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ARTICLE

China's Drought Disaster Risk Management: Perspective of Severe Droughts in 2009–2010

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Abstract China has been frequently and heavily affected by drought disasters. During 2009–2010, three large-scale severe droughts struck China, caused considerable social, economic, and ecological losses. These droughts showed significant regional differences. This study employs a two-stage transition framework comprising "entry" and "exit" transitions to discuss disaster risk management of drought in China, by taking the three droughts as comparative case studies. Chinese society's response in the exit transition is examined and the underlying factors that enable the entry trigger are diagnosed. The policy responses that lead to the exit transition from these drought disasters were appropriate, but there is substantial room for improvement in management strategy regarding both entry and exit transitions. This article suggests that government policies should emphasize entry-prevention measures that reduce adverse impacts early in a drought episode rather than focus solely on improving performance in achieving a rapid exit transition from drought.

Keywords China, disaster entry transition, disaster exit transition, drought disasters

1 Introduction

Throughout its history, China has experienced frequent and serious drought disasters. Drought is believed to be the major cause of a 40 percent drop in China's population in the sixteenth and seventeenth centuries (Wakeman 1985; Temple 2002) and to have been a significant driving variable that led to the collapse of the Ming Dynasty (Shen et al. 2007). Since 1949, droughts have accounted for nearly 35 percent of annual agricultural losses caused by all natural disasters in China (Song et al. 2003). Each year, tens of millions of hectares of crops suffer from yield loss because of drought (Wu and Gao 2009). Drought has been a particularly difficult challenge in China's management of natural disaster risks because it is an insidious, slowly developing hazard that creeps stealthily upon society rather than striking suddenly and violently.

From January 2009 to April 2010, China endured three severe drought episodes. The intensity of the meteorological drought in each of the three disasters reached the once in every 100 year level. The droughts affected vast areas and lasted for comparatively long periods. Thus these droughts severely affected the regional socioeconomic systems of the impacted areas. Millions of people and livestock had difficulty accessing drinking water, the survival of tens of millions of hectares of crops was placed at risk, and a profound, long-term impact was imposed on the economy, society, and ecological environment. Chinese society mobilized considerable resources to relieve the impacts, under a highly centralized system as usual, with direct leadership from the central government. The response to each drought was essentially successful in terms of saving lives and ensuring local food security and social stability. Nevertheless, many issues are in need of discussion if the next step is to shift China's drought disaster risk management from a crisis response approach to a risk management approach.

This article discusses the issues of drought disaster risk management in China on the basis of comparative case studies of the three severe drought disasters between 2009 and 2010. The key question to address is: what are the critical factors that eased China's "entry" into a drought disaster state and hindered its "exit" from the disaster state to a normal state? Diagnostic studies of these issues can provide an overview of the status quo of China's drought disasters and its management. After presenting the method and data used in the diagnostic comparative case study, we provide an overview of the three drought disasters. This review includes analysis of the hazards and their impacts, and then summarizes and evaluates the actions of Chinese society in the exit transition. Experience and lessons learned for improvement of response actions in the exit transition are highlighted.

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Drought entry issues are then investigated, and cross-event comparisons are used to reveal regional differences. On the basis of these analyses, policy recommendations are made to the Chinese government.

2 Method and Data

In this study, the conceptual framework of disaster entry and exit transition analysis is employed. This structure was developed by the International Human Dimensions Programme on Global Environmental Change core project on Integrated Risk Governance (IHDP-IRG 2009). In this conceptual framework, the disaster entry transition refers to the process and mechanisms by which a given social-ecological system switches into emergency or crisis mode (for example, in dealing with a hurricane or financial collapse), while an exit transition refers to situations in which the corresponding system switches back from emergency or crisis mode, to a more normal mode. The conditions that prevail in this reversion to greater normalcy may or may not reflect the same system state that existed before the crisis.

The transition from natural hazards to natural disasters is a typical process of human-nature interaction, and there have been several conceptual frameworks developed to capture this shift experience. For instance, the well-known pressure and release (PAR) model conceptualizes disasters as the result of interaction between hazards and vulnerability (Wisner 2004). Similarly, regional disaster system theory considers natural disasters as the outcome of interactions between regional (mainly natural) environment, natural hazards that form in that environment, and the social-ecological system (SES) that is exposed to risk (Shi 1996).

The transition framework builds on these natural hazard models and work on the social amplification of risk (Kasperson et al. 1988; Kasperson and Kasperson 1996; Lofstedt and Renn 1997; Pidgeon, Kasperson, and Slovic 2003). A robust SES may have a high threshold of entry; that is, a disaster may not be easily triggered by hazards. For instance, a region where buildings and infrastructure are commonly reinforced may not suffer any loss should there be a magnitude 5 earthquake. However, in the case of a less resilient SES, an entry transition can be easily triggered, the region can suffer heavily, and there may be no self-organized exit transition. The Haiti earthquake is a typical example of this more vulnerable case.

The essential motivation for undertaking the transition study is to reveal the processes and mechanisms by which a social-ecological system enters and leaves the "disaster" state. The transition study tries to answer questions such as when do the entry and exit transitions begin? What are the critical factors that trigger entry and exit transitions? How would entry and exit transitions be altered should the SES change? Policies regarding risk management can benefit from these answers. In a certain sense, the transition framework resembles an integration of vulnerability and resilience studies. But the transition framework focuses more on the interaction processes rather than the static characteristics of the SES. It is particularly concerned about the dynamic transformation of the system (including the dynamic updating of coping capacity) when there is movement between different system states. The preliminary phase of an entry and exit transition study is to identify the key factors, having either positive or negative impacts, in the process of transition into and out of the disaster state. Diagnostic study is important in this phase to understand why a disaster happens and how a certain pattern of loss forms. The advanced phase is expected to model the transitions, with either dynamic models or complex system models. The entry and exit transitions are then formulated with partial differential equations (or other mathematical forms) and the state of the system is described accordingly.

This article is a preliminary application of the transition framework to the study of drought risk management. It employs a diagnostic approach that has three stages: (1) analysis of the transition from hazard to disaster so as to understand how impacts occur; (2) analysis of the exit transition to evaluate society's response and identify areas for improvement; and (3) analysis of larger contextual issues that ease the entry transition. To provide some necessary insights, two comparative analyses are conducted in the study. The first comparison is made between the full impact of drought at its peak and the final loss (social, economic, and ecological) claimed, by which the overall effect of the exit response is evaluated and positive and negative factors in the exit transition are identified. The second comparison is a cross-event/region comparison to determine the regional characteristics that ease the entry transition, since the three droughts occurred in different parts of China.

This study uses a wide range of data. Officially released meteorological information, impact and loss statistics, and information on drought-mitigation activities were collected from the websites of the China Meteorological Administration (CMA), State Flood Control and Drought Relief Headquarters (SFDH), and National Disaster Reduction Center of the Ministry of Civil Affairs (NDRC-MCA). These data are basically released daily or weekly, depending on the severity of the drought at the time. Quarterly or annual statistical data were obtained from the National Bureau of Statistics of China (NBSC). The study also employs field survey data collected by the authors on field surveys organized by the Expert Panel of the National Disaster Reduction Committee of China (EP-NDRCC). The survey data allow deeper insights into socioeconomic life and particularly mitigation activities in local villages that were not revealed by the statistical data. These data serve the purpose of the study well and are highly credible as they were originally acquired to determine the cause and impact of drought and make policy recommendations to the NDRCC and the State Council.

3 The 2009–2010 Drought Disasters in China: Overview

There were three intensive meteorological droughts in the 2009–2010 period: in late 2008 and early 2009 (hereinafter referred to as the 2009 spring drought), the summer of 2009 (the 2009 summer drought), and September 2009 to early 2010 (the 2010 spring drought). The name of each drought relates to the season of the most severe impact. Since it is difficult to present the dynamics of the chronic events, Figure 1 provides snapshots of the spatial patterns of the three droughts. Basic features of each drought are listed in Table 1.

In the 2009 spring drought, the rainfall in the affected regions was generally 50–80 percent lower than in the corresponding period of a normal year. Hebei Province had the lowest rainfall for the corresponding period since 1951 and it was the third lowest in Henan Province (China National Climate Center 2009a). In early February 2009, the drought reached its peak, with the main affected places in the major winter wheat producing areas of the Yellow River, Huai River, and Hai River plains.

During the 2009 summer drought, from June to 15 August, the rainfall in the affected regions was 30–80 percent lower than in the corresponding period of a normal year. The average rainfall for Liaoning, Jilin, Inner Mongolia, Hebei, and Shanxi was only 127.6 mm, the lowest for the corresponding period since 1951 (China National Climate Center 2009b).

