Nat Hazards (2008) 47:65–73
DOI 10.1007/s11069-007-9197-z

ORIGINAL PAPER

Flood hazard in Hunan province of China: an economic loss analysis

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Received: 2 September 2007 / Accepted: 22 November 2007 / Published online: 7 March 2008

Abstract Natural and man-made disasters have been increasing and affecting millions of people throughout the world. Floods are the most common natural disasters affecting more people across the globe than all other natural or technological disasters and also are the most costly in terms of human hardship and economic loss. In order to explore the total economic loss, components of economic loss, and factors influencing economic loss during flooding, a retrospective study was carried out in year 2000 in areas that suffered floods in 1998 in Hunan province, China. A total of 10,722 families were investigated using a multistage sampling method. We found that the total economic loss to the 10,722 families investigated was US$ 8.925 million; translating into an average economic loss of US$ 832.45 per family and US$ 216.75 per person. Economic loss related to property loss, income loss, and increased medical cost accounted for 57.38%, 40.00%, and 2.62% of the total economic loss, respectively. Economic loss was significantly related to a family's pre-flood income; duration of the flood; severity of flood; and type of flood. River floods yielded the highest economic loss and drainage problem floods yielded the lowest loss. We recommended that flood-related preventive measures should focus on the prevention of river floods and shortening the duration of floods with the view of significantly minimizing economic losses associated with floods.

Keywords Flood disaster · Economic loss · Retrospective study · Robust multiple linear regression analysis · China

1 Introduction

In recent years, natural and man-made disasters have been increasing and affecting millions of people throughout the world (EM-DAT 2006). Floods are the most common natural disasters affecting more people across the globe (140 million people per year on average) than all other natural or technological disasters (WHO 2003). Floods are also the

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most costly in terms of human hardship and economic loss (Mason Jr. 1995). China is a country where natural disasters occur frequently. During the 1990s, 6 out of 10 years witnessed major floods along the main river basins. In some areas, flooding occurred every year (Ministry of Water Resources 2004). A global analysis of the effects of flooding in terms of number of people killed, populations affected, and economic loss ranked China as the first among the top 10 countries (EM-DAT 2006).

In general, flood-related damages can be classified as either tangible or intangible. Tangible damages, which can be expressed in monetary value, are of two types: direct (agricultural, environmental, etc.) and indirect (business interruption, impact on regional or national economy, etc.). Intangible damages can be expressed in terms of health and psychological losses (Dutta et al. 2003).

In 1998, severe floods occurred in China affecting over 180 million people (one-seventh of China's population) in 29 provinces. The floods also caused 4,150 human casualties; destroyed 6.85 million houses; and resulted in the relocation of 18.39 million residents of the affected areas. The direct economic loss was about US$ 4 billion (Ministry of Water Resources 1999). Although there have been some reports on flood loss estimation models (Dutta et al. 2003; Atthanan and Suphat 2001) the impact of floods on business (Tierney et al. 1995), and economic loss caused by different types of flood (del Ninno et al. 2001), there have been no report on the components of economic loss and the factors determining economic loss in relation to different type and severity of flood.

We, therefore, conducted a retrospective study in Hunan province in year 2000 aimed at elucidating the components of flood-related economic loss and factors determining such economic losses.

2 Materials and methods

2.1 Study area

The study was conducted in Hunan, an inland province located at the south of the middle reaches of the Yangtze River in southern China. The area is flood-prone, and suffers mainly river floods, flash floods, and drainage problem floods. River floods are caused by flooding of the river outside its regular boundaries, often as a result of high precipitation levels. Flash floods usually occur as a result of local rainfalls with high intensity while drainage problem floods occur as a result of regular drainage systems not able to handle high precipitation levels (Jonkman 2005).

From June 10 to September 19, 1998, a flood disaster occurred by high precipitation level in Hunan province which is located at the south of the middle reaches of the Yangtze River in southern China. The floods collapsed 939,000 houses, destroyed 1.46 million hectare crops, and about 1 million residents needed to be evacuated (Zhu 2005). The floods occurred mainly in Dong-Ting Lake areas, lying south of the middle reaches of the Yangtze River and the west of JingGuang railway, including river floods and drainage problem floods. At the same time, a flash flood occurred in mountainous areas, in the northwest of Dong-Ting Lake and 225 km distance from Yangtze River.

2.2 Sampling

We used a multistage sampling method to select study subjects. In the first stage of sampling, we randomly selected eight counties (seven with damages from drainage problem and river floods, and one with damages from flash flood) from 38 affected counties (33 had experienced damages from drainage problem and river floods, and five had experienced flash flooding). In the second stage of sampling, we randomly selected 40 townships (50%) from the eight selected counties. In the third stage of sampling, we randomly selected 310 villages (50%) from the selected townships. Finally, we randomly selected 11,521 households (50%) from the selected villages. Household was the basic unit of our research.

