Science and Technology Trends
Safety Research and Risk Management Policy in Asia

Towards Integrated Risk Governance: Progress in Science and Technology for Disaster Risk Reduction in China

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1. Introduction

1.1 Background

China is one of the only few countries in the world that is affected by almost every kind of natural hazards. More than 100 types of natural hazards, except volcanic eruptions, frequently hit China. Among these natural hazards are earthquakes, typhoons, floods, drought, sandstorms, storm surges, landslides and debris flow, hailstorms, cold waves, heat waves, epidemics, pests and rodent diseases, forest and grassland fires, and red tides. With its vast territory, all provinces (autonomous regions and municipalities) in China bear a different damage extent from natural disasters. For example, as the country is dominated by an extremely variant Asian monsoon, it has had a long history with drought, which occurs almost every two years in the past two thousand years. In addition, on average, the eastern coastal areas are hit by seven tropical cyclones every year. China suffers from frequent earthquakes as it is located in the region where the Eurasian, Pacific, and Indian Ocean plates meet. As a mountainous country, landslide and debris flow are also normal.

In the past 40 years, the annual direct economic losses in China caused by weather, climate, floods, earthquakes, geological, agriculture, and oceanic disasters amount to about 3% of the gross domestic product (GDP). The annual average number of deaths is over 10,000 (China National Committee of Disaster Reduction, 2011). In the past three decades, there is an uptrend of migration from inland regions to the coastal regions and heavy investment of fixed asset in the eastern China. Currently, more than 70% of the cities and 50% of the population are located in this region, the exposure level of natural hazards is getting higher. With rapid social and economic growth in the context of global climate change, it is foreseeable that China will enter a new era of high disaster risk, and that the disaster risk governance will become even more challenging.

1.2 Achievements in disaster prevention and reduction in China

Developing Legal and Institutional Mechanism: As a response to the call from the United Nation's (UN) International Decade for Natural Disaster Reduction (IDNDR) in 1989, the Chinese government established a committee under the State

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Council as an interministerial coordinating mechanism. The committee is responsible for drafting the key disaster reduction policy and plan, coordinating major disaster reduction activities across the country, and guiding the local government in this regard. Since then, the Chinese government has gradually adapted the concept of comprehensive disaster reduction by focusing on the enhancement of the comprehensive capacity of disaster prevention and reduction, as well as by implementing coordination and cooperation among the government agencies and regions.

For example, efforts for the coordination in defending against all natural disasters, planning disaster prevention and reduction strategies, and utilizing all resources were made. Legal, administrative, market, and technical approaches have been integrated to minimize the mortality and financial losses. China is currently in the transition process—from single disaster reduction to comprehensive disaster reduction, from rescue-oriented to combined rescue and reduction, and from disaster mitigation to disaster risk reduction (Figure 1).

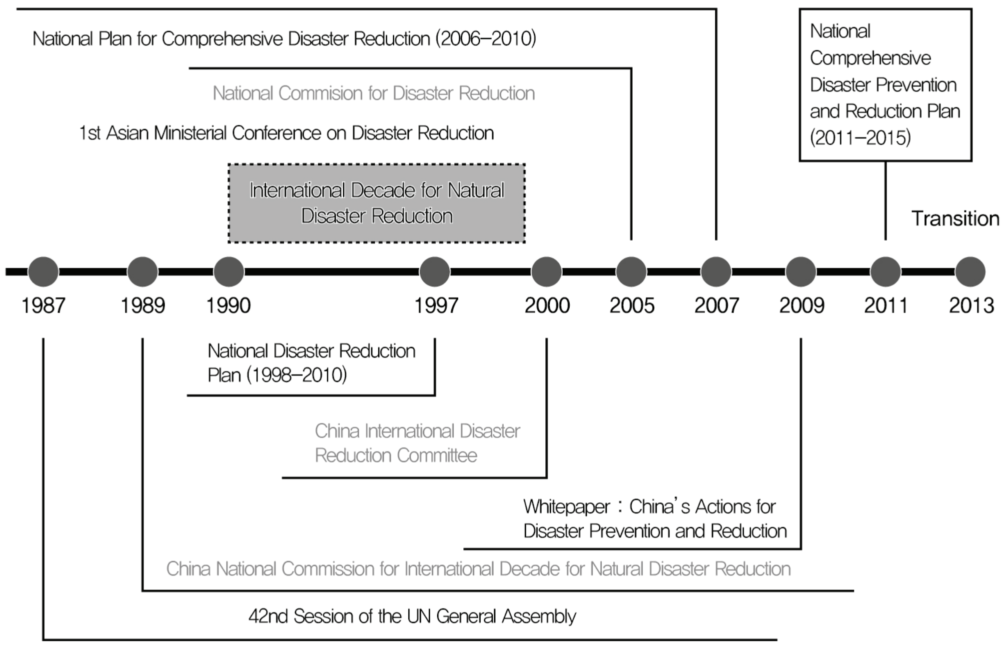

Figure 1. Progress of the National Integrated Disaster Prevention and Reduction in China