Starting from early September 2009, the rainfall in southwestern China was below normal. In the following months, Guangxi, Yunnan, Guizhou, Sichuan, Chongqing, and eastern Tibet had high temperature and little rainfall. From 1 September 2009 to 23 February 2010, the average rainfall in Yunnan

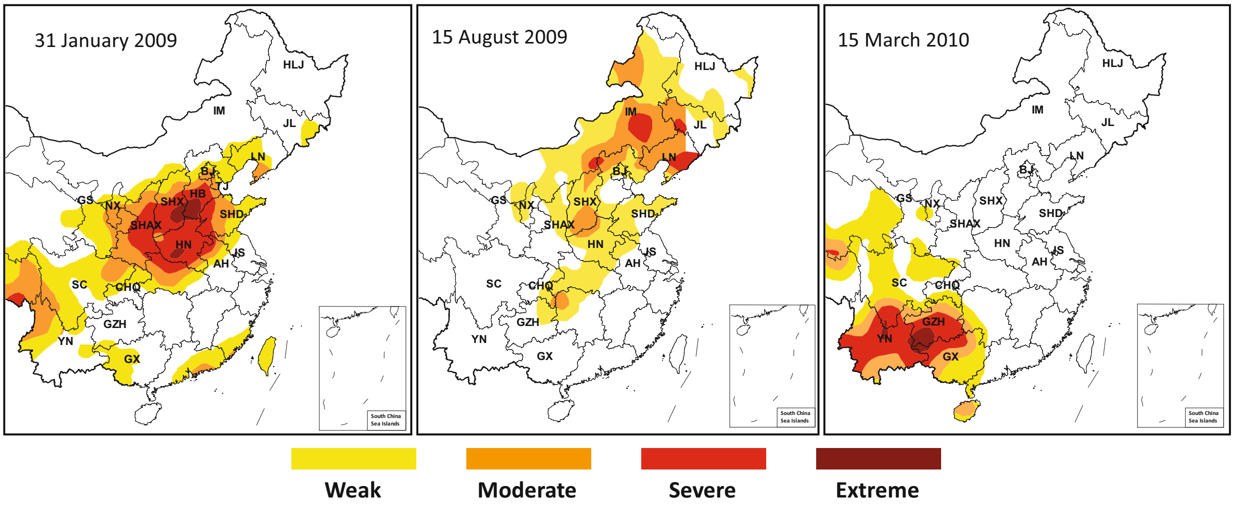

Figure 1. Snapshots of the spatial pattern of the 2009–2010 severe droughts in China

Abbreviations: HLJ—Heilongjiang Province; JL—Jilin Province; IM—Inner Mongolia Autonomous Region; LN—Liaoning Province; BJ—Beijing Municipality; TJ—Tianjin Municipality; HB—Hebei Province; SHD—Shandong Province; SHX—Shanxi Province; SHAX—Shaanxi Province; HN—Henan Province; AH—Anhui Province; JS—Jiangsu Province; CHQ—Chongqing Municipality; SC—Sichuan Province; GZH—Guizhou Province; YN—Yunnan Province; GX—Guangxi Province.

Data source: China National Climate Center 2009–2010.

Table 1. Basic features of the 2009–2010 severe droughts in China

Features	2009 spring drought[a]	2009 summer drought[b]	2010 spring drought[c]
Starting	Mid-Nov. 2008	End-Jun. 2009	Early-Sep. 2009
Ending	End-Feb. 2009	Early-Nov. 2009	Early-May 2010
Duration	3 months	5 months	6 months
Peak date of the drought	7 Feb. 2009	16 Aug. 2009	–
Major areas affected	The major producing area for winter wheat, including HN, AH, SHD, JS, SHX, HB, and GS	Southeast IM, north SHX, north HB and LN, southwest JL and HLJ	GX, YN, GZH, SC, and CHQ
Meteorological cause	Relatively high temperature and low precipitation	Low precipitation	High temperature and low precipitation
Return period	30–50 a	50–100 a	50–100 a

Data source: [a]China National Climate Center 2009a; [b]China National Climate Center 2009b; [c]China National Climate Center 2010.

Province was 163.3 mm, the lowest since 1952. Meanwhile, the average temperature in the province was 15.1°C, the highest since 1952 (China National Climate Center 2010).

3.1 Drought Impact

The three drought disasters greatly affected regional socioeconomic life in the stricken provinces. The impacts are summarized in Table 2. The major impact categories listed in daily official release of impact and statistical data include the affected crops, people, and livestock. The area of crops and numbers of people and livestock affected are regarded as a proxy of the overall severity of droughts. For people and livestock, the primary concern is whether they have access to a steady and continuous supply of drinking water. "Difficulty in access to drinking water" is an indicator always used to describe drought impact in China. According to the national standard, difficulty in access to drinking water refers to the case that the distance to a water source (supply point) exceeds 1000 m (one way) or there is a 100-m difference in elevation, or rural areas are without rainfall for more than 100 days. For crops, potential yield loss is the focus due to its significance to feeding the Chinese population. Further information about the situations in the affected regions is provided in the following section.

3.1.1 Direct Impacts of the Droughts

During the droughts, many local people had difficulty accessing drinking water because their regular water supply became unavailable. Those people mainly resided in areas with scarce water resources, hilly/mountainous areas, and rural areas far from cities and towns (NDRC-MCA 2009a). Most had to travel miles to get water to meet the most basic living requirements. There was little water for washing and bathing, and water for agriculture and industry was basically unavailable.

The 2009 spring drought threatened the production of winter wheat. The 2009 summer drought mainly affected crops to be harvested in the autumn. The 2010 spring drought was long lasting, covering almost the entire growth period of winter crops in southwestern China. Each drought introduced uncertainty into China's food grain availability and there were moderate temporary fluctuations in the market price when the droughts emerged (Zhengzhou Commodity Exchange 2009). Cash crops in the drought affected provinces also suffered heavy losses, such as tree fruits (EP-NDRCC 2009b), perennial sugar cane, coffee, walnut, and medicinal and oil crops (EP-NDRCC 2010). In Yunnan Province, 200,000 ha of cash crops were moderately affected, with one fifth of that without any harvest. There were two major direct effects of drought on animal husbandry: the lack of drinking water and declined supply of foraging grass. By 10 August 2009, 200,000 livestock in Inner Mongolia Autonomous Region had died due to the drought (EP-NDRCC 2009b). Furthermore, silkworm breeding, as one of the most well-known industries of Yunnan Province, suffered heavy losses (EP-NDRCC 2010).

With the reduced outputs of agriculture and the livestock industry, the food processing industry was also affected because of an inadequate input of raw materials, such as sugar, coffee, silkworm, tea, tobacco, and oil products. A reduction in sugar production of 400,000 tons was estimated for Yunnan Province alone, which corresponds to an economic loss of about RMB 2 billion Yuan (EP-NDRCC 2010; *China Daily* 2010a).

Droughts also dried up some rivers and suspended electricity generation at some hydropower plants in southwestern China (EP-NDRCC 2010). In some areas of Inner Mongolia and Yunnan Province, drought resulted in the wide spread of pests. The report of the 2010 field survey showed that the area of forest suffered from diseases and pests was 137,000 ha, 70.7 percent larger than that of the same period in 2009 (EP-NDRCC 2010). It also triggered secondary impacts that are shown in the following section.

3.1.2 Indirect Social and Economic Impacts

In the 2009 summer drought and 2010 spring drought, rural communities of the heavily affected areas faced a particularly poor food security situation. Local farmers had limited stocks of grains, and local markets were in short supply (*China*

Table 2. Impacts of the 2009–2010 severe droughts in China

		2009 Spring Drought[a]	2009 Summer Drought[b]	2010 Spring Drought[c]
Difficulty in access to drinking water (million)	People	3.56	3.01	20.88
	Livestock	0.96	5.22	13.68
Affected crops at the worst period (million ha)	Affected	10.13	10	6.73
	Heavily affected	5.25	3.90	–
Major types of crops affected		Winter wheat	Maize, soybean, sorghum, grains	Spring grain crops and cash crops
Affected population (million)		87.31	28.64	61.31
Crops with yield loss (estimated) (million ha)	≥ 10% yield loss	–	9.75	5.03
	≥ 30% yield loss	–	2.28	1.12
Direct economic losses (RMB billion Yuan[†])		–	22.87	23.66[d]

Note: [†]1 US Dollar = RMB 6.8 Yuan (approximately).

