From Citizens to Satellites : Third-Wave Data Approaches in China Towards a New Environmental Data Paradigm in China

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Environmental management in China is at a critical crossroads. Double-digit annual economic growth has expanded per capita GDP more than 30-fold since China began market reform in 1978, and the country is today the world's second largest economy. China's industrial growth and increased consumption have also led to pernicious levels of air pollution, a precipitous increase in greenhouse gas emissions, and widespread water and soil contamination. The 2016 Environmental Performance Index (EPI) ranked China 109th out of 180 countries, indicating that the country's environmental quality has fallen behind other emerging economies like Brazil, South Africa, and Russia.¹ One in five deaths in China can be attributed to air pollution and climate change impacts, such as more frequent and severe droughts, are worsening at an alarming rate. The need for China to address its mounting environmental crisis is plainly urgent.

The clear imperative to reduce pollution, clean up contamination, and diminish environmental degradation is, unfortunately, not met with data commensurate to create effective policies and develop best management practices.² Experts have historically criticized China's economic data, such as GDP growth, describing the reported information as inaccurate and misleading.³ Some observers have gone so far as to condemn China's entire statistical reporting system as "enmeshed in a wind of falsification and embellishment" that has led to "universal falsification of statistics."⁴ China's environmental data, in particular, are notoriously opaque and problematic. Researchers have pointed to problems with data availability, interruptions in time series, and inconsistencies between sources reporting energy and air quality statistics.⁵ China's government has historically considered a large portion of environmental data, including soil quality statistics, to be state secrets.⁶

To address these issues, China's leadership has emphasized developing more quantitative, scientific approaches to environmental management. Adopting a goal to achieve an "ecological civilization" (*shengtai wengmin*), China's leaders have increased the number of energy and environment-related indicators in both the 12th (2011-2015) and 13th (2016-2020) Five-Year Plans, the country's major social and economic development blueprints. The 13th FYP includes the greatest number of binding environment-related targets, with 10, of any FYP.⁷ To support and track progress towards these targets, China requires major investment in monitoring and data collection systems.

Introducing 'Third Wave' Data

Information communication technologies (ICT), high-performance computing (HPC), and large-scale data generation (i.e. "big data" such as satellite remote sensing, etc.) have opened the door to new modes of monitoring and managing the environment. Utilizing inventive and cutting-edge techniques to analyze these emerging Third Wave Data sources could fill critical information gaps and enhance linkages between policymaking and monitoring.



Third Wave Data encompasses new information sources from individual citizens to satellites. Citizen science methods engage individuals in data collection, combining scientific rigor with public participation, and empowering citizens to influence decisions that affect their lives.⁸ Citizen-sourced data can provide real-time information at finer spatial scales than traditional data collection methods. On the other end of the scale, big data – defined as "data whose size forces us to look beyond tried-and-true methods"⁹ – can uncover hidden issues and trends, spurring key research questions that do not arise when examining small sets of information.



Box 1: Key Definitions in Third-Wave Data

Figure 1. Clarifying relationships between different types of Third Wave Data introduced in this paper. Source: authors

Definitions of key terms within third wave data, an emerging field of inventive and cutting-edge techniques to collect information, are often subject to debate. Many of these fields are still working to achieve a consensus around the key characteristics of these activities. The definitions below strive to reflect commonly-accepted working definitions of these terms.

Citizen Science: Citizen science involves members of the public in scientific research projects to address real-world environmental challenges.¹⁰ Globally, citizen science encompasses "thousands of research projects [...] engaging millions of individuals [...] in collecting categorizing, transcribing, or analyzing scientific data," often at scales or resolutions unattainable by individual researchers or research teams.¹¹

Big Data: Definitions of big data vary. Some experts focus on the datasets' size, and define a big dataset as one that is so large it is "beyond the ability of typical database software tools to capture, store, manage, and analyze." ¹² Others describe big data as an attitude among "businesses, non-profits, government agencies, and individuals that combining data from multiple sources could lead to better decisions."¹³ For the purposes of this paper, we define big data as "the ability of society to harness information in novel ways to produce useful insights or goods and services of significant value" and to accomplish, at a large scale, tasks that "cannot be done at a smaller one, to extract new insights or create new forms of value."¹⁴ Big data may find new ways to analyze existing information without additional participation from those who originally generated it – for instance, by using social media activity to estimate population density.



