Preliminary Evaluation of the Benefit of Disaster Prevention from Rainstorms Using the Integrated Disaster Risk Governance Model

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Abstract

China experiences many types of natural disasters each year. Among these, rainstorms have one of the greatest impacts across the country. Rainstorms are strongly seasonal, occurring mainly during the summer to autumn in mainland China. They can cause significant damage and loss directly and from secondary disasters, such as landslides. This paper used integrated disaster risk governance theory and current sociological and economic methods, along with information on the characteristics of China's meteorological disaster prevention and reduction measures, to evaluate disaster prevention. The focus was on rainstorm meteorological services and disaster prevention behaviour. Sources included a literature review and examples from relevant fields and from the government-led, sectoral linkage and public participation disaster prevention system in China. The processes of rainstorm disaster prevention and mitigation meteorological services, along with disaster prevention behaviour, were used to identify a hierarchy of relevant indicators and parameters to establish and score an evaluation index system. This paper examined four case study rainstorm events which occurred in 2018 as a preliminary evaluation of the meteorological services index and calculation of the social and economic benefits of rainstorm disaster prevention and reduction. The evaluation methods used in this study can also provide the government and stakeholders with techniques to improve the overall meteorological services ability and the efficiency of disaster prevention and reduction. We found that the benefit of disaster prevention and reduction varied quite widely between the four rainfall events. The overall benefit from use of meteorological services in response to rainstorms showed a saving of between 0.278 and 61.58 billion yuan in the four different rainstorm events. The public satisfaction indexes for the four rainstorms in 2018 ranged from 78.5 to 86.4. There were also differences between the self-assessment of meteorological services and evaluation of disaster prevention behaviour.

Keywords: rainstorm disaster, risk governance, meteorological disaster, meteorological service, benefit of disaster prevention

1. Introduction

The meteorological definition of torrential rain (hereinafter “rainstorms”) is precipitation in excess of 50 mm over 24 hours. Rainstorms are one of the most common meteorological disasters in China especially during the rainy season. According to the statistics, from January to September 2020 there were 45 heavy precipitation weather events, with an area precipitation of 622 mm, causing 21 floods in major rivers. This was 13% more than the average over the same period. Among the Chinese

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government's disaster prevention and mitigation systems, a large amount of labour and resources are used to deal with rainstorm disasters. A scientific understanding of how to measure the benefits of meteorological services in rainstorm disaster prevention and mitigation is an important goal of this work. Here, we integrated current evaluation technology and sociological research methods to propose a socioeconomic benefit assessment method based on the disaster prevention and reduction system in China. The descriptive and statistical approach was based on the integrated disaster risk governance theory and the characteristics of China's meteorological disaster prevention and reduction mechanisms. We constructed an evaluation index system for disaster prevention focused on the meteorological services capability and disaster prevention behaviour. The evaluation index system can also be used for assessing prevention and reduction processes for other severe weather disasters.

2. Research Framework

The evaluation of the benefits of rainstorm disaster prevention and mitigation focused on an assessment of rainstorm meteorological services and of the effectiveness of rainstorm defence behaviour. We reviewed the literature and examples in relevant fields, including the Government-led, Sectoral Linkage and Public Participation disaster prevention system in China. The entire process of meteorological services for rainstorm disaster prevention and mitigation was combined to select the relevant indicators and parameters to establish the evaluation index system and develop calculation formula.

2.1 Evaluation of Rainstorm Meteorological Services

A comprehensive assessment of rainstorm meteorological services was used to identify and score the specific evaluation indexes (Table 1). The effect of rainstorm meteorological services was divided into different hierarchical levels and assigned a value to obtain an overall score for each indicator.

Table 1: Evaluation indicator system of rainstorm meteorological services

Key Indicator	First-level Metrics	Second-level Metrics
Comprehensive Evaluation of Rainstorm Meteorological Service	Rainstorm forecast and early warning indicators	Accuracy evaluation of Forecast
		Timeliness evaluation of early warning released
	Public Weather Service Indicators	Channel diversity and early warning coverage of forecast and early warning distribution
		Rainstorm Defence Proposal Release
	Decision-making Meteorological service indicators	Timeliness of decision-making meteorological services
		Response, feedback and measures of the local government
	Specialized Meteorological Services indicators	Timeliness of specialized meteorological services
		Response, feedback and measures from industry
	Social feedback indicators	Public feedback
		Media feedback

2.2 Rainstorm Defence Behaviour Evaluation

The evaluation of the benefit of rainstorm defence behaviour was based on the government-led, sectoral linkage and social participation disaster prevention system. From this, the overall organizational level and disaster prevention and mitigation capabilities were calculated using the metrics established in this research. The specific evaluation indicator system is shown in Table 2.