<u>*Enhancing Science and Technology Capacity:*</u> In the recent years, to provide a safe environment for China's fast social and economic development, Chinese scientists and engineers have developed remote disaster monitoring, meteorology forecasting, hydrology, flood monitoring and early-warning notification, earthquake monitoring, geological disaster monitoring, environmental monitoring, and other similar systems. The monitoring and early-warning capacity against natural disaster has been greatly enhanced for the entire nation. For example, the five-grade disaster information platform has been set up to provide the needed information in a timely manner. This is to support the decision makers and allow them to respond to the disasters more efficiently and effectively. A complete

early-warning information disclosure system-including cell phones, TV and radio stations, as well as the Internet—has been developed to provide early-warning information and disseminate disaster information to the general public in high risk zones and other disaster-prone areas.

With substantial improvement in remote sensing, geospatial information system, satellite navigation, and other relevant forefront technologies, scientists in China have also made significant progress on understanding the occurrence, cause, and evolution of disasters. This has enabled China to enhance its technical capacity, with respect to its disaster monitoring, early-warning, risk assessment, emergency management, and restoration planning. By carrying out a nationwide land resources survey, and a geological disaster and environmental survey, a comprehensive national, provincial, city, and county geological disaster database has been built, and national disaster risk maps have also been compiled (Figure 2).

Figure 2. Risk Level Map of Integrated Natural Disasters in China (Shi, 2011)

Investing heavily on megascale engineering projects: The role of megascale engineering projects in reducing disaster risk factors in disaster-prone regions has been recognized by the Chinese government since 1949. For example, to meet the challenge of the increasing degradation in arid and semiarid regions, the central government implemented five key forestry and sandy desertification control programs, i.e., the Three North Shelterbelt Development Program (3NSDP), the Conversion of Cropland to Forest Program (CCFP), the Natural Forest Protection Program (NFPP), the Sand Source Control Program in Beijing and Tianjin (SSCP), and the Grazing Ban for Grassland Restoration Program

(GBGRP) (Table 1). Since 2006, through the adoption of the Hyogo Framework for Action implementation guideline of integrated disaster risk governance, the emphasis is now on strengthening the implementation of new engineering projects for the purpose of reducing social vulnerability and for the development of a systematic approach for ecosystem restoration to strengthen natural disaster prevention and mitigation capacity.

Table 1. Five key forestry and desertification control programs in China

Key Projects	Total Investment (unit : USD 1million)	Major Achievements
3NSDP 1978–2010	20	26.47 million ha of afforestation land
CCFP 2002–2010	400	9.26 million ha of cropland was converted into forest land
NFPP 2000–2010	130	forest area increased by 14.00 million ha, timber production reduced by 220 million m^3
SSCP 2001–2010	70	6 million ha of cropland was returned to the forest
GBGRP 2003–2010	35	518.66 million ha of grassland was protected with a fence and 12.40 million ha of severely degraded grassland was reseeded

2. National Comprehensive Disaster Prevention and Reduction Plan (2011–2015): Lessons Learned from the Great Wenchuan Earthquake

2.1 The Great Wenchuan Earthquake

China is one of the countries in the world that is most affected by severe seismic disasters. According to the historical records, from the 20th century on, the death toll caused by earthquakes within the corresponding period amounted to 600,000, which accounts for 42% of the death toll in the world.

The Great Wenchuan Earthquake (GWE) occurred at 14:28 on May 12, 2008 in the Sichuan Province of China. With a magnitude of 8.0 on the Richter scale, the GWE thereby far exceeds the well-known Tangshan Earthquake in 1976, which had the maximum intensity of 11. The earthquake affected a total area of approximately 500,000 km^2, which covers 417 counties, cities and districts; 4,667 towns and 48,810 villages in 10 provinces (Shi et al., 2012). As of October 10, 2008, it was found that the earthquake claimed a total of 87,150 victims, among them 69,227 were confirmed and 17,923 were missing. More than 374,600 people were injured. The homes of more than 5 million people were assessed as either collapsed or damaged. Some towns and numerous villages were almost entirely destroyed. The regional and national infrastructures were also severely damaged, including 24 expressways, 163 national and provincial highways, 7 major railway lines, and 3 railway branch lines, as well as numerous power, communication, radio, television, and water conservancy facilities. Based on the survey of the Ministry of Civil Affairs (jointly undertaken with relevant regions and sectors), the total of the direct economic losses in Sichuan, Gansu, and Shaanxi Provinces alone was USD 120 billion (Shi et al. 2012).