2.3 Data collection

A retrospective investigation was carried out on January 2000 (18 months after the floods) and completed within a month, using a structured questionnaire in a face-to-face interview. The time between flood and interview was almost identical for all interviewee. Selected staffs of the local centers for disease control and prevention were trained to conduct the interviews. Each interview lasted for about 25 min, and data obtained included types and degrees of flood experienced in 1998; family's income level during the flood year and the preceding year; and the direct economic loss in the flood year. Basic information on every family member was obtained as well as their medical records before and in the year of the flood.

2.4 Data management and analysis

Flood-related damages can be classified as either tangible or intangible (Dutta et al. 2003). We considered both tangible and intangible damages in our economic analyses. Property loss (PL) caused by the floods reflected direct tangible damages and income loss (IL) reflected indirect tangible damages. Income loss was computed as the difference in income between the year preceding the flood and the year of the flood. Increased medical cost (IMC) for family members in flood year distracting such cost in the preceding year was used to reflect as intangible damages. Therefore, economic loss, in this study, was calculated based on three parameters: income loss (IL), property loss (PL), and increased medical cost (IMC). The main analytical variables included the average economic loss per person (AEL), the average income loss per person (AIL), the average property loss per person (APL), and the average increased medical cost per person (AIMC). All the variables were defined as follows:

AEL = AIL + APL + AIMC.

AIL = (the total income of the family in the year before flood) − (the total income of the family in flooding year)/family size.

APL = the total property loss within the family/family size.

$$\text{AIMC} = \frac{\sum_{i=1}^{j} (\text{the medical cost in flooding year - medical cost in the year before flooding})}{j}$$

(j is the family size)

In addition to flood types, the affected areas were also divided into three groups by severity of flood suffered: mild (affected area <50%), moderate (affected area 50–75%), and severe (affected area >75%) floods. Using average income of each family member in the year before flooding as the index of economic status of each family, study families were classified into four groups with the quartile distribution of income (<US$ 125.00, 125.00–208.75, 208.75–312.49, 312.49–1666.63). The duration of flood was also divided into four categories (quartiles: <10, 10–40, 40–90, 90–102 days).

We entered and edited the data by Visual FoxPro 6.0 and analyzed the data using SAS 9.0 and Stata 8.0. The first stage of analysis involved the use of Kolmogorov–Smirnov test to assess the distribution of AEL. An abnormal distribution was observed (Skewness = 5.802, Kurtosis = 74.209, $\chi^2 = 121.41$, $p \leq 0.001$), resulting in the adoption of a nonparametric test (Kruskal–Wallis test) to analyze the determining factors of AEL. In order to compare AEL between groups, the AEL for each group was rank transformed and ANOVA test used. The measure of central tendency was described using the mean and median. The duration of floods did not follow the normal distribution curve and so the relationship between total economic loss and the duration of floods was analyzed using rank correlation.

We further used multivariate analysis to explore the independent effect of different putative factors on economic loss. This involved the use of multiple linear regression to analyze the residuals of the models. The analysis showed outliers (Cook's D tests: cook > 4/10722). In order to attenuate the impact of influential outliers, robust multiple linear regression analysis was conducted using Stata 8.0 (rreg procedure). Average economic loss per family member (US$) was the dependent variable, while the independent variables included flood type (flash floods = 0, 0; drainage problem floods = 1, 0; river floods = 0, 1); flood severity (mild = 1, moderate = 2, severe = 3); duration of flood (days); and the average income per person in the year before flooding (US$).

3 Results

A total of 11,521 families participated in this study. Of them, 799 families had incomplete data and were therefore excluded, leaving 10,722 families (93.06%) with complete data for analysis. Family members who died before the flooding year or who were born after the flooding year were excluded, yielding a total of 41,179 persons for analysis. The average family size was 3.84. Among the 10,722 eligible families, 5,279 (49.2%) suffered from drainage problem flood, 4,147 (38.7%) had river flood, and 1,296 (12.1%) had flash flood. For severity of flood, 4,219 families (39.3%) suffered from mild flood, 2,743 (25.6%) had moderate flood, and 3,760 (35.1%) had severe flood.