Table 2: Evaluation indicator system of rainstorm defence behaviour

Key Indicator	First-level Metrics	Second-level Metrics
Rainstorm Defence Behaviour Evaluation	Government Guiding	Rainstorm defence organization system
		Rainstorm defence emergency management
		Ability of personnel transfer and sheltered
		Water conservancy, emergency shelters and other construction projects evaluation
	Departmental Interaction	Emergency treatment
		Emergency support
	Public Participation	Defence capability

2.3 Calculation of Benefit Value of Disaster Prevention and Reduction for Rainstorm Meteorological Services

The benefit value of disaster prevention and mitigation from rainstorm meteorological services is usually calculated using two indicators which measure the reduction in the number of casualties and avoid economic losses. The data in this project included official statistical data from the Ministry of Emergency Management of the People's Republic of China (MEM) and survey data from an independent survey company. The main evaluation indexes included:

- Reduction in the number of casualties
- Reduction in economic losses
- Integrated benefits value of rainstorm meteorological services for disaster prevention and reduction.

The formulas for calculating these indexes are listed in Table 3.

Table 3: Formulas for benefit value of disaster prevention and reduction from rainstorm meteorological services

(1) Calculation Formula of Number of Casualties Reduced

$$\boldsymbol{R_m = A_m \times C_{Rm}}$$

$\boldsymbol{R_m}$ The number of casualties reduced in a rainstorm process, unit: 100 Million.

$\boldsymbol{A_m}$ The actual transfer and resettlement number in a certain rainstorm process, unit: person.

$\boldsymbol{C_{Rm}}$ The ratio of human casualties that may occur if no resettlement measures are taken during a rainstorm process, unit: %.

(2) Calculation Formula of Public Savings in Economic Losses

$$\boldsymbol{P_b = T \times \frac{1}{n} \sum_{i=1}^{n} A_p}$$

$\mathbf{P_b}$ The public's total amount of derogatory benefits caused by using of meteorological services, units: 100 million yuan.

$\mathbf{A_p}$ Impairment losses generated for personal usage of meteorological services, unit: yuan.

$\mathbf{n}$ Number of valid samples for investigation, unit: person.

$\boldsymbol{T}$ Population in the area affected by rainstorm, unit: person.

（3）Calculation Formula of Comprehensive Benefit Value of Disaster Prevention and Mitigation

$$B = \frac{AMG(1-S)}{1-MG(1-S)}$$

B Comprehensive benefit value of disaster prevention and mitigation in a rainstorm process, units: 100 million yuan.

A Direct economic loss in a rainstorm process, unit: 100 million yuan.

M Comprehensive evaluation of meteorological service of a rainstorm process.

G Rainstorm defence behaviour evaluation of local government in a rainstorm process.

S Inevitable loss coefficient in a rainstorm process.

In 2018, an investigation into the benefit value of disaster prevention and reduction from rainstorm meteorological services was carried out by the China Meteorological Administration Public Weather Service Centre, in association with an independent survey company. This research surveyed 3618 members of the public and 587 government and linkage staff, giving a total of 4025 valid samples. Details are shown in Table 4.

Table 4: Survey sample number for four rainstorm events in 2018

Time	24–27, June	8–11, July	15–18, July	16–21, August	Total
Provinces	Anhui, Henan, Jiangsu, Shandong, Sichuan,	Gansu, Shaanxi, Sichuan	Beijing	Anhui, Henan, Jiangsu, Liaoning, Shandong	
Number of Public samples	1519	757	561	781	3618
Number of Government and stakeholders	171	167	52	197	587

3. Results and Discussion

3.1 Statistical Data of Damage and Losses from Rainstorms

Based on the statistics compiled by MEM, Table 5 shows the social and economic costs of four major rainstorms in 2018.

