varies by province; 2/3 of the provinces have less than 50% coverage of urban population in the SO_2 concentration data. Only a small fraction of the 600 cities with air quality monitoring have data publicly available on MEP Web site.
Methodology: City level mean concentrations of SO_2 are weighted by city population, to generate the province level mean concentrations.
Target: 40; 80
Target source: WHO; China Ministry of Environmental Protection
Summary statistics:

Minimum: 7	Maximum: 78.13	Mean: 50.95	Standard Deviation: 18.23

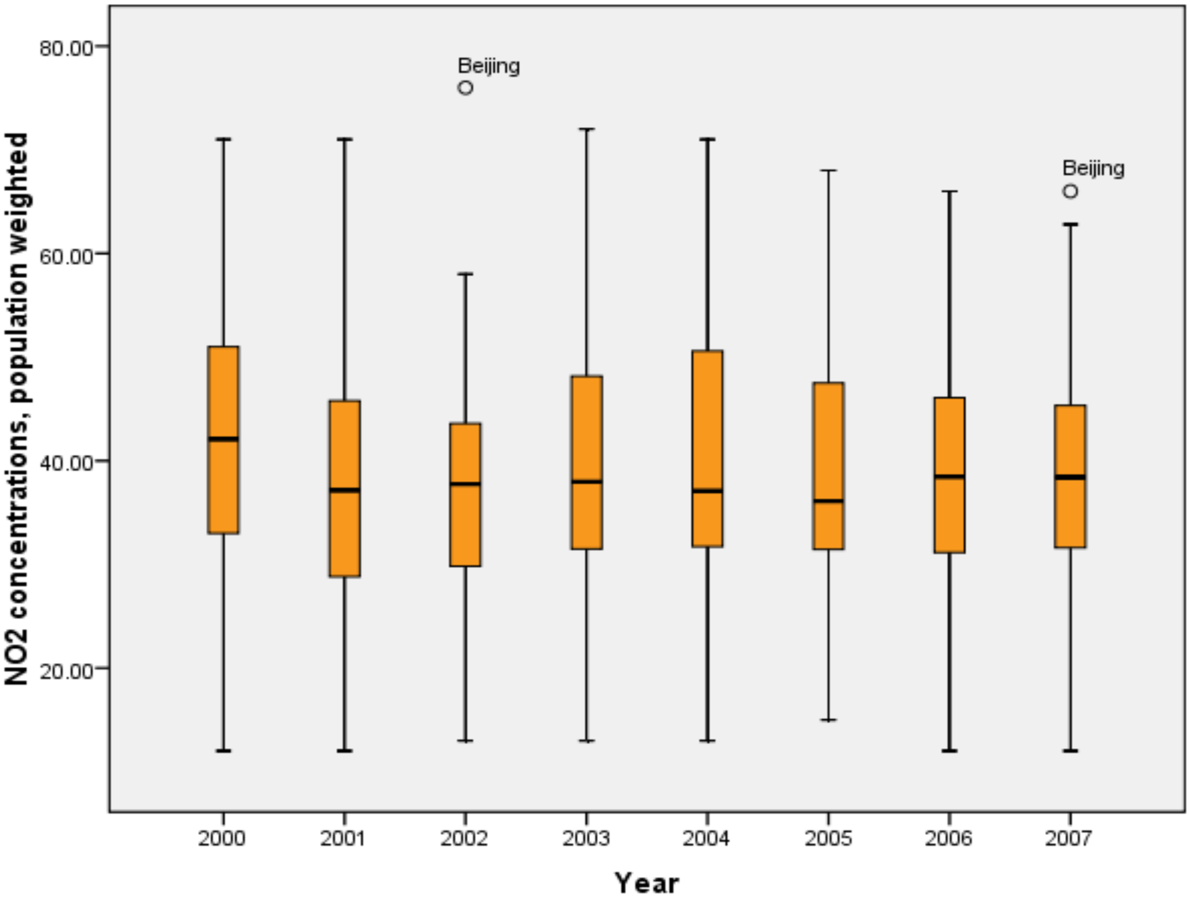
Time series distribution: outliers and extreme values



Indicator: NO2

Policy category: Environmental Health
Indicator name: Population weighted NO2 concentrations
Unit of measurement: μg/m³
Data source: Ministry of Environmental Protection
Time period: 2000-2007
Data coverage and transparency: varies by province; 2/3 of the provinces have less than 50% coverage of urban population in the NO2 concentration data. Only a small fraction of the 600 cities with air quality monitoring have data publicly available on MEP Web site.
Methodology: City level mean concentrations of NO2 are weighted by city population, to generate the province level mean concentrations.
Target: 60
Target source: China Ministry of Environmental Protection; no yearly target from WHO
Summary statistics:
Minimum: 12 Maximum: 66 Mean: 39.12 Standard Deviation: 11.67

Time series distribution: outliers and extreme values

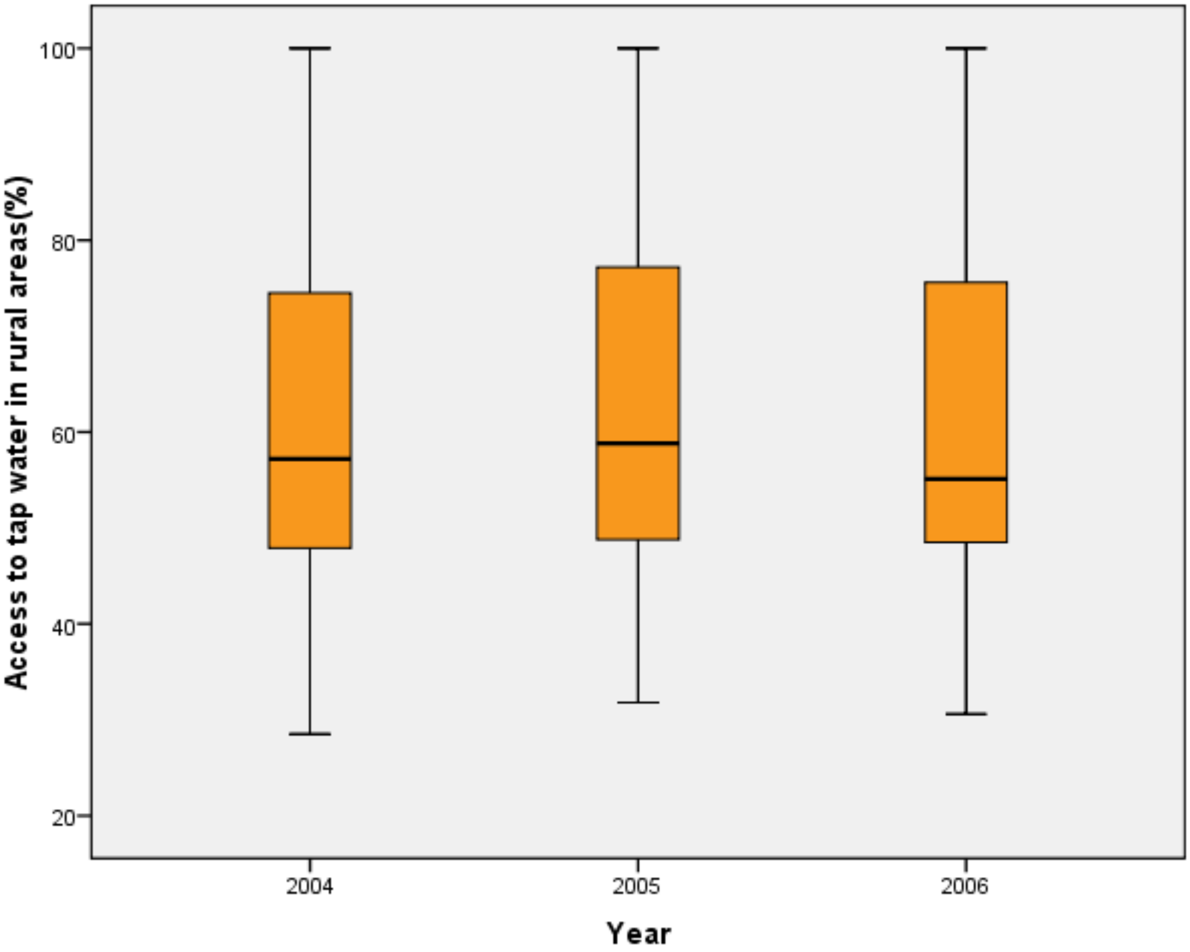


Indicator: RURTAP

Policy category: Environmental Health
Indicator name: Access to tap water in rural areas
Unit of measurement: %
Data source: China Environmental Statistical Yearbook
Time period: 2004-2006
Data coverage and transparency: Data for Xizang province are not publicly available.
Methodology: not available
Target: 75%
Target source: China's 11th five year plan of sanitation.
Summary statistics:

Minimum: 30.6	Maximum: 100	Mean: 61.18	Standard Deviation: 19.47

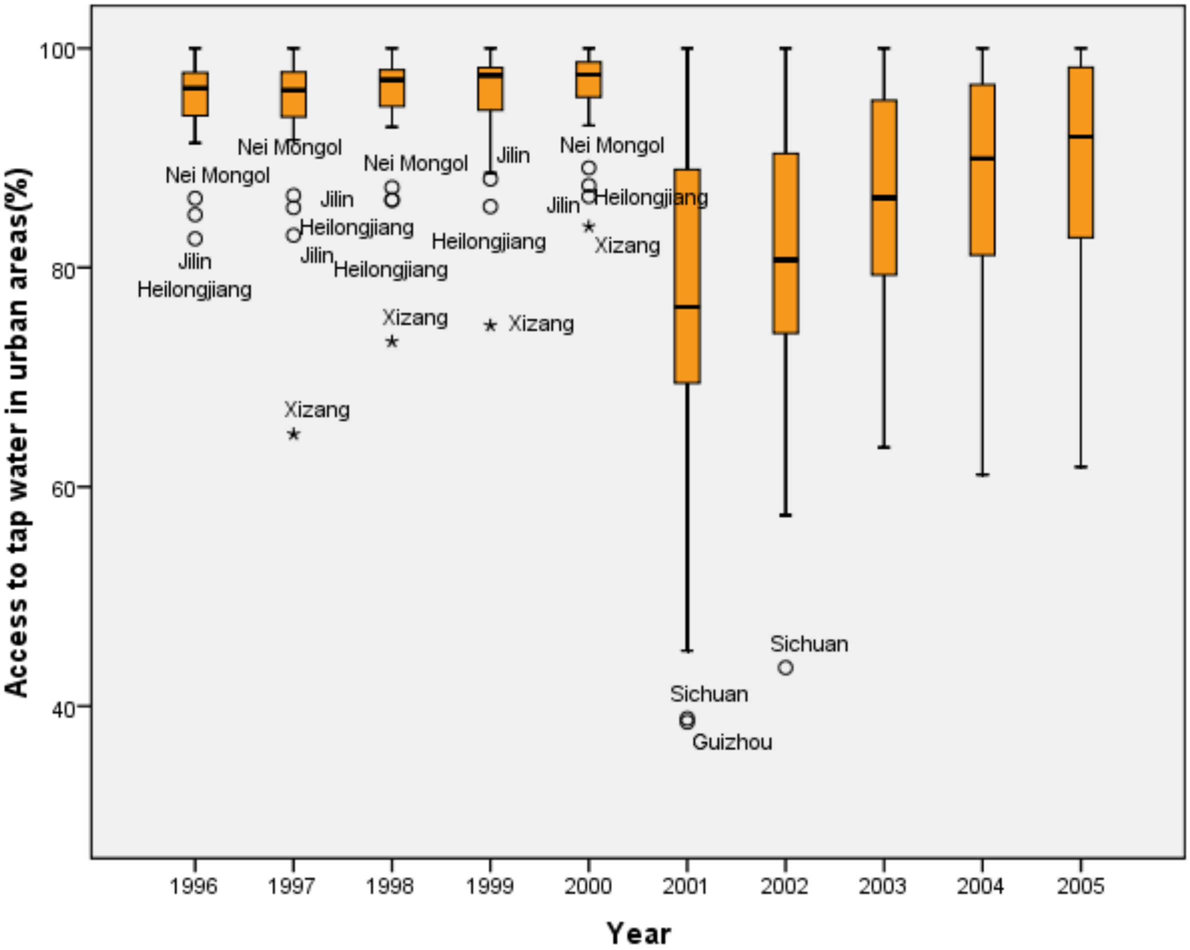
Time series distribution: outliers and extreme values:



Indicator: URBTAP

Policy category: Environmental Health
Indicator name: Access to tap water in urban areas
Unit of measurement: %
Data source: China Environmental Statistical Yearbook
Time period: 1996-2005
Data coverage and transparency: Data available for all provinces.
Methodology: not available
Target: 100%
Target source: Expert's judgment
Summary statistics:
Minimum: 61.82 Maximum: 100 Mean: 89.23 Standard Deviation: 10.35

Time series distribution: outliers and extreme values:

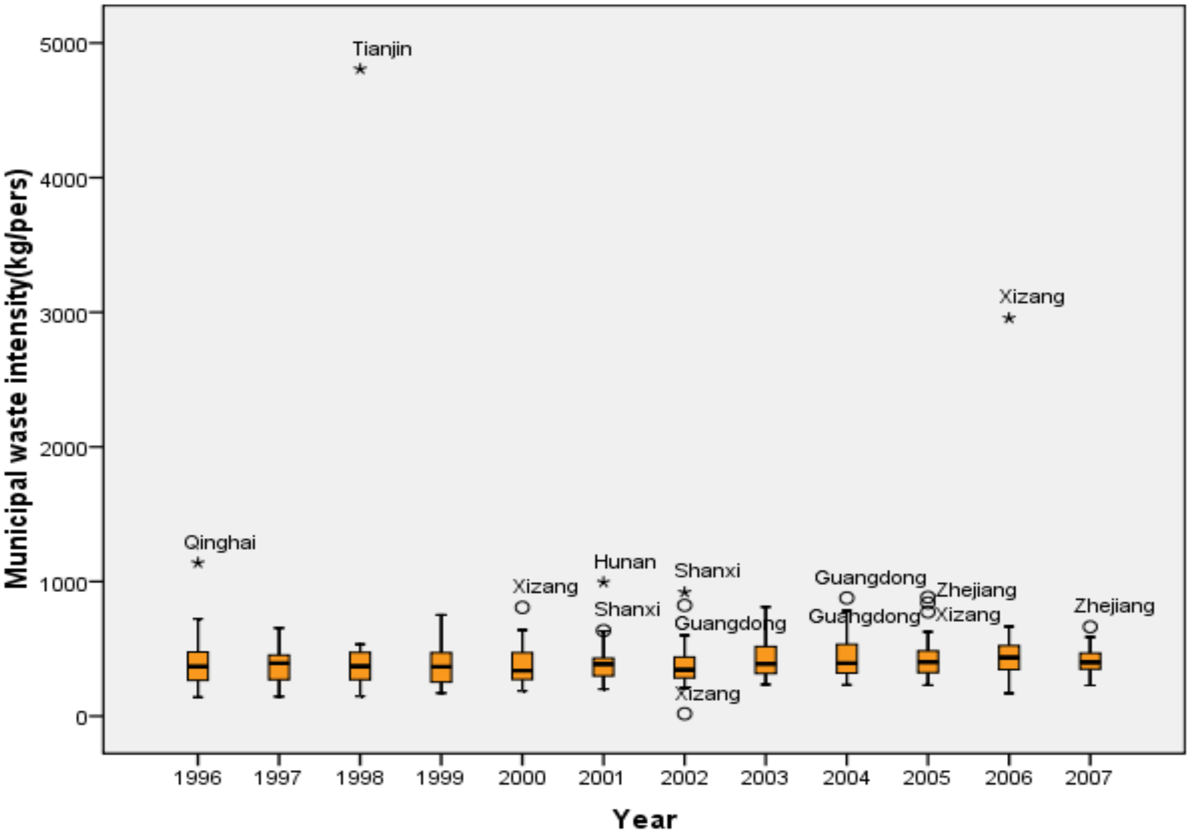


Indicator: MSW_PC

Policy category: Environmental Health
Indicator name: Municipal waste intensity
Unit of measurement: kg/person
Data source: China Statistical Yearbook
Time period: 1996-2007
Data coverage and transparency: Data available for all provinces.
Methodology: not available
Target: not available
Target source: not available
Summary statistics:

Minimum: 228.32	Maximum: 663.08	Mean: 412.09	Standard Deviation: 99.45

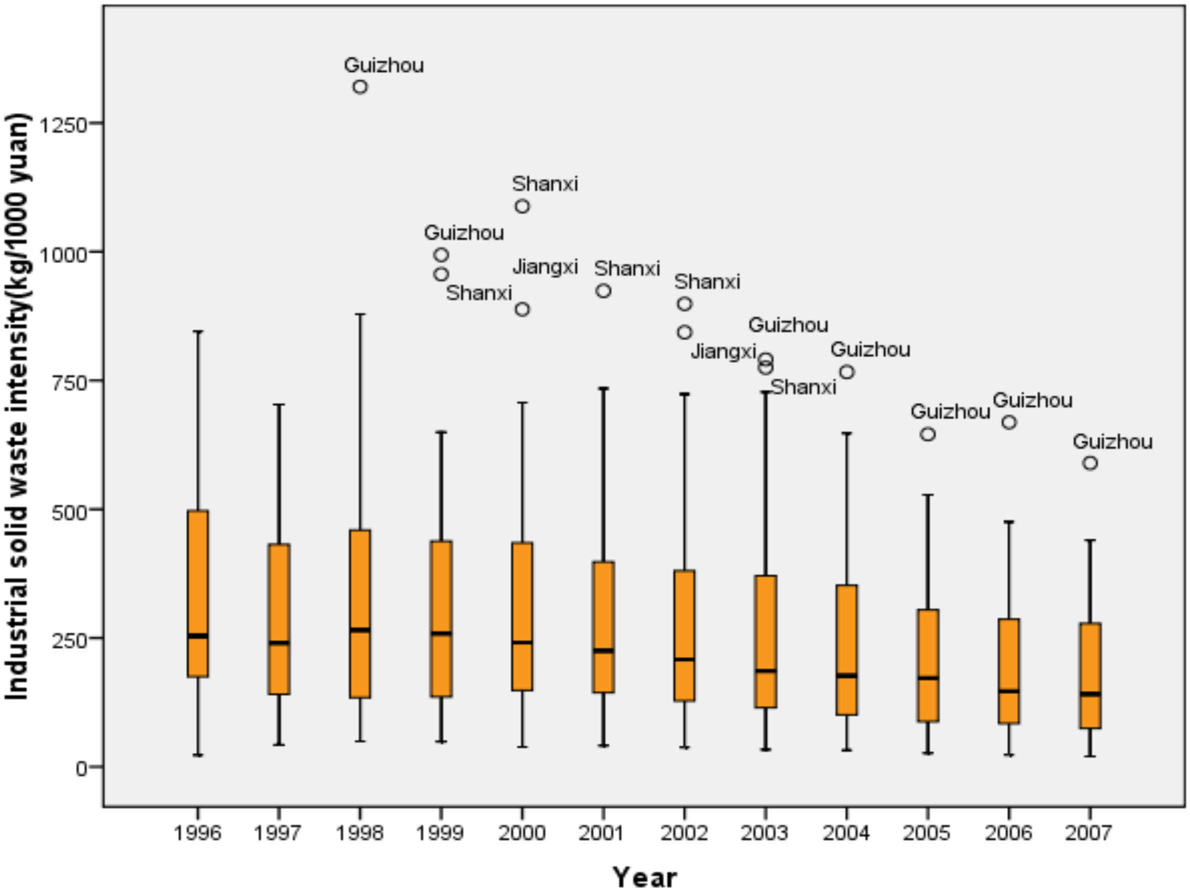
Time series distribution: outliers and extreme values



Indicator: ISWINT

Policy category: Environmental Health
Indicator name: Industrial solid waste intensity
Unit of measurement: kg/1000 ¥
Data source: China Statistical Yearbook
Time period: 1996-2007
Data coverage and transparency: Data available for all provinces.
Methodology: Industrial solid waste intensity is calculated by dividing the quantities of industrial solid wastes (ISW) generated to industrial value added (IVA). No information is available regarding how the data is industrial waste data is collected, methodology of aggregation at the provincial level, and representativeness.
Target: not available
Target source: not available
Summary statistics:
Minimum: 19.87 Maximum: 589.67 Mean: 193.05 Standard Deviation: 141.47

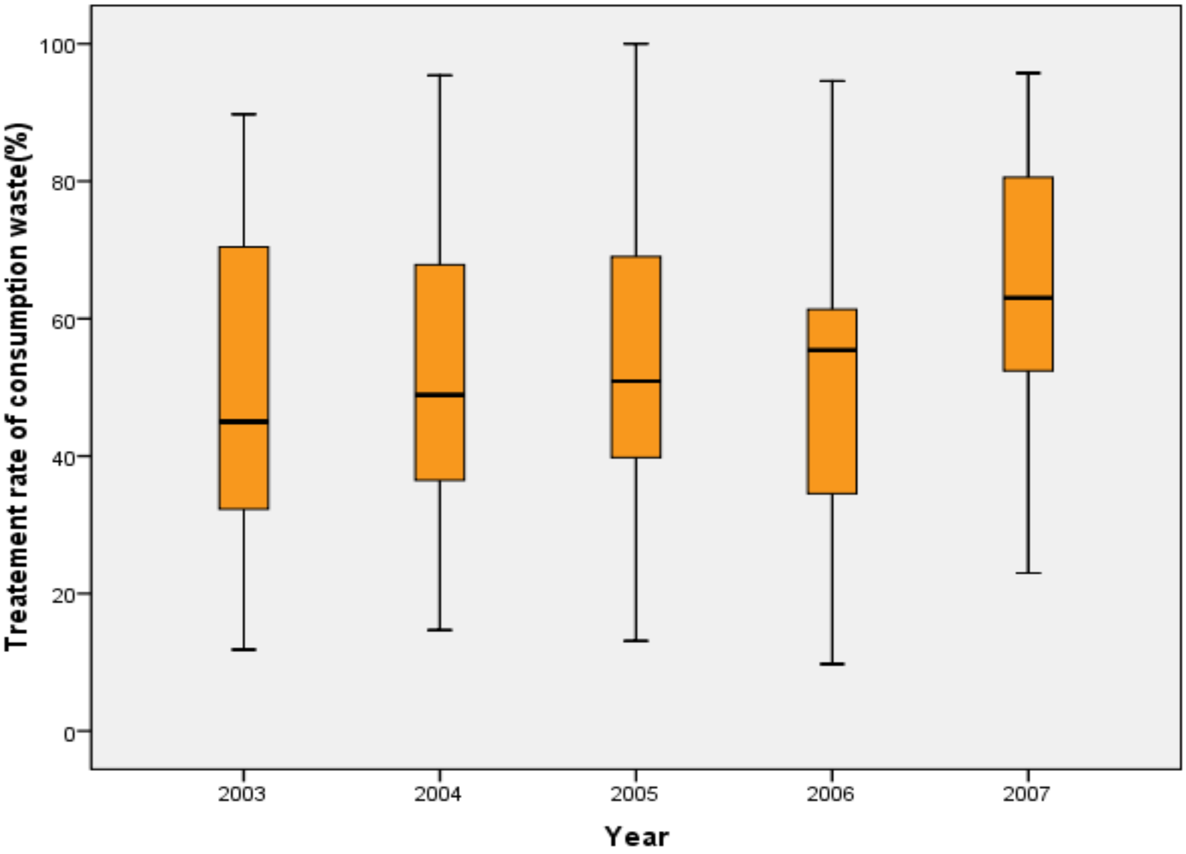
Time series distribution: outliers and extreme values



Indicator: MSW_T

Policy category: Environmental Health
Indicator name: Municipal solid waste treated
Unit of measurement: %
Data source: China Statistical Yearbook
Time period: 2003-2007
Data coverage and transparency: Data for Xizang province are only available for year 2006 and 2007.
Methodology: Municipal solid waste treated is the proportion of harmless treated municipal waste in urban areas. No information is available regarding how the data is industrial waste data is collected, methodology of aggregation at the provincial level, and representativeness.
Target: 60% in 2010
Target source: China's 11th Five-Year Plan
Summary statistics:
Minimum: 22.97 Maximum: 95.73 Mean: 63.07 Standard Deviation: 20.52

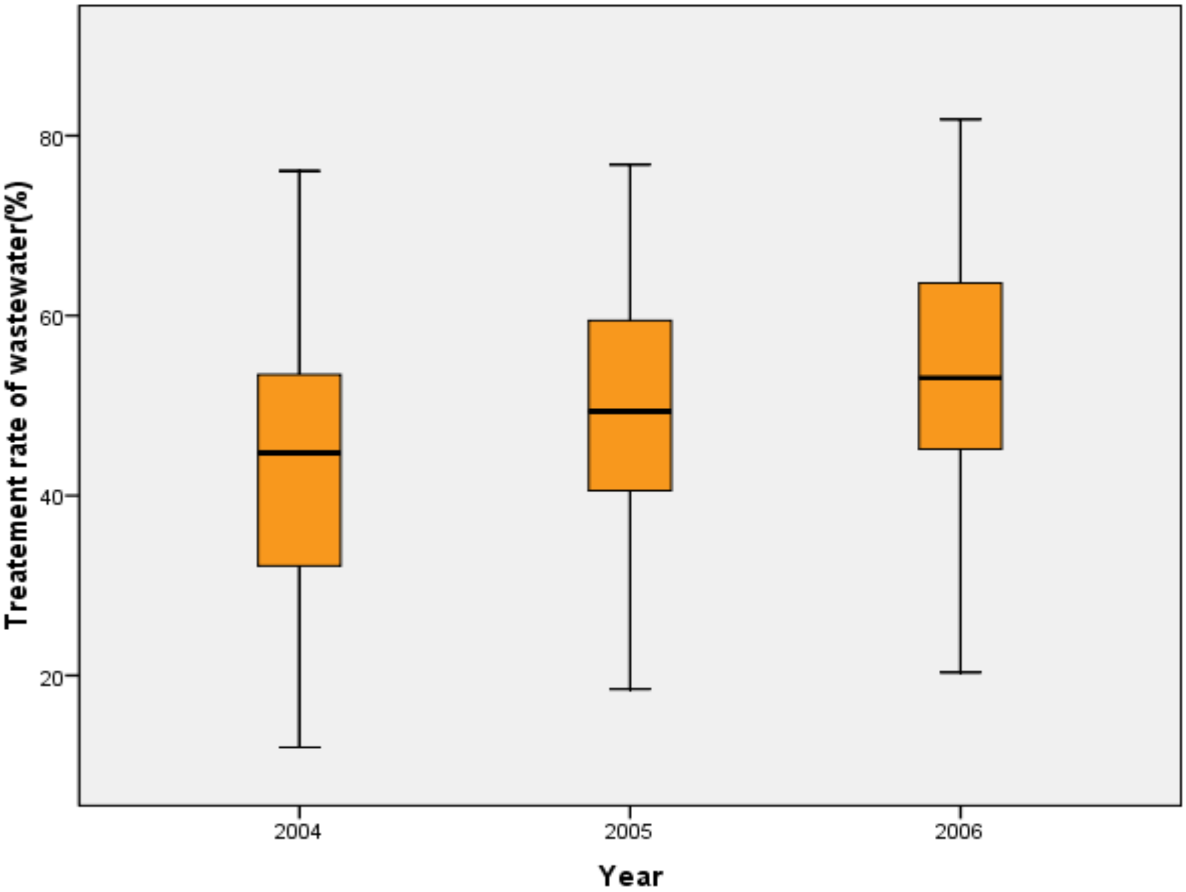
Time series distribution: outliers and extreme values



Indicator: MWW_T

Policy category: Environmental Health
Indicator name: Municipal waste water treatment
Unit of measurement: %
Data source: China Statistical Yearbook
Time period: 2004-2006
Data coverage and transparency: Data for Xizang province are not available
Methodology: Municipal waste water treatment is the proportion of municipal wastewater treated from the total municipal wastewater. No information is available regarding how the data is industrial waste data is collected, methodology of aggregation at the provincial level, and representativeness.
Target: not available
Target source: not available
Summary statistics:
Minimum: 20.37 Maximum: 81.82 Mean: 53.31 Standard Deviation: 15.05