Data source: [a]NDRC-MCA 2009a; [b]NDRC-MCA 2009b; [c]SFDH 2010; [d]NDRC-MCA 2010.

Daily 2010b). Data for the city of Chaoyang in Liaoning Province in September 2009 show that the population suffered from a grain shortage reached 1.38 million owing to the drought, out of the 3.43 million total population. The shortage of grains until the end of the year and the end of the following year was estimated to be 80,000 and 250,000 tons, respectively.

At the macro level, the three droughts have not obviously affected the overall grain security in China. On the one hand, the actual yield decrease due to the droughts was a relatively small portion of the current annual grain production in China. On the other hand, with a sound grain reserve system established, China can effectively cope with a grain yield reduction due to natural disasters so as to stabilize the market supply and spot prices and ensure grain security. During the 2009 and 2010 droughts, the central government sent reserve grain to drought-stricken regions to alleviate local food shortages (Watts 2010) and successfully controlled the local grain price (Shi and Hu 2009).

The aspirations of many local rural households were broken in the 2009 summer drought and 2010 spring drought. Most grain producers and herdsmen in the drought-afflicted districts received nothing from their investments. In the city of Chaoyang in Liaoning Province, the poverty-stricken population increased from 645,000 before the disaster to 1.54 million afterward (EP-NDRCC 2009b). The disaster affected not only grain yield but also the production of other agricultural products such as sugar cane, white mulberry, and coffee. The recovery of livelihoods is particularly challenging. The local people were encouraged to seek temporary job opportunities in economically more developed cities far from home.

Severe damage also occurred to ecological systems and in a number of cases compromised medium term recovery efforts. According to the ecotone protection plan of China (Ministry of Environment Protection 2008), at least three ecotones were affected by the 2009 summer drought and 2010 spring drought: the northern ecotone of agriculture and animal husbandry, the southwestern karst ecotone of stone desertification, and the southwestern mountainous ecotone of agriculture and animal husbandry. The long-lasting drought resulted in great damage to and even drying up of vegetation (forest, bush, and grass). The damage to vegetation exacerbates grassland degradation in mixed agriculture and animal husbandry zones, further worsening wind erosion and sandstorms in the northern part and soil-water loss in the southwestern part of China. In the Karst econtone, the damage to vegetation accelerates stone desertification, which is extremely difficult to recover particularly by natural process.

3.1.3 Drought Disaster Chain

Although the major impacts are listed above separately, their interlinkages are worth noting. To explore the causal relationships among different types of impact, the concept of the drought disaster chain is employed. A disaster chain is a structured series of events, including direct or indirect impacts of a hazard or primary or secondary disasters induced by a primary hazard (Shi 2003). The structure of a disaster chain is in most cases like that of a tree, with one or two nodes representing the primary hazard (root) and a group of nodes representing direct and indirect impacts/primary and secondary disasters. Nodes without children nodes are leaf nodes. Nodes are connected with links (arrows), showing the causal (triggering) relationship between each pair of direct and indirect impacts, or primary and secondary disasters. The complete path from the root to a leaf node following the direction of links is called a chain, and all the chains woven together form a disaster tree. Different from the standard tree structure, there are generally alternative paths between a given pair of root and leaf nodes, and therefore, several chains can be parallel to each other.

The disaster chains for each of the three drought disasters of 2009 and 2010 are derived through diagnostic analysis according to the field survey reports (EP-NDRCC 2009a, 2009b, 2010). The links among primary, secondary, and even tertiary impacts applicable to each drought case are connected and structured in Figure 2. The starting point of the chain is drought, and there are five ends (leafs), including ecological security and food security problems. There are direct and indirect impacts at different levels between the start and ends, with links indicating the causal relationship between each pair of nodes. The hierarchy of the disaster chain is shown with the dashed gray lines: impacts of the same level are connected with such line. The nodes and structure of the disaster chains differ in each case, showing the regional variation in the development of drought impacts in China. For instance, the disaster chain for the 2009 spring drought is the simplest among the three, consisting of only two chains: (1) drought → water shortage → vegetation damage → grain crop failure and (2) drought → water shortage → drinking water security problem.

It is important to know the typical structure of the disaster chain for a certain type of hazard for a specific region and time. Disaster risk reduction measures for entry prevention and response during the time a disaster is taking place can benefit from the use of a disaster chain, which can provide valuable information about the transition mechanism from hazard to disaster. Meanwhile, risk assessment models can also be developed on the basis of the disaster chain structure by introducing a Bayesian network with probability and conditional probabilities (IHDP-IRG 2009). Discussions on the modeling of disaster chain are ongoing (for example, Shi et al. 2010; Helbing and Kuhnert 2003) and applications are expected to emerge. The crucial remaining work is to quantify the disaster chain with conditional probabilities estimated for each link, and loss assessment for each node provided the existence of other simultaneous impacts.

4 Exit Transitions

The nationwide, centralized, top-down response scheme employed for the large-scale freezing-rain and snow disaster

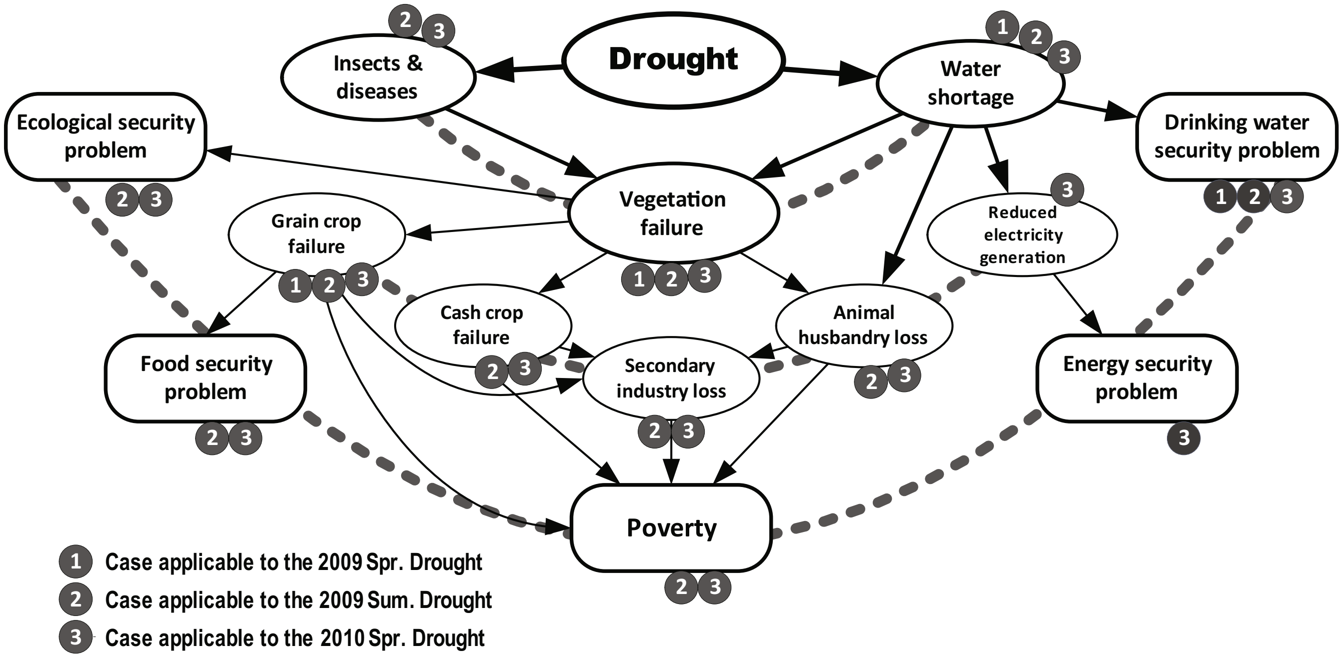

Figure 2. Disaster chains for the 2009–2010 severe droughts in China. The dashed gray lines connect impacts of the same level, that is, direct impacts, indirect impacts, and long-term socioeconomic impacts

in early 2008 and the Wenchuan Earthquake on 12 May 2008 (Shi and Liu 2009; Shi et al. 2009) was again adopted to respond to the three severe drought disasters in 2009–2010. This system is characterized by direct involvement of paramount leaders and a top-down system for actions. Drought response was promoted from the central government with decisions made at the SFDH, the overall coordinating government agency among all drought disaster reduction-related ministries, including the Ministries of Land and Resources, Water Resources, Agriculture, Civil Affairs, Finance, National Development and Reform Commission, and China Meteorological Administration. Those ministries are members of the SFDH and are responsible for specific actions. A state of emergency was declared for each of the three droughts and resources (funds, equipment, technicians and experts, and other support sources) were mobilized accordingly. Drought mitigation resources were allocated to and used by local governments, the coordinating hub at the local level. Besides the government departments, military forces were also mobilized to engage in drought mitigation activity through the Central Military Commission.