Table 5: Number of deaths, people impacted and temporarily resettled, and economic losses from four rainstorms in 2018 (Data from MEM)

	24–27, June	8–11, July	15–18, July	16–21, August
Population impacted by rainstorm(10 thousands)	116.8	373	1.6	1549.3
Emergency transfer of resettlement number (10 thousands)	2.00	39.1	0.69	28.5
Economic loss (1 Billion yuan)	2.55	16.53	0.206	29.51

The death toll (person)	6	19	0	53

3.2 Public Evaluation of Rainstorm Meteorological Services

During rainstorms, the cooperating investigation agencies conducted evaluations on public weather services in areas where the rainstorm occurred. The surveys evaluated public satisfaction with rainstorm meteorological services, the accuracy and timeliness of services, and the practicality and convenience evaluation of five indicators. The survey results are summarized in Figure 1 and Figure 2.

According to the results of the public weather service survey, public satisfaction with the rainstorm meteorological services was lower than the meteorological services satisfaction in 2018, which was 89.8. In terms of the public's evaluation of the four indicators of accuracy, timeliness, practicality and convenience, the overall evaluation scores were also lower than the average values released by the China Meteorological Administration (CMA) and National Bureau of Statistics of China. Looking at the relative scores, the public's assessment of the accuracy of meteorological services was relatively lower than that of the other three indicators. The evaluation scores range from 76.4 to 82.9 (Figure 2).

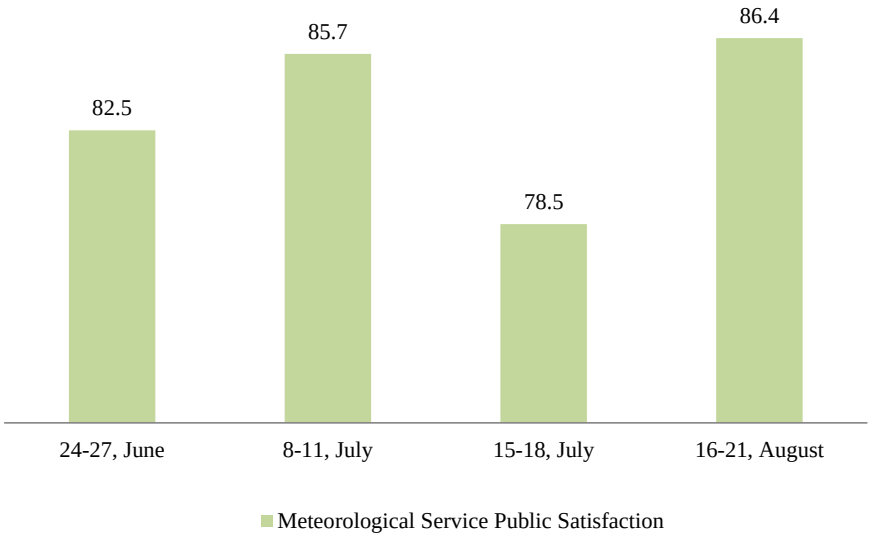

Figure 1: Meteorological service public satisfaction indexes for four rainstorms in 2018

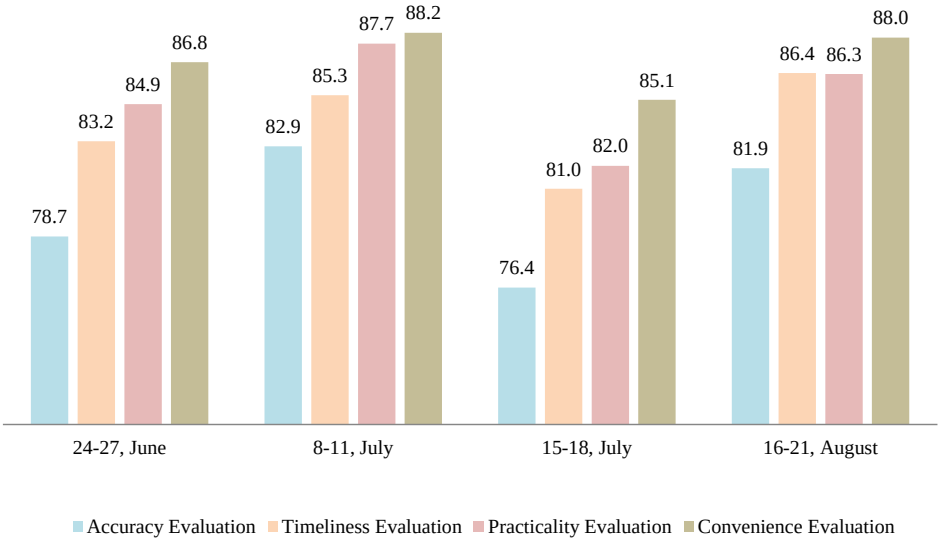

Figure 2: Evaluation of rainstorm public weather service accuracy, timeliness, practicality and convenience

3.3 Rainstorm Meteorological Service Self-evaluation Results and Rainstorm Defence Behaviour Evaluation

Based on the assessment of four rainstorms in 2018, the rainstorm meteorological services self-evaluation and the evaluation of government organizations, departmental linkages and public participation of defensive behaviour showed different characteristics (Figure 3). There were obvious gaps in the evaluation results. Although they covered the same four rainstorm events, the two evaluation index systems were not created in the same way, and the similarities and differences between them need further analysis.