Crowdsourcing: Definitions of crowdsourcing vary, but this activity is typically understood as "a type of participative online activity in which an individual, an institution, a non-profit organization, or company proposes to a group of individuals," who voluntarily respond to this open call for help. ¹⁵ Crowdsourcing tasks draw on participants' work, money, knowledge and/or experience to execute the project, and also benefits the participants, whether through an economic reward, social recognition, self-esteem, or the development of individual skills.¹⁶

Public Engagement in Environmental Management: Public engagement in environmental management involves "members of the public in the agenda-setting, decision-making, and policy-forming activities of organizations/institutions responsible for policy development." This can occur through public communication, where the project sponsor provides information about a project or policy to the public; through consultation, where the public provides information or feedback to the project sponsor; and through participation, where there is a two-way flow of information between the public and the project sponsor.¹⁷

Social Media: Forms of electronic communication, such as Facebook, Twitter, Weibo, and WeChat, "through which people create online communities to share information, ideas, personal messages, etc."¹⁸

Gamification: The application of games or game-like elements, such as point scoring, competition with others, or rules of play, to a task, to encourage participation and engagement.¹⁹ Gamification can help encourage participation in citizen science and crowdsourcing initiatives. Several initiatives also try to capitalize on the popularity of existing games, encouraging users to collect environmental data as they play.²⁰

Augmented Reality: The use of technology to overlay digital information on an image being viewed through a device, such as a cell phone.²¹ Augmented reality is a feature of many games, such as Pokemon Go, and can be an element of gamification efforts.





Third-Wave applications could revolutionize policy-making by leveraging the power of big data and precision of citizen science. In this series of papers we examine Third Wave data's potential for addressing China's environmental challenges. The first, "Addressing Gaps in China's Environmental Data: The Existing Landscape," evaluates what data are currently publicly available for key environmental issues in China, from air, water and soil quality to biodiversity and habitat, fisheries and climate change. We detail the existing policy landscape and context for managing each issue in China, and what data are available as well as existing gaps. The second paper, "The Potential for Citizen-Generated Data in China," provides an overview of citizen science initiatives both globally and in China, highlighting some of the challenges in applying these approaches.

Current State of Big Data Initiatives in China

China's government has recently embraced the idea of using big data in environmental policymaking. On August 31 2015, the Chinese General Office of the State Council issued the *Action Plan for Promoting Big Data*. Subsequently in March 2016, the Ministry of Environmental Protection (MEP) approved the *Scheme for Building an Ecological Environment Monitoring Network*, a high-level plan for "Ecological Big Data Construction." In these plans, big data is defined as a combination of datasets that are characterized by large volume, various types, fast data processing speed, and high potential value. The network is expected to be completed in 2021. ²²

MEP's plan for an ecological big data platform proposes a science-based policymaking approach that incorporates "one ideology, two systems, and three platforms" (see Figure 3).²³ This approach sets the network's principles and objectives that guide the development and application of the platform, with aims that include improving data quality, centralizing data management, promoting data sharing and opening, and data-driven policy making. The three platforms consist of an environmental cloud platform, a management platform, and an application platform (Figure 3). The big data intensive green cloud platform is the IT infrastructure layer, providing unified basic support services for big data processing and application; the big data management platform is a data resource layer, providing unified data collection for the big data applications, analysis, and processing and other support services; the big data application platform is the business application layer, providing integrated services to large data applications in various fields.





Smarten up Wudang with Big Data

The national Ecological Big Data Construction's first urban pilot site is currently under development in the Wudang District of Guiyang city, Guizhou province. So far, 120 monitoring stations with real-time monitoring, online data transmission, and data comparison technologies have been completed. Health advisories and real-time readings from each monitoring station of environmental quality indicators, such as air quality, water, and noise levels, are available to the public via a mobile app.²⁵ Citizens can plan outdoor trips according to environmental conditions at the 120 stations, some of which are located in popular destinations such as public parks.²⁶





Figure 4. At an international marathon hosted in Wudang in July, 2016, residents and contestants used an mobile app named "Air Quality Doctor" (first row) to track PM_{2.5}, PM₁₀, temperature, and humidity in the area. Air quality monitors were installed (second row left), and display boards with air quality readings (second row middle) were set up next to the marathon course, all managed and controlled through the monitoring platform (second row right). *Source: Xinhua*²⁷

Once completed, the monitoring network's fine spatial resolution will be unprecedented in China. A total of 266 monitoring stations are expected to be built at almost every corner of Wudang, covering an area of 686 square kilometers. The network also includes a pollution warning system that traces pollution to its source quickly and accurately. If a station's readings exceed mandated limits, the central platform will immediately notify the station's manager and request pollution control actions. Through the platform's big data analytics, exact pollution sources, such as factories and construction sites, can be determined and set for inspection.²⁸