2.2 Lessons Learned from the Response to the Great Wenchuan Earthquake

The massive Wenchuan Earthquake is a rare and catastrophic natural disaster. It was not only the most destructive earthquake in China's recorded history, but it was also the most difficult period in terms of rescue and recovery efforts compared with any earthquake that has been recorded since the establishment of the People's Republic of China (PRC). Through the arduous efforts of governments from all levels, including the military, scientists, engineers, the general public, the media, and NGOs, the basic living conditions and the safety of people from these disaster areas were effectively secured, and public order was also promptly restored. Even postdisaster reconstruction works were undertaken in an orderly manner before the rescue activities ended. Although the overall immediate responsiveness of China and the coordination of the national and international disaster relief were successful, much still remains to be done. Some of the weaknesses are listed below (Shi et al, 2012).

Low Levels of Disaster Resistance in Urban and Rural Constructions: For example, it was found that based on the earthquake resistance and fortification requirements, distributions of power grids, highways, and other major infrastructures in the region were not fully designed. In rural areas, almost no inspection for disaster prevention and protection has occurred.

Weak Capacities of Emergency Rescue and Relief in Disaster Areas: The emergency rescue capability was extremely low. There was a lack of trained personnel, equipment for search and rescue, communication, and epidemic prevention material. The number and variety of materials reserves could barely meet the demand for catastrophe response. The emergency production reverse system was not established.

Imperfect Management System for Catastrophe Response: The central and local governments did not have sound emergency response systems for major natural disasters and emergencies. The transregional and transagency coordination mechanisms still needed improvement. A great number of the businesses and townships did not have emergency response plans or were difficult to be implemented.

Low Level of Monitoring, Warning, and Forecasting for Disastrous Earthquakes: As worldwide seismic forecasting and warning systems are still at the exploration stage, and short-term seismic forecasting is an extremely difficult process, China's instant reporting network for seismic intensities and early-warning systems were not fully established. For example, it took the China Earthquake Administration three days after the Wenchuan Earthquake to deliver a correct description of the epicenter model and intensity attenuation map.

2.3 Key Points on Science and Technology in the National Comprehensive Disaster Prevention and Reduction Plan (2011–2015)

Learning from the Great Wenchuan Earthquake, the Chinese government launched the 12th Five-year Special Planning for the National Technological Development of Disaster Prevention and Reduction. In the planning stage, it sets up an overall target, i.e., investing more in disaster-reduction projects, improving disaster early-warning and emergency response, enhancing the capability of science and technology, including the strengthening of personnel training and disaster reduction work in communities.

The key points that were highlighted for science and technology in the planning stage are as follows:

Investing more in disaster-reduction projects

Since 2011, China has engaged in a series of important disaster-reduction projects, including those that concern flood control, drought combat, earthquake prevention and relief, cyclone control, red tide, and other marine disaster prevention, desertification and sandstorm control, and ecological construction. For example, to reduce flood risks in major rivers, the construction and renovation of the dykes on the middle and lower reaches of the Yangtze River have been completed, and construction of standardized dykes on the lower reaches of the Yellow River is in full swing. Construction work on some major sections of these rivers is now capable of defying 100-year floods. The standard for key sea dykes has been raised to withstand the worst flood in 50 years.

Making new regulations for building construction in rural areas

After the 2008 Wenchuan earthquake in Sichuan Province, the Earthquake-proof Classification Standards for Construction Projects and the Earthquake-proof Construction Design Specifications have been revised. New technical guidelines for residential houses and school buildings in rural areas have been developed to serve as a guide for quality control on site selection, design, construction, and acceptance inspection. Combining this with poverty alleviation efforts, a total of USD 3 billion has been invested nationwide for the renovation and construction of 6 million rural houses. A school building renovation scheme has also been implemented throughout the country. Starting from 2009, the state has reinforced school buildings nationwide in order to make them meet the requirements for preventing and avoiding disasters that are caused by earthquakes, mountainside landslides, rock collapse, mud–rock flow, tropical heat wave, fire, etc.

Redesigning the transportation infrastructure of disaster prevention projects

A total of USD 300 million has been invested to renovate road embankments, roadbeds, bridge structures, and flood-proof and drainage facilities. This investment focused on disaster prevention facilities in mountainous and hilly areas. The disaster-prevention capability of China's ordinary highways has also been comprehensively improved.