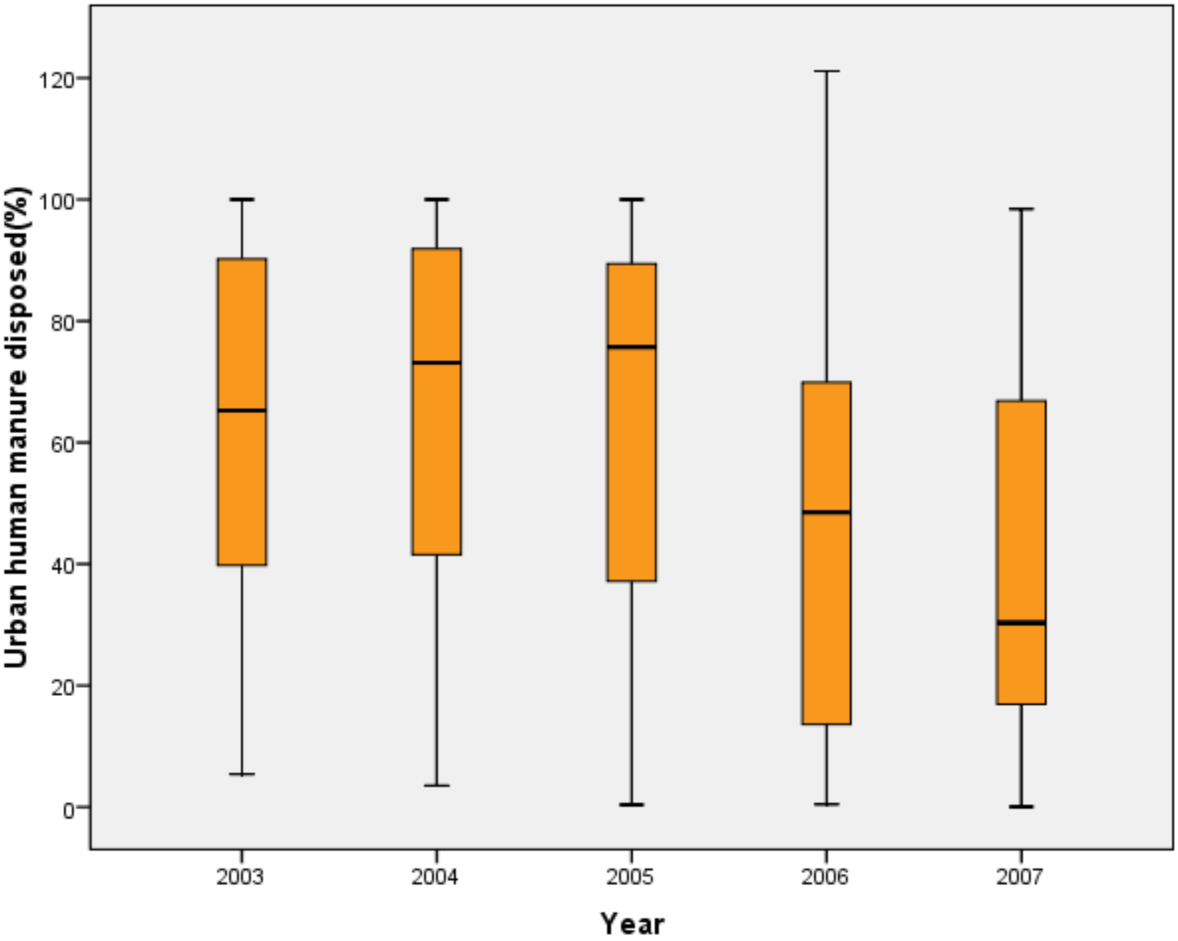
Time series distribution: outliers and extreme values



Indicator: SANU

Policy category: Environmental Health
Indicator name: Urban human waste disposal
Unit of measurement: %
Data source: China Statistical Yearbook
Time period: 2003-2007
Data coverage and transparency: Missing data for Fujian, Qinghai and Xizang
Methodology: Urban human waste disposal represents the ratio of urban human waste disposed to urban human waste collected and transported.
Target: 78% by 2010
Target source: China's 11th Five-Year Plan:
http://jst.jl.gov.cn/csjs/wjxx/t20071009_311792.htm
Summary statistics:
Minimum: 0.05 Maximum: 100 Mean: 44.43 Standard Deviation: 32.76

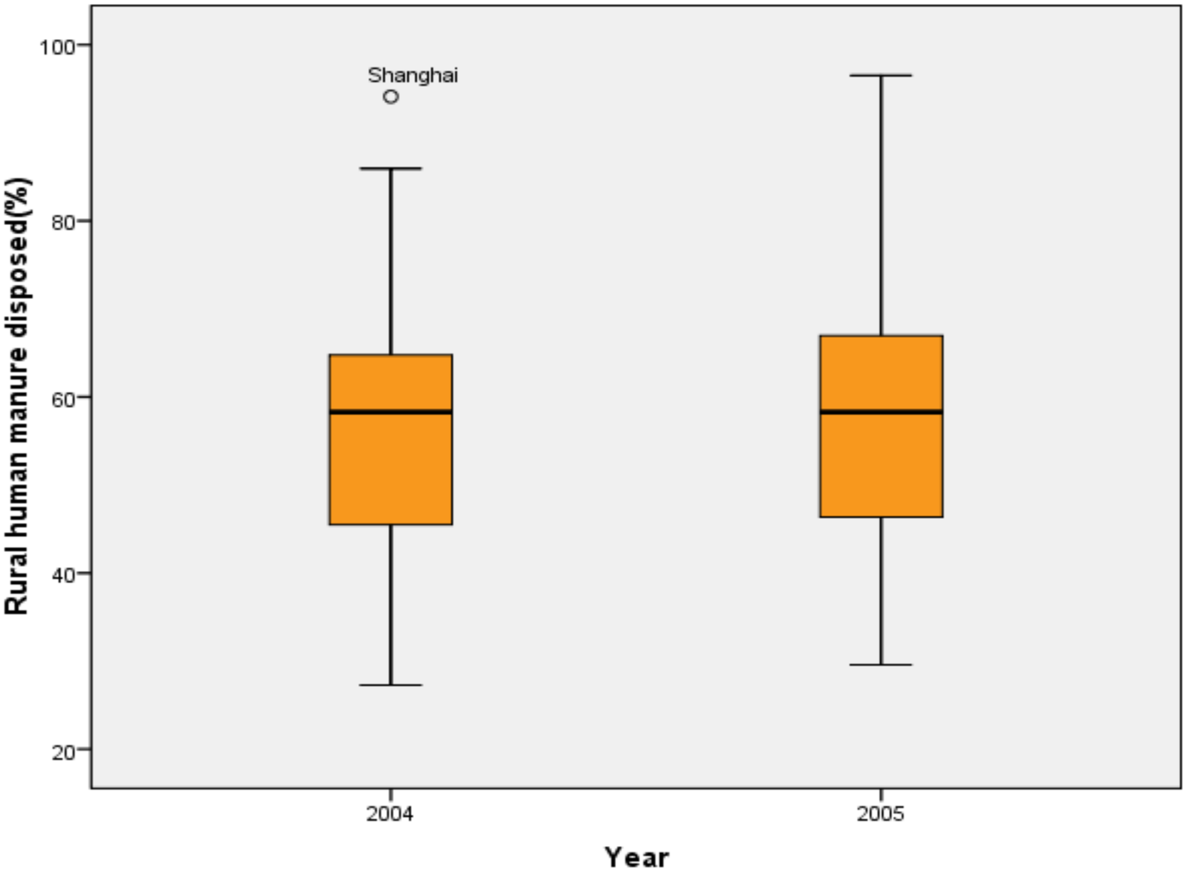
Time series distribution: outliers and extreme values:



Indicator: SANR

Policy category: Environmental Health
Indicator name: Rural human waste disposal
Unit of measurement: %
Data source: China Environmental Statistical Yearbook
Time period: 2004-2005
Data coverage and transparency: Missing data Xizang province
Methodology: Rural human waste disposal represents the ratio of rural human waste disposed to rural human waste collected and transported.
Target: 65% by 2011
Target source: Management project of improvement of rural drinking water supply and lavatory of 2009
Summary statistics:
Minimum: 29.57 Maximum: 96.5 Mean: 57.82 Standard Deviation: 16.89

Time series distribution: outliers and extreme values:

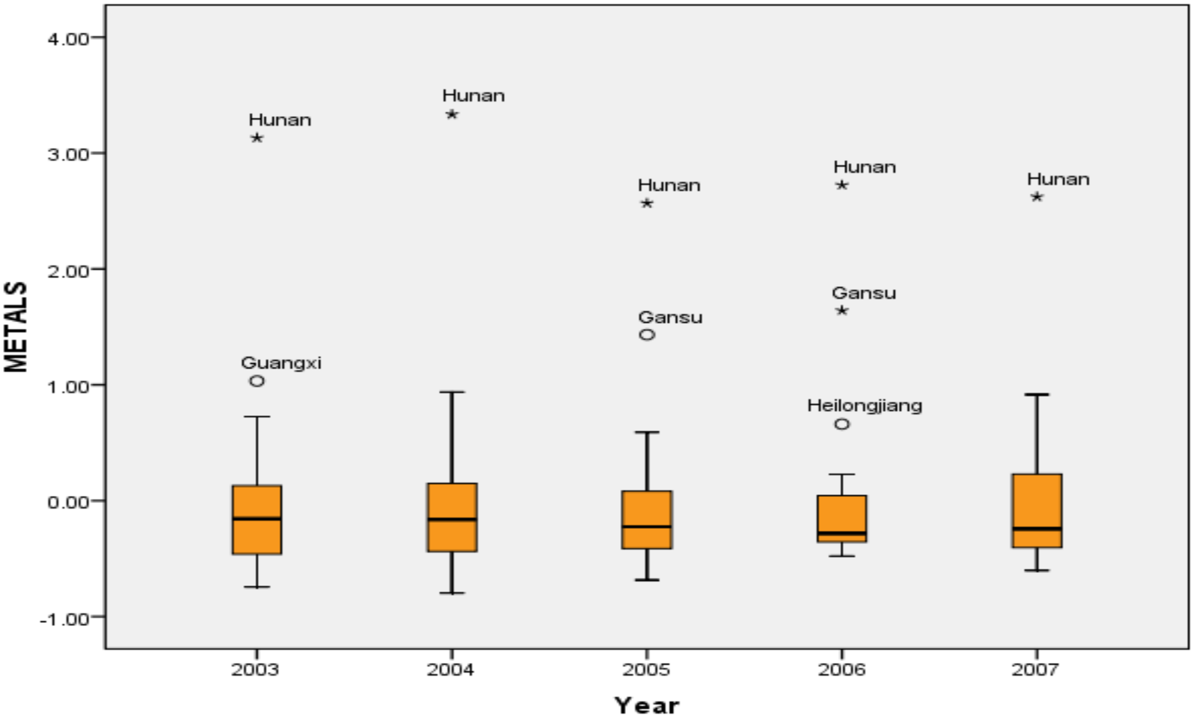


Indicator: METALS

Policy category: Environmental Health
Indicator name: Heavy metals
Unit of measurement: standard score (z score)
Data source: China Environmental Statistic Yearbook
Time period: 2003-2007
Data coverage and transparency: Missing data for Xizang province
Methodology: Hazardous wastes are discarded materials with properties that make them potentially harmful to human health or the environment. Hazardous wastes can include things such as chemicals, heavy metals, or substances generated as byproducts during commercial manufacturing processes, as well as discarded household products like paint thinners, cleaning fluids, and old batteries. Toxic pollutants discharged in industrial wastewater included in this measurement comprise heavy metals such as: Pb-lead, Cd-Cadmium, Bz-Benzene, Cr-Chromium, As-Arsenic, Hg- Mercury and CN-Cyanide. The following quantity of a specific pollutant discharged is called a pollution equivalent:
Mercury 0.0005 kg
Cadmium 0.025 kg
Hexavalent Chrome 0.02 kg
Lead 0.025 kg
Arsenic 0.02 kg
Volatile Hydroxy - benzene 0.08 kg
Cyanide 0.05 kg
Target: not available
Target source: not available
Summary statistics:

Minimum: -0.62	Maximum: 2.61	Mean: -0.02	Standard Deviation: 0.65

Time series distribution: outliers and extreme values:

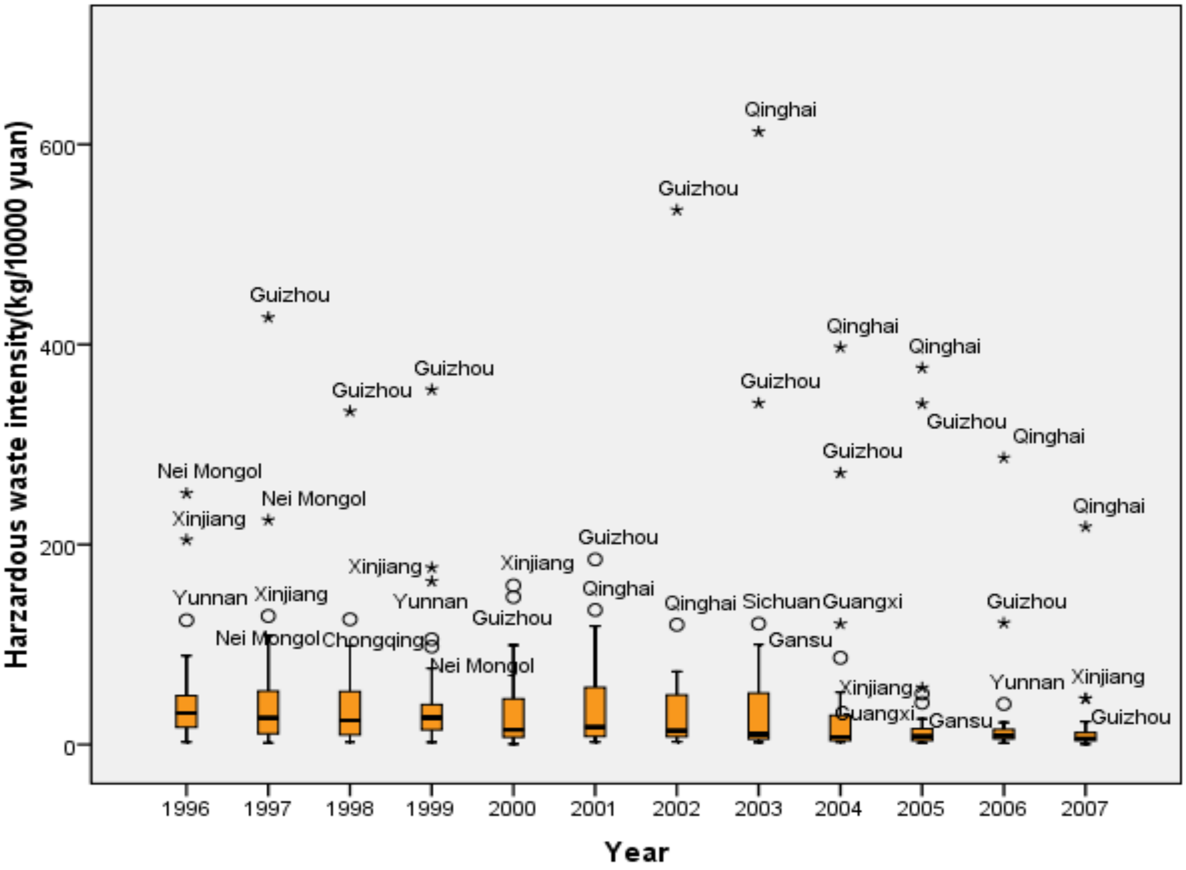


Indicator: HAZINT

Policy category: Environmental Health
Indicator name: Hazard waste intensity
Unit of measurement: kg/1000 ¥
Data source: China Statistical Yearbook
Time period: 1996-2007
Data coverage and transparency: Missing data for Xizang province.
Methodology: Hazardous waste intensity is calculated by dividing the quantities of dangerous or hazardous wastes to industrial value added (IVA). No information is available regarding how the hazardous waste data is collected, methodology of aggregation at the provincial level, and representativeness.
Target: not available
Target source: not available
Summary statistics:

Minimum: 0.37	Maximum: 217.63	Mean: 16.84	Standard Deviation: 39.47

Time series distribution: outliers and extreme values

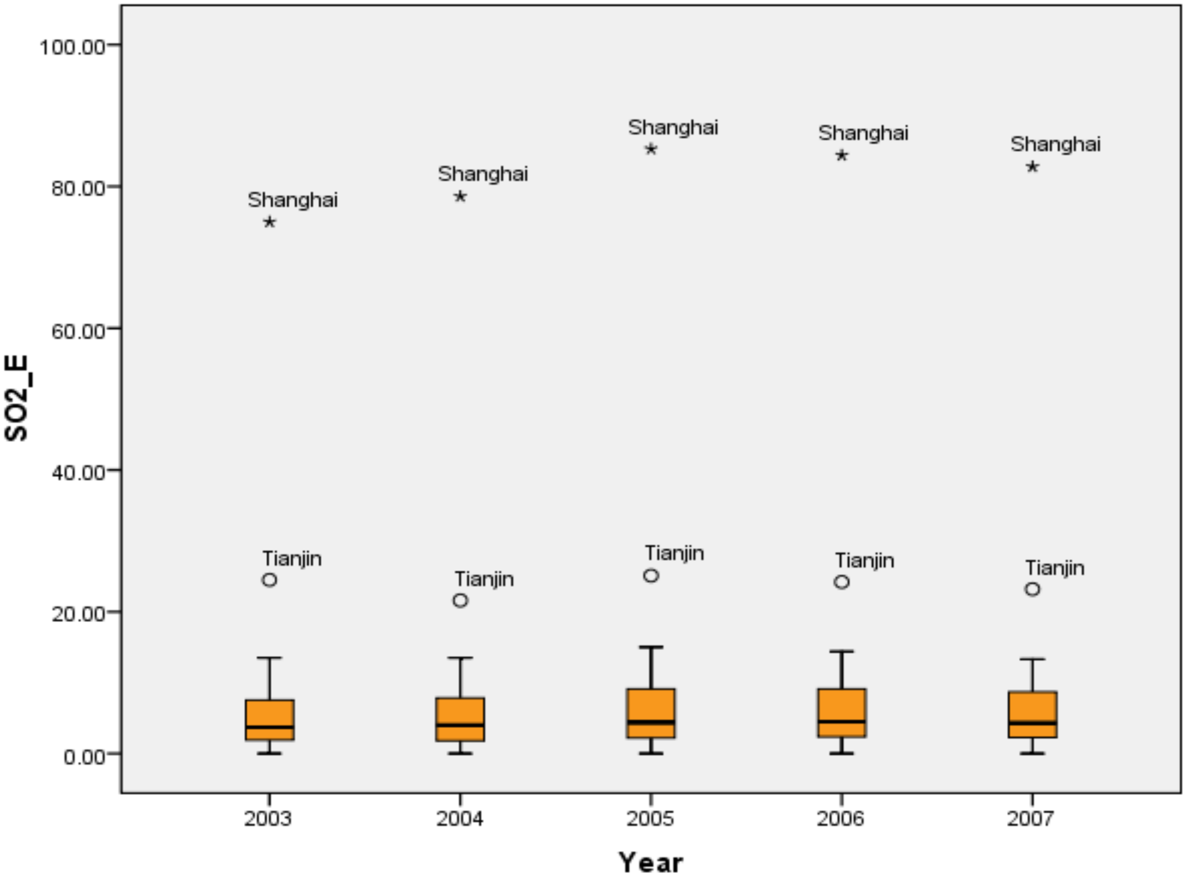


Indicator: SO2_E

Policy category: Ecosystem Vitality
Indicator name: SO2 emissions per populated land area
Unit of measurement: tons/square km.
Data source: Ministry of Environmental Protection
Time period: 2003-2007
Data coverage and transparency: No missing data at the provincial level
Methodology: The sulfur dioxide emissions were divided by the land area populated at more than five persons per square kilometer. No information is available regarding how the sulfur dioxide data is collected, methodology of aggregation at the provincial level, and representativeness.
Target: not available
Target source: not available
Summary statistics:

Minimum: 0.01	Maximum: 82.8	Mean: 8.35	Standard Deviation: 14.62

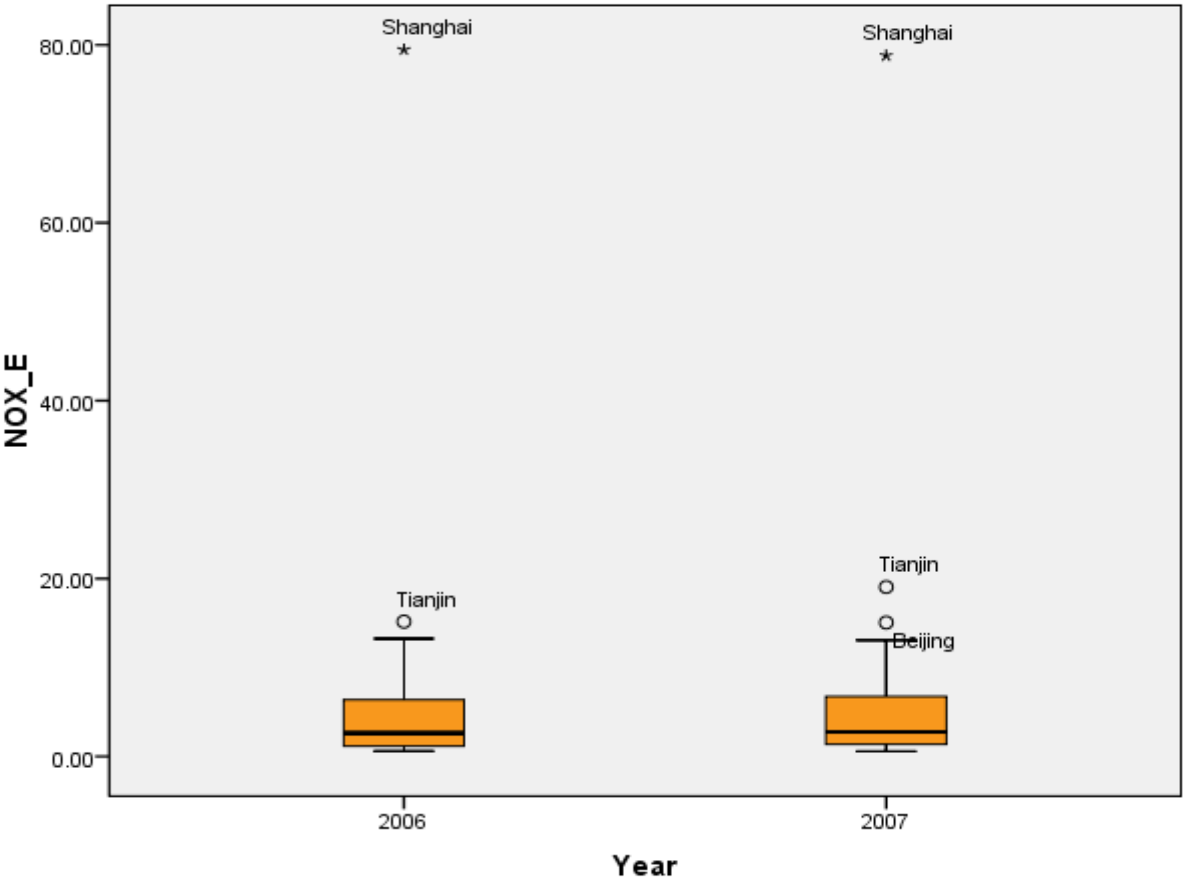
Time series distribution: outliers and extreme values



Indicator: NOX_E

Policy category: Ecosystem Vitality
Indicator name: NOX emissions per populated land area
Unit of measurement: tons/square km.
Data source: Ministry of Environmental Protection
Time period: 2006-2007
Data coverage and transparency: Missing data for Xizang province.
Methodology: The nitrogen oxides emissions were divided by the land area populated at more than five persons per square kilometer. No information is available regarding how the nitrogen oxides data is collected, methodology of aggregation at the provincial level, and representativeness.
Target: not available
Target source: not available
Summary statistics:
Minimum: 0.58 Maximum: 78.80 Mean: 7.05 Standard Deviation: 14.29

Time series distribution: outliers and extreme values

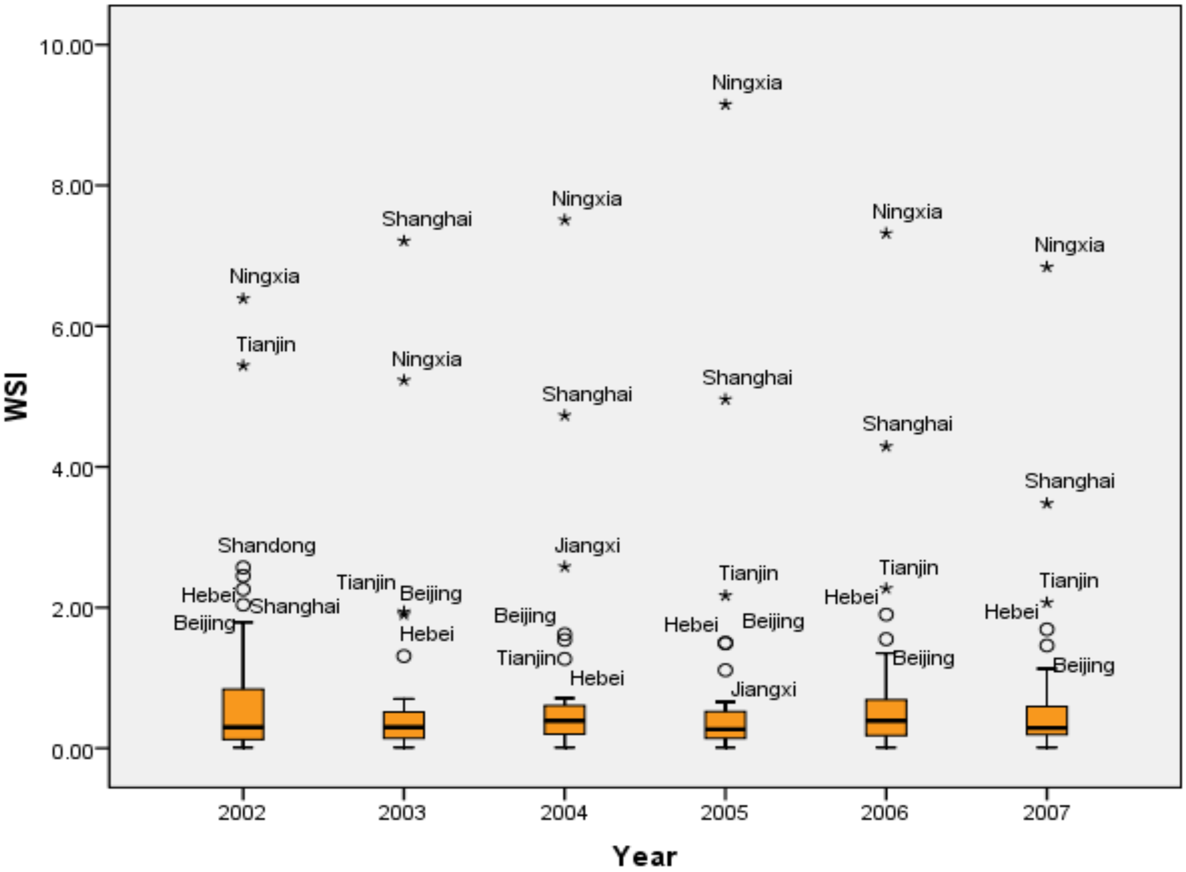


Indicator: WSI

Policy category: Ecosystem Vitality
Indicator name: Water Scarcity Index
Unit of measurement: ratio
Data source: China Statistical Yearbook
Time period: 2002-2007
Data coverage and transparency: No missing data at the provincial level.
Methodology: Water Scarcity Index is the ratio of total consumption of water to the total water resources. The total consumption of water includes water used for agriculture, industry and households.
Target: 0.4
Target source: Expert judgment
Summary statistics:

Minimum: 0.01	Maximum: 6.84	Mean: 0.78	Standard Deviation: 1.34

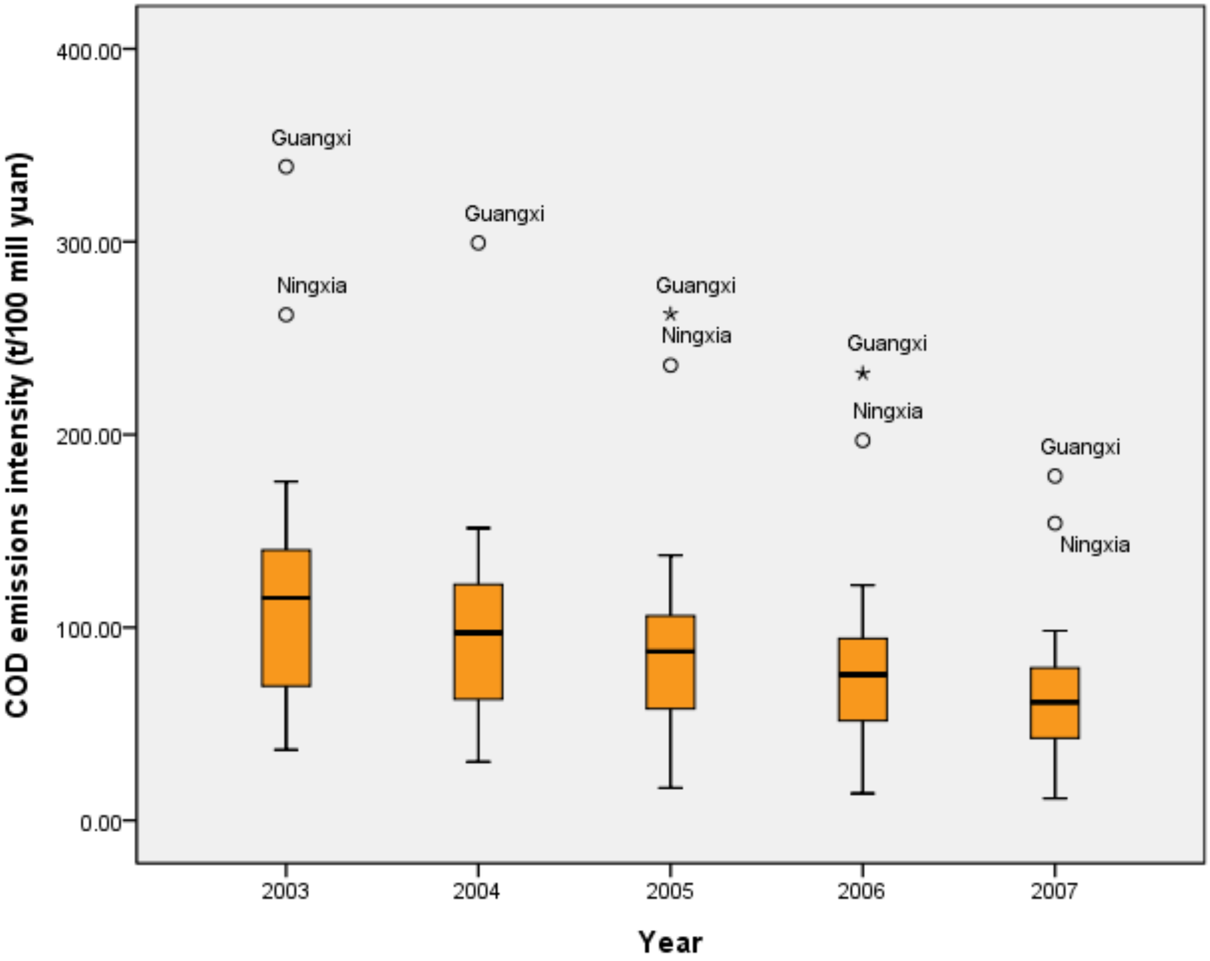
Time series distribution: outliers and extreme values