Bottom-up Open Data and Big Data Movement

Chinese cities, businesses, academic institutions, and non-governmental organizations were pioneering open data and big data movements long before the national big data policy was released in 2015. Opening government data is one of the 10 key projects included in China's big data action plan, but data opening should not be confused with big data applications. When information is opened up by the government, raw monitoring data or survey data becomes available in machine-readable formats (standard computer languages, such as CSV and XLS, that can be read automatically by a web browser or computer system) to be "freely used, modified, and shared by anyone for any purpose." ²⁹ The opened datasets are not necessarily big data as defined above (e.g., big in volume or requiring fast processing speed), yet bringing together more and more open governmental data can connect isolated datasets, building a foundation for future big data applications. Big data development in the U.S. followed a similar path. The launch of data. gov, a publicly available database of government information and an important part of the Obama Administration's Open Government Directive (OGD), was instrumental in promoting access to governmental data and facilitating the U.S. big data movement.³⁰

Open data is distinct from data disclosure (Figure 3). The traditional mode of government information disclosure involves the release of information that has been processed by the government for public distribution.³¹ These types of data are shared in non-machine readable formats, such as PDFs or scanned low-resolution images, which makes data dissemination and processing difficult. In China, only a few cities and ministries have opened up high quality government data, whereas most jurisdictions have barely achieved full government information disclosure. Among the national ministries, the National Bureau of Statistics (data.stats.gov.cn) updated its



website in 2013 and became the first national agency to open up its data. China Meteorological Administration has followed suit, recently providing Application Program Interfaces (APIs) for developers to build software applications.



Source: adapted from Zheng (2015)³²

Chinese cities are improving official data transparency as they develop Smart City Plans. Early in 2011, Shanghai launched a two-year Smart City Plan with an emphasis on the implementation of cloud computing technology.³³ Shanghai also began collecting, cataloging, and opening up government data to the public in the same period. By January 2013, 320 cities had started construction of smart cities with an investment of 300 billion RMB.³⁴ Among the cities that adopted Smart City Plans, a handful stood out as leaders in opening up high quality governmental data, including Shanghai, Ningbo (Zhejiang Province), Wuxi, Foshan (Guangzhou Province). These cities have built websites that provide high-quality data far better than that from other provinces and most national ministries. The datasets from these cities each come with detailed metadata information, such as release date, degree of openness, frequency of update, and can be downloaded in one or more machine-readable format. The Lab for Digital and Mobile Governance at Fudan University Shanghai evaluated several city government's opened data quality and concluded that data opening is still at a developmental stage in China. As cities improve data transparency and openness, they need to address problems including the lack of machine-readable datasets, unclear data authorization rules, and infrequent data updates.³⁵

Key Findings

- China's government has made progress enhancing environmental data's availability to the public, yet data provision is inconsistent between issues. Some issues, like air quality, have received wide international and domestic attention, resulting in vast improvements in spatial and temporal coverage of pollution data. Other issues, including water quality and soil pollution, have not seen as much investment nor an increase in data provision. Some areas, including climate change and energy, have received high-level policy attention but lack transparent, publically available data.
- The government has also introduced a number of measures to strengthen citizen science pathways for environmental data collection, but these have been adopted unevenly. The MEP's 2014 "Guidance Opinion on Promoting Public Participation in Environmental Protection" (Guidance Opinion), along with its 2015 "Measures for Public Participation in Environmental Protection (Trial Version)", support and clarify the role of public participation in environmental monitoring. However, the implementation of these guidelines has varied widely. For instance, while approximately 156 Environmental Protection Bureaus (EPBs) have created Weibo accounts dedicated to handling environmental affairs, in line with MEP's 2014 Guidance Opinion, a much smaller subset applies these to share detailed information and engage with citizens' questions.³⁶
- Top leadership in China has emphasized using innovative big data platforms to improve environmental monitoring, presenting an opportunity for innovation. Minister of Environmental Protection Chen Jining recently emphasized the development of an "ecological big data platform," and efforts are underway to incorporate big data for air pollution control and forest monitoring. Embracing big data could help China leapfrog traditional monitoring techniques to better manage urgent environmental problems. Emerging information platforms and big data technologies, however, have an uncertain path



forward, and it is unclear how the government will use new sets of information in decision-making processes.