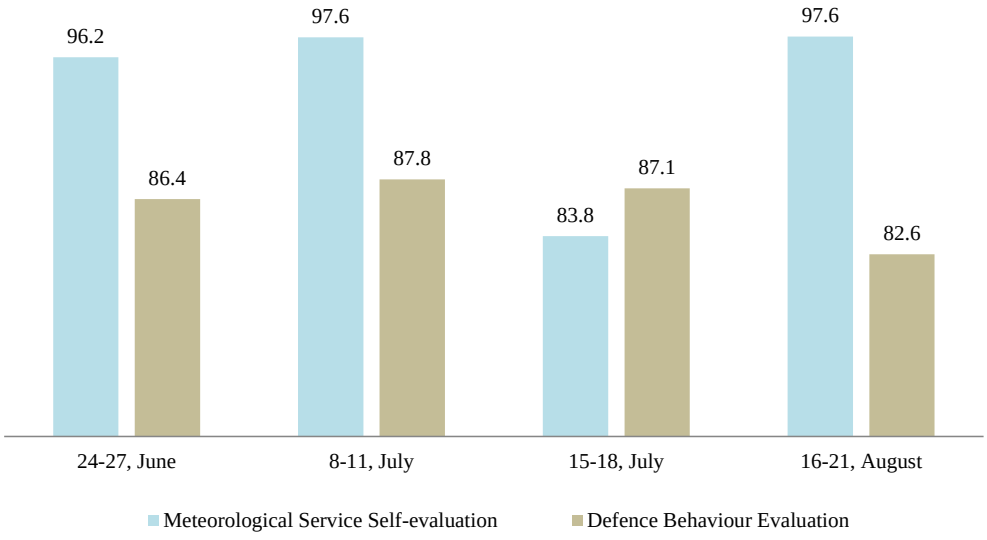

Figure 3: Results of rainstorm meteorological services self-evaluation and defence behaviour evaluation

3.4 Comprehensive Benefit Value of Disaster Prevention and Mitigation

According to the method of calculating the benefit value of disaster prevention and reduction for rainstorm meteorological services (see Table 3), the public use of meteorological services in response to rainstorms led to an average per capita saving of between 369.7 and 873.9 yuan / person in the four different rainstorm events. The overall value of the benefits of disaster prevention and mitigation ranged from 0.278 to 61.58 billion yuan and there were noticeable differences among the different rainstorms.

Table 6: Overall benefit value of disaster prevention and mitigation of four rainstorm events in 2018

	24−27, June	8−11, July	15–18, July	16–21, August
Average saving losses of public (yuan / person)	402.6	873.9	369.7	795.7
Public saving losses （1 Billion yuan)	0.209	3.26	0.059	12.33
Comprehensive benefit value of disaster prevention and mitigation (1 Billion yuan)	5.89	33.1	0.278	61.58

4. Conclusions

A quantitative evaluation of rainstorm meteorological services for disaster prevention and mitigation was carried out to calculate their overall benefit value. The conclusions and limitations of this research are summarized as follows:

- The rainstorm meteorological service evaluation of the effectiveness of disaster prevention and mitigation is operational, but there are still many specific details that need to be adjusted and improved. For example, it is difficult for independent survey agencies to obtain data from the decision-making departments and associated organisations. The survey sample gallery also needs to be developed and improved.
- Further study should be carried out to investigate the relationships between some of the findings here. Parts of the self-assessment data and early warning information release data need to be standardized and unified to improve their usability.
- Finally, the comparability of the evaluation results needs further verification and testing. The overall benefit value of disaster prevention and mitigation for rainstorm meteorological services had a wide range from 0.278 billion to 61.58 billion yuan for different rainstorm events. Understanding how to verify the science and rationale behind the benefit values should also be an important topic in future research.

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