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Human impact on floods and flood disasters on the Yangtze River

Hongfu Yin *, Changan Li

School of Geosciences, China University of Geosciences, Wuhan 430074, China

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Abstract

In the middle reaches of the Yangtze River, the floods have become more and more frequent, and the water level rises higher than before. The damages are becoming ever more serious. This is primarily a consequence of human activity in the river basin. Three aspects deserve particular attention. First, destruction of vegetation has led to soil erosion in the upper reaches. In the past 30 years, the forest cover has been reduced to half, while the area exposed to severe erosion doubled in size. In the long run, this can be expected to increase flooding. Second, land reclamation and siltation has reduced lake sizes. This has resulted in decrease of the flood storage capacity. Third, the construction of levees has caused flood levels to rise due to restricted flood discharge capacity. Establishment of the Great Jinjiang levee caused silting up of the riverbed and valley in the mid-reaches of Yangtze. Consequently, the discharge capacity decreased to 60,000–68,000 m^3/s, which is sufficient only for ordinary floods. This article concludes that the deteriorating flood situation is the result of inappropriate human intervention in the natural environment. It is suggested that the appropriate strategy should change from “keeping the flood away” to “giving the flood way”. Related tactics and strategies under consideration are briefly summarized.

Keywords: Flood disaster; Human intervention; Yangtze River

1. Flood disaster

In 1998, the entire Yangtze drainage area suffered from tremendous flooding. This was the largest flood since 1954. The water level at peak was higher in the middle reaches although the flood discharge was less than in 1954. The duration of the high water level was also long—more than 70 days (Changjiang Water Resources Commission, Ministry of Water Resources, P.R. China (CWRC), 1999). The economic loss was 166 billion yuans (20 billion US dollars). The flood was caused by unusually high precipitation between June and August (670 mm), due to a strong El Niño event. It was soon discovered that the high water level and its long duration are not isolated phenomena, but representative of the two general tendencies of flood disasters in the middle reach of Yangtze (Table 1). In 1998, along the middle reaches of the Yangtze, from Zhichen to Jiujiang, most hydrometric stations reported the highest recorded water level (Table 2), although the maximum discharge of 1998 was smaller than that of 1954.

2. Human intervention on the flood disaster

The height of the flood and its long duration are accentuated by the deteriorating human intervention

* Corresponding author. Fax: +86-27-87481392.
E-mail address: hfyin@cug.edu.cn (H. Yin).

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Table 1
Frequencies of flood disasters in Yangtze River

Dynasty or century	Total years	Average interval between floods (year)
Han Dynasty to Yuan Dynasty	1553	11
Ming Dynasty	276	9
Qing Dynasty	267	5
1950s	10	10
1960s	10	5
1970s	10	3.3
1980s	10	3.3
1990s	10	2.5

Data from Hubei Province.

within the river system. The types of degradation related to flood disaster are:

- Vegetation destruction and soil erosion in the upper reaches
- Shrinking of lake water volumes and their reduced connection with the Yangtze due to reclamation
- Restriction of channel capacity following levee construction, and the consequent rise of flood stage in the main course of the Yangtze.

2.1. Vegetation destruction and soil erosion in the upper reaches

In the 30 years from 1957 to 1986, forest cover of Yangtze drainage area was reduced by half, while the area undergoing erosion doubled in size (Table 3). In the first 6 months of 1999, 300,000 m^3 of wood have been collected, corresponding to a vegetated area of 1200 ha. It has been suggested, however, that the remarkable and instantaneous influence of vegetation loss and erosion on the Yangtze flood are not related. The arguments are based on following two aspects.