Indicator: COD

Policy category: Ecosystem Vitality
Indicator name: Intensity of COD emissions
Unit of measurement: t/100m yuan
Data source: China Statistical Yearbook
Time period: 2003-2007
Data coverage and transparency: No missing data at the provincial level.
Methodology: COD (chemical oxygen demand) is total discharges of COD divided by GRP.
Target: 10% reduction
Target source: China's 11th Five-Year Plan
Summary statistics:
Minimum: 11.33 Maximum: 178.49 Mean: 64.26 Standard Deviation: 35.16

Time series distribution: outliers and extreme values

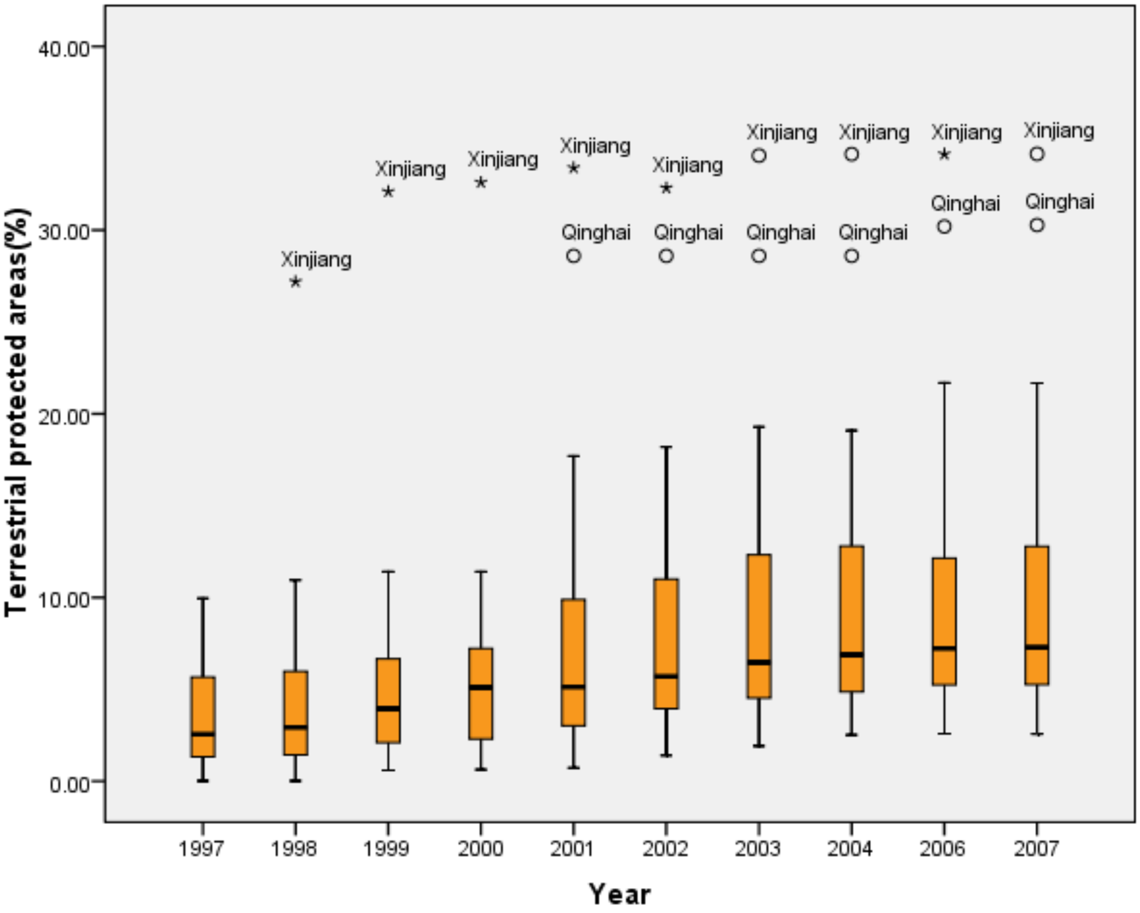


Indicator: TPA

Policy category: Ecosystem Vitality
Indicator name: Terrestrial Protected Areas
Unit of measurement: percent
Data source: China Statistical Yearbook
Time period: 1997-2007
Data coverage and transparency: No missing data at the provincial level.
Methodology: Percent of Province under Protected Status. The criteria for assigning a territory under protective status are included in "Principle for categories and grades of nature reserves (GB/T 14529-93).
Target: 13 by 2010
Target source: China's 11th Five-Year Plan.
Summary statistics:

Minimum: 2.57	Maximum: 34.15	Mean: 10.13	Standard Deviation: 7.54

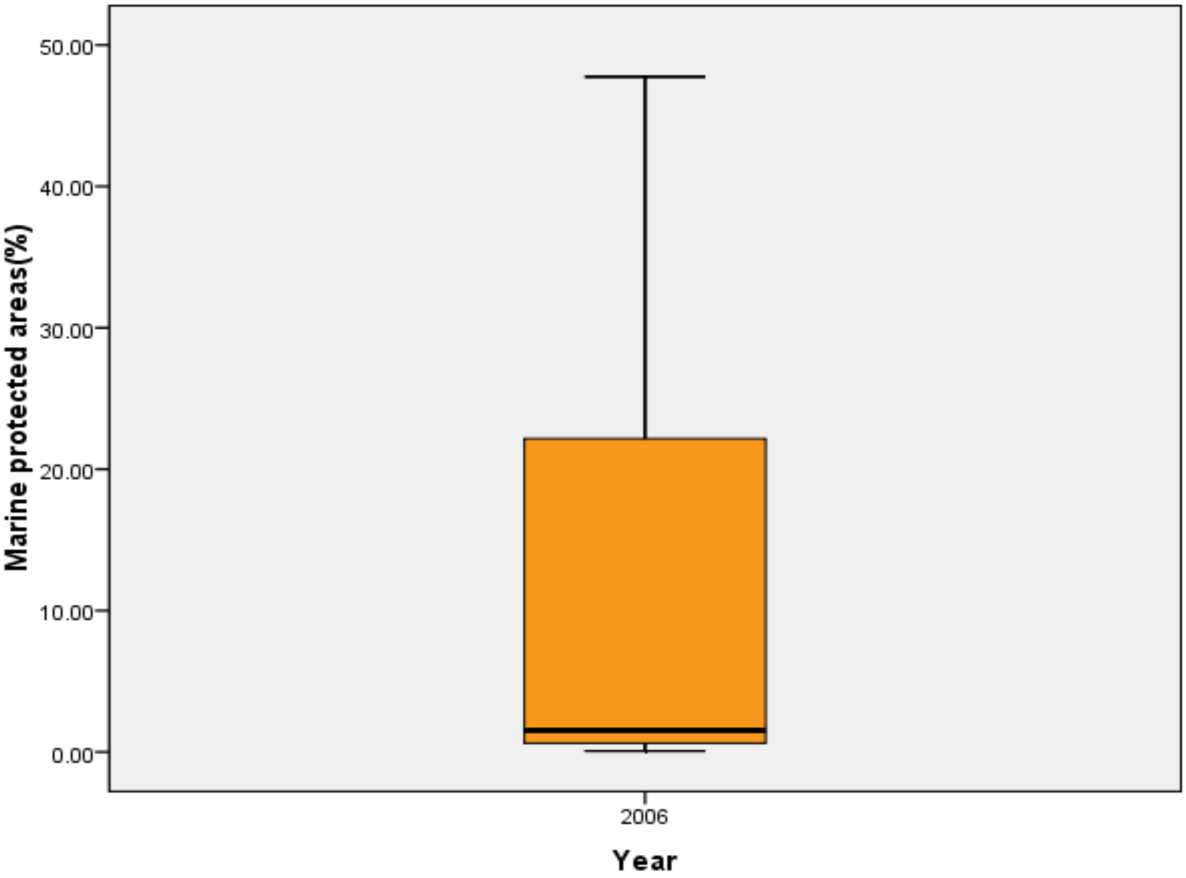
Time series distribution: outliers and extreme values



Indicator: MPA

Policy category: Ecosystem Vitality
Indicator name: Marine Protected Areas
Unit of measurement: percent
Data source: China Marine Statistical Yearbook
Time period: 2006
Data coverage and transparency: Missing data for Hebei province
Methodology: Percent of marine type natural reserves from the total offshore marine areas. No information is available regarding the coastal land areas.
Target: Not available
Target source: Not available
Summary statistics:
Minimum: 0.07 Maximum: 47.75 Mean: 11.67 Standard Deviation: 16.28

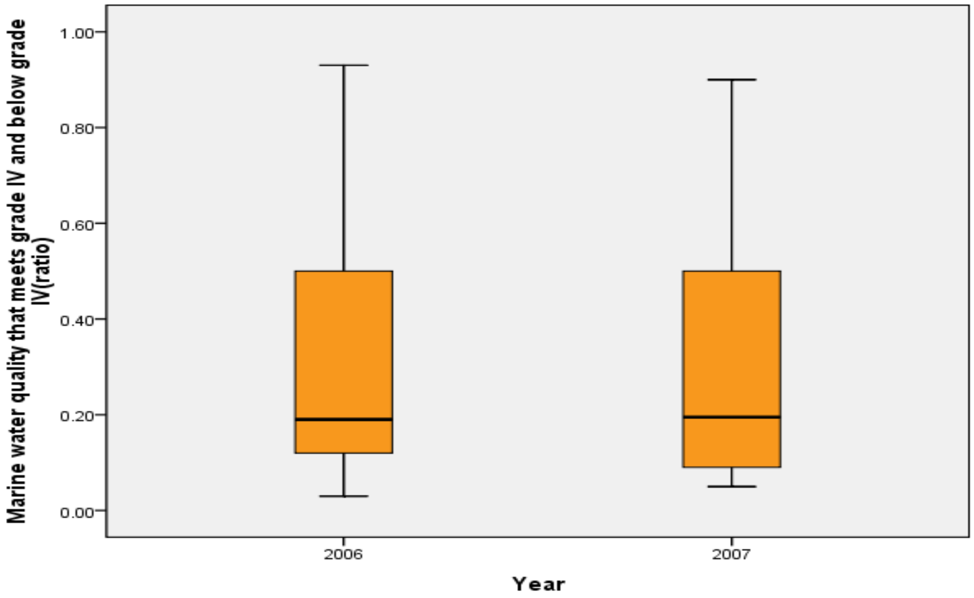
Time series distribution: outliers and extreme values



Indicator: WATQM

Policy category: Ecosystem Vitality
Indicator name: Water Quality of Offshore Marine Areas
Unit of measurement: ratio
Data source: Report on the Administration of the Use of Sea Areas
Time period: 2006-2007
Data coverage and transparency: Data available for all coastal provinces
Methodology: The indicator represents the ratio of monitoring points whose water quality meets grade IV and below grade IV. Information regarding water quality data of offshore area is included in the "Report on Environmental Quality of Offshore Area in China": http://www.sepa.gov.cn/hjjc09/jcxx/jagb/.
Sea water quality standards are included in:
http://english.mep.gov.cn/standards_reports/standards/water_environment/quality_standard/200710/t20071024_111791.htm.
Details on the offshore environmental monitoring issues are included in "Specification for offshore environmental monitoring",
http://www.sepa.gov.cn/tech/hjbz/bzwb/shjbh/sjcgfffbz/200811/W020081111568737999077.pdf.
Target: Not available
Target source: Not available
Summary statistics:
Minimum: 0 Maximum: 0.90 Mean: 0.28 Standard Deviation: 0.29

Time series distribution: outliers and extreme values

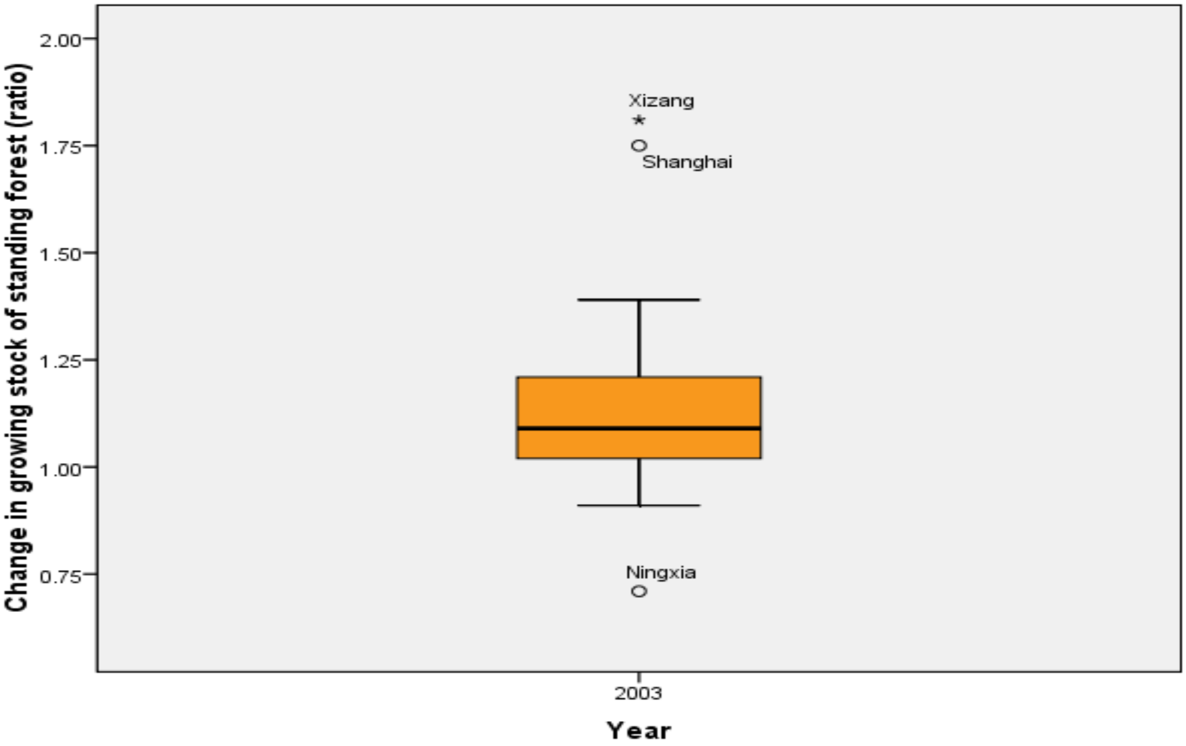


Indicator: FORGRO

Policy category: Ecosystem Vitality
Indicator name: Growing stock change
Unit of measurement: rate of change
Data source: China Statistical Yearbook
Time period: 1998; 2003
Data coverage and transparency: Missing data for province Chongqing and Sichuan
Methodology: Growing stock change is calculated as ratio between the total standing forest stock from the most recent survey (1999-2003) to the standing forest stock from the previous survey (1994-1998). The techniques and regulations for continuous forest investigation" are included in http://www.cfern.org/wjxz/..%5Cwjpicture%5Cupload%5Cwjxz%5Cwjxz2007-4-11-10-35-58.DOC

Target: ≥1
Target source: Expert judgment
Summary statistics:
Minimum: 0.71 Maximum: 1.81 Mean: 1.14 Standard Deviation: 0.23

Time series distribution: outliers and extreme values

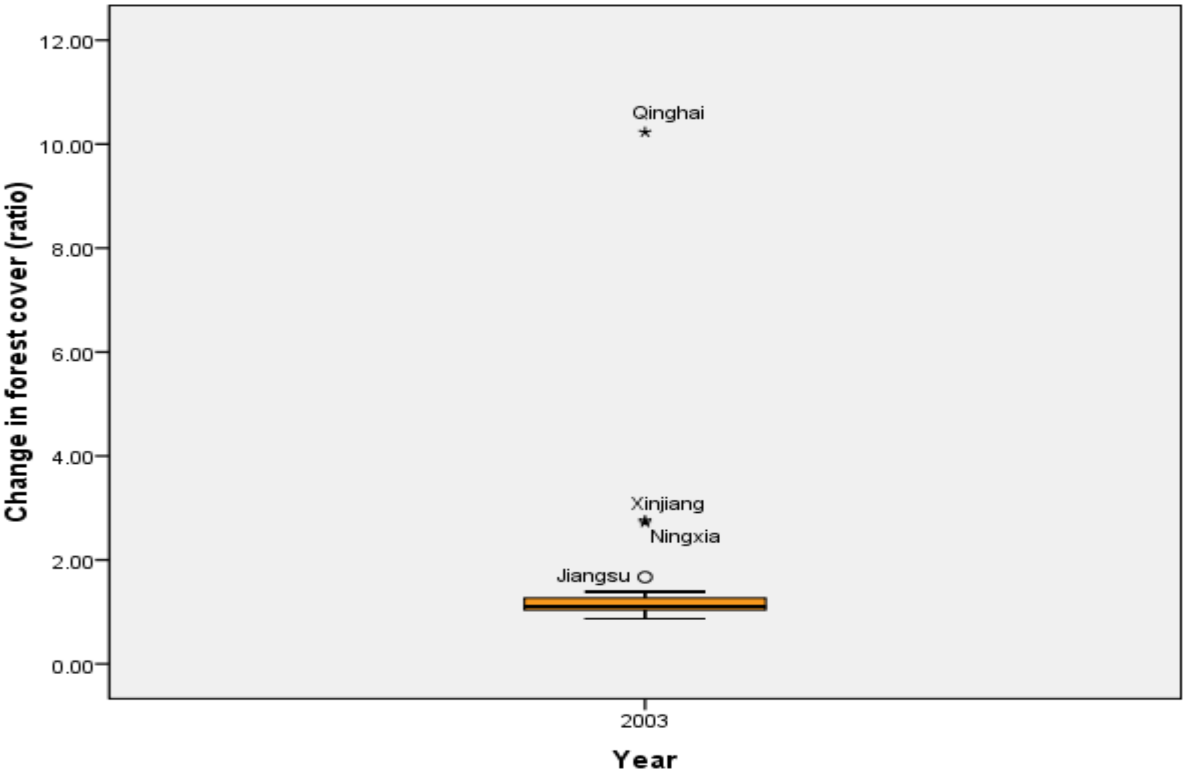


Indicator: FORCOV

Policy category: Ecosystem Vitality
Indicator name: Forest cover change
Unit of measurement: rate of change
Data source: China Statistical Yearbook
Time period: 1998; 2003
Data coverage and transparency: Missing data for province Chongqing, Sichuan and Xizang.
Methodology: Forest cover change is calculated as ratio between the forest cover from the most recent survey (1999-2003) to the forest cover from the previous survey (1994-1998). The techniques and regulations for continuous forest investigation" are included in http://www.cfern.org/wjxz/..%5Cwjpicture%5Cupload%5Cwjxz%5Cwjxz2007-4-11-10-35-58.DOC

Target: ≥1
Target source: Expert judgment
Summary statistics:
Minimum: 0.87 Maximum: 10.23 Mean: 1.57 Standard Deviation: 1.76

Time series distribution: outliers and extreme values

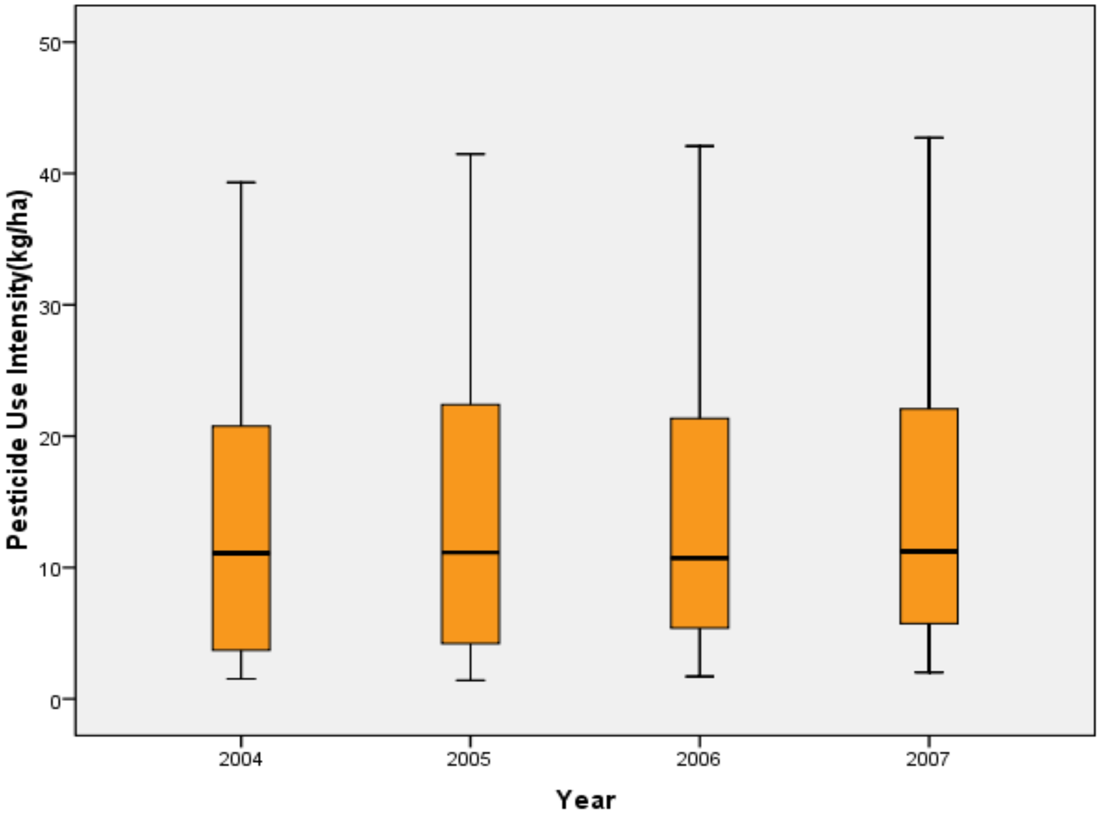


Indicator: PESTINT

Policy category: Ecosystem Vitality
Indicator name: Pesticides Use Intensity
Unit of measurement: kg/ha
Data source: China Statistical Yearbook
Time period: 2004-2007
Data coverage and transparency: Missing data for Guangdong province
Methodology: Pesticides use intensity is the amount of pesticide consumed for agriculture per hectare of temporary and permanent cropland. The pesticides accounted in this indicator are insecticides, herbicides, fungicides, acaricides, plant growth regulators, rodenticides, nematocides, molluscacides and fumigants. The most general pesticide China currently uses is insecticide, which occupies nearly 50% of the total use in pesticide.
Target: 3kg/ha
Target source: Indicators for National Ecological Demonstration Area Construction
Summary statistics:

Minimum: 2.01	Maximum: 42.72	Mean: 14.72	Standard Deviation: 11.76

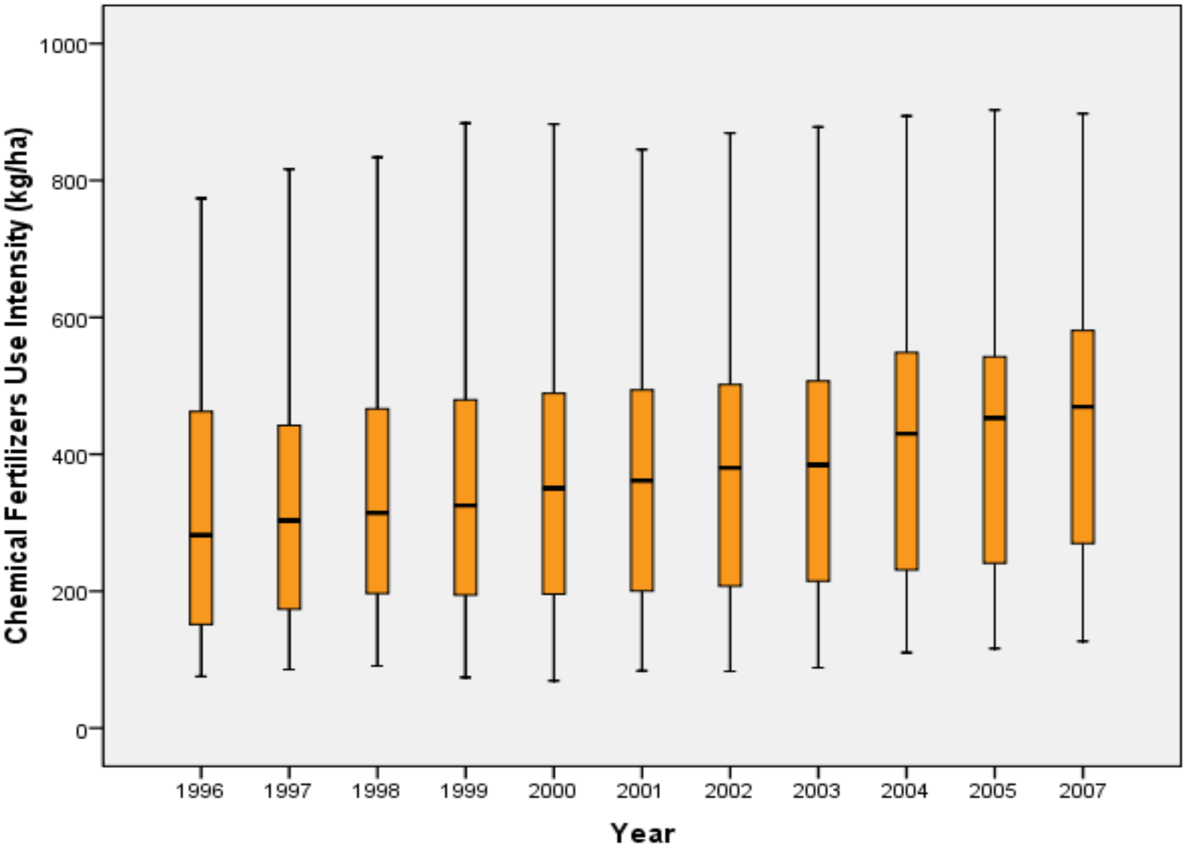
Time series distribution: outliers and extreme values



Indicator: FERTINT

Policy category: Ecosystem Vitality
Indicator name: Chemical Fertilizers Use Intensity
Unit of measurement: kg/ha
Data source: China Statistical Yearbook
Time period: 1996-2005, 2007
Data coverage and transparency: No missing data at the provincial level
Methodology: Fertilizer use intensity is the amount of fertilizer consumed for agriculture per hectare of temporary and permanent cropland. The fertilizers accounted in this indicator are nutrients nitrogen (N), potash (K2O), and phosphate (P2O5).
Target: 250kg/ha
Target source: Indicators for Eco-county (city) Construction
Summary statistics:
Minimum: 126.82 Maximum: 897.85 Mean: 440.82 Standard Deviation: 208.40

Time series distribution: outliers and extreme values

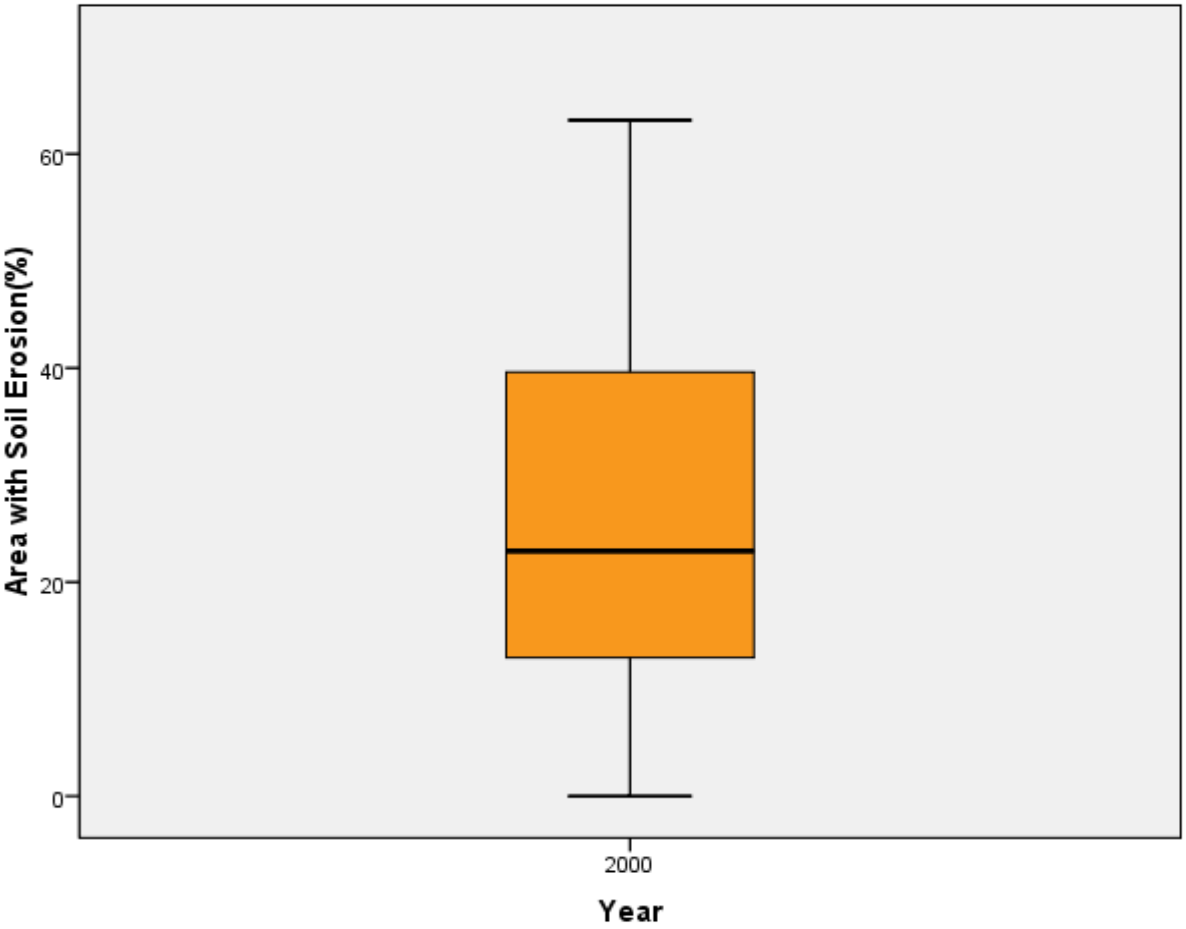


Indicator: SELAND

Policy category: Ecosystem Vitality
Indicator name: Soil erosion
Unit of measurement: %
Data source: China Soil Erosion Bulletin
Time period: 2000
Data coverage and transparency: No missing data at the provincial level
Methodology: Soil erosion indicator is calculated as a percentage of land area affected by soil erosion. No information is available regarding how the soil erosion is measured, methodology of aggregation at the provincial level, and representativeness.
Target: 34%
Target source: China's 11th Five-Year Plan
Summary statistics:

Minimum: 0	Maximum: 63.16	Mean: 28.41	Standard Deviation: 20.69

Time series distribution: outliers and extreme values

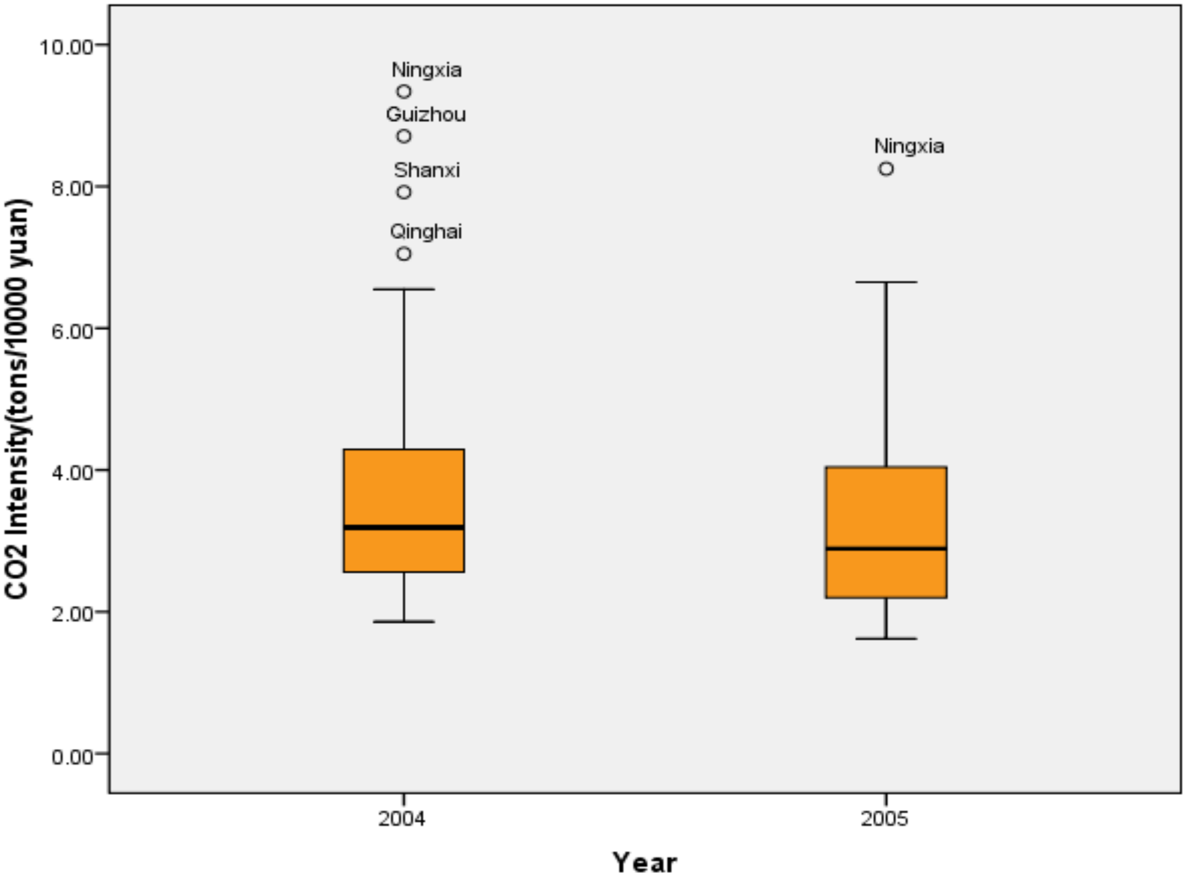


Indicator: CO2INT

Policy category: Economic Sustainability
Indicator name: CO2 Intensity
Unit of measurement: tons/10000 ¥
Data source: China Statistical Yearbook
Time period: 2004 - 2005
Data coverage and transparency: Missing data for Xizang province
Methodology: CO2 intensity is calculated by dividing the CO2 emission equivalent to the gross regional products within each province. CO2 emissions equivalent is calculated using IPCC methodology, using sectoral approach.
Target: not available
Target source: not available
Summary statistics:

Minimum: 1.62	Maximum: 8.25	Mean: 3.36	Standard Deviation: 1.55

Time series distribution: outliers and extreme values

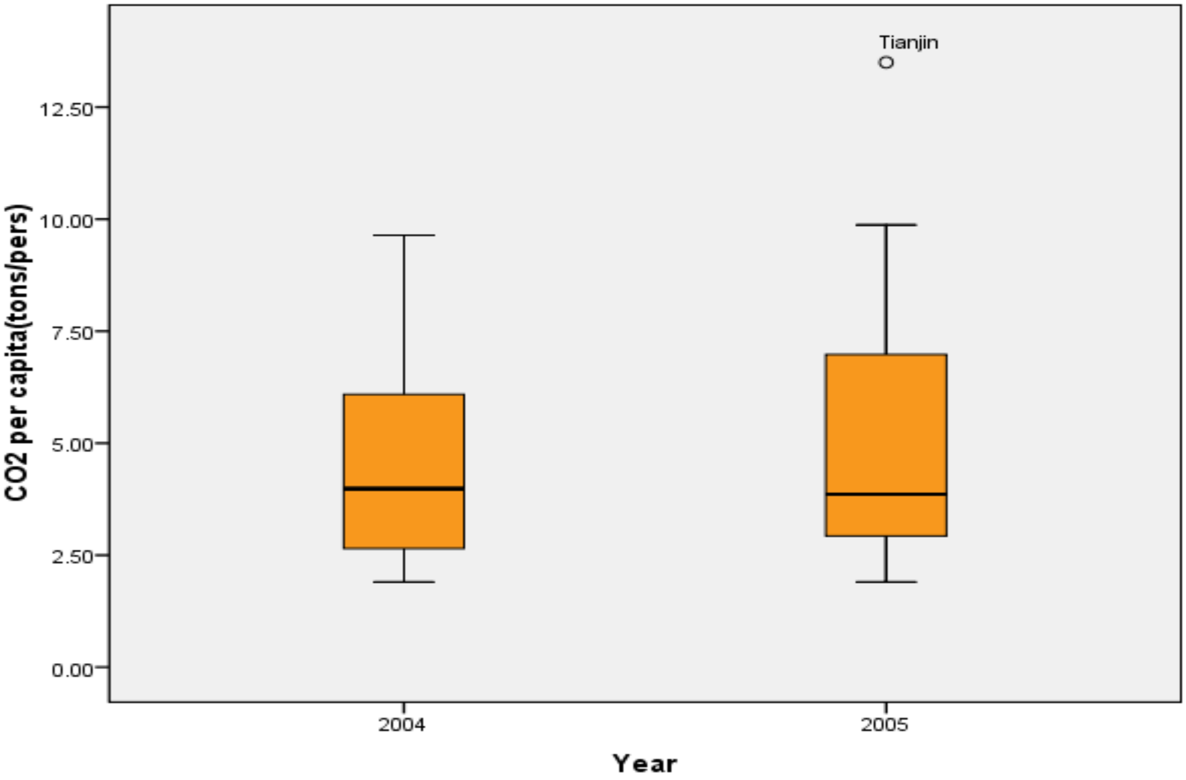


Indicator: CO2PC

Policy category: Economic Sustainability
Indicator name: Per capita CO2 emissions
Unit of measurement: tons/person
Data source: China Statistical Yearbook
Time period: 2004 - 2005
Data coverage and transparency: Missing data for Xizang province
Methodology: Per capita CO2 emissions are calculated by dividing the CO2 emission equivalent to the number of persons within each province. CO2 emissions equivalent is calculated using IPCC methodology, using sectoral approach.
Target: not available
Target source: not available
Summary statistics:

Minimum: 1.90	Maximum: 13.50	Mean: 4.92	Standard Deviation: 2.74

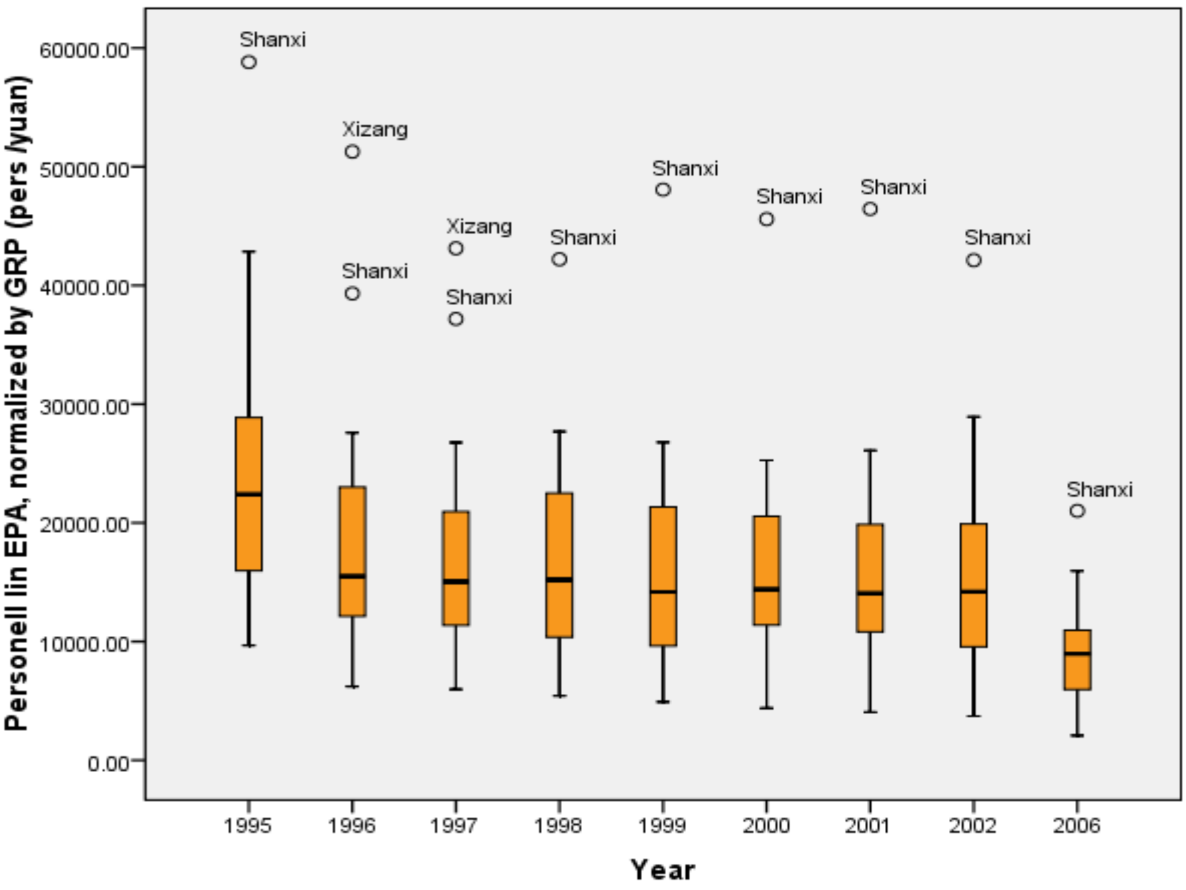
Time series distribution: outliers and extreme values



Indicator: GOVEMPL

Policy category: Economic Sustainability
Indicator name: Number of EPB employees on government payroll
Unit of measurement: persons/¥
Data source: China Statistical Yearbook
Time period: 1995 – 2002, 2006
Data coverage and transparency: No missing data
Methodology: Number of EPB employees on government payroll are weighted by regional gross domestic product.
Target: not available
Target source: not available
Summary statistics:
Minimum: 2090.41 Maximum: 21011.92 Mean: 8920.16 Standard Deviation: 4289.35

Time series distribution: outliers and extreme values

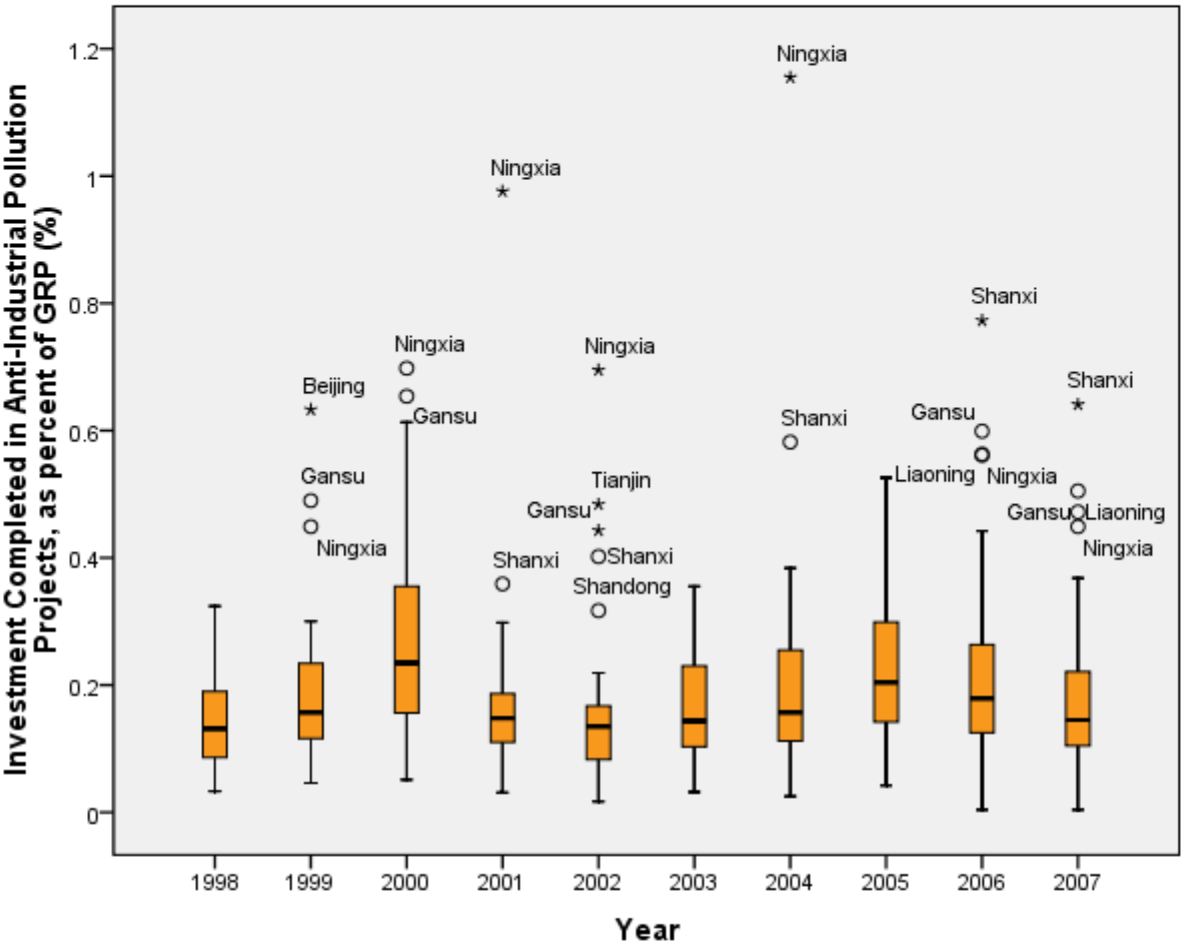


Indicator: INVPOLL

Policy category: Economic Sustainability
Indicator name: Investment in environmental protection, as percentage of GRP
Unit of measurement: %
Data source: China Statistical Yearbook
Time period: 1998-2007
Data coverage and transparency: No missing data
Methodology: Investment completed in anti-industrial pollution projects, as percent of GRP
Target: not available
Target source: not available
Summary statistics:

Minimum: 0	Maximum: 0.64	Mean: 0.20	Standard Deviation: 0.15

Time series distribution: outliers and extreme values



Indicator: EFFEC

Policy category: Economic Sustainability
Indicator name: Economic energy efficiency
Unit of measurement: tce/10000 ¥
Data source: China Statistical Yearbook
Time period: 1998-2007
Data coverage and transparency: Missing data for Xinjiang province
Methodology: Economic energy efficiency is the ratio of total energy consumption to GDP. Total Domestic Energy consumption refers to the total consumption of energy of various kinds by material production sectors, non material production sectors and households in the country in a given period of time. It is a comprehensive indicator to show the scale, composition and development of energy consumption. The total energy consumption includes that of coal, crude oil and their products, natural gas and electricity, However, it excludes the consumption of fuel of low calorific value, bio-energy and solar energy. Total domestic energy consumption can be divided into three parts:

(1)Final Energy Consumption: It refers to the total energy consumption by material production sectors, non material production sectors and households in the country (region) in a given period of time, but excludes the consumption in conversion of the primary energy into the secondary energy and the loss in the process of energy conversion.

(2)Loss during the Process of Energy Conversion: It refers to the total input of various kinds of energy for conversion, minus the total output of various kinds of energy in the country in a given period of time. It is an indicator to show the loss that occurs during the process of energy conversion.

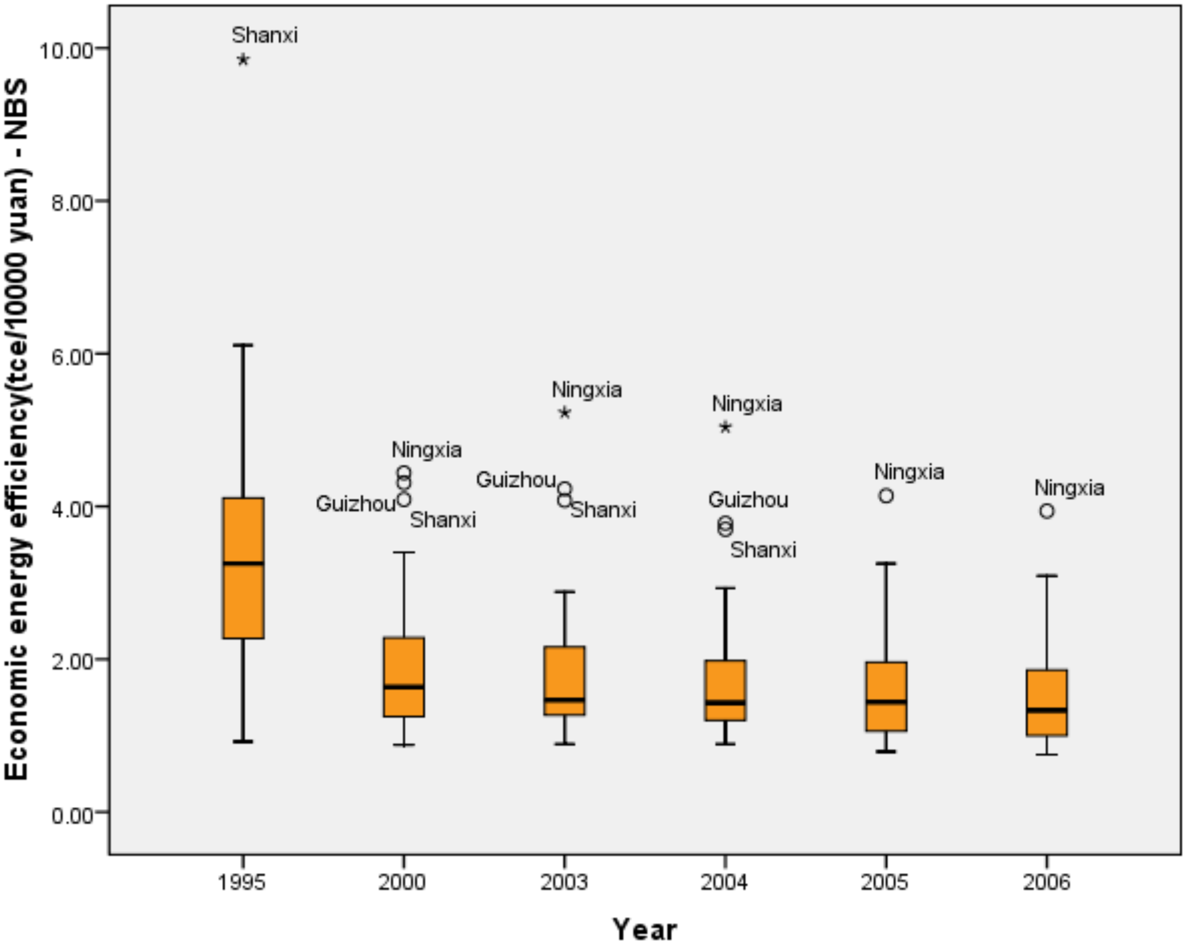
(3)Loss: It refers to the total of the loss of energy during the course of energy transport, distribution and storage and the loss caused by any objective reason in a given period of time. The loss of various kinds of gas due to gas discharges and stocktaking is excluded.

(NSB,2002, http://www.stats.gov.cn/english/programsandindicators/currentsurveysindicators/t20020517_19815.htm)

Target: varies by province, between 12 and 30%
Target source: NDRC
Summary statistics:

Minimum: 0.76	Maximum: 4.10	Mean: 1.62	Standard Deviation: 0.82

Time series distribution: outliers and extreme values

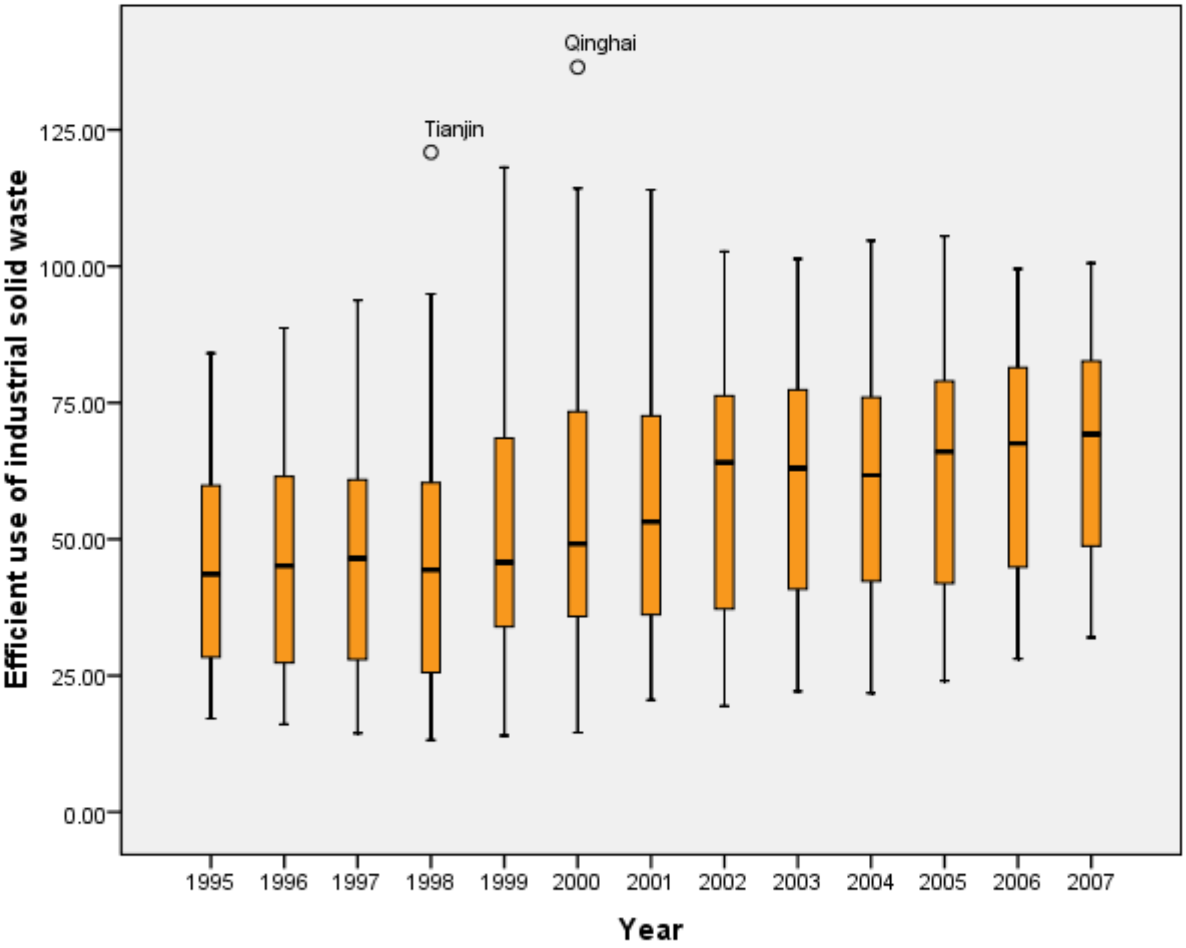


Indicator: EFFWASTE

Policy category: Economic Sustainability
Indicator name: Efficient use of waste
Unit of measurement: %
Data source: China Statistical Yearbook
Time period: 1995-2007
Data coverage and transparency: Missing data for Xizang province
Methodology: Efficient use of waste is the percentage of industrial solid wastes that are recycled (or utilized).
Target: 60% in 2010
Target source: China's 11th Five-Year Plan
Summary statistics:

Minimum: 29.88	Maximum: 98.41	Mean: 66.48	Standard Deviation: 21.24

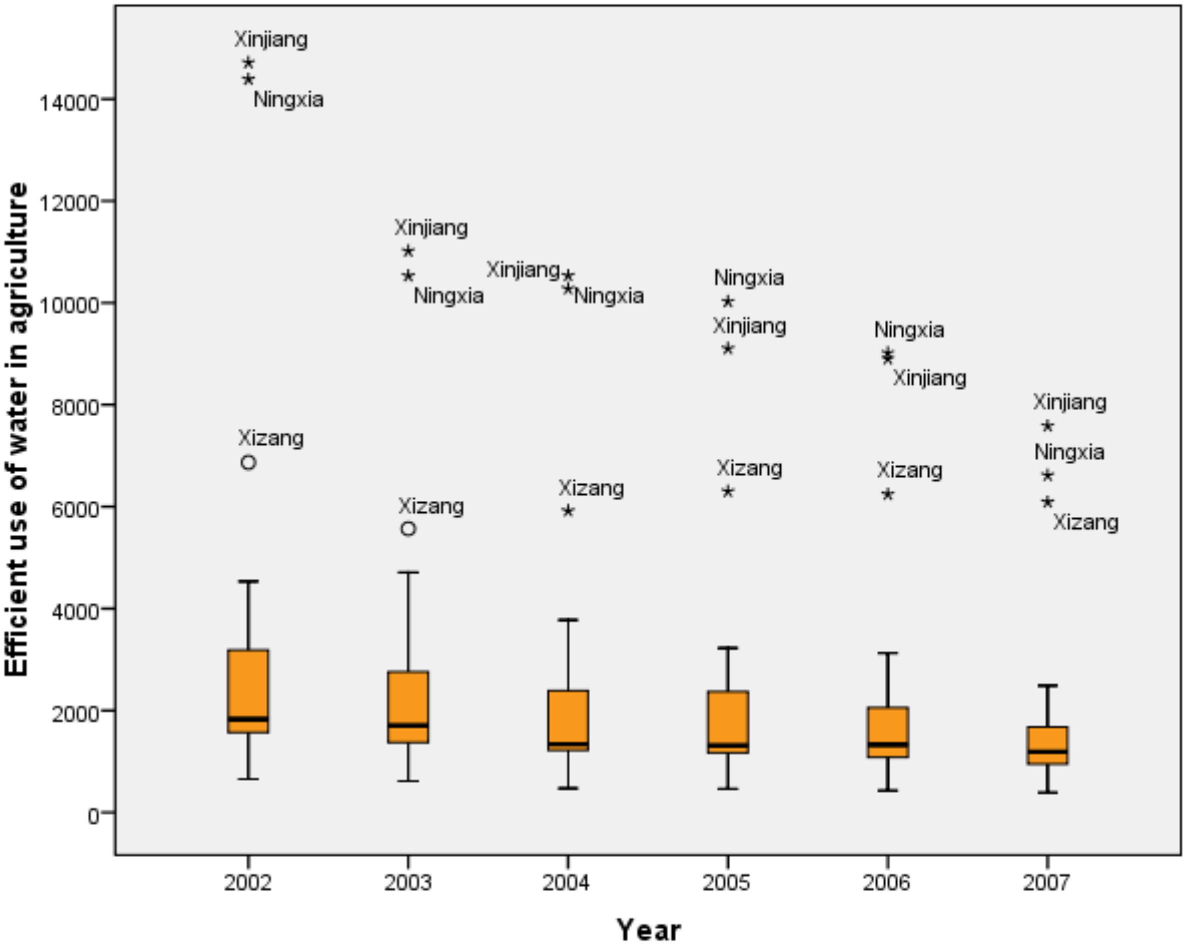
Time series distribution: outliers and extreme values