4.1 Coping Activities

The chief principles for actions were human-focused and prioritized on saving lives over protecting production. Temporary drinking water supply was considered the first priority. The supply of grains, cooking oil, meat, and vegetables in the local markets was secured and prices were kept normal. Drought relief for agricultural production (especially grain production) was organized and subsidized by the government because of the importance of basic food availability to overall food security. Secondary to this top priority, local governments provided off-farm income sources for producers with severe crop damage. Last but not least, efforts were devoted to reducing the damage to the regional ecological systems and preventing secondary emergencies such as the spread of infectious disease.

The *Drought Resistant Regulations of the People's Republic of China (Draft)* was reviewed and adopted by the executive meeting of the State Council on 11 February 2009 at the height of the 2009 spring drought. The formal version (CPG-PRC 2009) was officially promulgated on 26 February. The regulation specifies the duties of the government at all levels, defines a series of rules for major drought control, and specifies the assurance mechanism.

Beyond the efforts of the government, the mass media and citizens also played important roles. All major news media printed special headlines on drought control and disaster relief. Nationwide voluntary donations raised hundreds of millions of RMB Yuan for relief activities in each of the two spring droughts. Additionally, in the 2010 spring drought, drinking water was donated and delivered to people in the affected areas.

4.2 Achievements in the Exit Transitions

With the centralized top-down approach, tens of millions of people were involved in the mitigation of each drought together with other inputs (Figure 3). Specific inputs include the mobilization of people and the army, allocation of special funds, setting up water diversion projects, and sending

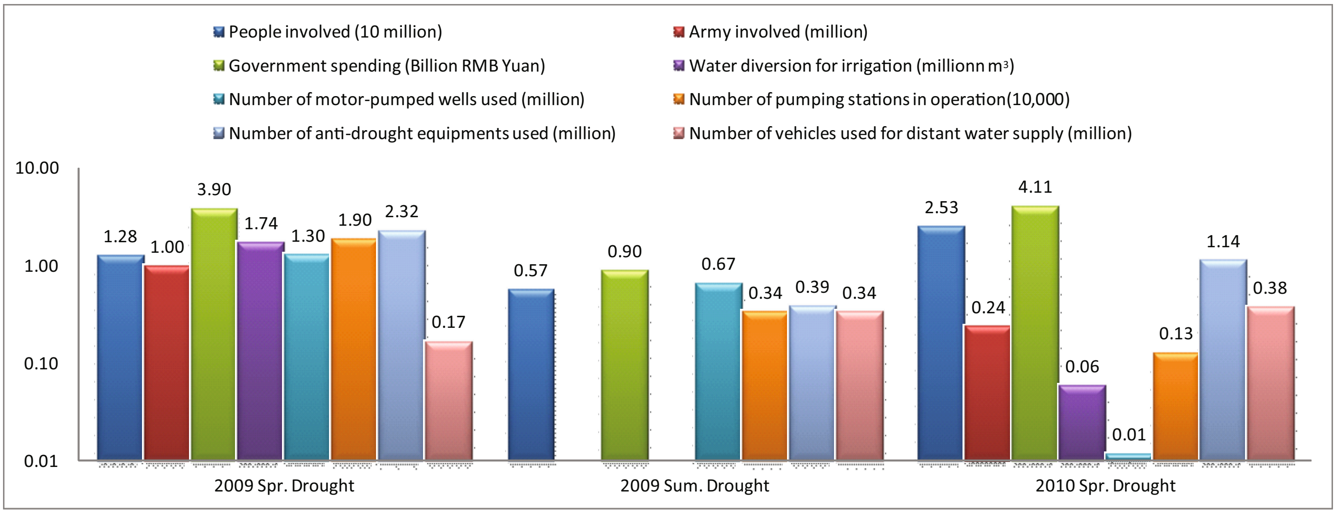

Figure 3. 2009–2010 Drought disaster response measures
Data source: SFDH 2009; Xinhua News Agency 2009; SFDH 2010.

different equipments including motor-pumps and vehicles to the heavily affected regions. The purpose was to provide subsistence water supply to people and livestock by distant transport or exploiting locally available groundwater sources.

The comparison between the drought impact at the hardest time and the final loss indicates that the response was largely successful. First, temporary drinking water supply was made available in a timely manner and there were no known deaths reported due to a lack of drinking water or ill-conditioned water quality. Second, the quick response saved large areas of crops. In 2009, the nationwide harvest of summer grain crops even increased slightly by 2.2 percent. This was the sixth consecutive year of national growth in grain yield due to the large harvest in unaffected regions, although the total yield was affected by the spring drought. Last but not least, appropriate response strategies guaranteed public order in the drought stricken provinces. There was no food shortage, famine, market disorder, or public security problems.

5 Entry Transition Mechanisms

This section elaborates on further diagnostic comparison of drought cases in terms of the entry-transition mechanism of drought disasters for different regions of China. The question to address here is: which set of underlying factors triggered the three drought disasters and which factors hampered the exit process? The diagnosis benefits from the analysis of cross-scale dynamics and comparisons.

5.1 Balance of Local Water Resources

The four panels in Figure 4 provide an overview of the benchmark water resource balance in the drought affected regions of China. These maps cover only the central and eastern parts of the country since our discussion of the 2009–2010 droughts is limited to these affected areas.

Figure 4a depicts the total water resources available in each province in central and eastern China. It is clear that in the droughts of 2009 the impacted central and northeast provinces were extremely short of water resources when compared with those southwest provinces affected by the 2010 spring drought. This is due to the climate condition of China under which the Asia Monsoon brings rainfall seasonally to mainly the eastern and southern parts of the country.

The mismatch between available water resources (Figure 4a) and the water supply ability (Figure 4b) of provincial-level administrative units reflects the huge difference in regional water conservancy facilities. In southwestern China, the existence of abundant water resources does not mean that the resources are readily available to use. Southwestern China is mainly a mountainous area and the topography makes it more difficult to construct water conservancy and water supply facilities. Meanwhile, in the region of the Yunnan–Guizhou Plateau, water storage in reservoirs is problematic owing to the extensively developed karst landform. Our field survey showed that water is available in many places, but the water was too distant or too deep underground for local people to access (EP-NDRCC 2010). In contrast, medium-sized rain-water harvesting systems in some villages greatly benefited the local people.

Figure 4c displays the annual aggregate sown area for all types of crops. A comparison between Figure 4a and Figure 4c indicates that regions with less water resources bear a heavier burden of crop production in China. The situation was different before the shift in the spatial distribution of China's grain production over the past four decades. Recent studies (for example, Liu, Yang, and Feng 2007; Lu and Mei 2007) show that from the 1970s to 2000s, the proportion of grain produced in northern China increased from 52.5 to 58.9