Development of a three-dimensional monitoring system

China is building a three-dimensional natural disaster monitoring system, which includes land monitoring, ocean and ocean bed observation, and space–air ground observation. Small satellites, named Constellation A and Constellation B, for environmental disaster-reduction monitoring have also been launched. A business application system that uses the disaster-reduction satellite has taken shape, providing advanced technological support to remote-sensing monitoring, as well as the evaluation of and decision-making for disaster reduction.

Enhancing Disaster Monitoring and Early-warning and Forecasting Capability

A disaster early warning and forecasting system has taken its initial shape. For example, to provide early warning and forecasts for meteorological hazards, the meteorological satellites FY-1, FY-2, and FY-3 were placed into orbit. A new generation of weather radar installations, which totaled to 146, has been developed. Ninety-one high-altitude meteorological stations that are equipped with an L-band upper-air meteorological sounding system have been established, and 25,420 regional meteorological observation stations are currently in operation. Special meteorological observation networks have been preliminarily built for studies of atmospheric elements, acid rain, sandstorm, thunder and lightning, as well as agricultural and transportation meteorology.

A hydrological monitoring network that is composed of 3,171 hydrological stations, 1,244 gauging stations, 14,602 precipitation stations, 61 hydrological experiment stations, and 12,683 groundwater observation wells has also been completed.

An early warning and forecasting system for floods, a groundwater monitoring system, a water resources management system, and a hydrological data system have also been established.

The earthquake monitoring and forecasting capability has also been significantly improved. Currently, China has 937 fixed seismic stations and over 1,000 mobile seismic stations that are capable of providing quasi real-time monitoring of earthquakes that are above 3 on the Richter scale. In addition, 1,300 earthquake precursor observation stations have been established, as well as a mobile observation network that is composed of over 4,000 mobile observation stations. Seismological forecasting and monitoring systems, at both the national and provincial levels, have taken their initial shape. A high-speed seismic data network composed of 700 information nodes has been built, and a cell phone message service to provide timely earthquake reporting has also been launched.

Oceanographic observation instruments, equipment, and facilities were renovated. Offshore observation capacity has been greatly enhanced. Buoy observation and cross-sectional survey abilities have been improved as a whole. A batch of marine observation stations has been constructed or renovated. The upgrading of the real-time communication system has been completed at some key observation stations. An observation and evaluation system for sea–air interaction and ocean climate changes has been developed for ocean disaster monitoring, which is closely related to climate changes such as sea level rise, coastal erosion, seawater intrusion, and saline tide.

Moreover, the country's three-dimensional monitoring system for forest and grassland fires, as well as sandstorms, has been improved. This system consists of satellite remote sensing, airplane cruise flight, video monitoring, as well as duty and ground detection and observation. Ground observation points have been set up in major sandstorm-stricken areas of North China at the national, provincial, municipal, and county levels in order to form a sandstorm monitoring network that would cover the entire area.

Improvement of the disaster prediction and comprehensive risk assessment techniques

Efforts were made to establish a disaster prediction model based on physical processes in order to improve the short-term forecasts. Basic researches on improving the prediction of natural disasters risks are supported, including the development of a comprehensive, multiscale, dynamic information processing, and decision optimization system, as well as the building of a national and regional natural disaster early monitoring and rapid alert technology platform.

By utilizing remote-sensing technology, digital observation technology, GPS precise positioning technology, and the integration of the disaster rapid assessment model developed system, which is based on GIS technology, new natural hazard risk assessment techniques were developed in order to determine the probability of disaster occurrence, as well as its intensity and spatial distribution, to support regional vulnerability assessment.

Innovating new materials, new technologies, and new equipment for disaster prevention and mitigation

The Chinese government encourages private sectors to invest more in the innovation and development of equipment for monitoring, communications, rescue, and disaster prevention, including construction equipment such as advanced life detection, rescue robot, large and heavy obstacle removers, and other similar scientific equipment.

3. Creating a Resilient Society in China: Challenges and Opportunities

The 2013 Global Assessment Report on Disaster Risk Reduction found that as one of the results of the interaction between the global social–economic system and the Earth's ecological system, the global economy's transformation over the last 40 years has led to a growing accumulation of disaster risks (UNISDR, 2013). Annually, economic losses already amount to hundreds and billions of dollars. Even though specific consequences differ among sectors and countries, countless everyday local events and chronic stresses that involve multiple disasters and disaster chains are an ongoing burden for an increasing number of countries.