- Incorporating Third Wave data into environmental management will require a strategy to guide the selection of monitoring strategies and the reconciliation of competing information. Competing data may originate from both government agencies with overlapping missions, and from big data or citizen science initiatives whose findings may challenge or diverge from official results. It will be crucial to establish a clear and consistent process for evaluating the legitimacy of data, and developing criteria -- such as data sensitivity, the urgency of data collection, and the ideal scale and resolution of the data -- to inform policy-makers' monitoring strategies. Figure 4 illustrates an example of a decision matrix that could help policymakers determine when and how to use different sources of environmental data.
- Citizen science initiatives face challenges in determining how to avoid further fragmenting the landscape of environmental monitoring in China. Existing environmental monitoring and management efforts face significant challenges from the "central-local divide" between the central government and regional and provincial levels of government. As citizen science initiatives continue to grow, they will need to balance the objectives of tailoring initiatives to their surroundings with the need to build datasets that can link with other datasets and efforts.
- Greater transparency and data availability are urgently needed to enact "next generation" environmental management. An estimated \$600 billion USD is needed every year in China³⁷ to finance energy and environmental projects including initiatives focused on pollution prevention, environmental remediation, renewable energy, and energy efficiency. The central government is able to contribute only an estimated 15 percent of the total investment required to meet the country's needs,³⁸ meaning that private institutions and new, innovative financial tools will be required to fill the gap. These investments hinge on transparent data for investors to identify projects and firms for financing. Asymmetric information between investors, companies, and government creates transaction costs and hurdles for funders.³⁹ The Ministry of Environmental Protection's new efforts to increase corporate environmental information disclosure in line with the 2015 Environmental Protection Law revisions should improve transparency from industrial polluters. As of September 2016, 755 companies have disclosed pollution discharge figures, representing around 80 percent of monitored enterprises.⁴⁰ More online systems like this MEP Environmental Information Disclosure Platform are needed for China to mainstream innovative green finance mechanisms.
- Measures and tools similar to international rankings and indices could be used in China to spur healthy competition for improving environmental performance. Global indices like the Environmental Performance Index (EPI) demonstrate the power of comparative rankings to inspire beneficial competition among national governments. China has begun to adopt data-driven indices, including the Institute of Public and Environmental Affairs' (IPE) Pollution Information Transparency Index (PITI).⁴¹ Such indices can gauge performance to identify leaders and laggards in different areas. Applying novel data management methods, such as real-time environmental monitoring and crowdsourced data (e.g., Alibaba-sponsored DangerMaps), to businesses and government departments in China could help officials calculate externalities, such as the costs of treating polluted water and public health expenditures stemming from air pollution.





Figure 6. An example decision matrix that could be used to help policymakers select different methods of data collection and public engagement to support environmental monitoring and management. *Source: authors*

Potential Partners and Next Steps

Certain approaches could be particularly helpful for leveraging Third-Wave data to support environmental management in China:

An Environmental Performance Index for China's Provinces

Indicators and indices are tools that can be used to assess environmental performance among government institutions and other entities at the local and provincial levels. Utilizing information from Third Wave data sources could make the invisible visible, enhancing transparency and shining a spotlight on areas where governments are performing well and where they stand to improve. The Chinese Academy for Environmental Planning, a thinktank tied to the Ministry of Environmental Protection, has piloted a provincial China Environmental Performance Index⁴² assessment system. This tool relies on official government data, which is inadequate to gauge performance on many issues. The incorporation of Third Wave data could vastly enhance the utility of such a performance measurement framework by filling critical gaps.



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Indices and indicators could be used to score environmental performance of large companies based on a set of metrics that evaluate a firm's environmental impacts as well as its reporting structure and transparency. These types of measures could evolve into stock market ESG Indices that track companies' environmental performance for shareholders and regulators.

Potential Partners: Environmental Information Center of the Ministry of Environmental Protection, and Institute of Public and Environmental Affairs (IPE).

An Environmental Big Data Center Platform

An Environmental Big Data Center Platform (EBDC) could act as a central hub for the collection of all types of environmental information. The EBDC's goals would include: utilizing new technologies, including social media and satellite remote sensing, to better understand the state of China's environment; analyzing and visualizing data; creating predictive models based on expert analyses; and connecting and fostering coordination between different types of data provides, including citizens, scientists, business and technology providers, and different levels of government. The EBDC would be modeled after a "big data lake," allowing for multiple formats and types of data to be shared.

This type of platform could include and inform citizen science initiatives, making use of citizen-generated data to develop a detailed picture of China's environment and identifying key data gaps across various sectors and geographies where citizen-science initiatives could help gather and ground-truth data. Citizen science initiatives could also be used to communicate EBDC's data visualizations and predictions. The EBDC could in turn support development of citizen science initiatives and coordination among different projects. Collecting data in a single repository would encourage and enable civil society to build on existing initiatives, reducing the expense of designing, testing and implementing projects "from scratch" and diminishing duplicative or redundant efforts.⁴³ A shared portal could also help identify successful strategies and best practices while pointing to potential partnerships and synergies across initiatives.

Potential Partners: Alibaba Foundation, Environmental Information Center at the Ministry of Environmental Protection, Institute of Public and Environmental Affairs (IPE), Wilson Center, and existing citizen science initiatives across China.

Examine Incentives Structures for Participation in Citizen Science Initiatives

While the potential to mobilize citizen science to fill data gaps and support environmental communication and management is vast, understanding how to engage and retain volunteers has proven more challenging. More information on the ways incentives drive different demographics, locations, and cultures could help tailor citizen science opportunities to engage different participants. Attempts to "gamify" citizen science, particularly through augmented reality games, such as Pokemon Go, have also generated high levels of interest, but would benefit from additional research and experimentation.