Indicator: EFFWATagr

Policy category: Economic Sustainability
Indicator name: Efficient use of water in agriculture
Unit of measurement: cubic meters/10000 ¥
Data source: China Statistical Yearbook
Time period: 2002-2007
Data coverage and transparency: No missing data
Methodology: Efficient use of water in agriculture is the ratio of water use in agriculture to the gross regional product.
Target: 30% in 2010
Target source: China's 11th Five-Year Plan
Summary statistics:
Minimum: 388.68 Maximum: 7583.18 Mean: 1774.23 Standard Deviation: 1750.51

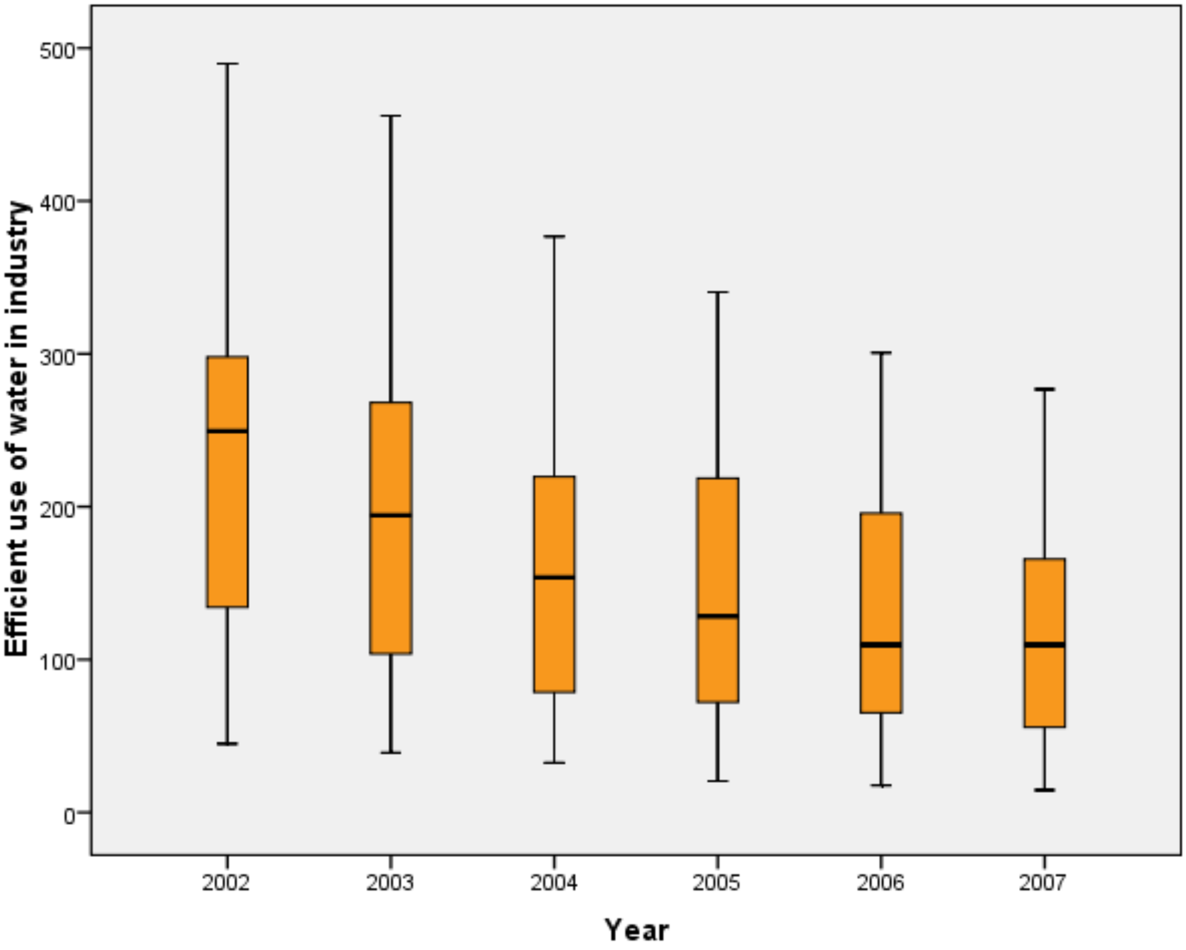
Time series distribution: outliers and extreme values



Indicator: EFFWATind

Policy category: Economic Sustainability
Indicator name: Efficient use of water in industry
Unit of measurement: cubic meters/10000 ¥
Data source: China Statistical Yearbook
Time period: 2002-2007
Data coverage and transparency: No missing data
Methodology: Efficient use of water in industry is the ratio of water use in industry to the gross regional product.
Target: 30% in 2010
Target source: China's 11th Five-Year Plan
Summary statistics:
Minimum: 14.52 Maximum: 276.87 Mean: 118.54 Standard Deviation: 76.03

Time series distribution: outliers and extreme values



VII. References

An, L., T. Shinsuke, J. Guibin and J. P. Giesy (2007). Persistent Organic Pollutants in Asia, Volume 7: Sources, Distributions, Transport and Fate (Developments in Environmental Science): Elsevier Science.

Andrews, S., I. Pictures and B. Watch (2008). "Seeing Through the Smog: Understanding the Limits of Chinese Air Pollution Reporting." China Environmental Series **10**: 5-32.

Aruvian Research. 2009. *Analyzing the Wind Power Industry in China*. http://www.researchandmarkets.com/research/e5541b/analyzing_the_wind.

Asian Development Bank (2006). People's Republic of China: Safe Drinking Water and Sanitation for the Rural Poor Beijing: National Center for Rural Water Supply and Technical Guidance.

Bai, Z., Z. Wang, T. Zhu and J. Zhang (2003). "Developing indoor air quality related standards in China." Journal of Asian Architecture and Building Engineering **2**(1): 55-60.

BAN and SVTC (2002). Exporting Harm: The High-Tech Trashing of Asia Seattle, WA and San Jose, CA: Basel Action Network and Silicon Valley Toxics Coalition.

Bartram, J., K. Lewis, R. Lenton and A. Wright (2005). "Focusing on improved water and sanitation for health." Lancet **365**(9461): 810-812.

Beach, M. (2001). "Water , pollution , and public health in China." Lancet **358**: 735.

Bei, Z., L. I. Huiming and W. Bin (2009). "Research on Urban Waste Information Management Based on the Concept of Recycling Economy." Urban Studies. 02.

Best, A., D. Blobel, S. Cavalieri, S. Giljum, M. Hammer, S. Lutter, C. Simmons and K. Lewis (2008). Potential of the Ecological Footprint for monitoring environmental impacts from natural resource use: Analysis of the potential of the Ecological Footprint and related assessment tools for use in the EU's Thematic Strategy on the Sustainable Use of Natural Resources. Report to the European Commission,, DG Environment.

Billig, P., D. Bendahmane and A. Swindale (1999). Water and sanitation indicators measurement guide. Title 2 Indicator Guides Washington, DC: Food and Nutrition Assistance Project, Bureau of Global Programs, United States Agency for International Development, Washington DC.

Bruno, F. and D. Cocchi (2007). "Recovering information from synthetic air quality indices." Environmetrics **18**(3): 345-359.

Bull, K. (1991). "The critical loads/levels approach to gaseous pollutant emission control." Environmental pollution **69**(2-3): 105-123.

Burnett, R.T., S. Cakmak, and J. Brook. 1998. The Effect of the Urban Ambient Air Pollution Mix on Daily Mortality Rates in 11 Canadian Cities. Canadian Review of Public Health, 89(3): 152-156.

Campbell-Lendrum, D. H., K. L. Ebi and A. K. Githeko (2003). Climate Change and Human Health. Risks and Responses. Geneva: World Health Organization.

Cao, J., R. Garbaccio and M. Ho (2009). "China's 11th Five-Year Plan and the Environment: Reducing SO2 Emissions." Review of Environmental Economics and Policy **3**(2): 231-250.

Cao, S., G. Xie, et al. (2010). "Total embodied energy requirements and its decomposition in China's agricultural sector." Ecological Economics **69**(7): 1396-1404.

Carpenter, S., N. Caraco, D. Correll, R. Howarth, A. Sharpley and V. Smith (2008). "Nonpoint pollution of surface waters with phosphorus and nitrogen." Ecological applications **8**(3): 559-568.

Chen, L. (2009). "“实行最严格的水资源管理制度 保障经济社会可持续发展” [Implementing the most strictest water resource management system will ensure socioeconomic sustainable development]". Retrieved 24 June, 2009, from http://www.mwr.gov.cn/xwpd/slyw/20090214214359540317.aspx.

China State Council (2008). China's Policies and Actions for Addressing Climate Change. Information Office of China's State Council. Beijing.

Center for International Earth Science Information Network (CIESIN), Columbia University; International Food Policy Research Institute (IFPRI); The World Bank; and Centro Internacional de Agricultura Tropical (CIAT). 2004. Global Rural-Urban Mapping Project (GRUMP), Alpha Version: Population Density Grids. Palisades, NY: Socioeconomic Data and Applications Center (SEDAC), Columbia University. Available at http://sedac.ciesin.columbia.edu/gpw.

CNEMC (2009). Internal communication: China's National Environmental Monitoring Center.

CSEP (2008). "Year Two: National 20-Percent Energy Efficiency Target for 2010." CSEP Newsroom. http://www.efchina.org/FNewsroom.do?act=detail&newsTypeId=1&id=4.

Dasgupta, S., K. Hamilton, K. Pandey and D. Wheeler (2006). "Environment during growth: accounting for governance and vulnerability." World Development **34**(9): 1597-1611.

Datong, N. (1997). An Assessment of the Economic Losses Resulting from Land Degradation in China. Occasional Paper of the Project on Environmental Scarcities, State Capacity, and Civil Violence. Toronto, Trudeau Centre for Peace and Conflict Studies at the University of Toronto.

Delzer, G. and S. McKenzie (2003). Five-Day Biochemical Oxygen Demand. National Field Manual for the Collection of Water-Quality Data: U.S. Geological Survey Techniques of Water-Resources Investivations Book 9. USGS: USGS.

"Drinking water pollution getting worse in China." (2006) China Daily. July 24 2006. http://www2.chinadaily.com.cn/china/2006-07/24/content_648290.htm.

Dudgeon, D., A. Arthington, M. Gessner, Z. Kawabata, D. Knowler, C. LÈvÍque, R. Naiman, A. Prieur-Richard, D. Soto and M. Stiassny (2005). "Freshwater biodiversity: importance, threats, status and conservation challenges." Biological Reviews **81**(02): 163-182.

EEA (2007). Europe's Environment: The Fourth Assessment Luxembourg: European Energy Agency, Office for Official Publications of the European Communities.

Emerson, J., D. Esty, M. Levy, C. Kim, V. Mara, A. de Sherbinin and T. Srebotnjak (2010). 2010 Environmental Performance Index New Haven: Yale Center for Environmental Law and Policy.

Environmental Monitoring of China (2010, 12 May). "Report of the 113 environmental key cites' air quality live report project"中国环境监测总站：《113 重点环境保护城市空气质量实时发布工作汇报》". Retrieved 30 June, 2010, from http://webcache.googleusercontent.com/search?q=cache:kf4k0Kmx9M0J:www.cnemc.cn/showtiaomu.aspx%3FID%3Dabbbc850-4d04-4210-aa56-b8321c876d59+中国环境监测总站+城市空气质量&cd=2&hl=en&ct=clnk&gl=us.

EPA (1995). Technical Guidance Manual for Developing Total Maximum Daily Loads: Biochemical Oxygen Demand/Dissolved Oxygen and Nutrients/Eutrophication Washington: US Environmental Protection Agency.

EPA (2007). "Chromium Compounds". Technology Transfer Network: Air Toxics Web Site. Washington: US Environmental Protection Agency. Retrieved 24 June, 2010, from http://www.epa.gov/ttnatw01/hlthef/chromium.html.

EPA (2009a). "Air Pollutants". Air. Washington, DC. Retrieved June 9, 2009, from http://www.epa.gov/ebtpages/airairpollutants.html.

EPA (2009b). "What is TRI?". Toxic Release Inventory Program. Washington. Retrieved 24 June, 2010, from http://www.epa.gov/tri/triprogram/whatis.htm.

EPA (2010a). "Laws, Policy and Guidance". Superfund. Washington: US Environmental Protection Agency. Retrieved 24 June, 2010.

EPA (2010b). "Summary of the Resource Conservation and Recovery Act". Laws & Regulations. Washington: US Environmental Protection Agency. Retrieved 1 July, 2010, from http://www.epa.gov/lawsregs/laws/rcra.html.

EPA (2010c). "Summary of the Toxic Substances Control Act". Laws & Regulations. Washington: US Environmental Protection Agency. Retrieved 24 June, 2010, from http://www.epa.gov/lawsregs/laws/tsca.html.

Esty, D., M. Levy, C. Kim, A. de Sherbinin, T. Srebotnjak and V. Mara (2008). Environmental Performance Index. Yale Center for Environmental Law and Policy New Haven.

Europa (2010). "Waste: Hazardous Waste". Environment. Retrieved 23 June, 2010, from http://ec.europa.eu/environment/waste/hazardous_index.htm.

European Union (1994). Directive 94/62/EC on Packaging and Packaging Waste. European Parliament and the Council of the European Union.

European Union (2005a). Communication on Thematic Strategy on the sustainable use of natural resources. Commission of the European Communities. Brussels.

European Union (2005b). Taking sustainable use of resources forward: A Thematic Strategy on the prevention and recycling of waste. Commission of the European Communities. Brussels.

European Union (2008). "Proposal for identification of Substances of Very High Concern: Annex XV reports to be commented by Interested Parties". European Chemicals Agency. Retrieved 23 June, 2010, from http://echa.europa.eu/consultations/authorisation/svhc/svhc_cons_en.asp.

FAO (2010). "AQUASTAT 2010". Aquastat: FAO's Information System on Water and Agriculture. Rome: Food and Agriculture Organization of the UN. Retrieved 11 Nov, 2010, from http://www.fao.org/nr/water/aquastat/countries/china/index.stm.

FAO (2006). Global Forest Resources Assessment 2005. Rome: Food and Agriculture Organization of the UN.

FAO (2010). Global Forest Resourced Assessment 2010: Key Findings. Rome: Food and Agriculture Organization of the UN.

Fang, M., C. Chan and X. Yao (2009). "Managing air quality in a rapidly developing nation: China." Atmospheric Environment. **43**(1): 79-86.

Feng, Z., Y. Huang, Y. Feng, N. Ogura and F. Zhang (2001). "Chemical composition of precipitation in Beijing area, northern China." Water, Air, & Soil Pollution **125**(1): 345-356.

Finkelman, R., H. Belkin and B. Zheng (1999). "Health impacts of domestic coal use in China." Proceedings of the National Academy of Sciences **96**(7): 3427.

Fuhrer, J., L. Skärby and M. Ashmore (1997). "Critical levels for ozone effects on vegetation in Europe." Environmental pollution **97**(1-2): 91-106.

Gale, F., B. Lohmar and F. Tuan (2005). China's New Farm Subsidies. Electronic Outlook Report from the Economic Research ServiceWRS-05-01. United States Department of Agriculture.

Grossman, G. and A. Krueger (1995). "Economic growth and the environment." Quarterly Journal of Economics **110**(2): 353-377.

Hickey, G., J. Innes, R. Kozak, G. Bull and I. Vertinsky (2005). "Monitoring and information reporting for sustainable forest management: An international multiple case study analysis." Forest Ecology and Management **209**(3): 237-259.

Huang, D. B., H. P. Bader, R. Scheidegger, R. Schertenleib and W. Gujer (2007). "Confronting limitations: New solutions required for urban water management in Kunming City." Journal of environmental management. **84**(1): 49-61.

Hubacek, K. and L. Sun (2005). "Economic and Societal Changes in China and their Effects onWater Use A Scenario Analysis." Journal of Industrial Ecology. **9**(1 2): 187-200.

International Energy Agency (IEA). 2010. “China overtakes the United States to become world’s largest energy consumer”. http://www.iea.org/index_info.asp?id=1479. Accessed July 20, 2011

"Interpretation and explanation: MEP designates 113 environmental[emphasizing air quality] key cities in its Five-Year Plan《解读：国家环保规划确定 113 个城市为环保重点城市》." (2007) Xinhua. 27 Nov. http://news.xinhuanet.com/politics/2007-11/27/content_7156709.htm.

IPCC (2007). Climate change 2007: Impacts, adaptation and vulnerability. Working Group II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report: Intergovernmental Panel on Climate Change.

Jialing, Z. (2007). The Management of Hazardous Waste in China. A China Environmental Health Project Research Brief, China Environment Forum and Western Kentucky University: a USAID-supported China Environmental Health Project.

Jin, T., M. Nordberg, et al. (2002). "Cadmium biomonitoring and renal dysfunction among a population environmentally exposed to cadmium from smelting in China (ChinaCad)." BioMetals **15**(4): 397-410.

JME (2005). Dioxins. Water Environment Partnership in Asia: Office of Dioxins Control, Japan Ministry of the Environment.

JMP (2006). Coverage Estimates of Improved Sanitation for China New York: Joint Monitoring Programme for Water Supply and Sanitation.

Karr, J. (1991). "Biological integrity: a long-neglected aspect of water resource management." Ecological applications **1**(1): 66-84.

Kassomenos, P., A. Skouloudis, S. Lykoudis and H. Flocas (1999). ""Air-quality indicators" for uniform indexing of atmospheric pollution over large metropolitan areas." Atmospheric Environment **33**(12): 1861-1879.

Kato, K. (2000). Improving Environmental Governance in Asia: Institute for Global Environmental Strategies.

Khan, S. and M. Hanjra (2009). "Footprints of water and energy inputs in food production-Global perspectives." Food Policy **34**(2): 130-140.

Knudsen, S. (Unknown). Quick Reference: Pollution Prevention Act (PPA) Ann Arbor, MI: Center for Sustainable Systems, University of Michigan.

Koo-Oshima, S. (2005). Water Quality Management in Agriculture - Workshop in China Rome: Food and Agriculture Organization.

Law of the People's Republic of China on Prevention and Control of Water Pollution (1984). People's Republic of China.

Lee, D. (2007). Child Mortality and Water Pollution in China: Achieving Millennium Development Goal 4. China Environmental Health Project Washington, DC: USAID.

Lehman, C. and D. Tilman (2000). "Biodiversity, stability, and productivity in competitive communities." Am Nat **156**(5): 534-552.

Lei, X., M. Tang, Y. Lu, L. Hong and D. Tian (2009). "Forest inventory in China: status and challenges." International Forestry Review **11**(1): 52-63.

Li, W. and H. Chan (2009). "Clean air in urban China: The case of inter-agency coordination in Chongqing's Blue Sky Program." Public Administration and Development **29**(1): 55-67.

Liu, J., Z. Ouyang, S. L. Pimm, P. H. Raven, X. Wang, H. Miao and N. Han (2003). "Protecting China's biodiversity." Science(Washington) **300**(5623): 1240-1241.

Liu, Y. (2006a). "China's drinking water situation grim; Heavy pollution to blame". ChinaWatch. WorldWatch Institute. Retrieved 18 June, 2010, from http://www.worldwatch.org/node/4423.

Liu, Y. (2006b). "Shrinking Arable Lands Jeopardizing China's Food Security". Chinawatch. Worldwatch Institute. Retrieved 13 July, 2010, from http://www.worldwatch.org/node/3912.

Lohmar, B. and F. Gale (2008) Who Will China Feed? Amber Waves

Lohmar, B., J. Wang, S. Rozelle, J. Huang and D. Dawe (2003). China's agricultural water policy reforms: increasing investment, resolving conflicts, and revising incentives. Agriculture Information Bulletin, Number 782. Washington: US Department of Agriculture Economic Research Service.

López, R. and S. Mitra (2000). "Corruption, Pollution, and the Kuznets Environment Curve." Journal of Environmental Economics and Management **40**(2): 137-150.

Lu, W. (2006). Resource-saving Society Development in China Beijing: Department of Environment & Resource Conservation, National Development and Reform Commission (NDRC).

Mao, J., Z. Lu and Z. Yang (2006). "The Eco-efficiency of Lead in China's Lead-Acid Battery System." Journal of Industrial Ecology **10**(1-2): 185-197.

McNaughton, S. (1993). Biodiversity and function of grazing ecosystems. Biodiversity and ecosystem function. E.-D. Schulze and H. Mooney. New York: Springer. **Volume 99:** 361-383.

MEP (2006). The National Eleventh Five-year Plan for Environmental Protection (2006-2010). Beijing: China Ministry of Environment.

MEP (2010). Special Report on Pollution Reduction Census of Pollution Sources Points out Direction for Pollution Reduction: An Interview with Wang Yuqing, Member of the 11th CPPCC Beijing: Ministry of Environmental Protection, PRC.

Millenium Ecosystem Assessment (2005). Ecosystems and Human Well-being: Synthesis. Washington, DC: Island Press.

MOC and SQSIQA (2002). GB 50325-2001. Code for indoor environmental pollution control of civil building engineering. Ministry of Construction and China State Quality Supervision-Inspection-Quarantine Administration.

NBS (2002). "Production and Consumption of Energy". Current Surveys Indicators. Beijing: National Bureau of Statistics of China. Retrieved 29 June, 2010, from http://www.stats.gov.cn/english/programsandindicators/currentsurveysindicators/t20020517_19815.htm.

NCCC (2004). The People's Republic of China Initial National Communication on Climate Change Beijing: National Coordination Committee on Climate Change, P.R.C. http://unfccc.int/resource/docs/natc/chnnc1exsum.pdf

NDRC (2006). The Outline of the Eleventh Five-Year Plan for National Economic & Social Development of the People's Republic of China Beijing: National Development and Reform Commission (NDRC), People's Republic of China.

NDRC (2007a). 11th Five-year Plan for Energy and resource development (国家发展改革委:《能源发展“十一五”规划》) Beijing: National Development and Reform Commission. http://www.ccchina.gov.cn/Website/CCChina/UpFile/File186.pdf.

NDRC (2007b). China’s National Climate Change Programme (《中国应对气候变化国家方案》) Beijing: National Development and Reform Commission (NDRC), People’s Republic of China.

NDRC, MWR and MOHURD (2007). 《节水型社会建设“十一五”规划》[11th Five-Year Plan for Water-saving Society Construction]. NDRC 国家发改委, Ministry of Water Resources 水利部 and Ministry of Housing and Rural-Urban Development (MOHURD) 建设部.

NEPA (1994). China: Biodiversity Conservation Action Plan Beijing: National Environmental Protection Agency, People's Republic of China.

Norris, P. (2001). Digital divide: Civic engagement, information poverty, and the Internet worldwide. Cambridge, UK: Cambridge University Press.

Noss, R. F. (1990). "Indicators for monitoring biodiversity: a hierarchical approach." Conservation biology **4**(4).

Noss, R. F. (1999). "Assessing and monitoring forest biodiversity-A suggested framework and indicators." Forest Ecology and Management **115**(2): 135-146.

NZME (2009). Good Practice Guide for Air Quality Monitoring and Data Management 2009. Auckland: New Zealand Ministry for the Environment.

OECD (2005a). China in the Global Economy: Governance in China Paris: Organization for Economic Co-operation and Development.

OECD (2005b). Policy Brief: Agricultural Policy Reform in China Paris: Organization for Economic Co-operation and Development.

OECD (2007). Environmental performance reviews: China Paris: Organization for Economic Co-operation and Development.

Orians, G. and D. Policansky (2009). "Scientific Bases of Macroenvironmental Indicators." Annual Review of Environment and Resources **34**: 375-404.

Ostrowska, Patrycja. 2008. Cadmium - Occurrence, use and methods of recycling. *Mineral Resources Management* 24(3): 255-260. (Polish)

OSHA (2009). "Cadmium: Health Effects". Washington: United States Department of Labor: Occupational Safety and Health Administration. Retrieved 24 June, 2010, from http://www.osha.gov/SLTC/cadmium/recognition.html.

Pacyna, E., J. Pacyna, K. Sundseth, J. Munthe, K. Kindbom, S. Wilson, F. Steenhuisen and P. Maxson (2009). "Global emission of mercury to the atmosphere from anthropogenic sources in 2005 and projections to 2020." Atmospheric Environment.

Papp, J. (2010). Chromium. Mineral Commodity Summaries, January 2010: US Geological Survey.

Pimental, D. and A. Wilson (2004). "World Population, Agriculture, and Malnutrition." World Watch Magazine. from http://www.worldwatch.org/node/554.

Prüss, A., D. Kay, L. Fewtrell and J. Bartram (2002). "Estimating the burden of disease from water, sanitation, and hygiene at a global level." Environmental Health Perspectives **110**(5): 537-542.

Prüss-Üstün, A. and C. Corvalan (2006). Preventing disease through healthy environments: Towards an estimate of the environmental burden of disease Geneva: World Health Organization.

Prüss-Üstün, A., D. Kay, L. Fewtrell and J. Bartram (2004). Unsafe water, sanitation and hygiene. Comparative Quantification of Health Risks: Global and Regional Burden of Disease due to Selected Major Risk Factors. M. Ezzati, A. D. Lopez, A. Rodgers and C. J. L. Murray. Geneva: World Health Organization. **2**.

Qiu, Xin, and Honglin Liu. 2008. China’s Environmental Super Ministry Reform: Background, Challenges, and the Future. Environmental Law Reporter, 2-2009, available at http://www.epa.gov/ogc/china/xin.pdf.

Richter, B., R. Mathews, D. Harrison and R. Wigington (2003). "Ecologically sustainable water management: managing river flows for ecological integrity." Ecological applications **13**(1): 206-224.

Rogich, D., A. Cassara, I. Wernick and M. Miranda (2008). "Material flows in the United States: A physical accounting of the US industrial economy." World Resources Institute, Washington, DC.

Saisana, M., and A. Saltelli (2006). “Appendix G: Uncertainty and Sensitivity Analysis of the EPI”, in D. Esty *et al.*, *Pilot 2006 Environmental Performance Index*, New Haven: Yale University. Available at http://ciesin.columbia.edu/repository/epi/data/2006EPI_AppendixG.pdf

Schindler, D. (1988). "Effects of acid rain on freshwater ecosystems." Science **239**(4836): 149-157.

Schofer, E. and A. Hironaka (2005). "The Effects of World Society on Environmental Protection Outcomes." Social Forces **84**(1): 25.

Seckler, D. (1996). The new era of water resources management: from" dry" to" wet" water savings: Iwmi.

SEPA (1996). GB 3095-1996. Ambient air quality standard. State Environmental Protection Agency of P.R.C.

SEPA (2002a). GB 3838-2002. Environmental quality standards for surface water. State Environmental Protection Agency of P.R.C.

SEPA (2002b). GB/T 18883-2002. Indoor air quality standard. State Environmental Protection Agency of P.R.C.

SEPA (2004). HJ/T167-2004. Technical specifications for monitoring of indoor air quality. State Environmental Protection Agency of P.R.C.

SEPA (2007). China Environment Bulletin 2007. State Environmental Protection Agency of P.R.C. Beijinghttp://www.mep.gov.cn/plan/zkgb/2007zkgb/.

Shalizi, Z. (2006). Addressing China's growing water shortages and associated social and environmental consequences Washington: World Bank.

Shalizi, Z. (2008). Water and Urbanization. China urbanizes: consequences, strategies, and policies. S. Yusuf and T. Saich: World Bank Publications.

Shao-feng, J., S. ZHANG, Y. Hong and X. Jun (2004). "Relation of industrial water use and economic development: water use Kuznets Curve [J]." Journal of Natural Resources. **3**.

Shen, D. (2006). "Access to Water and Sanitation in China: History, Current Situation and Challenges." Human Development Occasional Papers (1992-2007).

Shen, X.-m., J. F. Rosen, D. Guo and S.-m. Wu (1996). "Childhood lead poisoning in China." Science of the Total Environment **181**(2): 101-109.

Shili, W. (2006). Coping Strategies with Desertification in China. New Delhi, India, China Meteorological Administration.

Shooter, D. and P. Brimblecombe (2009). "Air quality indexing." International Journal of Environment and Pollution **36**(1): 305-323.

Smits, A. and Y. Chen (2004). Promoting Integrated River Basin Management and Restoring China's Living Rivers Beijing: CCICED Task Force on Integrated River Basin Management.

Suen, J. and J. Eheart (2006). "Reservoir management to balance ecosystem and human needs: Incorporating the paradigm of the ecological flow regime." Water resources research **42**(3): W03417.

Suocheng, D., K. Tong and W. Yuping (2001). "Municipal solid waste management in China: using commercial management to solve a growing problem." Utilities Policy **10**(1): 7-11.

Takiguchi, H. and K. Takemoto (2008). "Japanese 3R policies based on material flow analysis." Journal of Industrial Ecology **12**(5-6): 792-798.

Tilman, D. (1996). "Biodiversity: population versus ecosystem stability." Ecology **77**(2): 350-363.

Tilman, D. and J. Downing (1996). "Biodiversity and stability in grasslands." Ecosystem management: selected readings.

UNDP (2002). China Human Development Report 2002: Making Green Development A Choice Stockholm: UN Development Programme, Stockholm Environmental Institute.

UNDP (2006). Human Development Report 2006: Beyond Scarcity - Power, Poverty and the Global Water Crisis Washington, DC: UN Development Programme.

UNDP (2008). China Progress Towards the Millennium Development Goals: 2008 Report Beijing: Ministry of Foreign Affairs and the United Nations System in China.

UNDP (2010). "Goal 7: Ensure environmental sustainability". Millenium Development Goals. New York: United Nations. Retrieved 30 June, 2010, from http://www.undp.org/mdg/goal7.shtml.

UNEP (1999). Global environment outlook 2000. Nairobi: UN Environment Programme.

UNEP (2002). "Global Mercury Assessment". Chemicals. Nairobi: UN Environment Programme. Retrieved 24 June, 2010, from http://www.chem.unep.ch/mercury/.