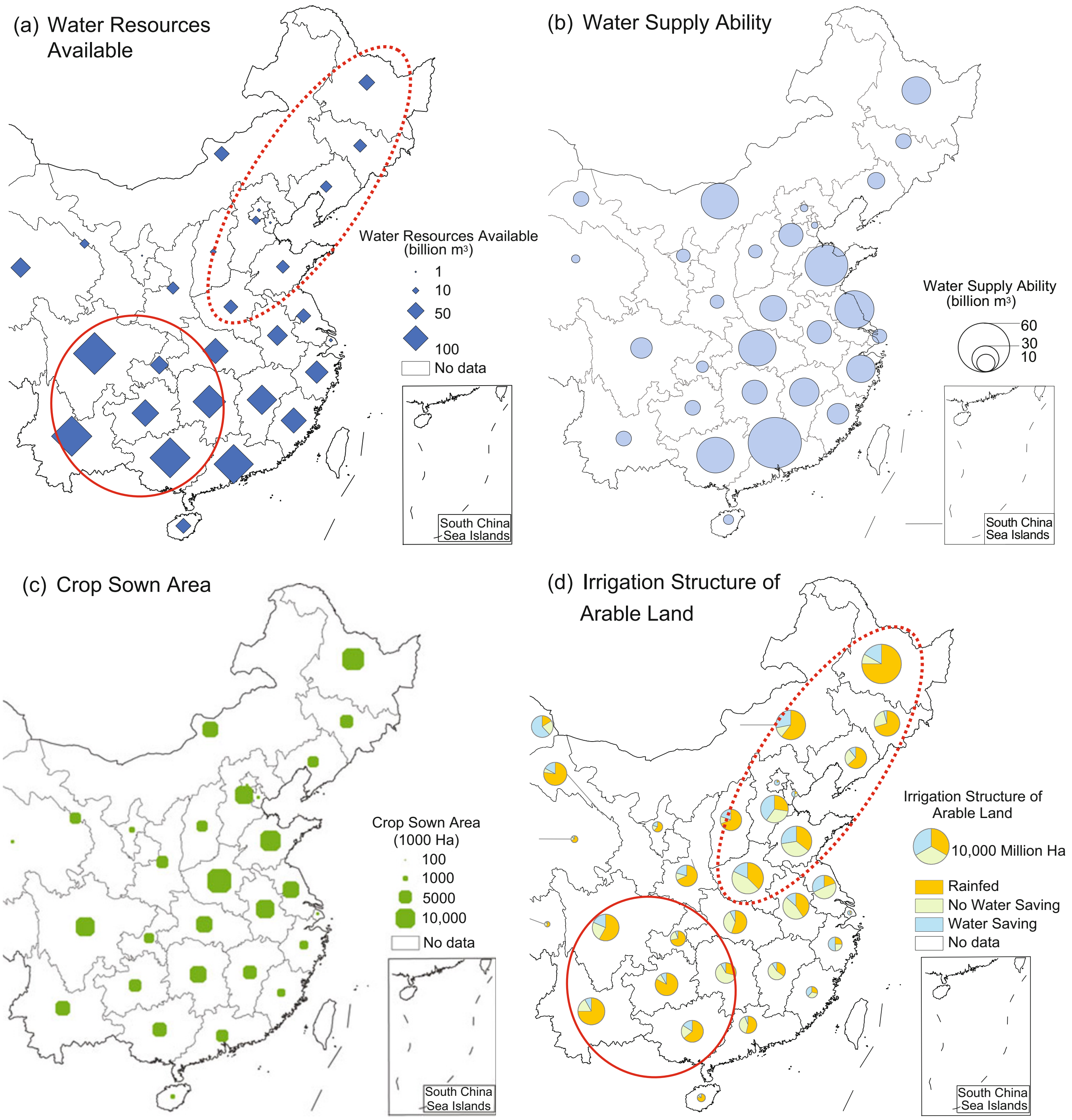

Figure 4. Water resources, water supply and irrigation capacities, and arable land in China. The dashed ellipse delineates the region affected by the 2009 droughts and the solid circle delineates the area affected by the 2010 spring drought
Data source: (a) and (c) NBSC 2009a; (b) Wang and Zuo 2009; (d) Area with Efficient Irrigation 2009.

percent. If the national average per capita grain consumption is taken as the criterion, regions with grain surplus changed from northeastern China, the Yangtze River Basin, and southern China in the 1970s to northeastern China and North China in the 2000s, which are exactly the drought-stricken provinces in the 2009 spring and summer droughts. Although there are many reasons for such change, urbanization and industrialization have been identified as the major driving forces of land-use change in southern and eastern China, changing the pattern of grain production nationwide (Tian and Wan 2000; Yang and Li 2000). As China has increased its agricultural production in regions with poorer water resources and higher variability in precipitation during the growing seasons, the increased overall exposure has substantially elevated the chances of drought entry transition.

Figure 4d shows the vulnerability of agricultural production in terms of guaranteed water supply, as well as the efficiency of water usage. In China, crop production is either rainfed, or using regular or water-efficient irrigation systems. Rain-fed agriculture is highly vulnerable to adverse weather conditions because it relies entirely on precipitation for water. Irrigation can to some extent reduce the risk of water shortage but such system is very water-consuming. Given the same amount of water, water-efficient irrigation systems can irrigate a much larger area of crops and therefore further reduce the dependence on natural precipitation. North China has more arable land than the other two drought-affected regions in this study, and a higher percentage of irrigated land, as well as water-efficient irrigation facilities. However, water availability is low in the area. The North China Plain has considerable groundwater overexploitation—the estimated annual usable groundwater amount is 1.8 billion m^3, whereas the current annual exploitation amounts to 2.9 billion m^3 (Shi et al. 2011). Although the percentage of effective irrigation area of the region exceeds 60 percent, when surface water dries up, there is also little groundwater to tap into. In contrast, agricultural production in southwestern China relies too much on rainfall, and it requires urgent improvement of the irrigation system for guaranteed and efficient water supply.

5.2 Local Economic Conditions

In China, the profit margin of grain crop production is small because the market price is low due to the intervention of the Chinese government. In the 2009 spring drought area, farmers were richer than those in the 2009 summer drought and 2010 spring drought areas. For instance, the annual per capita income of rural population is 5419.67, 4937.80, and 3369.34 Yuan in Heibei, Inner Mongolia, and Yunnan (NBSC 2010b). The proportion of farmers' off-farm employment income for the three regions is 41.5, 18.2, and 20.3 percent, respectively. Therefore, winter wheat was of less priority to most rural households in the 2009 spring drought area. Wheat production was more for self-sufficiency of staple food than the main source of income. This had two major consequences (Figure 5). At the beginning of winter 2008, there was insufficient pre-winter field preparation by most local farmers including pre-winter watering and soil-compacting, which resulted in water deficiency in the top soil layer (Jia et al. 2009). This substantially increased the crops' likelihood to suffer from drought and made the entry transition into severe drought impacts more likely to take place. When the drought occurred and the imbalance between water supply and demand materialized, many local households chose not to irrigate their crops, simply because the cost of such effort would have been higher than the potential gain from the harvest (EP-NDRCC 2009a; Niu 2009). Consequently, serious crop failure should have occurred if the Chinese government had not provided a considerable drought relief subsidy to local farmers.

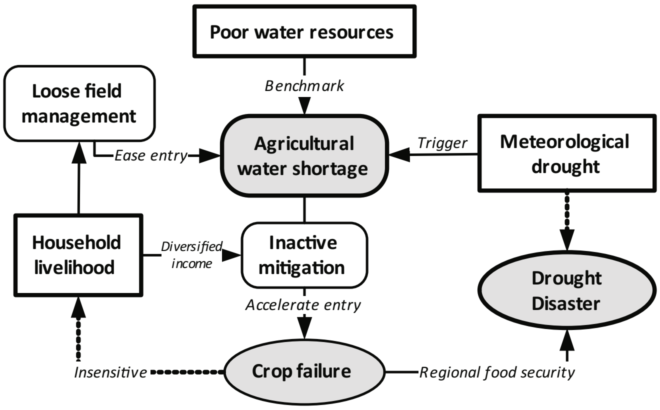

Figure 5. Disaster mechanism of the 2009 spring drought in North China

Source: Adapted from EP-NDRCC 2009a and Jia et al. 2009.

It is worth noting that drought disaster is included in Figure 6 even though local livelihoods are to some extent insensitive to crop failure because households have diversified sources of income and the gain from farming constitutes only a small portion of their total income. The question is: if local households are insensitive to the loss from crop failure then why is the drought regarded as a disaster? This is answered by recalling the drought disaster chains as depicted in Figure 2. Beyond the immediate impact of grain crop failure on food availability and income (poverty) of individual households, along the drought disaster chain a second link relates crop failure to regional food security problems. The drought-stricken regions are the major winter wheat producing area of China. Although diversified income enables local households to withstand the temporary income shocks induced by drought, the severe drought caused serious reduction in regional winter wheat production. Therefore, it was not a disaster in terms of individual households' food and income but was one in terms of overall grain production and food security.