We propose exploring the impact of different incentive structures, such as gamification, connection to personal interests or networks, and social responsibility, for engaging citizen scientists in China, to inform efforts to attract and retain volunteers. This effort could either investigate or support the deployment of existing citizen science initiatives, for instance by exploring the motives of data sharing from consumer-based air pollution sensors, such as TZOA, Air Quality Egg, or AirVisual Node, and/or survey attitudes toward citizen science more generally.

Potential Partners: Environmental Information Center at the Ministry of Environmental Protection, Institute of Public and Environmental Affairs (IPE), and existing citizen science initiatives (TZOA, Air Quality Egg, or AirVisual Node, among others).

Examine Barriers for Participation in Citizen Science Initiatives

While understanding incentive structures for participating in citizen science efforts is essential to ensure their success, equally important is determining what barriers might exist in China for successful citizen science efforts. Lack of trust, as illustrated in the early phases of the MEP's Black and Foul Water WeChat app,⁴⁴ can pose a major obstacle to citizens contributing to data collection and environmental monitoring efforts. A greater understanding of how issues of trust may influence citizen science campaigns, and how citizen science initiatives can be designed to address these worries, is needed.

Potential Partners: Institute of Public and Environmental Affairs (IPE) or other environmental NGOs in China.



Develop Methods for Data Quality Assurance

The proliferation of citizen-science and consumer-based environmental monitoring equipment has made it easier for citizens to participate in data collection and scientific research. As discussed in this paper, however, major questions still exist regarding the quality and accuracy of citizen-collected data. Further efforts could be invested in better testing the accuracy of citizen-collected data and comparing these data points to officially-reported statistics or results from academic studies. In particular, more information is needed regarding trade-offs and levels of uncertainty associated with citizen-based science and data collection efforts.

Potential Partners: Shanghai Qingyue, ShanShui Conservation Center, Green Hunan, Mike Bergin (Duke University Pratt School of Engineering),⁴⁵ and AirVisual.

Table 1. Summary of the environmental data landscape in China for key issues. Red signifies existing data and monitoring efforts are inadequate; Yellow signifies some progress has been made on monitoring, but overall data are still inadequate; Green represents an issue where China has made significant progress towards improved monitoring.

	Current Status of Data Availability	Data Gap(s)	Potential Big Data, Public Engagement, Crowdsourcing, and Citizen Science Applications
Air	China has greatly improved monitoring and public data provision for major air quality pollutants. Real-time monitoring data are now available for 338 cities. Data still lags, however, for indoor air quality.	While China has improved monitoring and public data provision for major air pollutants like fine particulate matter (PM2.5), PM10, SO2, NO2, O3, and CO, data lags for pollutants like Volatile Organic Compounds (VOCs), newly targeted in the 13th Five-Year Plan.	The development of a big data platform integrating multiple forms of satellite data, weather information could create sophisticated forecasting systems to alert citizens of potential high-pollution events. Citizen science campaigns could also help gather more fine- tuned data; particularly in areas that are not included within monitoring networks.
Water	Long regarded as "departmental resources" to remain hidden from the public, overall transparency and timeliness of water quality data lags far behind that of air quality. Even now, the scale of water pollution is still hidden from the public. Responsible ministries are unwilling to disclose results from past surveys and progress in construction of a national monitoring network is stalled. While real-time surface water data is publicly available in through the Ministry of Environmental Protection's Surface Water Quality Real-time Monitoring Data Automatic Publishing System, groundwater and drinking water data are published monthly only and sometimes with discrepancies across different ministries due to lack of coordination.	Water statistics are distributed across multiple ministries and Water statistics are distributed across multiple ministries and agencies. Data are often untimely, presented in inacessible formats (e.g. low resolution images), and without information on original data sources or methodologies.	NGOs like the Institute for Public and Environmental Affairs (IPE), Shanghai NGOs like the Institute for Public and Environmental Affairs (IPE), Shanghai Qingyue are working to make China's water pollution data more publicly accessible through online mapping platforms and apps. The MEP's 'Black and Smelly Water' app utilizing WeChat also employs citizen science and crowdsourcing techniques to better spot urban water pollution. Issues of trust and transparency still need to be addressed, however, for these new initiatives to be effective.
Soil	Soil pollution and soil quality have been critical yet sensitive topics in China, often considered a "state secret." Until the recent release of the MEP and MLP soil survey in 2014, very little public information on soil pollution was available. Soil pollution's close linkage to food safety, in particular, makes data on soil quality sensitive from the government's perspective.	Despite the first soil pollution survey being released in 2014, details about the spatial location of sampling sites, survey methodologies employed, the levels of exceedance for individual points, as well as the original survey results were not provided to the public.	The IPE compiled a soil pollution map with filtered data from 4,500 companies and 729 industrial parks in 13 heavy-polluting sectors such as petrochemicals, mining, metal smelting. The Ministry of Agriculture and MEP are developing a national monitoring network. 107 national arable land monitoring sites have been built, and 152,000 monitoring points will be established to closely observe and control pollution around agricultural production areas.