UNEP (2003). Monitoring and indicators: Designing national-level monitoring programmes and indicators. Convention on Biological Diversity. Montreal: UN Environment Program.

UNEP (2005a). Integrated Waste Management Scoreboard: A Tool to Measure Performance in Municipal Solid Waste Management Nairobi: UN Environment Programme.

UNEP (2005b). Solid Waste Management Nairobi: UN Environment Programme.

UNEP (2005c). The Songhua River Spill China, December 2005: Field Mission Report Nairobi: UN Environment Programme.

UNEP (2008a). Draft final review of scientific information on cadmium. Paper presented at the 25th session of the Governing Council/Global Ministerial Environmental Forum, Feb 16-20 Nairobi: UN Environment Programme: Division of Technology, Industry, and Economics.

UNEP (2008b). Draft final review of scientific information on lead. Paper presented at the 25th session of the Governing Council/Global Ministerial Environmental Forum, Feb 16-20 Nairobi: UN Environment Programme: Division of Technology, Industry, and Economics.

UNEP (2008c). "The 9 new POPs under the Stockholm Convention". Nairobi: UN Environment Programme. Retrieved 22 June, 2010, from http://chm.pops.int/Programmes/NewPOPs/The9newPOPs/tabid/672/language/en-US/Default.aspx.

UNEP (2009a). "About UNEP Chemicals Branch". Chemicals Branch. Nairobi: UN Environment Programme: Division of Technology, Industry, and Economics. from http://www.chem.unep.ch.

UNEP (2009b). "Sustaining life on Earth: How the Convention on Biological Diversity Promotes Nature and Human Well-Being". Convention on Biological Diversity. UN Environment Programme. Retrieved 24 June, 2010, from http://www.cbd.int/convention/guide/.

UNEP (2010). "2010 Biodiversity Target". Programmes & Issues: Convention on Biological Diversity. Nairobi: UN Environment Programme. Retrieved 1 July, 2010, from http://www.cbd.int/2010-target/.

UNEP and WHO (2010). "Toxic hazards". The Health and Environment Linkages Initiative (HELI). World Health Organization and UN Environment Programme. Retrieved 24 June, 2010, from http://www.who.int/heli/risks/toxics/chemicals/en/index.html.

UNEP World Conservation Monitoring Centre (2011). World Database on Protected Areas. Cambridge, UK: UNEP-WCMC.

UNIDO (2007). "Previous News and Events". UN Industrial Development Organization. Retrieved 24 June, 2010, from http://www.unido.org/index.php?id=6364.

United Nations (1989). Basel Convention on the Control of Transboundary Movement of Hazardous Waste and their Disposal. Basel: United Nations.

United Nations (1992). UN Framework Convention on Climate Change. New York: United Nations.

United Nations (1998a). Kyoto Protocol to the United Nations Framework Convention on Climate Change. New York: United Nations.

United Nations (1998b). The Rotterdam Convention on the Prior Informed Consent Proecedure for Certain Hazardous Chemicals and Pesticides in International Trade. Rotterdam: United Nations.

United Nations (2001). The Stockholm Convention on Persistent Organic Pollutants. Stockholm: United Nations.

United Nations (2004). Guidelines for the preparation of national communications by Parties included in Annex I to the Convention, Part I: UNFCCC reporting guidelines on annual inventoriesFCC/SBSTA/2004/8. New York.

United Nations (2007). Indicators of Sustainable Development: Guidelines and Methodologies. New York: United Nations.

United Nations (Unknown). "CERs issued by host party". CDM: Issuance. UN Framework Convention on Climate Change. Retrieved 20 Mar, 2009, from http://cdm.unfccc.int/Statistics/Issuance/CERsIssuedByHostPartyPieChart.html.

Wang, Q., W. Shen and Z. Ma (2000). "Estimation of mercury emission from coal combustion in China." Environ. Sci. Technol **34**(13): 2711-2713.

Wang, R. (2009). Sustainable Urban Development in China: A Literature Review on Issues, Policies, Practices, and Effects. School of Public Affairs. Los Angeles, CA: UCLA.

Wang, S., G. Cornelis van Kooten and B. Wilson (2004). "Mosaic of reform: forest policy in post-1978 China." Forest Policy and Economics **6**(1): 71-83.

Wang, X., F. Chen, et al. (2008). "Desertification in China: an assessment." Earth-Science Reviews **88**(3-4): 188-206.

Wang, X.-m., G.-y. Sheng, J.-m. Fu, C.-y. Chan, S.-C. Lee, L. Y. Chan and Z.-s. Wang (2002). "Urban roadside aromatic hydrocarbons in three cities of the Pearl River Delta, People's Republic of China." Atmospheric Environment **36**(33): 5141-5148.

Wang, Z. (2008). Urban Water Sanitation in China: Challenges and Opportunities. For 2nd PECC Water Management Seminar Noumea, New Caledonia: China National Committee for Pacific Economic Cooperation.

WEHAB (2002). A Framework for Action on Water and Sanitation Johannesburg: Water, Energy, Health, Agriculture, and Biodiversity Working Group for the World Summit on Sustainable Development.

Wei, J., J. Herbell and S. Zhang (1997). "Solid waste disposal in China-situation, problems and suggestions." Waste management & research **15**(6): 573-583.

Welsch, H. (2004). "Corruption, growth, and the environment: a cross-country analysis." Environment and Development Economics **9**(05): 663-693.

Wenhua, L. (2004). "Degradation and restoration of forest ecosystems in China." Forest Ecology and Management **201**(1): 33-41.

WHO (2000). Air Quality Guidelines for Europe, 2nd Ed Copenhagen: World Health Organization Regional Office for Europe.

WHO (2005a). Air Quality Guidelines: Global Update 2005 Geneva: World Health Organization.

WHO (2005b). WHO Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide: Global Update 2005 Geneva: World Health Organization.

WHO (2005c). WHO Air Quality Guidelines Global Update 2005: Report on a Working Group meeting, Bonn, Germany, 18-20 October 2005 Geneva: World Health Organization.

WHO (2008a). "Air quality and health". Media centre. Geneva: World Health Organization. Retrieved 29 June, 2010, from http://www.who.int/mediacentre/factsheets/fs313/en/index.html.

WHO (2008b). Evaluating household energy and health interventions: a full catalogue of methods Geneva: World Health Organization.

WHO (2008c). Guidelines for Drinking-water Quality, 3rd Edition Geneva: World Health Organization.

WHO (2009). "Diarrhea". Water-Related Diseases. Retrieved 18 February, 2009, from http://www.who.int/water_sanitation_health/diseases/diarrhoea/en/.

WHO (2010). "WHO / UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation: Introduction". Retrieved 20 June, 2010, from http://www.wssinfo.org/definitions/introduction.html.

WHO and UNICEF (2006). Meeting the MDG Drinking Water and Sanitation Target: The Urban and Rural Challenge of the Decade Geneva and New York: World Health Organization and UN Children's Fund.

WHO and UNICEF (2008). Progress on Drinking Water and Sanitation: Special Focus on Sanitation Geneva and New York: World Health Organization and UN Children's Fund.

Williams, J. (2005). Understanding the Overuse of Chemical Fertilizer in China: A synthesis of historic trends, recent studies, and field experiences: PREMIUM Research, National Science Foundation and Michigan State University.

World Bank (2005). Waste Management in China: Issues and Recommendations. Urban Development Working PapersWorking Paper No. 9. World Bank.

World Bank and State Environmental Protection Agency of P.R.C. (2007). Cost of Pollution in China: Economic Estimates of Physical Damages Washington, DC: World Bank. http://siteresources.worldbank.org/INTEAPREGTOPENVIRONMENT/Resources/China_Cost_of_Pollution.pdf.

World Water Forum (2006). World Water Forum Bulletin: A Summary Report of the 4th World Water Forum Mexico City: International Institute for Sustainable Development (IISD).

WRI (1997). Sustainable Agriculture: Agenda 21, Chapter 14. Rio +5: From Agenda to Action, 1-6. Washington: World Resources Institute.

WRI (1998). Regional Profile: China's Health and the Environment. World Resources 1998-1999: Environmental change and human health Washington, DC: World Resources Institute.

WRI (2007). World Resources 2000-2001: People and Ecosystems - The Fraying Web of Life Washington: World Resources Institute.

WRI (2009). "EarthTrends: The Environmental Information Portal". World Resources Institute. Retrieved 22 February, 2009, from http://earthtrends.wri.org.

WSSCC (2000). Vision 21: A Shared Vision for Hygiene, Sanitation and Water Supply and a Framework for Action: Water Supply and Sanitation Collaborative Council.

Wu, C., C. Maurer, Y. Wang, S. Xue and D. Davis (1999). "Water pollution and human health in China." Environmental Health Perspectives **107**(4): 251-256.

Xiangcan, J. (2003). "Analysis of eutrophication state and trend for lakes in China." Journal of Limnology **62**(2): 60-66.

Xie, J. (2008). Addressing China's water scarcity: recommendations for selected water resource management issues. Washington: World Bank Publications.

Xu, D. J. and G. Li (2006). "Biodiversity monitoring for and management of freshwater ecosystems in China: a discussion and position paper." Acta Hydrobiologica Sinica **30**(6): 692-696.

Xu, H., S. Wang and D. Xue (1999). "Biodiversity conservation in China: legislation, plans and measures." Biodiversity and Conservation **8**(6): 819–837.

Xue, L., U. Simonis and D. Dudek (2006). Environmental Governance in China: Report of the Task Force on Environmental Governance to the China Council for International Cooperation on Environment and Development (CCICED) Beijing: Wissenschaftszentrum Berlin für Sozialforschung (WZB).

Yang, Y. (2007). Pesticides and Environmental Health Trends in China. A China Environmental Health Project Factsheet, China Environment Forum and Western Kentucky University: a USAID-supported China Environmental Health Project.

Yao (2008) "China's environmental NGO's influence increases as total doubles in 3 years." Xinhua. 31 October.

Yoccoz, N. G., J. D. Nichols and T. Boulinier (2001). "Monitoring of biological diversity in space and time." Trends in Ecology & Evolution **16**(8): 446-453.

Yoder, C. and E. Rankin (1998). "The role of biological indicators in a state water quality management process." Environmental Monitoring and Assessment **51**(1): 61-88.

Yu, A. and L. Danqing (2006). "The Privatisation of Water Supply in China." Reclaiming Public Water (Chinese).

Zhang, J., D. L. Mauzerall, T. Zhu, S. Liang, M. Ezzati and J. V. Remais (2010). "Environmental health in China: progress towards clean air and safe water." The Lancet. **375**(9720): 1110-1119.

Zhou, J. (2000). "Principal forms of land consolidation and expansion in China." Land Reform **1**: 88-107.

Zhu, D. and J. Chang (2008). "Annual variations of biotic integrity in the upper Yangtze River using an adapted index of biotic integrity (IBI)." Ecological Indicators **8**(5): 564-572.

"陈竺提出从五方面加强农村环境卫生工作 ("Chen Zhu put forward a five-to strengthen the work of the rural sanitation")." (2008) China News of Traditional Medicine. 23 October 2008. http://www.gdaw.gov.cn/ArticleShow.asp?ArticleID=3205.

VIII. Appendices

Appendix 1: Evaluation of the two air quality data sets

A standard approach to environmental data evaluation is to compare data sets obtained from different sources or using different methodologies that measure the same thing. As indicated in this report, there are very few provincial level data sets in China for which there any sources apart from the officially reported statistics in the China Statistical Yearbook or the China Environmental Statistical Yearbook. Air quality was one exception. We were able to locate two data sets measuring annual average air pollutant concentration data at the city level spanning different time periods and different pollutants:

- Data set 1, henceforth referred to as the short-term data set (sts), covers 2004-2007 for PM_{10}, NO_2, and SO_2 with 191 observations. This data set was downloaded from the MEP Web site.
- Data set 2, henceforth referred to as the long-term data set (lts), covers 1998-2007 for SO_2; 1998-2000 for NO_X; 2000-2007 for NO_2; 2002 for TSP; and 2003-2007 for PM_{10}. The total number of cities with data for any one parameter is 147. This data set was obtained from provincial level State of Environment Reports.

The two data sets have cities that overlap, and oftentimes the concentration values for the same parameter and year differ between the data sets.

Missing data analysis at the city level

There are 211 cities in the combined data sets that have data for at least one parameter in one year. Table A1.1 shows the percentage of the 191 cities in the 2004-2007 data set that are missing data for a given parameter in a given year. Table A1.2 does the same for the 147 cities in the 1998-2007 data set.

Table A1.1. Percentage of missing cities based on data set 1 (2004-2007)

	PM_{10}	SO_2	NO_2
2004	32.46	21.99	27.75
2005	24.08	20.42	20.94
2006	50.79	46.07	45.03
2007	58.12	57.07	57.59

Note: total number of cities: 191

Table A1.2. Percentage of missing cities based on data set 2 (1998-2007)

	PM_{10}	SO_2	NO_2
1998	-	82.31	-
1999	-	79.59	-
2000	-	80.27	-
2001	-	78.23	77.55
2002	-	76.87	76.87
2003	71.43	66.67	67.35
2004	66.67	66.67	66.67
2005	80.95	80.95	80.95
2006	66.67	66.67	66.67
2007	66.67	66.67	66.67

Note: total number of cities: 147

Evaluation

The two city level concentration data sets were aggregated to provincial level. A weighted average concentration was developed for each province based on the city population size. So, for example, if in Province X there were measurements for Parameter M for two cities, City A (population 2m) and City B (population 1m), the value for Parameter M for each city would be multiplied by 0.66 for City A and 0.33 for City B to yield a provincial level weighted average.

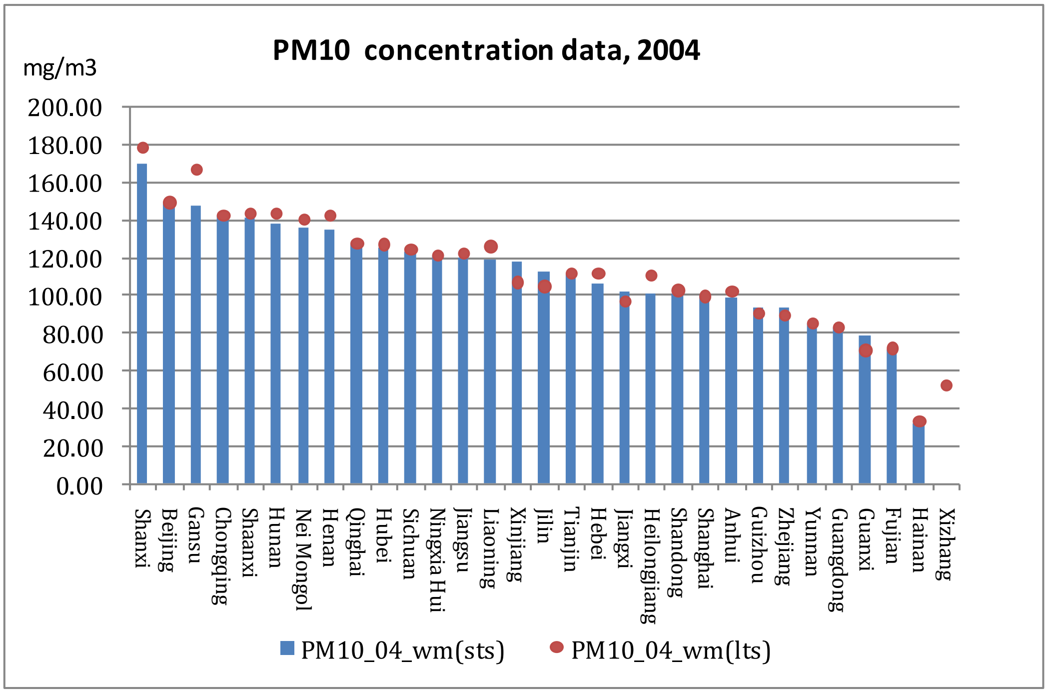
A visual inspection shows that there are relatively few differences between the two data sets. In addition, we conducted a Paired t-test in order to evaluate whether the true difference in means between the two data sets is statistically significant. The test was implemented separately for each parameter-year. For NO2, the results show that the only year with a significant difference in means is 2004 (90% significance level). For SO2, the differences in means is significantly different for data sets for the years 2004 and 2007 (90% significance level), while for PM10, the means are significantly different for year 2007 only (90% significance level).

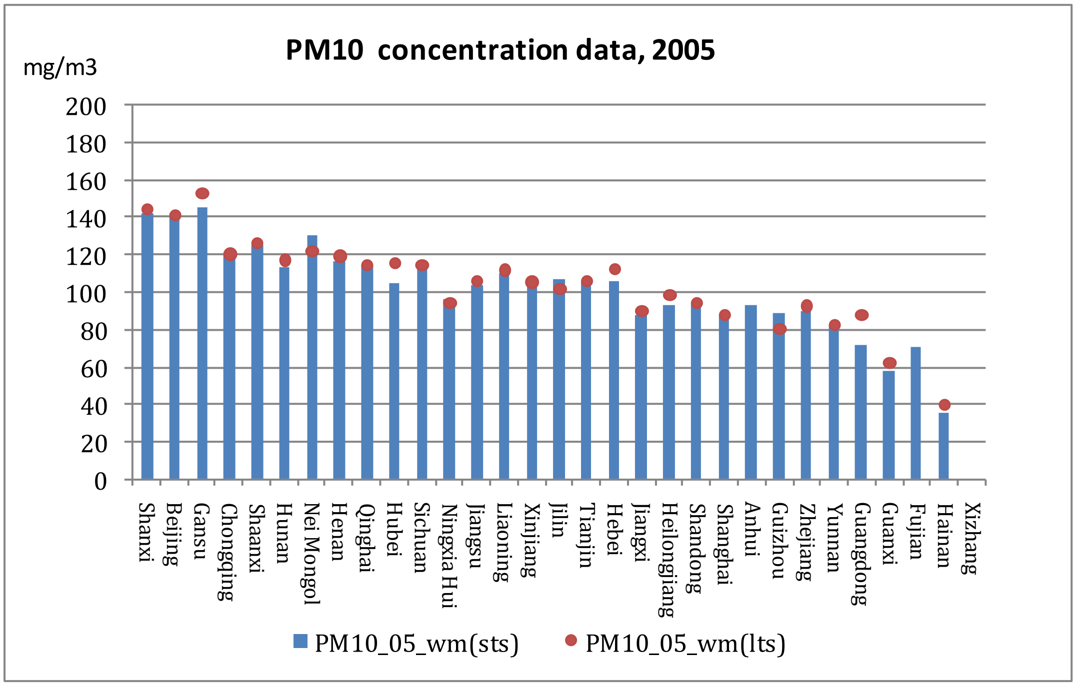
These results show that the two air quality data sets are, for the most part, significantly correlated. Nevertheless, the fact that two data sets from government sources do have some significant differences suggests that further investigation is needed with regard to the reliability of the data. It is an open question as to which of the two data sets better presents an accurate picture of urban air quality in each province.

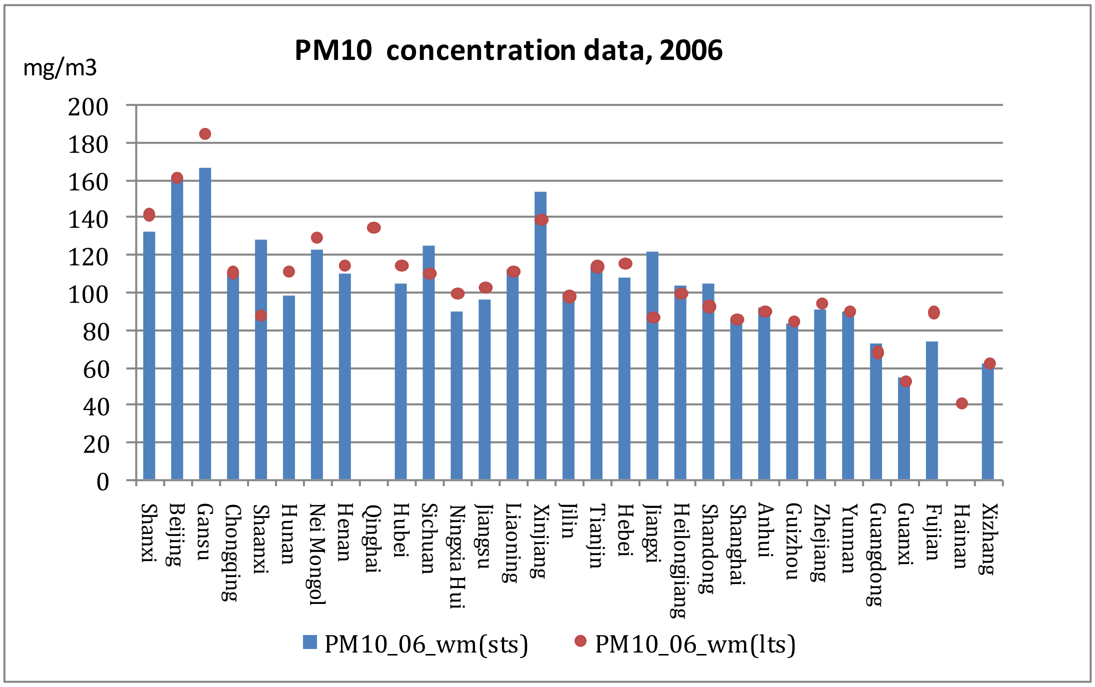
Particulate Matter – 10 microns

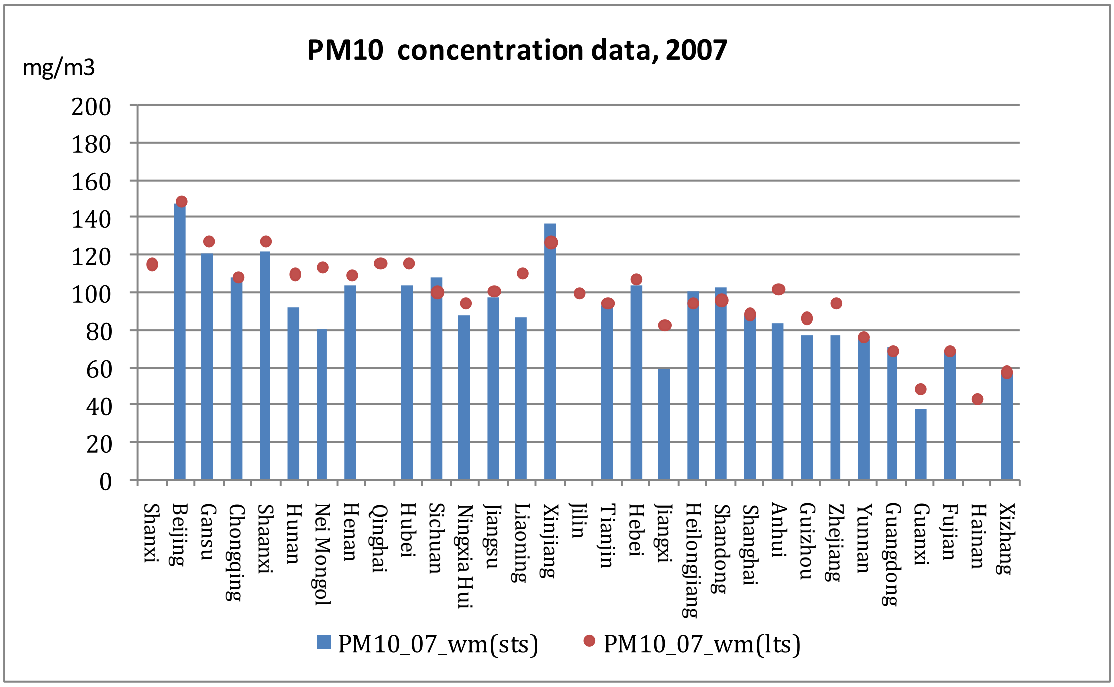
The values of PM_{10} concentration related to the 1998 -2007 "lts" city concentration data set and the 2003-2007 "sts" data set are displayed below, for all years with available data. All graphs are generated based on the rank order of year 2004. The visual evaluation of the two data sets indicates that the lts data set includes in most cases data for all provinces for PM_{10}.

Figures A1.1-4. Comparison of provincial average PM_{10} concentrations between short-term and long-term data sets (2004-2007)





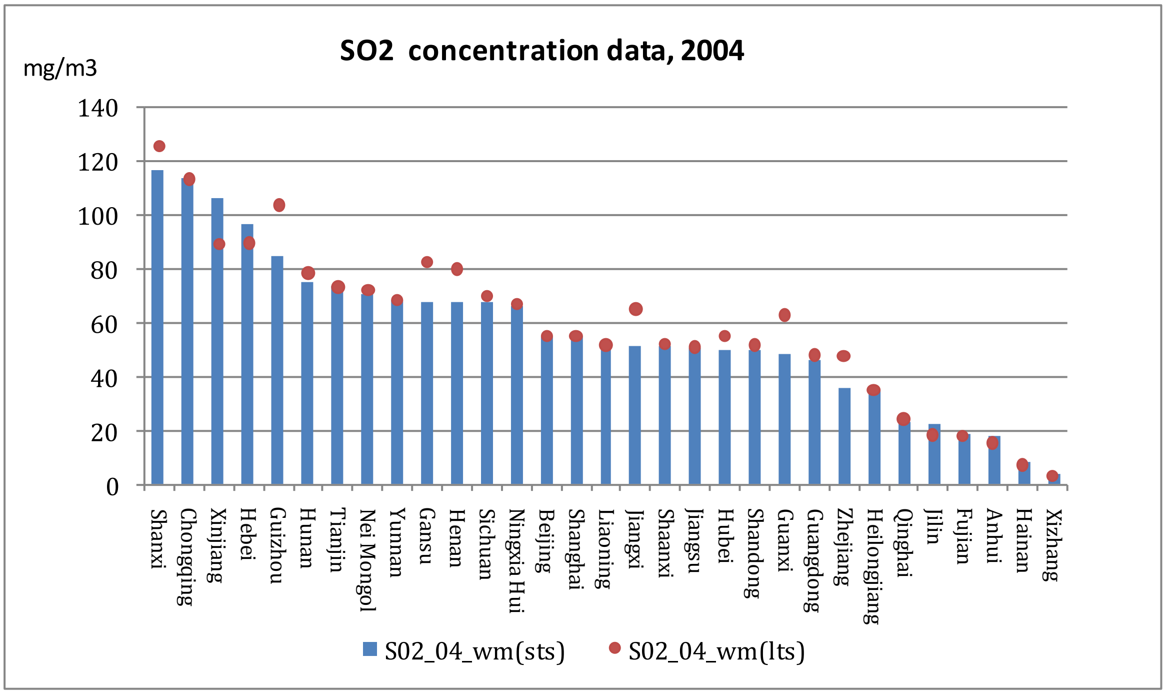

PM10 concentration data, 2006
mg/m3
200
180
160
140
120
100
80
60
40
20
0
Shanxi
Beijing
Gansu
Chongqing
Shaanxi
Hunan
Nei Mongol
Henan
Qinghai
Hubei
Sichuan
Ningxia Hui
Jiangsu
Liaoning
Xinjiang
Jilin
Tianjin
Hebei
Jiangxi
Heilongjiang
Shandong
Shanghai
Anhui
Guizhou
Zhejiang
Yunnan
Guangdong
Guanxi
Fujian
Hainan
Xizhang
PM10_06_wm(sts)
PM10_06_wm(lts)

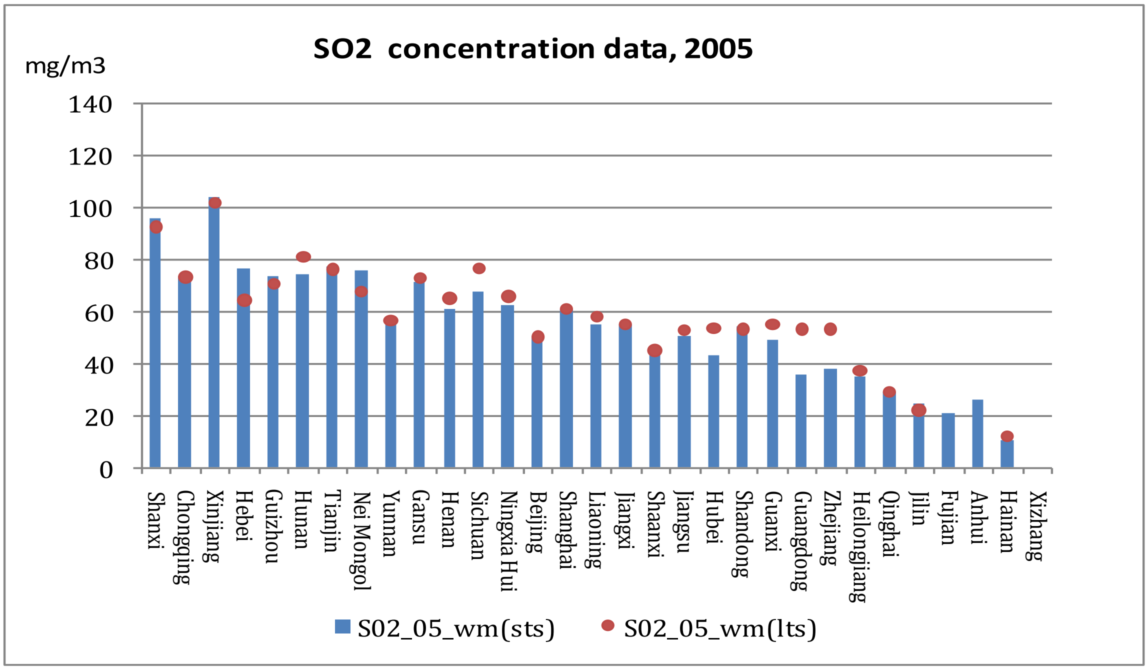

PM10 concentration data, 2007
mg/m3
200
180
160
140
120
100
80
60
40
20
0
Shanxi
Beijing
Gansu
Chongqing
Shaanxi
Hunan
Nei Mongol
Henan
Qinghai
Hubei
Sichuan
Ningxia Hui
Jiangsu
Liaoning
Xinjiang
Jilin
Tianjin
Hebei
Jiangxi
Heilongjiang
Shandong
Shanghai
Anhui
Guizhou
Zhejiang
Yunnan
Guangdong
Guanxi
Fujian
Hainan
Xizhang
PM10_07_wm(sts)
PM10_07_wm(lts)