The total economic loss to the 10,722 families was US$ 8.925 million. The average economic loss for each family was US$ 832.45; the average economic loss per person was US$ 216.75; and the median of economic loss per family member was US$ 125. Total property loss was US$ 5.12 million (accounting for 57.38% of total economic loss), with a median of US$ 62.5 per person. Total income loss was US$ 3.57 million (accounting for 40.00% of total economic loss), with a median of US$ 50 per person. Total increased medical cost was US$ 2.34 million (accounting for 2.62% of total economic loss), with a median of US$ 6.13 per person among those families with increased medical cost in the flood year in comparison with the preceding year (Table 1).

Table 1 also showed that economic loss was the highest in families that suffered from severe flood (AEL = US$ 273.59) and the lowest in families that suffered from mild flood (AEL = US$ 68.75). The primary economic loss in areas that suffered from severe flood

Table 1 Comparison of economic loss among families with different degrees of flood in 1998 in Hunan, China

Degree	Number of families	Total economic loss (million US$)	Median economic loss/person (US$)	Components of total economic loss (%)		
				PL	IL	IMC
Mild	4,219	2.11	68.75[a,b]	45.91	50.59	3.50
Moderate	2,743	1.99	115.62[c]	53.43	44.33	2.24
Severe	3,760	4.83	273.59	64.02	33.59	2.39
Total	10,722	8.92	125.00	57.38	40.00	2.62

AEL = average economic loss per person; PL = property loss; IL = income loss; and IMC = increased medical cost

[a] Compared with moderate $P < 0.01$; [b]compared with severe $P < 0.01$; [c]compared with severe $P < 0.01$

was related to property loss (64.02%) while areas that had mild flood primarily experienced economic loss related to income loss (50.59%) (Table 1).

Average economic loss was highest in families that suffered river floods (AEL = US$ 312.50), followed by families that suffered drainage problem floods (AEL = US$ 78.13), and then families that suffered flash floods was lowest (AEL = US$ 67.84). Economic loss was mainly related to property loss in families that suffered flash floods (69.78%) and river floods (60.20%), while economic loss in families that suffered drainage problem floods was mainly related to income loss (48.86%) (Table 2).

Property loss was the leading economic loss among low-income families (77.0%), while income loss was the primary economic loss among high-income families (51.98%). However, the absolute total property loss was higher in high-income families than in low-income families (Table 3).

Ranked correlation analysis showed a positive relationship between average economic loss per person and duration of flood: the longer the duration of flood, the higher the economic loss (Table 4).

The result of a robust multiple linear regression analysis showed that the main determinants of total economic loss were income level before flooding (standardized $\beta = 0.28$), duration of flood (standardized $\beta = 0.17$), and severity of flood (standardized $\beta = 0.15$) (Table 5).

Table 2 Comparison of economic loss among families with different types of flood in 1998 in Hunan, China

Type of flood	Number of families	Total economic loss (million US$)	Median economic loss/person (US$)	Components of total economic loss (%)		
				PL	IL	IMC
Drainage problem	5,279	2.45	78.12[a,b]	47.10	48.86	4.04
River	4,147	5.75	312.49[c]	60.20	37.87	1.93
Flash	1,296	0.72	67.84	69.78	26.84	3.38
Total	10,722	8.92	125.00	57.38	40.00	2.62

AEL = average economic loss per person; PL = property loss; IL = income loss; and IMC = increased medical cost

[a] Compared with river floods $P < 0.01$; [b]compared with flash flood $P < 0.01$; [c]compared with flash flood $P < 0.01$

Table 3 Comparison of economic loss, based on income levels, among families that suffered floods in 1998 in Hunan, China

Income level (US$)	Number of families	Total economic loss (million US$)	Median economic loss/person (US$)	Components of total economic loss (%)		
				PL	IL	IMC
<125.00 – (1)	2,121	1.15	75.00[a,b,c]	77.00	19.41	3.59
125.00 – (2)	3,497	2.42	125.00[d,e]	64.15	32.65	3.20
208.75 – (3)	2,229	1.79	134.37[f]	58.44	39.26	2.30
312.49 – 1666.63 (4)	2,875	3.57	225.00	45.94	51.98	2.08
Total	10,722	8.92	125.00	57.38	40.00	2.62

PL = Property Loss; IL = Income Loss; and IMC = Increased Medical Cost

[a] (1) compared with (2) $P < 0.01$; [b](1) compared with (3) $P < 0.01$; [c](1) compared with (4) $P < 0.01$; [d](2) compared with (3) $P < 0.01$; [e](2) compared with (4) $P < 0.01$; [f](3) compared with (4) $P < 0.01$

Table 4 Comparison of economic loss among families with different duration of flood in 1998 in Hunan, China