- In case of continuous rather than short-term heavy rain, the retaining ability of forest is inconspicuous. The analysis of data derived from six paired areas in the Yangtze drainage basin indicates that, on average, under 90 mm heavy rain, the depth of surface runoff is 60 mm in forested areas and 35 mm in non-forested areas. This analysis shows that forest does not retain more runoff. The runoff coefficient of floods is thereby not directly the reciprocal of forest coverage (Cheng et al., 1998). For example, the Shimeng Hydrographic Station, Hunan, on the Li River has a drainage area of 15,307 km^2, where the forest coverage reaches 50%, but during the 1998 flood, the flood runoff coefficient reached 84%.
- As mentioned above, forest coverage of Yangtze was reduced by half between 1957 and 1986. However, the silt discharge of Yichang Station at the head of the middle Yangtze remained comparable, averaging 5.3×10^8 tons per annum (CWRC, 1999). This implies that deforestation may not influence middle- or short-term silt discharge.

Notwithstanding these arguments, there is no doubt about the long-term influence of deforestation and erosion on the deterioration of flood disasters. Deforestation reduces seepage loss and the retaining capacity of precipitation reaching the surface, thereby increasing the rapid convergence of surface water. Meanwhile, more silt is carried by surface water downstream from the erosion area. Thus, deforesta-

Table 2
Flood levels (FL) and maximum discharges (MD) of middle and lower Yangtze hydrographic stations in 1998 and their ranks in flood record

Station	FL (m)	MD (m^3/s)	FL rank	MD rank
Zhichen	50.62	68,800	2	
Shashi	45.22	53,700	1	
Shishou	40.94	No data	1	
Jianli	38.31	46,300	1	1
Lianhuatang	35.80	No data	1	
Loushan	34.95	67,800	1	2
Hankou	29.43	71,100	2	2
Huangshi	26.31	No data	2	
Jiujiang	23.03	73,100	1	
Anqing	18.50	No data		
Datong	16.32	82,300	2	2

Source: modified from Wang and Wang, 1998.

Table 3
Forest cover and area undergoing erosion in the Yangtze drainage basin

Year	Forest cover (%)	Erosion area (km^2)	Erosion area/area of whole drainage basin (%)
1957	22	36.38×10^4	20.2
1986	10	73.94×10^4	41.0

Source: Yin et al., 1998.

tion and erosion certainly are negative human interventions with respect to Yangtze's floods.

2.2. Shrinking of water volume of lakes and their reduced connection with the Yangtze due to reclamation

This has resulted in the decrease of the flood storage ability of the lakes (Peng, 1996). Since 1949, more than one third of the middle and lower Yangtze's lakes have been reclaimed to cropland. The total area of the lakes and the total reservoir volume have been reduced by 10,000 km^2 and more than 50 billion m^3, respectively. The Tongting Lake shrank in area from 4350 km^2 in the 1940s to less than 2000 km^2 at present, and its water storage ability decreased from 29.3 to 17.4 billion m^3. The lake's siltation rate is 0.1 billion m^3 per year. Consequently, it functions less efficiently as a flood storage basin. The Poyang Lake shows the same tendency (Table 4).

2.3. Restriction of channel capacity and rise of flood level in the main course of Yangtze due to levee construction

The middle reaches of the Yangtze, especially the Changjiang–Hanshui Basin is located within a tectonic depression. About 80% of the surface water of the Yangtze drainage converges into this basin. Meanwhile, the basin has only one outlet: through the narrow gap at the Hubei–Jiangxi border. Before the 15th century, the middle reach of Yangtze in its natural condition was a branched river with semi-parallel channels. The channels wandered over the whole basin and deposited silts on floodplains, which finally formed the plain of the Changjiang–Hanshui Basin.

Increasing population of the plain required construction of levees for flood protection. By 1548, during the late Ming Dynasty, the whole northern bank of the middle Yangtze was protected by the integrated Great Jinjiang Levee, cutting off connections between the lakes and the Yangtze River. By 1873, four gaps had been successively formed along the southern bank to allow for southward discharge into the Tongting Lake. Since then, most of the river sediments can be deposited only in the channel and in the Tongting Lake. The deposition of four centuries on the southern plain and in contrast, the non-deposition on the northern side makes a difference of several meters in altitude between the higher south and the lower north. The northern plain or the Changjiang–Hanshui Plain proper became a lowland. An area of 176.4×104 ha, or ca. 40% of the total cultivated land of the plain are currently waterlogged. According to long-term records, the average silt discharge at Yichang at the entrance to the middle Yangtze is 5.3×10^8 tons per annum, whereas at Hankou of Wuhan City, it is 4.3×10^8 tons per annum. That indicates every year 1×10^8 tons of silt are deposited in the Jinjiang segment of the Yangtze and in the Tongting Lake.