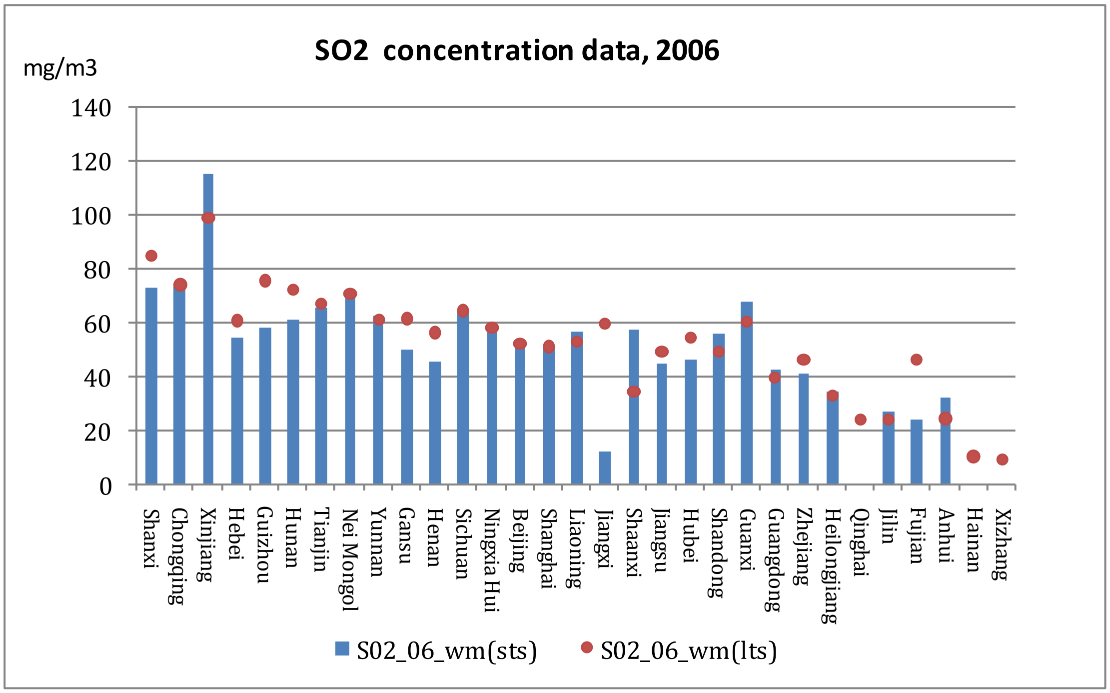
Sulphur dioxide (SO_2)

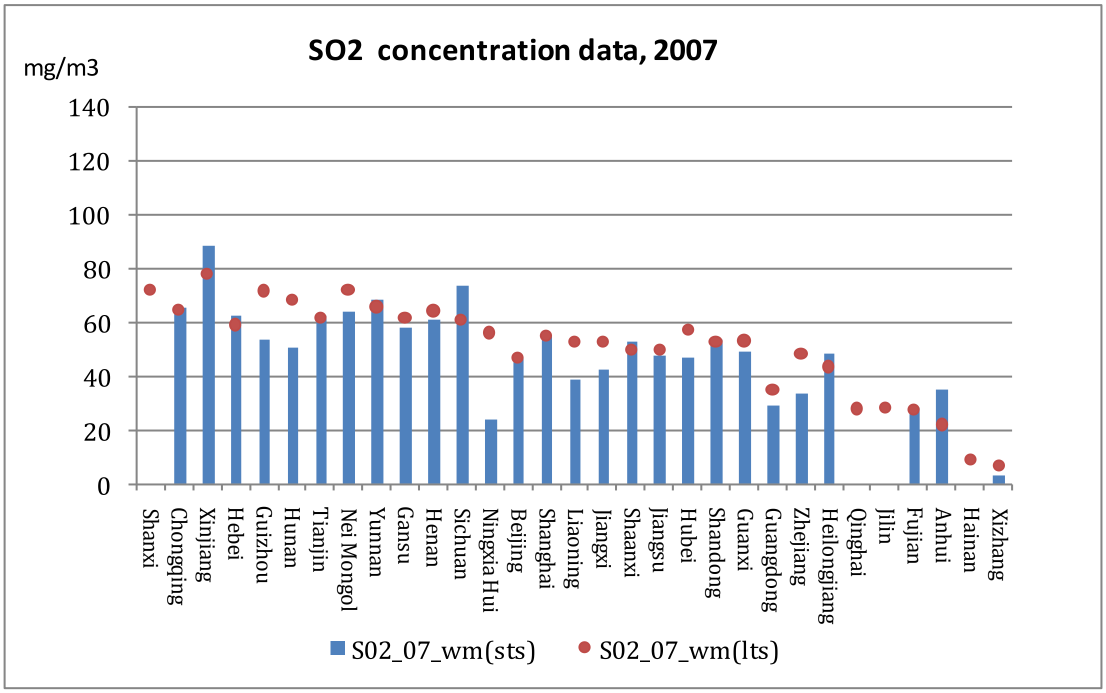
The graphs are generated based on the rank order of year 2004.

Figures A1.5-8. Comparison of provincial average SO_2 concentrations between short-term and long-term data sets (2004-2007)



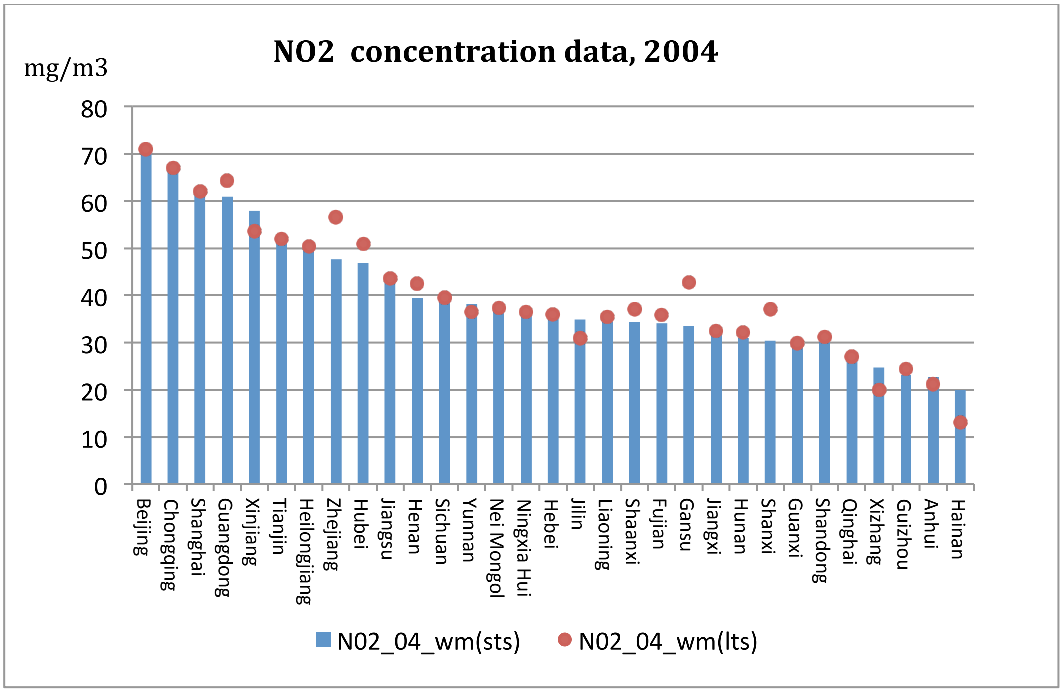


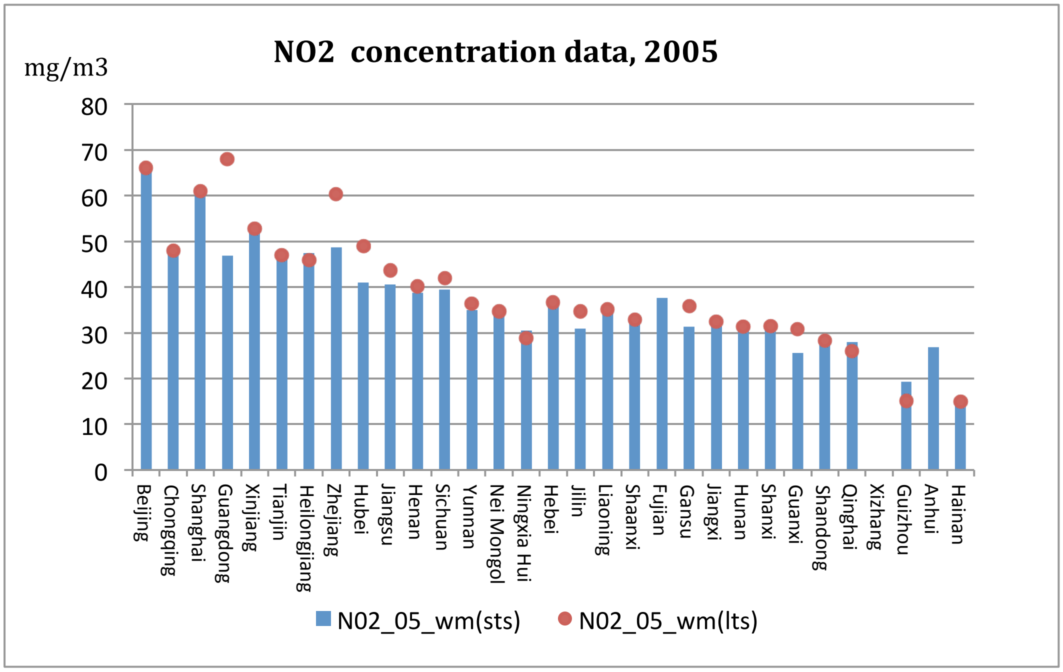

SO2 concentration data, 2006
mg/m3
140
120
100
80
60
40
20
0
Shanxi
Chongqing
Xinjiang
Hebei
Guizhou
Hunan
Tianjin
Nei Mongol
Yunnan
Gansu
Henan
Sichuan
Ningxia Hui
Beijing
Shanghai
Liaoning
Jiangxi
Shaanxi
Jiangsu
Hubei
Shandong
Guanxi
Guangdong
Zhejiang
Heilongjiang
Qinghai
Jilin
Fujian
Anhui
Hainan
Xizhang
■ S02_06_wm(sts)
● S02_06_wm(lts)

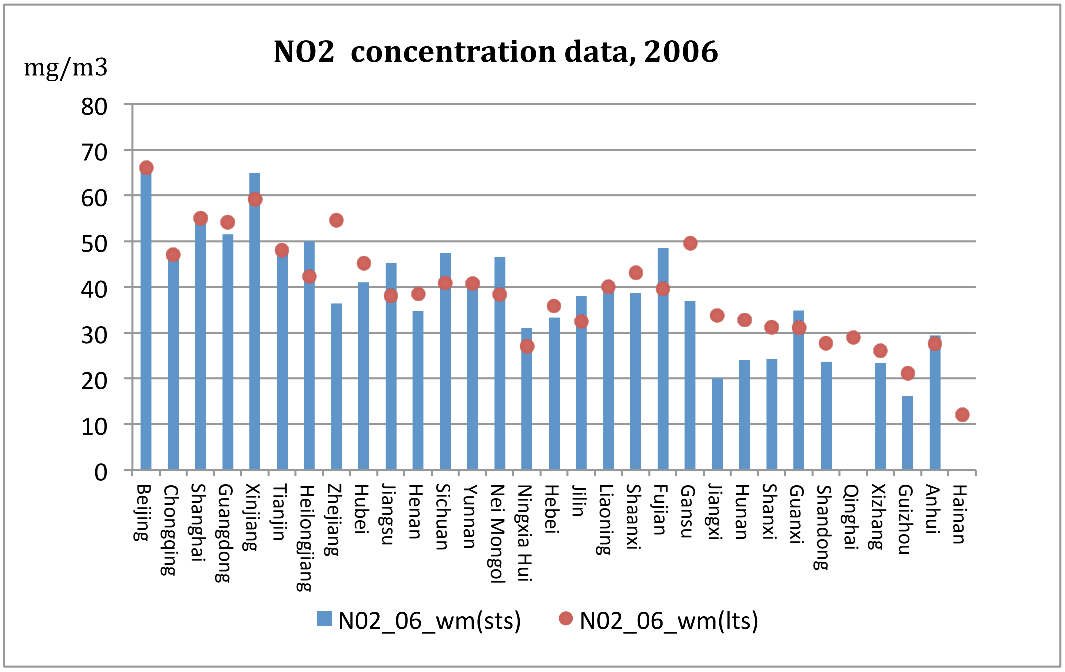

SO2 concentration data, 2007
mg/m3
140
120
100
80
60
40
20
0
Shanxi
Chongqing
Xinjiang
Hebei
Guizhou
Hunan
Tianjin
Nei Mongol
Yunnan
Gansu
Henan
Sichuan
Ningxia Hui
Beijing
Shanghai
Liaoning
Jiangxi
Shaanxi
Jiangsu
Hubei
Shandong
Guanxi
Guangdong
Zhejiang
Heilongjiang
Qinghai
Jilin
Fujian
Anhui
Hainan
Xizhang
■ S02_07_wm(sts)
● S02_07_wm(lts)

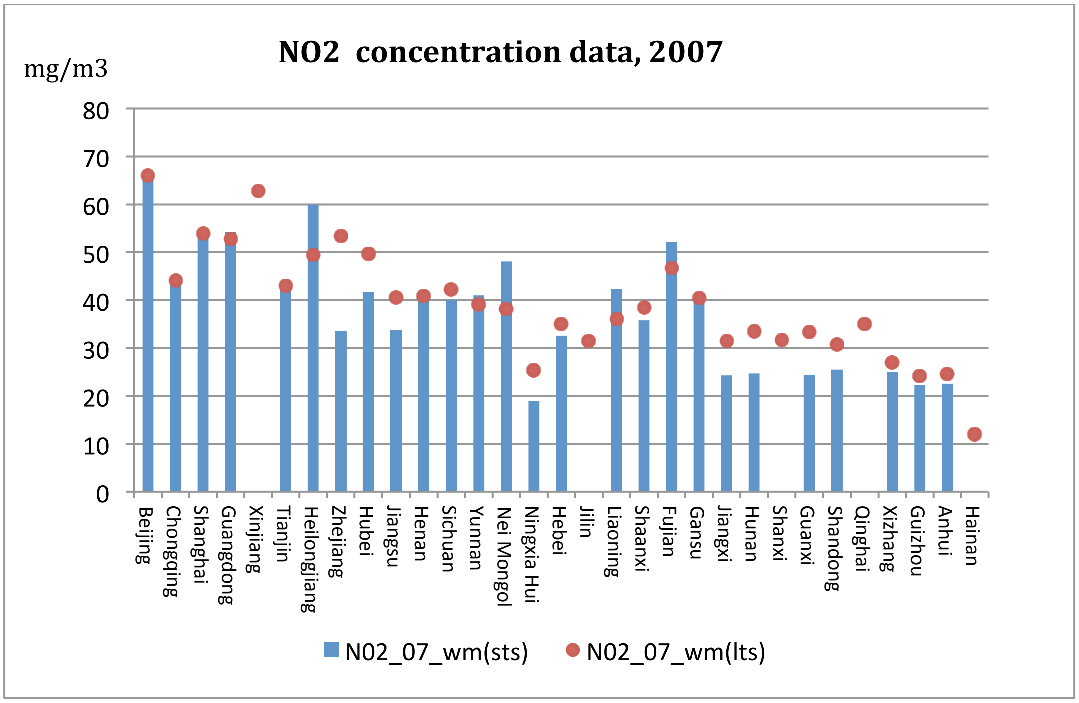
Nitrogen dioxide

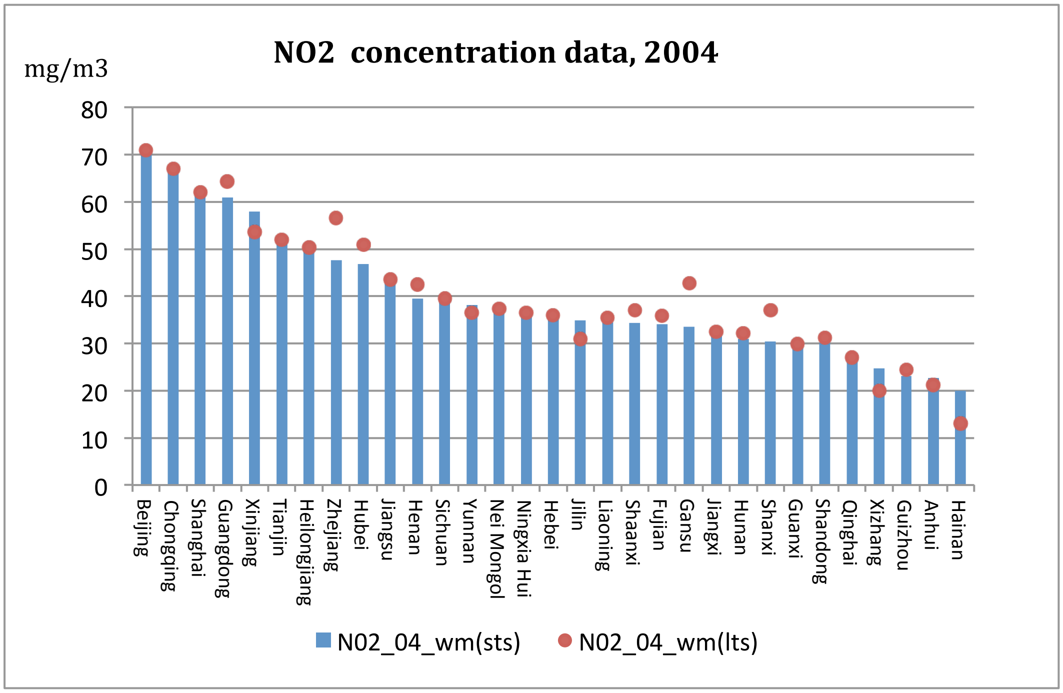
Figure A1.9-12. Comparison of provincial average NO_2 concentrations between short-term and long-term data sets (2004-2007)

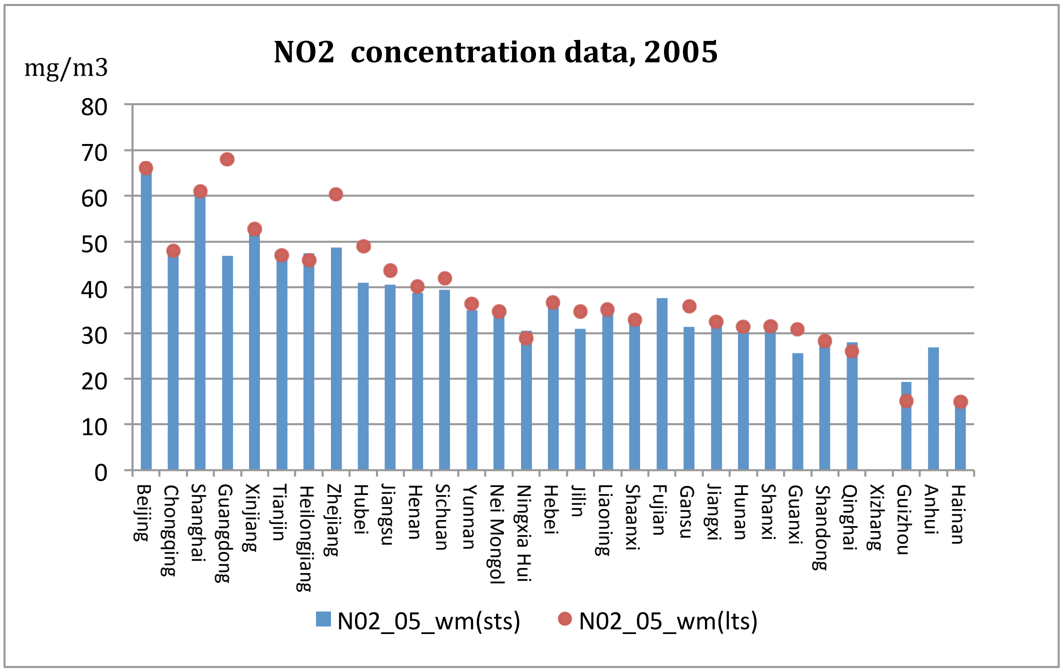


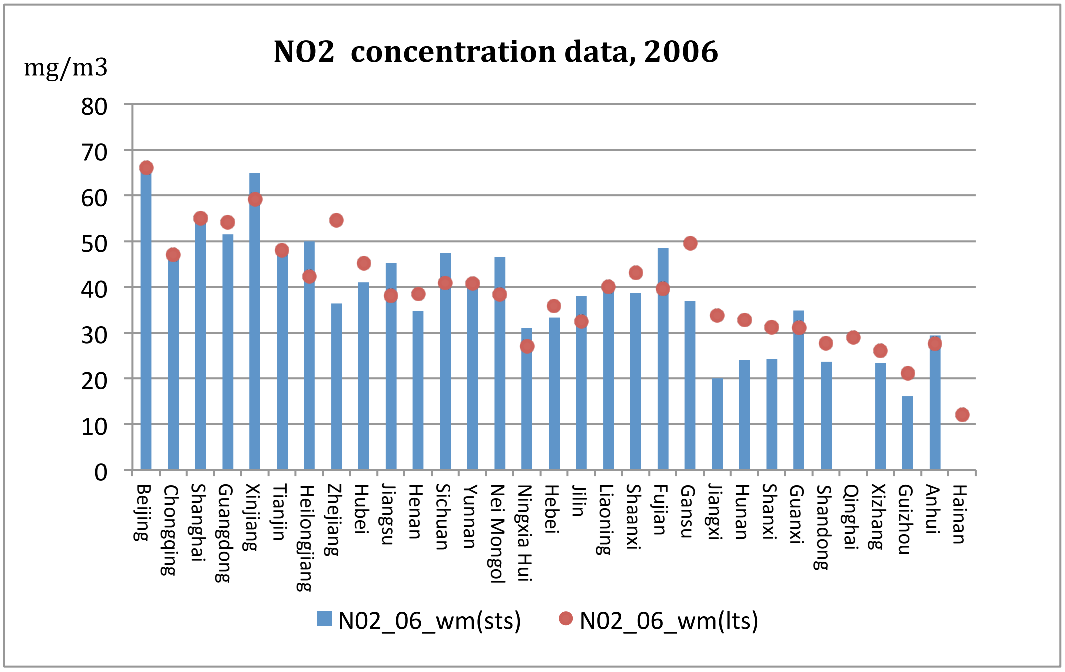


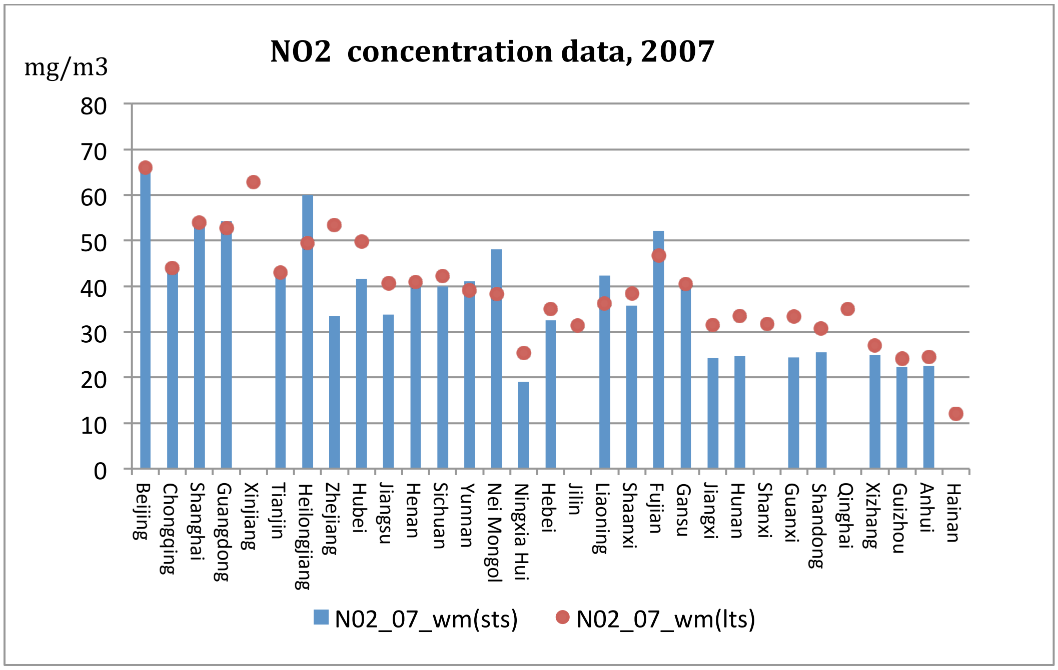

NO2 concentration data, 2006
mg/m3
80
70
60
50
40
30
20
10
0
Beijing
Chongqing
Shanghai
Guangdong
Xinjiang
Tianjin
Heilongjiang
Zhejiang
Hubei
Jiangsu
Henan
Sichuan
Yunnan
Nei Mongol
Ningxia Hui
Hebei
Jilin
Liaoning
Shaanxi
Fujian
Gansu
Jiangxi
Hunan
Shanxi
Guanxi
Shandong
Qinghai
Xizhang
Guizhou
Anhui
Hainan
N02_06_wm(sts)
N02_06_wm(lts)


NO2 concentration data, 2007
mg/m3
80
70
60
50
40
30
20
10
0
Beijing
Chongqing
Shanghai
Guangdong
Xinjiang
Tianjin
Heilongjiang
Zhejiang
Hubei
Jiangsu
Henan
Sichuan
Yunnan
Nei Mongol
Ningxia Hui
Hebei
Jilin
Liaoning
Shaanxi
Fujian
Gansu
Jiangxi
Hunan
Shanxi
Guanxi
Shandong
Qinghai
Xizhang
Guizhou
Anhui
Hainan
N02_07_wm(sts)
N02_07_wm(lts)


NO2 concentration data, 2004
mg/m3
80
70
60
50
40
30
20
10
0
Beijing
Chongqing
Shanghai
Guangdong
Xinjiang
Tianjin
Heilongjiang
Zhejiang
Hubei
Jiangsu
Henan
Sichuan
Yunnan
Nei Mongol
Ningxia Hui
Hebei
Jilin
Liaoning
Shaanxi
Fujian
Gansu
Jiangxi
Hunan
Shanxi
Guanxi
Shandong
Qinghai
Xizhang
Guizhou
Anhui
Hainan
N02_04_wm(sts)
N02_04_wm(lts)


NO2 concentration data, 2005
mg/m3
80
70
60
50
40
30
20
10
0
Beijing
Chongqing
Shanghai
Guangdong
Xinjiang
Tianjin
Heilongjiang
Zhejiang
Hubei
Jiangsu
Henan
Sichuan
Yunnan
Nei Mongol
Ningxia Hui
Hebei
Jilin
Liaoning
Shaanxi
Fujian
Gansu
Jiangxi
Hunan
Shanxi
Guanxi
Shandong
Qinghai
Xizhang
Guizhou
Anhui
Hainan
N02_05_wm(sts)
N02_05_wm(lts)


NO2 concentration data, 2006
mg/m3
80
70
60
50
40
30
20
10
0
Beijing
Chongqing
Shanghai
Guangdong
Xinjiang
Tianjin
Heilongjiang
Zhejiang
Hubei
Jiangsu
Henan
Sichuan
Yunnan
Nei Mongol
Ningxia Hui
Hebei
Jilin
Liaoning
Shaanxi
Fujian
Gansu
Jiangxi
Hunan
Shanxi
Guanxi
Shandong
Qinghai
Xizhang
Guizhou
Anhui
Hainan
N02_06_wm(sts)
N02_06_wm(lts)


NO2 concentration data, 2007
mg/m3
80
70
60
50
40
30
20
10
0
Beijing
Chongqing
Shanghai
Guangdong
Xinjiang
Tianjin
Heilongjiang
Zhejiang
Hubei
Jiangsu
Henan
Sichuan
Yunnan
Nei Mongol
Ningxia Hui
Hebei
Jilin
Liaoning
Shaanxi
Fujian
Gansu
Jiangxi
Hunan
Shanxi
Guanxi
Shandong
Qinghai
Xizhang
Guizhou
Anhui
Hainan
N02_07_wm(sts)
N02_07_wm(lts)

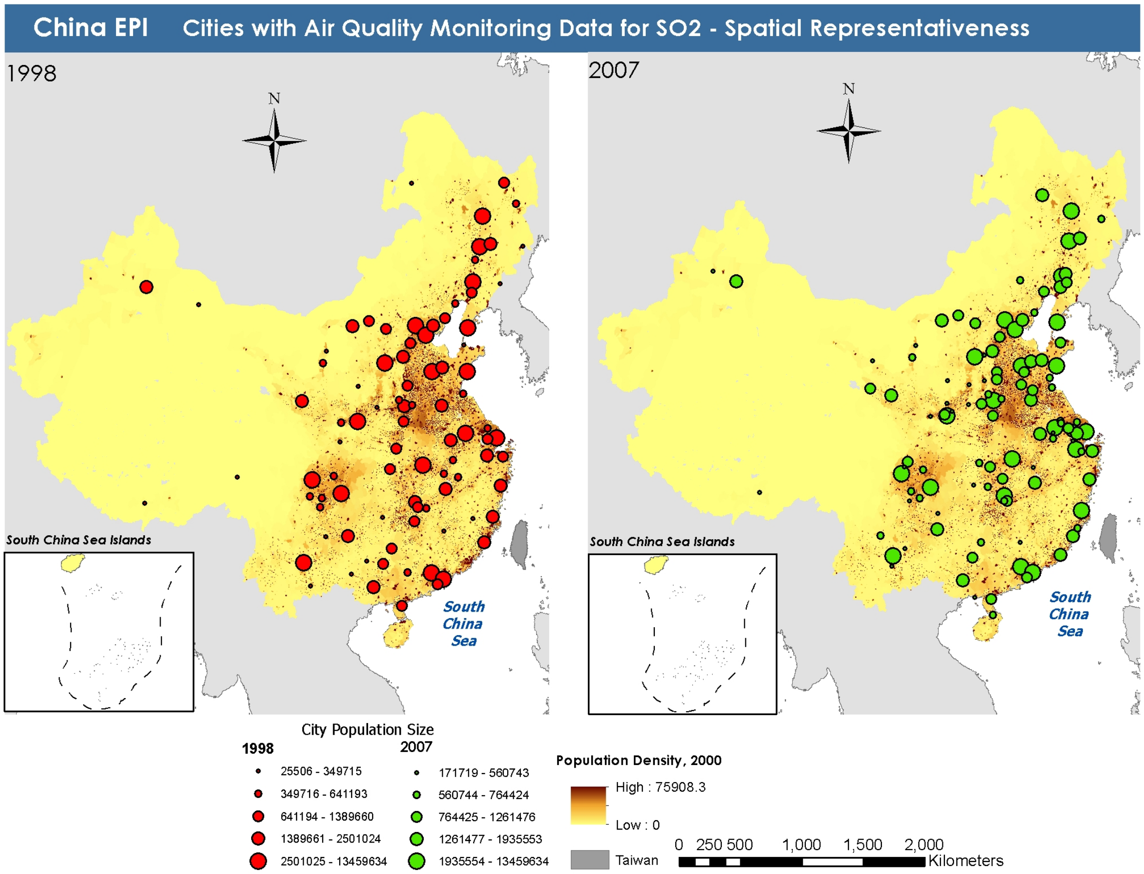
Appendix 2: Geographic and urban coverage of air quality data

Spatial representativeness

The data sets analyzed in this appendix are the same ones that were analyzed in Appendix 1. None of the air quality parameters had complete coverage for all 147 cities covered by both data sets.