Duration of flood (days)	Number of families	Total economic loss (million US$)	Median economic loss/person (US$)	Components of total economic loss (%)		
				PL	IL	IMC
<10 – (1)	2,309	0.95	53.12[a,b,c]	56.51	39.29	4.20
10 – (2)	3,023	1.71	93.75[d,e]	49.87	46.90	3.23
40 – (3)	2,697	2.38	150.00[f]	54.48	41.77	3.75
90 – 102 (4)	2,693	3.89	338.33	62.45	36.05	1.50
Total	10,722	8.92	125.00	57.38	40.00	2.62

PL = property loss; IL = income loss; and IMC = increased medical cost

[a] (1) compared with (2) $P < 0.01$; [b](1) compared with (3) $P < 0.01$; [c](1) compared with (4) $P < 0.01$; [d](2) compared with (3) $P < 0.01$; [e](2) compared with (4) $P < 0.01$; [f](3) compared with (4) $P < 0.01$

Table 5 The results of robust multiple linear regression analysis on average economic loss[a] during floods in 1998 in Hunan, China

	β	$s_{\bar{x}}$	*B'	t	P
Income level before flood	0.405	0.01	0.28	72.14	0.00
Duration of flood	1.133	0.03	0.17	36.09	0.00
Flood severity	54.69	1.70	0.15	32.08	0.00
Drainage problem floods[b]	−25.59	4.42	−0.04	−5.79	0.00
River floods[b]	55.55	4.80	0.09	11.58	0.00
Constant	−88.10	5.47	0	−16.10	0.00

Hypothesis test for model: $F = 2598.29$, $P < 0.001$, adjusted $R^2 = 0.548$; *B': standardized regression coefficient

[a] AEL = average economic loss per person

[b] Compared to flash flood

4 Discussion

The computed total economic loss for the 10,722 families investigated was US$ 8.925 million. This translated into an average economic loss of US$ 832.45 per family and US$ 216.75 per person. These levels of economic loss do not compare very well with the estimations given by Wan (1998), for the same national disaster. Wan estimated an average economic loss of US$ 170.92 per person among flood victims in China. The difference could be attributed to regional/provincial differences as well as the method for the assessment. While our assessment was based on direct investigation of individual economic loss, Wan's estimation was based on the government's indirect estimates.

Out of the total economic loss, the property loss accounted for 57.38%, the income loss accounted for 40.00%, and increased medical cost accounted for only 2.62%. During and right after flood, local government supplied fresh water, inhabitancy sterilization, and preventive medicine at free of charge to affected residents, which may have offset some of the need of medical cost. del Ninno et al. (2001) investigated 757 flooded households in rural Bangladesh, and found that the average property loss per household was US$ 119.83, lower than our finding of US$ 477.52 (US$ 5.12 million/10,722). This difference could be attributed to the economic differences between the two countries. Furthermore, Nai (1995) reported that the flood-associated property loss in Shenzhen was about 1,250 US$ per person, which was even higher than our average. The GDP in Shenzhen was much higher than the correspondence year in Hunan, which may explain the differences in flood-associated property loss observed in the two studies. It is also worth mentioning that neither Carlo del Ninno nor Nai counted the total economic loss per household. They also did not provide the proportions of property loss and income loss. Meng et al. (2003) reported that the medical cost was higher in flooded areas than in non-flood area and, therefore, concluded that floods could bring about increased medical burden among victims. However, they did not report the increased medical cost in relation to pre-flood medical expenditure and the proportion in total economic loss, as we have done.

The relationship between economic loss and flood type was significant not only in the nonparametric test but also in the multivariate analysis. River floods yielded the highest economic loss. Results of the multivariate analysis showed that economic loss was greater among families that suffered flash floods than among those who suffered drainage problem floods. However, the absolute economic loss was higher in drainage problem areas than in flash flood areas, which was showed in univariate analysis. This may be because that the economic level is lower and the duration of flood is shorter in flash flood area than in drainage problem area, and both the economic level and duration of flood are positively related with the economic loss. When the economic level and the duration of flood were adjusted in the same level by multivariate model, the result was different from univariate analysis. Generally, drainage problem floods occur slowly, and so people have enough time to prepare for a potential disaster. While river floods usually occur suddenly and, therefore, one has little time available to take actions aimed at preventing loss, particularly property loss (Hen 2004; Li et al. 2004). It is, therefore, necessary to have river floods as the main focus of anti-flood strategies.