In contrast, in the villages hit by the 2009 summer drought and 2010 spring drought, the rural family income structure was relatively simple and the proportion of agricultural revenue (including crops and livestock) was high. For example, this number was 67.6 percent in Yunnan and 66.3 percent in Inner Mongolia (NBSC 2010b). At the beginning of the seasons, without any awareness of the coming droughts, farmers invested a large proportion of their capital stock into crop production. When the droughts occurred, they had too limited resources (including water resources, motor-pumps, irrigation facilities, and other infrastructure) at hand to cope, even though they were exceptionally motivated. These are completely different cases (Figure 6) compared to the previous one. Thus there is a vicious cycle of being vulnerable because of limited resources and coping measures and increasing poverty due to disasters, which is the so-called "poverty trap" described in literature (Azariadis and Stachurski

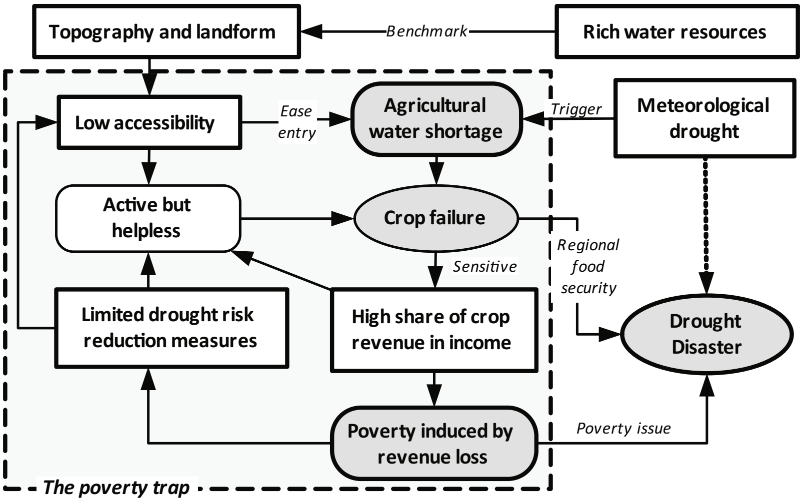

Figure 6. Disaster mechanism of the 2010 spring drought

2005). Compared with the 2009 spring drought, crop failure in these two cases induced both rural household poverty and regional food security problems.

6 Discussion and Policy Recommendations

The Chinese government spent substantial funds on drought relief (Figure 3), bringing about considerable achievements (Table 3). The decision by the Chinese government to relieve drought disaster at all costs was appreciated when severe drought disasters were happening. The government made every effort to allocate resources to ensure adequate drinking water supply was available and food security existed (including both crop production and local market supply in the drought-stricken areas). These decisions saved lives, ensured food security, and eased post-disaster recovery. Nevertheless, by examining both entry and exit transitions together, particularly the former, it can hardly be claimed that the Chinese strategy of drought management was completely successful.

6.1 Entry and Exit Trade-Off

The government budget may be spent on entry-prevention measures such as adjusting the land-use pattern, improving infrastructure, or developing drought-resistant crops, which can lower the probability of disasters being triggered by hazards; or on exit-acceleration activities like rapid and coordinated response and smooth recovery of livelihoods, which can substantially relieve direct and indirect impacts of a drought disaster. Instead of spending on disaster relief after a disaster has actually occurred, investing in entry-prevention measures is also important, and sometimes it could be more cost-efficient. In China's case, RMB 22.5 billion Yuan government spending is needed annually until 2020 to improve 90 percent of its rural water facilities (including both drinking water and irrigation water systems), if the central government is to share half of the burden for investment (China Irrigation and Drainage Develop Center and Center for Rural Drinking Water Safety, Ministry of Water Resources 2009). The actual subsidy from the central government to the water development project was RMB 3 billion Yuan in 2008. In contrast, the total government spending in response to the three drought disasters added up to nearly RMB 8 billion Yuan (Figure 4). What if more government budget is used for entry prevention? Would a better result, a more comprehensive drought risk reduction be achieved? The key to the optimal structure of such government spending is a sound cost-benefit analysis. It could either focus on the benefit of one unit of extra government spending in terms of disaster entry prevention or exit acceleration, or the cost to achieve one extra unit of risk

Table 3. Drought disaster mitigation achievements

	2009 Spring Drought	2009 Summer Drought	2010 Spring Drought
Temporary drinking water supply	1.76 million people 0.54 million livestock	1.50 million people[a] 0.89 million livestock[a]	20.88 million people[c] –
Crops irrigated (million ha)	12.4	3.1[b]	2.1[c]
Crops saved (million ha)	5.57	5.1[b]	–
Crop harvest[d]	A nationwide increment of 2.2%	A nationwide reduction of 0.6%, 2.3 million tons	A nationwide reduction of 0.8%, 0.4 million tons

Data source: [a]SFDH 2009; [b]Xinhua News Agency 2009; [c]SFDH 2010; [d]NBSC 2009b, 2010a.

reduction. Opportunity cost in government expenditure must be addressed and the difficulty in the analysis is how to evaluate and quantify social-ecological benefits besides economic benefits. Benefits for social, institutional, and ecological subsystems must be taken into account. These benefits include but are not limited to the stability of social order, addressing humanitarian concerns, and the maintenance of ecological service and good environment conditions.

6.2 Strengthen Entry-Prevention Strategies

There is a clear concentration of people and agricultural production that exceeds regional water supply capacity in many regions of China, either due to the low availability of water resources or inadequate water storage and delivery infrastructure. National and regional macro land-use planning has to ensure food security and ecological and environmental security, and reduce natural disaster risks. Grain production should again be concentrated in those regions with favorable environmental conditions, including good soil, water, and landform conditions. The burden of crop production in northern China could be reduced by increasing production in southern China, mainly in the Yangtze River Basin. In regions with vulnerable ecological environments and subjected to frequent disasters, for example, the northern ecotone of agriculture and animal husbandry and southwestern hilly regions, it is much preferable to grow fewer grain crops but more vegetation with higher ecological value since different types of ecosystems serve to maintain eco-environment quality differently (Costanza et al. 1997). The country should continue to implement, on a large scale, the project of "Grain for Green" (Uchida, Xu, and Rozelle 2003), and further strengthen its support for the development of animal husbandry. A long-term compensatory mechanism needs to be established for those who lose their opportunities of income from cropping.

Better control over and more efficient use of limited water resources is central to any drought mitigation policy. Key water conservancy projects are still needed in some parts of China to better buffer seasonal and annual precipitation fluctuations. Such projects may allow both flood control and drought relief. In rural areas, it is of higher priority to construct small- and medium-sized water-harvesting projects. Meanwhile, water-efficient irrigation facilities should be widely adopted and water-efficient agriculture is required to conserve water resources. The average irrigation water use efficiency in China was 48.3 percent in 2008 (China Irrigation and Drainage Develop Center and Center for Rural Drinking Water Safety, Ministry of Water Resources 2009), almost 20 percentage points below that in developed countries. In this sense, there is a great potential for the improvement of the quality of life for the Chinese people through consuming even less water should this gap be bridged.

Improving the resilience of local communities at risk to drought shocks is of paramount importance. As the first priority, a safe drinking-water supply system should be provided to an additional 100 million rural residents in China. Secondly, rural household livelihood structure ought to be changed to be more resilient to natural disaster impacts. The government may further increase the grain acquisition price so that producers have a larger profit margin and greater incentive to manage their crops. A more diversified livelihood system ought to be established and the proportion of crop revenue in a household's total income must be reduced. For instance, local people should be encouraged to seasonally migrate to larger cities to seek for temporary job opportunities. The government should provide preliminary training to these fresh workers so that they can get a job more easily. For those rural households whose income is sensitive to weather events, crop insurance coverage should contribute more to reducing income fluctuation induced by weather. In the case of farmers who have lost capital for purchasing seeds, fertilizer, and pesticide, microcredit, government subsidies, or preferential loans may be of great assistance for recovery.

6.3 Exit Smoothing Actions: Improving Inter-Departmental Coordination and Strengthen the Role of the Market

Drought exit transitions would improve if interdepartmental coordination was strengthened. In the three droughts studied, a state of emergency was announced to mobilize resources and promote relief activities. But multiple announcements were made by different government agencies with completely different criteria. In China, SFDH, MCA, and other relevant government departments all have their own schemes for declaring an emergency and their classifications of levels of emergency differ.

At SFDH, an emergency is defined according to the *State Emergency Response Scheme for Flood Control and Drought Relief* (CPG-PRC 2006) and the criteria are based on the number of provinces/cities having a certain percentage of the population experiencing drinking-water supply problem and the proportion of crops for which there is a shortage of irrigation water. The MCA reacts according to the *Emergency Action Manual for Natural Disaster Relief of the MCA* (CPG-PRC 2011) and the standard is the size of the population in need of drinking water and food aid from the government. The CMA has its own classification system based on a metrological drought index. The MOA (Ministry of Agriculture) also has an emergency plan for agricultural drought. During the droughts of 2009 and 2010, the above government agencies announced various levels of emergencies at different times and in an inconsistent manner, even though they are all members of the SFDH. Apparently, their actions were hardly coordinated and the effectiveness of the emergency response was undermined.