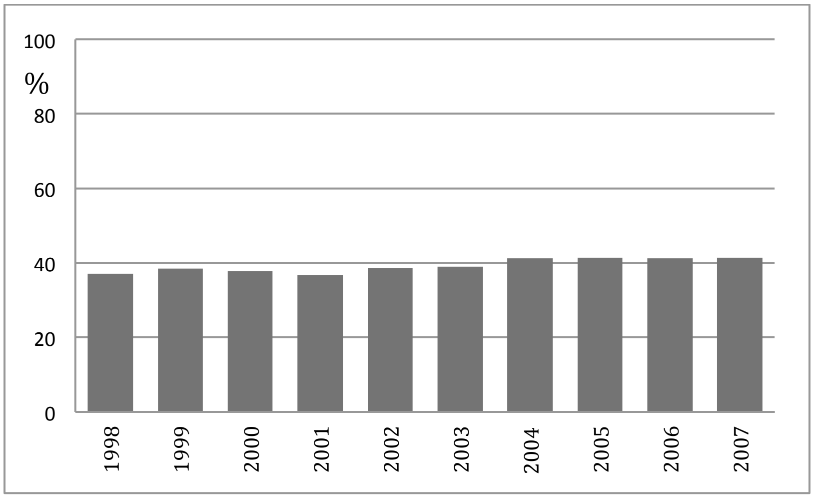
The following maps displays the cities with available PM10, SO_2 and NO_2 concentration level data, for the earliest and latest year of available data.. The cities are represented with red and green dots, sized by population, and are overlaid on the 2000 population density.

The map below shows an overall good spatial representativity of the SO_2 data. The data cover all provinces, and are located in populated areas, however, some high density cities located in Henan, Jiangsu, Shandong, Anhui, Guanxi and Sichuan are missing measurements.



To assess data coverage, we examine the percentage of China's urban population that is in cities that report air quality data. Figure A2.1 shows that less than 50% of the urban population of China is covered by the SO_2 air quality data. The highest coverage, 41.4%, was achieved in 2007.

Figure A2.1. **Percent of Urban Population in Cities with SO_2 Data Available**



Similar results are shown by analyzing the NO_2 geographic and urban data coverage. Only 53 of the monitored cities are available in year 2000, and 113 cities in 2007.

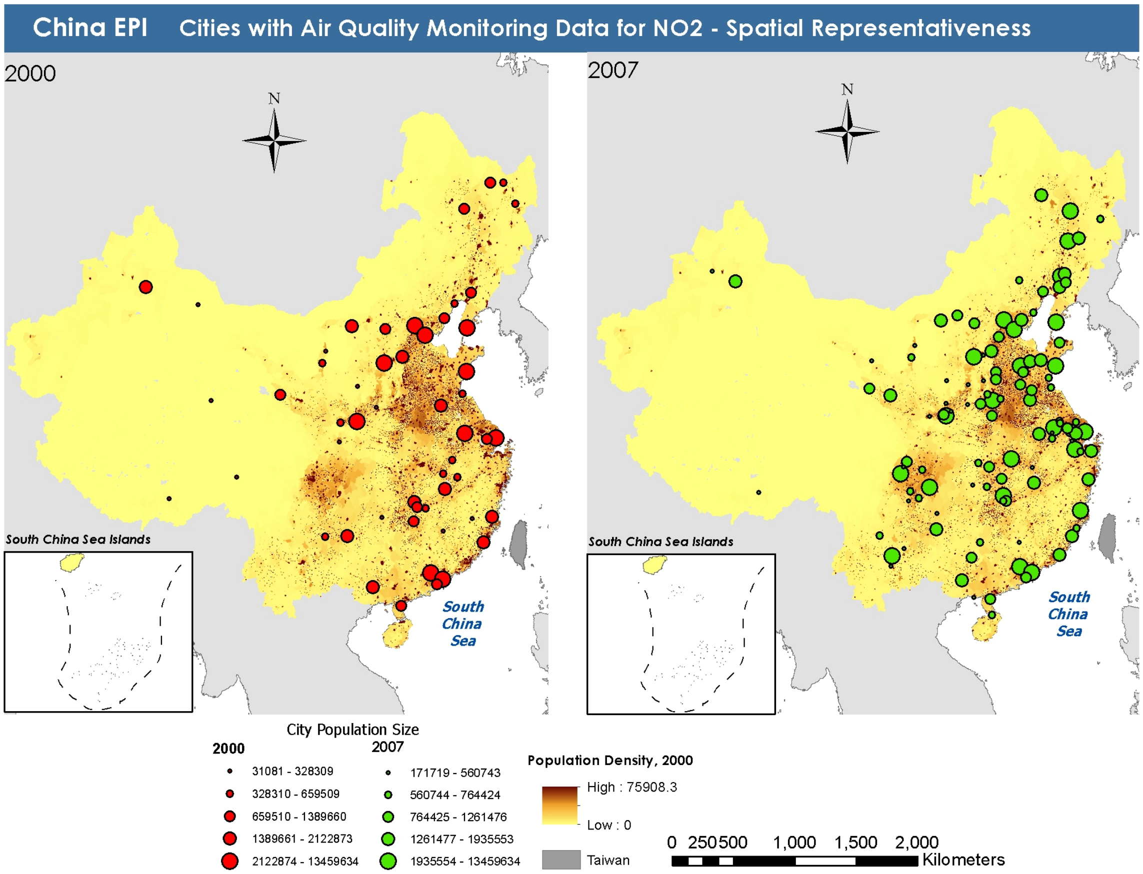


Figure A2.2 shows that the highest overall percentage of urban populations covered by NO_2 monitoring data, across all provinces, is 41.37%, which was achieved in 2007.

Figure A2.2. Percent of Urban Population in Cities with NO_2 Data Available

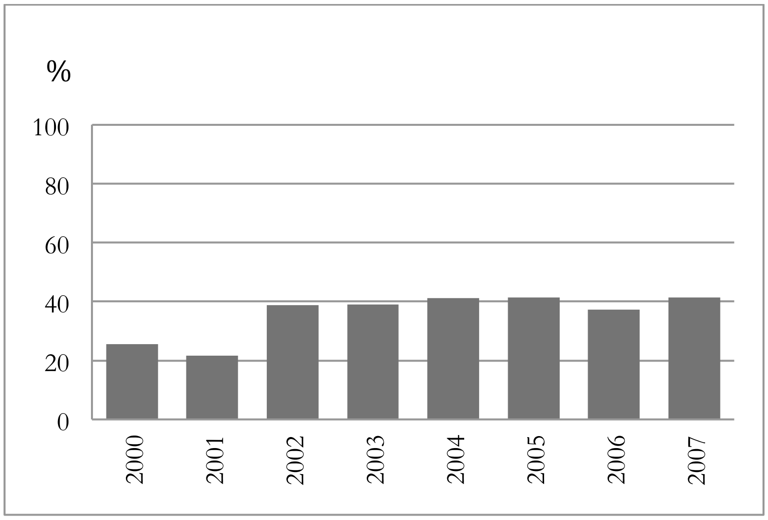


Figure A2.3 shows the percent of provincial and urban population included in cities that report PM_{10}, SO_2 and NO_2 concentrations for the year with the highest coverage (2007).

The geographic and urban data coverage for PM10 are shown below:

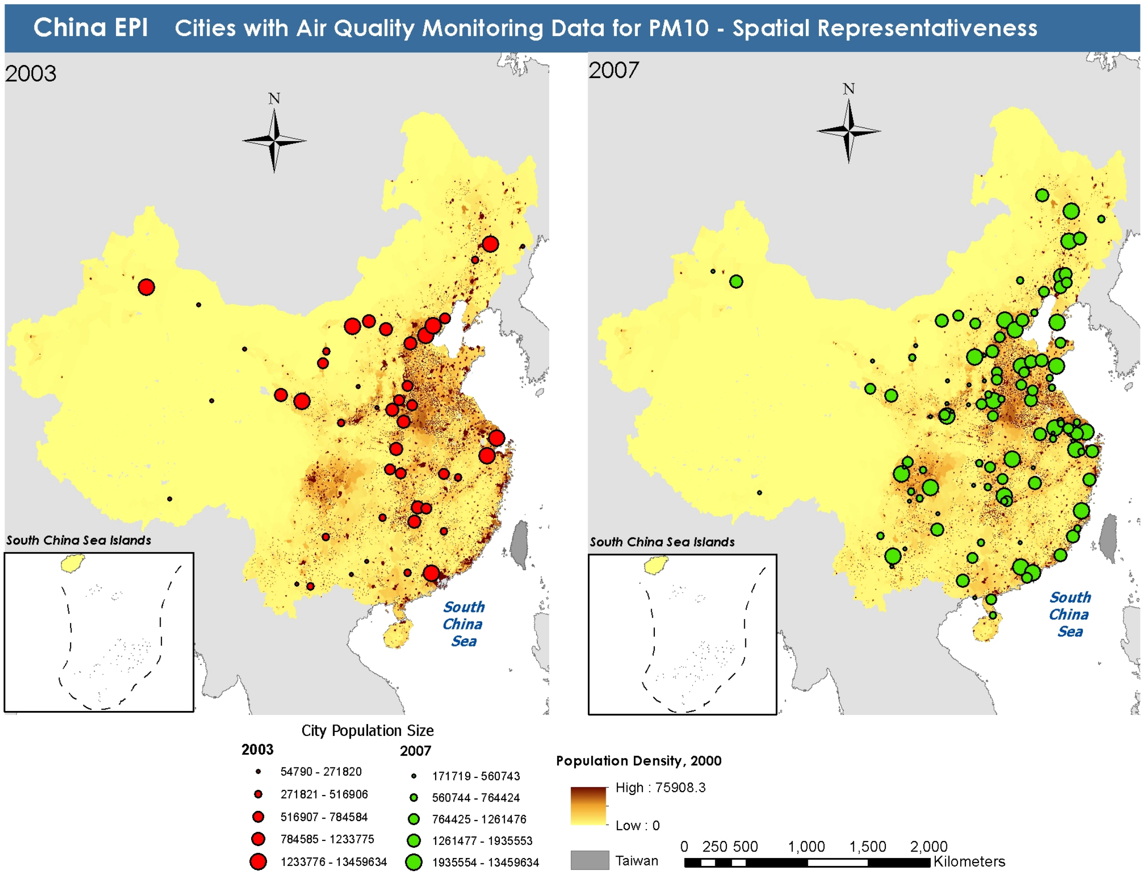
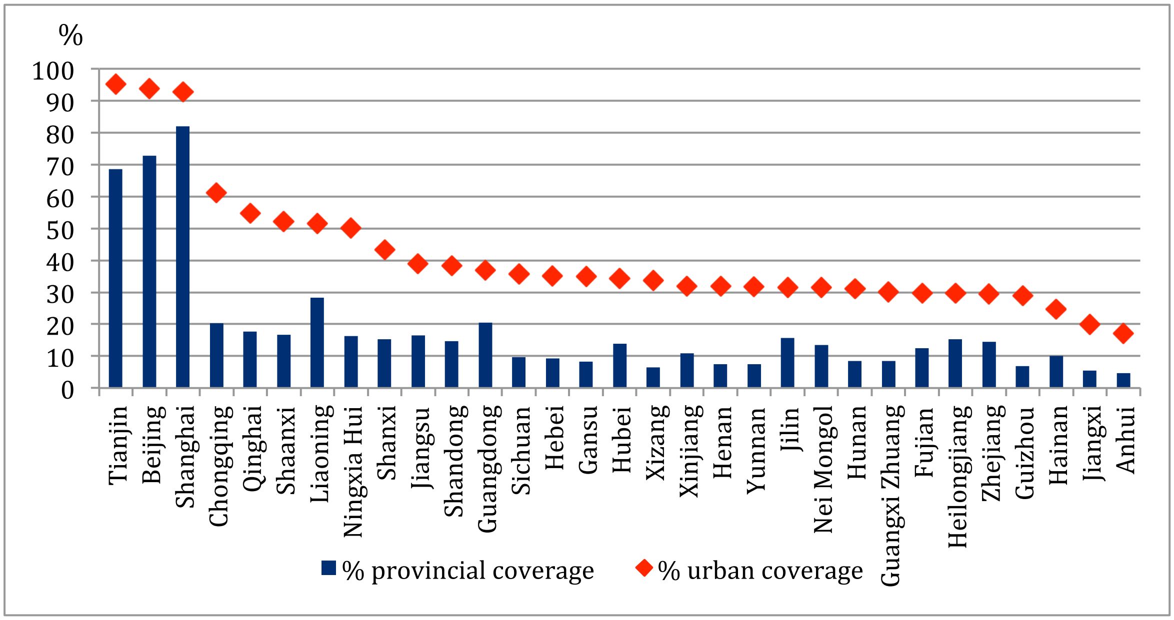


Figure A2.3. Percentage of Total and Urban Population by Province in Cities Reporting Air Quality Data, 2007



Appendix 3: New Environment and Energy Targets in China's 12th Five-Year Plan

China's 12th Five-Year Plan[70] was approved in March 2011 at the annual meeting of the National People's Congress (NPC). China's Five-Year Plans are intended to be blueprints that outline key economic and development targets for the country over a five-year period. In addition to the 118-page 12th Five-Year Plan, a series of reports were issued,[71] including a Work Report by Premier Wen Jiabao that provides an assessment of the previous five years and a summary of highlights of the new Five-Year Plan. The combination of all these reports provides a number of policy targets and development goals for China over the next five years.

Notably, the Plan places high priority on both climate change and environmental issues. The 12th Five-Year Plan is not only the first to mention climate change, but the Plan goes further, adopting as part of national, binding law the climate pledges China first made at the United Nations Framework Convention on Climate Change (UNFCCCC) Copenhagen climate summit in December 2009. Binding targets for a range of other environment and energy issues are also included in the Plan, including important air and water quality pollutants that were absent from previous five-year plans. The Plan further outlines specific policies and measures to guide implementation and facilitate achievement of these goals.

To reach these targets without sacrificing economic growth, the Chinese government is emphasizing a more sustainable development trajectory over the next five years. In the 12th Five-Year Plan, the government set a slower 7 percent annual GDP growth rate as an aspirational target to emphasize quality and sustainability of economic growth. As Premier Wen states in his Work Report, "We are keenly aware that we still have a serious problem in that our development is not yet well balanced, coordinated, or sustainable," citing "growing resource and environmental constraints hindering economic growth" and other negative impacts from a historical pursuit of high growth.[72] Even though the Chinese economy grew at an average annual rate of 11.2 percent over the last five-year period, setting a much lower annual GDP growth target signals the Chinese leadership is serious about more sustainable growth. The Plan also places a strong emphasis on reuse and recycling, or what the Chinese call "circular economy."

The following sections provide a brief overview of the major energy and environment-related targets in the 12th Five-Year Plan.

---

[70] An English translation of the 12th FYP can be found here: http://www.cbichina.org.cn/cbichina/upload/fckeditor/Full%20Translation%20of%20the%2012th%20Five-Year%20Plan.pdf.

[71] Premier Wen's Work Report, the NDRC Draft Plan for National Economic and Social Development, and the Ministry of Finance Budget Report can all be found online: http://blogs.wsj.com/chinarealtime/2011/03/05/china-npc-2011-reports-full-text/

[72] Wen, Jiabao. Report on the Work of the Government, delivered at the Fourth Session of the Eleventh National People's Congress. March 5, 2011. Available online: http://online.wsj.com/public/resources/documents/2011NPCWorkReportEng.pdf

Energy and Climate

Separate targets for energy and climate were introduced for the first time in the 12th Five-Year Plan. By 2015, China aims for a 16 percent reduction in energy intensity (energy use per GDP) and a 17 percent reduction in carbon intensity (carbon emissions per GDP). These both are consistent within the target 40 to 45 percent reduction in carbon intensity from 2005 levels that was first announced in the UN-led climate talks in Copenhagen in December 2009 and then reaffirmed in Cancun in November 2010. The separation of the energy and CO_2 emissions targets ensures that provinces implement energy policies with carbon goals clearly in mind.

Senior Chinese officials in the lead up to the release of the Plan also indicated that the Chinese government was considering a total energy consumption cap at 4 billion tons coal equivalent (tce).[73] The introduction of an absolute target marks a notable shift from intensity-based to the more stringent absolute reduction targets.

Over the past five years China achieved a 19.1 percent reduction in energy intensity largely through improving industrial energy efficiency. In the new Plan, there are both new policies to promote greater industrial efficiency, and plans to include all other sectors of the economy, including both new and existing buildings. Also included is the transport sector, in which the Plan includes proposals for the construction of 35,000 km of high-speed rail and a goal to connect every city with a population greater than 500,000. The Plan also suggests a ramping up of the successful Top 1,000 enterprises program, which targeted the top 1,000 energy-consumers for efficiency improvements in the 11th Five-Year Plan.[74]

Non-fossil energy

The Plan also includes a goal of 11.4 percent non-fossil fuels in primary energy consumption by 2015. While part of this goal will include renewable energy, China also plans to install 40 additional gigawatts of nuclear capacity by 2015. China currently has around 10 GW of installed nuclear capacity, which means that with the achievement of this five-year target, China is move closer to a target of 70 GW by 2020.[75] With the attainment of these goals, China will have the world’s highest installed capacity of nuclear energy by 2020.

However, the earthquake and resulting tsunami disaster that hit the Fukushima-Daichii reactor in March 2011 has caused the Chinese government to rethink their ambitious nuclear energy targets. Since the Fukushima incident, China has stopped approval of new nuclear reactor facilities and is planning to upgrade emergency procedures for nuclear power plants.[76] As of June 2011, China has six nuclear power plants in operation, with 12 under construction and an additional 25 plants

---

[73] Xinhua. 2011. China to Cap Energy Use at 4 Bln Tonnes of Coal Equivalent by 2015. http://english.cri.cn/6909/2011/03/04/1461s624079.htm

[74] Price, L., et al. 2008. China's Top-1000 Energy- Consuming Enterprises Program: Reducing Energy Consumption of the 1000 Largest Industrial Enterprises in China. Lawrence Berkeley National Laboratory. Available online: http://ies.lbl.gov/iespubs/LBNL-519E.pdf.

[75] People’s Daily Online. 2011. China's nuclear power capacity to see 7-fold increase in next 10 years. http://english.peopledaily.com.cn/90001/90778/90862/7120511.html

[76] UPI. 2011. China to boost nuclear safety standards. May 9. http://www.upi.com/Business_News/Energy-Resources/2011/05/09/China-to-boost-nuclear-safety-standards/UPI-27211304965339/

approved. Although longer-term goals for nuclear will probably not be impacted, senior Chinese officials have noted that nuclear development will slow during the next two to three years.[77]

Forests

The 12th Five-Year Plan puts into place significant commitments toward meeting China's commitments on forestry made at the Copenhagen climate summit in 2009.[78] In the Plan itself and Premier Wen's Work Report, the Chinese government sets a goal to increase the area of forest cover by 12.5 million hectares by 2015 and a forest stock volume goal of 600 million m^3. The forest cover area goal is more or less in line with China's Copenhagen commitment of increasing forest cover by 40 million hectares over 2005 levels by 2020. The volume stock target is new target in the Plan and is more ambitious because it seeks to achieve almost half of the 15-year target of 1.3 billion cubic meters by year 2020.

Environmental Pollutants

While the previous Five-Year Plan only included reduction targets for sulfur dioxide and chemical oxygen demand (COD), the 12th Five-Year Plan expands the list of national priority pollutants to include ammonia nitrogen and nitrogen oxides. The binding reduction targets for sulfur dioxide and COD are set at 10 percent, and 8 percent for ammonia nitrogen and nitrogen oxides. COD and ammonia nitrogen are major water pollutants, while sulfur dioxide and nitrogen oxides are major air pollutants. In the last Five-Year Plan it was determined that China exceeded the 10 percent reduction target for both COD and sulfur dioxide, achieving a 14.3 percent decrease in COD and 12.5 percent decrease in sulfur dioxide, according to Premier Wen's Work Report.

To help ensure provinces meet the new targets, the Ministry of Environmental Protection announced in January 2011 single-year goals of 1.5 percent reduction for all four pollutants.[79] The Plan also notes the implementation of an "index evaluation system" to allocate targets to provinces and to track their progress toward meeting reductions. Furthermore, although not included in the national Five-Year Plan, the Ministry of Environment has formulated a blueprint to reduce heavy metals, including lead, mercury, chromium, cadmium, and arsenic, 15 percent from 2007 levels.[80]

Other targets

The Plan includes a goal to reduce water consumption per unit of value-added industrial output by 30 percent, as well as to increase the water efficiency of agricultural irrigation to a coefficient of 0.53. While these are water utilization targets, the Plan lacks specifics regarding targets for the

---

[77] Hook, L. 2011. China's nuclear freeze to last until 2012. April 12. http://www.ft.com/cms/s/0/68694fe0-6525-11e0-b150-00144feab49a.html#axzz1O89nIP67

[78] China's submission to the Copenhagen Accord. 2010. UNFCCC. http://unfccc.int/files/meetings/cop_15/copenhagen_accord/application/pdf/chinacphaccord_app2.pdf

[79] Xinhua. 2011. China sets 2011 pollution control goal, warns of challenges. Jan. 13. http://news.xinhuanet.com/english2010/china/2011-01/13/c_13689609.htm

[80] http://www.chinadaily.com.cn/china/2011-02/19/content_12043264.htm

preservation of lakes and rivers, as well as specific goals for improving the quality of these water bodies. Despite the relatively sparse details regarding water resources in the 12th Five-Year Plan, water is and will continue to be a critical resource for China, particularly as it continues to face severe water shortages and record droughts.[81]

In terms of agriculture, the Plan sets a goal to maintain farmland reserves at no less than 1.818 billion mu (121.2 million hectares). It also details plans to strengthen land-use planning and monitoring, to formulate land conservation standards and to reinforce evaluation of land use and conservation.

While these are the major energy and environment targets included in the 12th Five-Year Plan, they are by no means exhaustive. Individual ministries as well as provinces will base their own five-year plans on the national Plan and provide more detail in the coming months.

Table 1. Summary of major environmental and energy-related targets in the 12th Five-Year Plan.

Target		**2010**	**2015**	**Change over 5 years (%)**	**Forecast or Binding**
Farmland reserves (billion mu)		1.818	1.818	0	binding
Decrease in water consumption per unit of value-added industrial output (%)				30	binding
Increase of water efficiency coefficient in agricultural irrigation		0.5	0.53	0.03	forecast
Increase of non-fossil fuel usage in primary energy consumption (%)		8.3	11.4	3.1	binding
Decrease in energy consumption per unit of GDP (%)				16	binding
Decrease in CO2 emissions per unit of GDP (%)				17	binding
Total decrease in emissions of major pollutants (%)	Chemical Oxygen Demand (COD)			8	binding
	Sulphur Dioxide (SO2)			8	
	Ammonia Nitrogen			10	
	Nitrous Oxides			10	
Forest Increase	Forest coverage rate (%)	20.36	21.66	1.3	binding
	Forest stock (m^3)	137	143	6	

Adapted from the 12th Five-Year Plan.

---

[81] Hook, L. 2011. China faces worst drought in 50 years. *The Financial Times*. May 24. http://www.ft.com/intl/cms/s/0/7d6e4db8-861e-11e0-9e2c-00144feabdc0.html#axzz1OCGIlGIy

IX. List of Acronyms

ADB	Asian Development Bank
API	Air Pollution Index (China)
AQI	Air Quality Index (US EPA)
AQSIQ	General Administration of Quality Supervision, Inspection and Quarantine (China)
AR4	4th Assessment Report of the IPCC
BAN	Basel Action Network
BTEX	Benzene, Toluene, Ethylene, Xylene
CAEP	Chinese Academy for Environmental Planning
CAS	Chinese Academy of Sciences
CBD	Convention on Biological Diversity
CDM	Clean Development Mechanism
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act (USA)
CFCs	Chloroflurocarbons
CIESIN	Center for International Earth Science Information Network, Columbia University
CMA	China Meteorological Agency
CNEMC	China's National Environmental Monitoring Center
COD	Chemical Oxygen Demand
CSEP	The China Sustainable Energy Program
DALYs	Disability-Adjusted Life Years
DMC	Domestic Material Consumption
EAP	Environmental Action Programme (Europe)
EDTA	Ethylenediaminetetraacetic acid (a POP)
EEA	European Energy Agency
EF	Ecological Footprint
EIA	Environmental Impact Assessment
EMC	Environmentally Weighted Material Consumption
EPA	Environmental Protection Agency (USA)
EPB	Environmental Protection Bureaus (China)
EPCRA	Emergency Planning and Community Right-to-Know Act (USA)
EPI	Environmental Performance Index
EU	European Union
FAO	UN Food and Agriculture Organization
FMPI	Forest Management Planning Inventory (China)
FMU	Forest Management Unit (China)
FYP	Five Year Plan (China)
GATT	Global Agreement on Tariffs and Trade (WTO)
GDP	Gross Domestic Product
GHG	Greenhouse Gas
HANPP	Human Appropriation of Net Primary Production
HCB	Hexachlorobenzene (a POP)
IAQ	Indoor Air Quality
IBI	Index of Biotic Integrity
IPCC	Intergovernmental Panel on Climate Change

ISW	Industrial Solid Waste
IVA	Industrial Value Added
JME	Japan Ministry of the Environment
JMP	Joint Monitoring Programme (WHO & UNICEF)
LCA	Lifecycle Analysis
LEAC	Land and Ecosystem Accounts
MDG	Millennium Development Goal (UN)
MEA	Millennium Ecosystem Assessment (UN)
MEP	Ministry of Environmental Protection (China)
MFA	Material Flow Accounting
MLR	Ministry of Land and Resources (China)
MOA	Ministry of Agriculture (China)
MOC	Ministry of Construction (China)
MOH	Ministry of Health (China)
MOHURD	Ministry of Housing and Rural-Urban Development (China)
MWR	Ministry of Water Resources (China)
NCCC	National Communication on Climate Change to the UNFCCC (China)
NDRC	National Development and Reform Commission
NEPA	National Environmental Protection Agency of China
NFI	National Forest Inventory (China)
NGO	Nongovernmental Organization
NMVOCs	Non-methane volatile organic compounds
OECD	Organization for Economic Co-operation and Development
OMI	Ozone Monitoring Instrument
PCBs	Polychlorinated biphenyls
PM	Particulate Matter
POPs	Persistent Organic Pollutants
PPA	Pollution Prevention Act (USA)
ppb	parts per billion
PRC	Peoples' Republic of China
RCRA	Resource Conservation and Recovery Act
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals (EU)
RSP	Remote Sensing Plot
SAC	Standardization Administration of China
SAWS	State Administration of Work Safety (China)
SDIs	Sustainable Development Indicators (EU)
SEPA	State Environmental Protection Agency of China
SMC	Sound Material-Cycle Society (Japan)
SQSIQA	China State Quality Supervision-Inspection-Quarantine Administration
SVTC	Silicon Valley Toxics Coalition
TOC	Total Organic Carbon
TSCA	Toxic Substances Control Act
TSP	Total Suspended Particulate
UN	United Nations
UNDP	United Nations Development Programme
UNDSD	United Nations Division for Sustainable Development
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme

UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children's Fund
UNIDO	UN Industrial Development Organization
USAID	United States Agency for International Development
VOCs	Volatile Organic Compounds
WEHAB	Water, Energy, Health, Agriculture, and Biodiversity Working Group for the World Summit on Sustainable Development
WHO	World Health Organization
WRI	World Resource Institute
WSI	Water Scarcity Index