In our research, we used the size of areas affected by the flood to define the severity levels of flood. The more severe the floods were, the greater the total economic loss, as well as the greater the proportion of loss related to property. This finding compares well with those of Hen (2004) and del Ninno et al. (2001), who related property loss to the depth of water, velocity of the flood, and the duration of flood. Not only do floods result in property loss, but also affect agricultural yields leading to famine in the affected areas

(Feng et al. 2000; Agriculture Office and Meteorological Administration of Guangdong province 2000). There is, therefore, the need to take the fight against floods very seriously.

Our study also showed that the impact of flood on income loss was severer among high-income earners than low economic earners, and that poor communities suffered more property loss in relative term than richer communities. However, because poor communities usually have fewer assets, the absolute property loss was higher in the richer communities than in poor communities. These findings are consistent with those of del Ninno et al. (2001). Feng et al. (2000) in comparing the economic loss caused by flood between Jiangsu and Anhui province also showed similar results.

5 Conclusions

Flood-related economic loss is significantly associated with the severity and duration of flood as well as economic levels of the affected residents. Severe and longer-lasting floods result in higher economic losses. River floods result in the greatest economic loss.

Acknowledgments This research was supported by China Medical Board in the USA (Grant#98-689). We also wish to thank Linbao Xiang (CDC Director, Yiyang city), Xiumin Zhang (CDC Director, Anxiang county), Huaxian He (CDC Director, Yueyang city), Linlin Li (CDC Director, Xiangxi autonomy city and Senlin Tang (CDC Director, Datong lake district) for their cooperation.

References

Agricultural Office and Meteorological Administration of Guangdong province (2000) Chapter 10: flood hazard and Dragon Boat water hazard. Guangdong agro-meteorological disasters and disaster prevention and mitigation measures (in Chinese), 1st edn. China Meteorological Press, Beijing

Atthanan L, Suphat V (2001) Intangible flood damage quantification. Water Resour Manage 15(5):343–362

del Ninno C, Dorosh P, Smith L, Roy DK (2001) The 1998 floods in Bangladesh: disaster impact, household coping strategies and response. IFPRI Research Report 122 IFPRI, Washington, DC

Dutta D, Herath S, Musiake K 2003 A mathematical model for flood loss estimation. J Hydrol 277(1–2):24–49

EM-DAT (2006) Disaster Profile for Floods. EM-DAT: international disaster database. http://www.em-dat.net/disasters/profiles.php. Accessed 26 Oct 2006

Feng Q, Tao SY et al (2000) The relationship between different socio-economic structures and flood losses (in Chinese). Rainstorm & Disasters 1:1–7

Health Evidence Network. (2004) What are the human health consequences of flooding and the strategies to reduce them? *WHO Regional Office for Europe, Health Evidence Network.* http://www.euro.who.int/HEN/Syntheses/short/20041210_1. Accessed 6 July 2007

Jonkman SN (2005) Global perspectives on loss of human life caused by floods. Nat Hazards 34:151–175

Li SQ, Tan HZ et al (2004) A study on the health status of residents affected by flood disasters (in Chinese). Chin J Epidemiol 25(1):36–39

Mason Jr., RR (1995) Stream gaging and flood forecasting. US Department of the Interior, US Geological Survey, Fact Sheet-209–295. http://water.usgs.gov/wid/FS_209-95/mason-weiger.html. Accessed 20 Feb 2007

Meng W, Yang TB, Tan HZ et al (2003) Study on hospitalization expenses of flood disaster areas' residents of Dongting Lake in Hunan province in 1998 (in Chinese). Chin J Epidemiol 24(8):689–693

Ministry of Water Resources (1999) China big floods 1998 (in Chinese). China Water Resources and Hydroelectricity Publishing House, Beijing

Ministry of Water Resources, People's Republic of China (2004) Minister Wang's Address at the Ministerial Conference of the 3rd World Water Forum. http://www.mwr.gov.cn/english1/20040817/38869.asp. Accessed 6 Feb 2007

Nai WA (1995) Analysis of 1993 flood-related damages in Shenzhen (in Chinese). Pearl River 4:12–14

Tierney KJ, Joanne MN, James MD (1995) The Impact of the 1993 Midwest floods: business vulnerability and disruption in Des Moines. Cities and Disasters, 2nd edn. Charles C. Thomas, Springfield, IL, pp 254–273

Wan QZ (office of state flood control and drought relief headquarters) 1998 Flood disaster report (in Chinese). Flood control and drought relief 4:205–208

WHO (2003) World Disasters Report, 2003. Chapter 8: Disaster data: key trends and statistics. http://www.ifrc.org/publicat/wdr2003/chapter8.asp. Accessed 6 July 2007

Zhu YC 2005 A century of floods. chapter 13 (in Chinese). http://www.nsbd.com.cn/NewsDisplay.asp?Id=123109. Accessed 26 July 2007