Potential Big Data, Public Engagement, **Crowdsourcing, and Citizen Science** Applications



Unlike many widely-used international Despite the large number of national databases, biodiversity governmental data on natural resources and biodiversity mainly takes the form online and have yet to be digitized of large-scale surveys, often conducted from their original print versions. They by different agencies. While a major are scattered on different agencies' step forward was the completion of a own websites. They are hidden in national biodiversity assessment in 2012, disorganized website structures and China still lacks a central monitoring formats. network for biodiversity and habitat, which is one reason why data are so sparse and difficult to access.

Chinese and subnational surveys conducted, these surveys are difficult to access

International organizations like the UN World Conservation Monitoring Centre collect terrestrial and marine protected areas data from governments around the world and transparently publish this information on protectedplanet.org. Citizen science campaigns have the potential to improve species data, although major gaps and the results were never published online. often published in inaccessible data challenges exist, including spatial coverage, data quality and verification.



On the national level, three kinds of data are reported monthly, annually, and biannually to different institutions. Once a year, the Bureau of Fisheries under the Ministry of Agriculture publishes the China Fisheries Yearbook with fishery and aquaculture data that is compiled and analyzed from submissions of 31 local administrative units. Subject areas of data include production, sector structure, and investment in fisheries, among others.

a major problem. Low compliance incentives to collect and report data exist, compounded by the lack of a monitoring system to verify data low. Overreporting of fish catch data by China resulted in misestimation of global fisheries data, although China's strides over the last few years to their fishing operations and data. improve its reporting practices.

Implementation of data collection is Advancements in satellite technology and big data can better track and monitor fishing operations. Global Fishing Watch, for instance, utilizes an Automatic Identification System (AIS) that collects massive amounts of data by quality, mean fisheries data quality is satellites and terrestrial receivers to identify fishing behavior based on the movement of vessels over time. Third-party watchdog organizations like these can help to pressure government has made significant governments to be more transparent about



China's State Forestry Administration (SFA) regularly conducts national 5-year forest inventories to assess China's total forest area, forest cover, and growing stock.

Prior to the launch of the forestry big China currently boasts a forest monitoring data platform in 2016, SFA's annual forestry development reports did not provide separate data on area of natural forests and plantation, not to mention the amount of restored forestland. The only official available data disaggregated by natural forests Qinghai, and Ningxia Province. and plantation by province come from SFA's NFIs are conducted every five years. Data on forest health are also lacking.

big data network, which was launched in 2015 and contains over 1 petabyte of data. The network has been expanded to Beijing-Tianjing-Hebei, Yangtze River Economic Zone, and regions covered in the "One Belt One Road" national initiative, including Gansu,

Climate Change

provincial and national levels. The most recent time China reported its carbon emissions was in November 2012 for its Second National Communication on Climate Change to the UNFCCC, which only included data from 2005.

data disclosed in China.

Energy data exists in China, both at the While energy data exists in China, In 2007 the NBS established a Statistics both at the provincial and national Indicators, Monitoring and Evaluation System levels, there currently lacks timely (SME) with three major goals: to implement greenhouse gas emissions data or a statistical monitoring, verification, and other relevant climate information. indicators system to assess energy intensity. Despite policies mandating a national The SME, however, is still under development. greenhouse-gas statistical monitoring There is potential to link China's existing system in 2007, there is currently no Continuous Emissions Monitoring (CEMs) of up-to-date official carbon emission air pollution data to carbon dioxide emissions.



Endnotes

1 Hsu, A. (2016). The 2016 Environmental Performance Index. Yale University, New Haven, CT. http://www.epi.yale.edu.

2 Mol, A.P.J. (2009). Environmental governance through information: China and Vietnam. Singapore Journal of Tropical Geography, 30:114–129; Hsu, A., A. de Sherbinin, H. Shi. 2012. Seeking truth from facts: the challenge of environmental indicator development in China. Environmental Development, 3:39-51.

3 Sinton, J. (2001). Accuracy and reliability of China's energy statistics. China Economic Review, 12:373-383; The Economist. 2008. An aberrant abacus. http://www.economist.com/finance/displaystory.cfm?story_id=11290833.