An upgraded public-private partnership could enhance the effectiveness of the integrated disaster risk transfer system. The government-sponsored crop insurance program (Wang et al. 2011) did not contribute much to post-drought livelihood recovery in the three drought cases. In the 2009 spring drought, RMB 260 million Yuan was paid to approximately one million wheat producers in seven provinces, with 120 million of the payment sent to Anhui Province alone (Tong 2009). In the 2009 summer drought, insurance companies in total paid out RMB 1.95 billion Yuan in Inner Mongolia, Liaoning, and Jilin Provinces, covering 3.47 million ha of crops—about half of the affected cropland area in these places. The situation was the worst for the 2010 spring drought due to the lack of government subsidies and insurance products.

Several issues are attributed to this unsatisfactory situation, including Chinese crop producers' perception of crop insurance and inadequate attractiveness of the current insurance coverage (Zhou 2010). Drought is a peril that is not included in the basic combo coverage, in which flood, hail, strong wind, and freezing are included. Farmers can purchase drought insurance only when a special insurance policy is provided by the insurance company. There is thus a gap between demand and supply. Government subsidies are one way to cope temporarily with such a gap, by providing incentives to and increasing awareness of potential policy holders. But its side effect of distorting the market and limited efficiency reduces the efficacy of such subsidies.

In order to allow crop insurance to play a more significant role in post-disaster recovery of livelihood, China will need an integrated risk transfer system, synthesis of a number of financial instruments based on an independent and objective risk quantification and capital allocation. The first priority for China is to improve risk assessment through modeling of natural hazards with catastrophic potential. An objective and convincing loss-exceedance probability curve can allow policyholders, insurers and reinsurers, regulatory agencies, and the government to have a clear picture about the true cost of risk transfer, and develop hazard risk insurance schemes tailored for the actual situation of rural China.

Several issues require emphasis in the primary insurance layer. First, the design of a crop insurance program should incorporate incentive mechanisms to promote producer-level disaster prevention and relief activities. An optimal crop insurance program could help achieve risk reduction in crop production when the transfer of producers' income risk is accomplished. The second issue is the promotion of public-private partnerships. The government should maintain provincial and central catastrophe reserves, which can be used to directly cap peak losses for primary insurers or provide them excess-of-loss reinsurance (Cummins, Lewis, and Phillips 1995). Meanwhile, subsidies should also be delivered to insurers because the transaction cost in China is substantially high (Wang et al. 2011), taking into account current agricultural practice in China. Last but not least, index-based crop insurance may partially solve the problem, as in many developing countries (Ibarra and Skees 2007; United Nations 2007).

7 Conclusion

From late 2008 through the second quarter of 2010, there were severe droughts in China with a return period of once in a hundred years in some regions. The hazards affected large populations, caused heavy agricultural losses, and had deep and long-term socioeconomic impacts in some areas, including the local poverty problem. The response from the Chinese government was well organized, and basically successful. With broad public support, Chinese society completed the exit transition smoothly, and people's lives and livestock were saved. But there is still a considerable room for both public and private sectors to perform better in the exit transition, including addressing the interagency coordination deficiencies in the top-down disaster response system and upgrading the weak performance of crop insurance.

The entry-transition mechanisms of the three disasters were completely different due to their regional differences. In northern China, limited water resources were overstretched by pre-drought regional socioeconomic activities, especially agricultural production. This made the region vulnerable to variability in precipitation. In contrast, there are plenty of water resources in southwestern China, but the landform and geological conditions make it extremely difficult for some villages to access surface water. Local household income structures also shape different entry-transition mechanisms. Owing to the low profitability of grain cropping, proper field preparation and irrigation were sometimes neglected, increasing the risk of soil water deficiency and crop failure. Poor rural households had even fewer resources to cope with a severe and extended drought.

In the context of global environmental change there are data and projections indicating that China can experience more severe droughts in the near future (Song et al. 2005; Tao et al. 2006; Zhai et al. 1999; Cruz et al. 2007). Change in the environment at a global scale cannot be dealt with by a single region and in a relatively short time span. The only option is to build the resilience and adaptivity of our SES so that it is more capable of withstanding adverse environmental changes. This would result in a robust system with a high threshold before tipping over into a disaster state and with high resilience so that the SES can exit a disaster state more quickly and smoothly. The essential purpose of an entry and exit study is to find the way to change individual and societal behavior appropriately, that is, to "adapt." The adjustment of land-use pattern, restructuring of people's income and livelihoods, and improvement of government management of drought risk through a comprehensive cost-benefit analysis on entry-prevention and exit-acceleration approaches, for example, are all ways toward a successful adaptation.

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References

Area with Efficient Irrigation Facility in First-Level Water Resources Divisions and Provinces (2008). 2009. *China Flood and Drought Management* 2009 (S1): 201–02 (in Chinese).

Azariadis, C., and J. Stachurski. 2005. Poverty Traps. In *Handbook of Economic Growth*, edited by P. Aghion and S. N. Durlauf. Elsevier.

China Daily. 2010a. *Sugar Shares Sweeten on Drought*. 24 March 2010. http://www.chinadaily.com.cn/bizchina/2010-03/24/content_9633753.htm.

———. 2010b. *Drought Leaves Millions in Short of Food*. 22 May 2010. http://www.chinadaily.com.cn/china/2010-05/22/content_9880812.htm.

China Irrigation and Drainage Develop Center and Center for Rural Drinking Water Safety, Ministry of Water Resources. 2009. *China Water-Efficient Irrigation Development Report 2008*. http://www.jsgg.com.cn/Files/PictureDocument/2009120115182028825424279 1.doc (in Chinese).

China National Climate Center. 2009a. *China Drought & Flood Climate Bulletin* 227 (in Chinese).

———. 2009b. *China Drought & Flood Climate Bulletin* 242 (in Chinese).

———. 2009–2010. *National Drought Monitor*. http://cmdp.ncc.cma.gov.cn/influ/dust.php (in Chinese).

———. 2010. *China Drought & Flood Climate Bulletin* 250 (in Chinese).

Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R. V. O'Neill, J. Paruelo, R. G. Raskin, P. Sutton, and M. van den Belt. 1997. The Value of the World's Ecosystem Services and Natural Capital. *Nature* 387: 253–60.

CPG-PRC (The Central People's Government of the People's Repulic of China). 2006. *State Emergency Response Scheme for Flood Control and Drought Relief*. http://www.gov.cn/yjgl/2006-01/11/content_155475.htm (in Chinese).

———. 2009. *Drought Resistant Regulations of the People's Republic of China*. http://www.gov.cn/zwgk/2009-03/06/content_1252625.htm (in Chinese).

———. 2011. *Emergency Action Manual for Natural Disaster Relief of the MCA*. http://www.mca.gov.cn/article/zwgk/fvfg/jzjj/201111/20111100191129.shtml (in Chinese).

Cruz, R. V., H. Harasawa, M. Lal, S. Wu, Y. Anokhin, B. Punsalmaa, Y. Honda, M. Jafari, C. Li, and N. Huu Ninh. 2007. Asia. In *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by O. F. Canziani, M. L. Parry, J. P. Palutikof, P. J. van der Linden, and C. E. Hanson, 469–506. Cambridge: Cambridge University Press.

Cummins, J. D., C. Lewis, and R. D. Phillips.1995. *Pricing Excess-of-Loss Reinsurance Contracts against Catastrophic Loss*. Center for Research on Risk and Insurance, Wharton School of the University of Pennsylvania. http://fic.wharton.upenn.edu/fic/papers/98/9809.pdf.

EP-NDRCC (Expert Panel of National Disaster Reduction Committee of China). 2009a. *Assessment and Response Proposal for North China Severe Drought and Its Impact*. February 2009. Internal Report (in Chinese).

———. 2009b. *Northern China Drought Disaster Survey Report*. September 2009. Internal Report (in Chinese).

———. 2010. *Yunnan Drought Disaster Survey Report*. March 2010. Internal report (in Chinese).

Helbing, D., and C. Kuhnert. 2003. Assessing Interaction Networks with Applications to Catastrophe Dynamics and Disaster Management. *Physica A: Statistical Mechanics and Its Applications* 328 (3): 584–606.

Ibarra, H., and J. Skees. 2007. Innovation in Risk Transfer for Natural Hazards Impacting Agriculture. *Environmental Hazards* 7 (1): 62–69.

IHDP-IRG (Integrated Risk Governance Project, International Human Dimensions Programme on Global Environmental Change). 2009. *Integrated Risk Governance Project: Science Plan*. http://www.irg-project.org/index.php?id=docu.

Jia, H. C., J. Wang, Y. Yue, H. Zhou, R. Li, T. Gao, and Y. Bai. 2009. Construction and Application of Index System of Winter Wheat Drought Risk Assessment—A Preliminary Cognition Based on Fieldwork of Spring Drought in North China in 2009. *Journal of Catastrophology* No. 4: 20–25 (in Chinese).