Silting up of riverbed and banks has caused a remarkable rise in the flood level. Thus, the flood discharge ability of the Yangtze is decreasing. The discharge capability of upper Jinjiang section, near

Table 4
Decrease of areas and volumes of Tongting and Poyang Lakes

Year	Tongting Lake			Poyang Lake		
	Water level at Chenlinji (m)	Area (km^2)	Volume (10^8 m^3)	Water level at Hukou, (m)	Area (km^2)	Volume (10^8 m^3)
1949	33.5	4350	293	21.0	5200	No data
1954	33.5	3915	268	21.0	5050	323
1971	33.5	2820	188	No data	No data	No data
1977	33.5	2740	178	21.0	3840	262
1995	33.5	2623	167	No data		

Source: Ge et al., 1998.

Table 5
Silting up of valley flats along the middle Yangtze

Locality	Period	Rate of silting (mm/year)	Data source
Upper Jinjiang	1965–1995	36 (average)	Ouyang, 1981
Lower Jinjiang	1952–1976	60 (average)	Ouyang, 1981
Bank outside Renming Dayuan	1956–1976	36 (average)	Yin et al., 2000
13 localities along Jinjiang (Jinzhou-Haoxue, Jianli)	1998 flood	656	Yin et al., 2000
Yangluo and Huashan (Wuhan)	1998 flood	370	Yin et al., 2000
Hankou (Wuhan)	1954–1997	260–340	Lu et al., 1999

Yichang, of the Yangtze is 60,000–68,000 m^3/s. Since 1877, the flood peak discharge has surpassed 60,000 m^3/s 24 times. Such a capacity therefore now can only control flooding, which occurs up to once every 5–10 years. Extraordinary floods such as those of 1931 and 1954 reached 100,000 m^3/s. The 1870 flood even reached 110,000 m^3/s. In such cases, a great disaster is unavoidable. During the 1998 flood, the flood level was disastrously 13 m higher than the levee-protected plain along the Jianli segment of the Jinjiang Levee.

It has been argued that because measurements of the riverbed depth do not show overall shallowing, there is not sufficient evidence to attribute the flood-level rise to riverbed silting, and also to levee construction. However, the silting rates of valley flats along Jinjiang and around the city of Wuhan have been proved to be quite high (Table 5). Valley flat siltation is an important factor of the high flood level, even if the riverbed does not become shallower. Because the flood not only covers the riverbed, but also the valley flat, silting up of the flat will compensate any deepening of the riverbed and reduce the size of the discharge capability. In order to discharge the same flood volume, the water level must be raised.

3. Conclusions

The worsening flood risk in the middle Yangtze is not only a natural process, but also the result of inappropriate human intervention in its drainage basin. Many of the human activities may seem necessary, temporarily and regionally, but in a long-term and larger perspective these may prove to be harmful. The direct losses caused by the 1998 Yangtze flood—166 billion yuans or 20 billion US dollars—should force us to reconsider the human–river relationship. We should change the strategy from “keeping the flood away” to “giving the flood way ”. This may include the following specific strategies and tactics (Yin and Li, 1999).

Strategies

- Integrating flood control construction with environmental protection
- Concurrent regulation of levee consolidation, flood storage and discharge
- Combined control of the river and lakes, water and sediment
- Cooperative tackling by national, regional and local administration
- High-tech decision-making system on flood control

Tactics

- Soil erosion control in the upper reaches
- Establishment of flood-diversion areas
- Consolidation of the main levees along the river; basement and lateral erosion
- Flood reservoir construction
- Excavation of discharge channels
- Planned silt discharge and drainage of waterlogged areas

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