4 Rawski, T.G. (2001). What is happening to China's GDP statistics? China Economic Review. 12:347–354.

5 Sinton, 2001; Zhang, Q., D.G. Streets, K. He, Y. Wang, A. Richter, J.P. Burrows, I. Uno, C.J. Jang, D. Chen, Z. Yao, and Y. Lei. 2007. NOx emission trends for China, 1995-2004: the view from the ground and the view from space. Journal of Geophysical Research. Vol. H2; Yardley, J. 2008. Consultant Questions Beijing's Claim of Cleaner Air. NY Times. 10 January. Available: http://www.nytimes. com/2008/01/10/world/asia/10china.html. Last accessed: January 25, 2013; Guan, D., Z. Liu, Y. Geng, S. Lindner, and K. Hubacek. 2012. The gigatonne gap in China's carbon dioxide inventories. Nature Climate Change, 2:672-675.

6 Hornby, L. (2014). China admits widespread soil pollution in 'state secret' report. The Financial Times. 18 April. Available: http://www.ft.com/cms/s/0/c250bd4c-c6b4-11e3-9839-00144feabdc0.html#axzz4M00Wmpda.

7 孙秀艳, & 刘毅. (2016, March 9). "十三五"规划纲要草案中资源环境指标增至10项. 人民网. Retrieved from http://finance.people.com. cn/n1/2016/0309/c1004-28183208.html

8 Citizen Science: Public Participation in Environmental Research. 2012. Eds. Dickinson, Janis L. and Rick Bonney. Ithaca, NY; Irwin, Alan. 2001. "Constructing the scientific citizen: Science and democracy in the biosciences." Public Understand of Science, 10:1–18; Bäckstrand, Karin. 2003. "Civic Science for Sustainability: Reframing the Role of Experts, Policy-makers and Citizens in Environmental Governance." Global Environmental Politics, 3(4):24-41.

9 Press, G. (3 September 2014). 12 Big Data Definitions: What's Yours? Forbes. Retrieved from: <u>http://www.forbes.com/sites/gilpress/2014/09/03/12-big-data-definitions-whats-yours/#863745421a97</u>.

10 Wiggins, A. and Crowston, K. (2011). From Conservation to Crowdsourcing: A Typology of Citizen Science. Proceedings of the 44th Hawaii International Conference on System Sciences. Retrieved from: <u>https://www.computer.org/csdl/proceedings/hic-ss/2011/4282/00/07-04-02.pdf</u>.

11 Bonney, R., Shirk, J.L., Phillips, T.B., Wiggins, A., Ballard, H.L., Miller-Rushing, A.J., and Parrish, J.K. (2014). Next Steps for Citizen Science. Science 343 (6178), 1436-1437. DOI: 10.1126/science.1251554.

12 Press, G. (3 September 2014). 12 Big Data Definitions: What's Yours? Forbes. Retrieved from: <u>http://www.forbes.com/sites/gilpress/2014/09/03/12-big-data-definitions-whats-yours/#863745421a97</u>.

13 Press, G. (3 September 2014). 12 Big Data Definitions: What's Yours? Forbes. Retrieved from: <u>http://www.forbes.com/sites/gilpress/2014/09/03/12-big-data-definitions-whats-yours/#863745421a97</u>.

14 Press, G. (3 September 2014). 12 Big Data Definitions: What's Yours? Forbes. Retrieved from: <u>http://www.forbes.com/sites/gilpress/2014/09/03/12-big-data-definitions-whats-yours/#863745421a97</u>.

15 Estellés-Arolas, E., and González-Ladrón-de-Guevara, F. (2012). Towards an integrated crowdsourcing definition. Journal of Information Science XX(X): 1-14. DOI: 10.1177/016555150000000

16 Estellés-Arolas, E., and González-Ladrón-de-Guevara, F. (2012). Towards an integrated crowdsourcing definition. Journal of Information Science XX(X): 1-14. DOI: 10.1177/016555150000000



17 Rowe, G. and Frewer, L.J.. (2005). A Typology of Public Engagement Mechanisms. Science, Technology, & Human Values, 30 (2): 251-290. DOI: 10.1177/0162243904271724.

18 Merriam-Webster Online Dictionary. Social Media. Retrieved from: <u>http://www.merriam-webster.com/dictionary/social%20me-dia</u>. Accessed 29 July 2016.

19 Oxford English Dictionary. Gamification. Retrieved from: http://www.oxforddictionaries.com/us/definition/american_english/ gamification. Accessed 31 August 2016.

20 Marshall, C. 22 August 2016. Pikachu Power: Can it Transform the Industry? E & E Publishing, LLC. Retrieved from: <u>http://www.eenews.net/stories/1060041882</u>. Accessed 31 August 2016.

21 Merriam-Webster Online Dictionary. Augmented Reality. Retrieved from: <u>http://www.merriam-webster.com/dictionary/augment-ed%20reality</u>. Accessed 31 August 2016.

22 "China Ecological Environment Big Data Platform Will Be Built in 5 Years," accessed October 3, 2016, http://www.chinaenviron-ment.info/Policy/201602/t20160223_24150.html.