Kasperson, R. E., and J. X. Kasperson. 1996. The Social Amplification and Attenuation of Risk. *Annals of the American Academy of Political and Social Sciences* 545 (1): 95–105.

Kasperson, R. E., O. Renn, P. Slovic, H. S. Brown, J. Emel, R. Goble, J. X. Kasperson, and S. Ratick. 1988. The Social Amplifications of Risk. A Conceptual Framework. *Risk Analysis* 8 (2): 177–87.

Liu, Y. J., Y. Z. Yang, and Z. M. Feng. 2007. The Change of the Main Regions for China's Food Grain Production and Its Implications. *Resources Science* 29 (2): 8–14 (in Chinese).

Lofstedt, R., and O. Renn. 1997. The Brent Spar Controversy: An Example of Risk Communication Gone Wrong. *Risk Analysis* 17 (2): 131–36.

Lu, W. C., and Y. Mei. 2007. Empirical Studies on the Variation and Contributing Factors of Regional Grain Production Structure in China—Based on Spatial Econometrics Models. *China Agricultural University Journal of Social Sciences Edition* 24 (3): 140–52 (in Chinese).

Ministry of Environment Protection. 2008. *Outline of National Ecotone Protection Planning*. http://www.zhb.gov.cn/gkml/hbb/bwj/200910/W020081009352582312090.pdf (in Chinese).

NBSC (National Bureau of Statistics of China). 2009a. *China Statistical Yearbook 2009*. Beijing: China Statistics Press.

———. 2009b. *National Economic and Social Development Statistical Bulletin of the People's Republic of China*. http://news.xinhuanet.com/politics/2010-02/25/content_13047677.htm.

———. 2010a. *Bulletin on the Grain Yield of Year 2010*. http://www.stats.gov.cn/tjdt/zygg/gjtjjgg/t20101203_402687721.htm.

———. 2010b. *China Statistical Yearbook 2010*. Beijing: China Statistics Press.

NDRC-MCA (Naitonal Disaster Reduction Center, Ministry of Civil Affairs). 2009a. Nationwide Disaster Monthly. *China Disaster Reduction* No. 4: 61–63 (in Chinese).

———. 2009b. Nationwide Disaster Monthly. *China Disaster Reduction* No. 11: 58–62 (in Chinese).

———. 2010. Nationwide Disaster Monthly. *China Disaster Reduction* No. 6: 64 (in Chinese).

Niu, S. P. 2009. Despite Drought "Emergency", China Wheat Crop OK. *Reuters*. 8 February 2009. http://www.reuters.com/article/idUSSP427363.

Pidgeon, N., R. E. Kasperson, and P. Slovic, eds. 2003. *The Social Amplification of Risk*. Cambridge: Cambridge University Press.

SFDH (State Flood Control and Drought Relief Headquarters). 2009. *Northern China Experiencing Severe Drought, SFDH Announces A Grade III Drought Emergency*. http://fxkh.mwr.gov.cn/ztbd_1/2009khzt/201107/t20110721_301647.html (in Chinese).

———. 2010. *Drought in Southwest China Continues, 20.88 Million People Thus Lack of Drinking Water*. http://www.gov.cn/jrzg/2010-04/08/content_1576597.htm (in Chinese).

Shen, C., W. C. Wang, Z. Hao, and W. Gong. 2007. Exceptional Drought Events over Eastern China during the Last Five Centuries. *Climatic Change* 85 (3–4): 453–71 (in Chinese).

Shi, J., Z. Wang, Z. Zhang, Y. H. Fei, Y. Li, F. Zhang, J. S. Chen, and Y. Qian. 2011. Assessment of Deep Groundwater Over-Exploitation in the North China Plain. *Geoscience Frontiers* 2 (4): 593–98.

Shi, P. J. 1996. Theory and Practice of Disaster Study. *Journal of Natural Disasters* 5 (4): 6–17 (in Chinese).

———, ed. 2003. *Atlas of Natural Disaster System of China*. Beijing: Science Press.

Shi, P. J., and Y. H. Liu. 2009. Chinese Paradigm for Integrated Large Scale Disaster Risk Governance. *Journal of US-China Public Administration* 6 (6): 18–28 (in Chinese).

Shi, P. J., L.Y. Liu, J. A. Wang, W. Xu, W. H. Fang, and M. Wang. 2009. Experiences and Lessons of Large-Scale Disaster Governance in China—Perspective to the Response of Wenchuan Earthquake Disaster, 12 May 2008. Paper presented at the IHDP 2009 Open Meeting. 26–30 April 2009, Bonn, Germany.

Shi, P. J., J. B. Shuai, W. F. Chen, and L. L. Lu. 2010. Study on Large-Scale Disaster Risk Assessment and Risk Transfer Models. *International Journal of Disaster Risk Science* 1 (2): 1–8.

Shi, Y., and J. H. Hu. 2009. State Reserve Intervenes into the Market and Stabilizes Wheat Price. *First Finance Daily*, 3 February 2009, A16 (in Chinese).

Song, L. C., Z. Y. Deng, and A. X. Dong. 2003. *Drought*. Beijing: China Meteorological Press (in Chinese).

Song, Y., E. Simelton, D. Chen, and W. Dong. 2005. Influence of Climate Change on Winter Wheat Growth in North China during 1950–2000. *ACTA Meteorologica Sinica* 19 (4): 501–10.

Tao, F., M. Yokozawa, Y. Xu, Y. Hayashi, and Z. Zhang. 2006. Climate Changes and Trends in Phenology and Yields of Field Crops in China 1981–2000. *Agricultural and Forest Meteorology* 138 (1–4): 82–92.

Temple, R. 2002. The Modern World: A Joint Creation of China and the West. In *Proceedings of the International Conference on the Review and Forecast of Chinese Science and Technology*,111–19. Beijing: Science Press.

Tian, W. M., and G. H. Wan. 2000. Technical Efficiency and Its Determinants in China's Grain Production. *Journal of Productivity Analysis* 13 (2): 159–74.

Tong, J. 2009. Guoyuan Agriculture Insurance Compensate for the Drought Disaster and over 500,000 Peasants Gained Benefits. *China Insurance News*. 6 August 2009, 001 (in Chinese).

Uchida, E., J. Xu, and S. Rozelle. 2003. "Grain for Green" in China: Cost-Effectiveness and Sustainability of a Conservation Set-Aside Program. Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Montreal, Canada, 27–30 July 2003.

United Nations. 2007. Developing Index-Based Insurance for Agriculture in Developing Countries. *Sustainable Development Innovation Briefs* No. 2: 1–8.

Wakeman, F. E. Jr. 1985. *The Great Enterprise: The Manchu Reconstruction of Imperial Order in Seventeenth Century China*, Vol. 1. Berkeley: University of California Press.

Wang, J. A., and W. Zuo. 2009. *Geographic Atlas of China*. Beijing: SinoMaps Press.

Wang, M., P. J. Shi, T. Ye, M. Liu, and M. Q. Zhou. 2011. Agriculture Insurance in China: History, Experience, and Lessons Learned. *International Journal of Disaster Risk Science* 2 (2): 10–22.

Watts, J. 2010. China Sends Emergency Food to Drought-Stricken Provinces. *The Guardian*. 25 March 2010. http://www.guardian.co.uk/environment/2010/mar/25/china-drought-emergency-food.

Wisner, B. 2004. *At Risk: Natural Hazards, People's Vulnerability, and Disasters*. London, New York: Routledge.

Wu, Y. C., and H. Gao. 2009. The Relief Records of Severe Drought Disasters since the Founding of P. R. China. *China Flood and Drought Management* 19 (A01): 39–65 (in Chinese).

Xinhua News Agency. 2009. *Review: Drought Impact Alleviated, Good Harvest of Autumn Crops Expected Nationwide*. http://www.gov.cn/jrzg/2009-08/31/content_1405640.htm (in Chinese).

Yang, H., and X. B. Li. 2000. Cultivated Land and Food Supply in China. *Land Use Policy* 17 (2): 73–88.

Zhai, P., A. Sun, F. Ren, X. Liu, B. Gao, and Q. Zhang. 1999. Changes of Climate Extremes in China. *Climatic Change* 42 (1): 203–18.

Zhou, M. Q. 2010. *Research on Demand and Willingness to Pay of Policy-Oriented Rice and Cotton Insurance in Hunan Province*. Master's thesis of Beijing Normal University (in Chinese).

Zhengzhou Commodity Exchange. 2009. *ZCE Monthly Report* No. 12: 4. December 2009 (in Chinese).