In the chair's summary of the Fourth Session of the Global Platform for Disaster Risk Reduction, the relationship between development and disaster risk reduction was clearly identified. It stated that "Both the accumulation and reduction of disaster risk are closely intertwined with the fields of sustainable development, environmental protection, climate change, as well as human mobility. It is important that the policies in these areas are designed to be mutually reinforcing, whether at the local, national, or international levels. Emphasis was placed on integrated, multisectoral approaches to disaster risk reduction, and to strengthening the disaster risk reduction in key sectors, such as education, agriculture and health. Development and resilience are unlikely to be sustained unless disaster risk is explicitly addressed in all development initiatives" (UNISDR, 2013).

China, like many countries in the world, is facing enormous challenges caused by the combination of the long-term adverse impact of unmitigated climate change and environmental degradation and short-term disruptions of disasters, which have led to conflicts over the access to natural resources, mass movements of human population, and a potential possibility of increasing the social and political instability.

Recognizing the challenges from significantly increasing the capability of resisting shocks and strengthening the ability of disaster recovery, as well as maximizing its potential opportunities at the same time, the need to create a resilient society has been frequently increasing within China's scientific community (Jiang, 2013).

In the past three decades, supported by the fast economic development, China's capability of managing emergency and disaster relief has been significantly improved. In addition, the emergency response and disaster mitigation planning process in China appears to be good at coping with short-term emergency needs; however, it is still less suited to coping with long-term disaster risks. Therefore, to create a resilient society in China, which emphasizes on the balance between emergency response and long-term development goal, a scientific and technological breakthrough must be made to deal with the following challenges:

Challenge 1: The increasing degree of complexity in the social-ecological systems

Recent studies showed that as the social–ecological system, by its nature, is not driven by single, linear forces but by complex interactions between multiple environmental, social, political, and governance factors (Shi et al., 2012), there is an increasing risk of systematic failure both in subsystems and systems as a whole. In many recent global events, the causes of entering the collapse and/or standstill modes of major systems were not from a single but from the interaction of a combination.

Challenge 2: The problem of the science/policy interface

As more and more government officials are now well educated and trained in various scientific studies, both in the natural and social sciences, the technological disciplines, as well as the policy and decision makers increasingly rely on the scientific community to get recommendations, suggestions, and sometimes, even policy options, during the policy and decision-making processes. To respond to these requests, the development of an interface for science and policy has been paid with great attention by government agencies, universities, and research institutions in China. However, most efforts have been made so far by several organizations that focus on the development of a direct dialog platform between the scientists and the government decision makers. Unfortunately, most of the time, this linear model of science and policy relationship has been observed to end up with the "problem of little effect," i.e., the observation that large quantities of knowledge produced for the benefit of policies are never used in policy-making (In't Veld & de Wit, 2000).

Challenge 3: Lack of human capital

As resilience-based sustainable development must be comprehensive in nature, it does require integrated responses from individuals, communities, organizations, and governments from around the world to work together with a strong commitment of building an alternative future. It is evident that it requires a better understanding between scientists and policymakers. Unfortunately, current education systems in China do not provide trained human capital that is capable of improving the dialog between the sciences and policy. More efforts must be made to educate and train our future generations through a multidisciplinary method.

4. Conclusions

Affected by almost every kind of natural hazards, China has both suffered gained great experience in living with disasters. In the past three decades, the fast economic growth have made China's disaster management stronger. In the meantime, the impacts of the recent natural disasters are intensifying and spreading from local to region and even nationwide, which have led to considerable social, economic, and ecological losses.

Based on lessons learned from the 2008 Great Wenchuan Earthquake, the capability of disaster prevention and mitigation in China has been significantly improved, in particular, in the fields of the sciences and technology. However, as the number, type, and severity of disasters increase in China, the entire social–ecological system is now facing great risks of an increasing potential system failures in several subsystems, such as the financial market, transportation, power generation, communication, as well as water, food, and energy distribution (Ye, 2014). The economic cost and social consequences of failure in these sociotechnical systems are expected to exponentially escalate.

It is evident that building up a resilient society is not simply a technological issue. People from different disciplines, different sectors, and different government agencies must cooperate with each other and adapt a systematic approach in order to effectively deal with all the potential risks. To do so, it is expected that the sciences and technology could play a more important role to improve communication between government policymakers and experts from various disciplines. Moreover, with the continuous enhancement of the capability in monitoring, identifying, early warning, and mitigating the potential impacts of disasters, policymakers could expect more help from the sciences and technology to deal with complex issues through a constant examination and evaluation of policies, plans, and actions to minimize the impact of disaster risks.

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