23 Ministry of Environmental Protection. (n.d.). Releasing the Guidance on Ecological Environmental Big Data Platform Construction. Retrieved October 4, 2016, from http://www.mep.gov.cn/gkml/hbb/bgt/201603/t20160311_332712.htm

24 Ministry of Environmental Protection. (2016). Releasing the Guidance on Ecological Environmental Big Data Platform Construction. Retrieved October 4, 2016, from http://www.mep.gov.cn/gkml/hbb/bgt/201603/t20160311_332712.htm

25 新华网. (2016). 贵阳首个生态环境大数据试点项目在乌当开始运行. Retrieved October 4, 2016, from http://www.gz.xinhuanet. com/2016-07/22/c_1119264450.htm

26 新华网. (2016). 贵阳首个生态环境大数据试点项目在乌当开始运行. Retrieved October 4, 2016, from http://www.gz.xinhuanet. com/2016-07/22/c_1119264450.htm

27 新华网. (2016). 贵阳首个生态环境大数据试点项目在乌当开始运行. [Online image] Retrieved October 4, 2016, from http://www.gz.xinhuanet.com/2016-07/22/c_1119264450.htm

28 新华网. (2016). 贵阳首个生态环境大数据试点项目在乌当开始运行. Retrieved October 4, 2016, from http://www.gz.xinhuanet. com/2016-07/22/c_1119264450.htm

29 The Open Definition - Open Definition - Defining Open in Open Data, Open Content and Open Knowledge. (n.d.). Retrieved October 4, 2016, from http://opendefinition.org/

30 Bertot, J. C., & Choi, H. (2013). Big data and e-government: issues, policies, and recommendations (p. 1). ACM Press. https://doi. org/10.1145/2479724.2479730

31 Zheng, L. (n.d.). 开放政府数据价值与发展. Retrieved October 4, 2016, from http://study.big-data.org.cn/course/kanke/60

32 Zheng, L. (2015). 中国地方政府开放数据现状、问题与难点.[Online image]. Retrieved October 4, 2016, from http://www.tripvivid.com/articles/4423

33 上海市推进智慧城市建设2011-2013年行动计划(2011年9月28日). (2011). Retrieved October 6, 2016, from http://www.shanghai. gov.cn/nw2/nw2314/nw2319/nw22396/nw22403/u21aw544325.html

34 国脉物联网. (2014, May 6). 国内外智慧城市建设与发展趋势分析. Retrieved October 6, 2016, from http://www.urbanchina. org/n/2014/0506/c369544-24982299.html



35 大数据文摘. (2015). 2015 中国开放政府数据"探显"报告. Retrieved October 4, 2016, from http://www.cbdio.com/BigDa-ta/2015-10/12/content_3948412.htm

36 Institute of Public & Environmental Affairs (IPE) and Natural Resources Defense Council (NRDC). (2015). New Mindsets, Innovative Solutions: 2014-2015 PITI Assessment. Retrieved from: <u>https://www.nrdc.org/sites/default/files/piti2014-15-en.pdf</u>.

37 UN Environment Programme (UNEP). (2016). On eve of G20 Summit, China puts green finance centre stage. Available: http://www.unep.org/newscentre/default.aspx?DocumentID=27084&ArticleID=36254.

38 People's Bank of China, United Nations Environment Programme, "Establishing China's Green Financial System" 15 March. Available: https://www.cbd.int/financial/privatesector/china-Green%20Task%20Force%20Summary.pdf.

39 G20. (2016). "G20 Green Finance Synthesis Report." 15 July. Available: http://www.g20.org/English/Documents/Current/201608/P020160815359441639994.pdf.

40 Ministry of Environmental Protection. Environmental Information Disclosure of Chinese Enterprises. Retrieved October 4, 2016, available: http://114.251.10.87/eeid/info/select/index.action

41 IPE and NRDC. (2016). New mindsets, innovative solutions: 2014-15 PITI Assessment. Beijing. Available: https://www.nrdc.org/ sites/default/files/piti2014-15-en.pdf.

42 Chinese Academy for Environmental Planning (CAEP). 2016. Chinese environmental performance assessment system. Available: http://118.123.13.161:9009/Home

43 Bonney, R., Shirk, J.L., Phillips, T.B., Wiggins, A., Ballard, H.L., Miller-Rushing, A.J., and Parrish, J.K. (2014). Next Steps for Citizen Science. Science 343 (6178), 1436-1437. DOI: 10.1126/science.1251554.

44 Phillips, T. (2016). A 'black and smelly' job: the search for China's most polluted rivers. The Guardian. Retrieved from: https://www.theguardian.com/world/2016/jun/22/black-smelly-citizens-clean-chinas-polluted-rivers.

45 Mike Bergin's lab conducts testing of numerous consumer air quality sensors. See: http://cee.duke.edu/faculty/michael-bergin.





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