Forest and Flood: Aftermath of the 1998 Yangtze River Flood

by

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ABSTRACT

There has been a long debate over the effect of logging on flood events. The 1998 Yangtze River Flood sounded the alarm for Chinese Government to take actions to protect her environment for sustainable development and Chinese Government proposed strict logging ban after this disaster. Unexpectedly, these well-intentioned environmental policies received controversy criticism from the international community. The main reason behind this phenomenon is that the relationship between forest and flood is still unclear. Based on intense literature research, this paper uses Yangtze River Watershed as a specific example to explore the relationship between forests, floods, and the biophysical environment. Chinese Government's policy taken after 1998 Yangtze River Flood will also be evaluated according to conclusions made regarding the relationship between logging and flood.

KEYWORDS

Forest, Flood, Yangtze River, Logging, China, Policy

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1. INTRODUCTION

The relationship between forest and flood has been a long-standing debate (Van Dijk et al., 2009). This debate is intense as it relates to issues such as forest industry, conservation, economic development, human security, etc. This conflict needs urgent re-evaluation considering climate change, insect epidemics and deforestation worldwide (Alila et al., 2009). The most common and conventional view about the relationship between forest cover and flood is that forest behaves like a "sponge" which can soak up water during precipitation and release it slowly into the watershed afterwards (Day & Evening, 2005). However, many politicians and scientists hold the point that the conventional understanding of the relationship between forest and flood is a misconception. Instead, they believe that relationship between forest and flood is tenuous. In this case, debate over the relationship between forest and flood tends to be more political as the debate is often related to the policies that a government adopts to prevent or mitigate flood events.

The 1998 Yangtze River flood devastated large areas of central China (Zong & Chen, 2000) and resulted in damage of US $ 30 billion (Day & Evening, 2005). Deforestation and slope farming were blamed to be the main causes of this big flood (Yin et al., 2005). In response, Chinese government adopted two major programs, namely, Natural Forest Protection Program (NFPP) and the Slope Land Conversion Program (SLCP), to increase ecological conservation in this area by reducing deforestation, increasing afforestation and regulating agricultural activities (Yin et al., 2005).

After the 1998 Yangtze River flood, Chinese government pays more attention to environmental protection, especially to protection of forest land. Large area of agriculture land was converted back into forest stand with cash compensation and seedling/seed subsidies to farmers (Yin et al., 2005). Other environmental protection policies are also in place, among which the most famous one is the Green Wall of China. It is obvious that China has enforced many fiscal policies to increase the amount of forest land cover all over the country at about 1.2 million ha per year (FAO, 2011). However, the conception that forest has little or no effect on flood frequency and intensity will dramatically depreciate Chinese government's effort on environmental protection. In the following content, current arguments against Chinese government's environmental policy after 1998 Yangtze River flood will be discussed and be proved as indefensible.

This paper is composed of four main sections. Firstly, this paper starts with analysis of Yangtze River basin, land use changes and geomorphology changes, which describes Yangtze River Watershed and the environmental changes happened in this watershed over the past few decades. Following that, there will be a description of 1998 Yangtze River flood. Thirdly, Chinese Government's environmental reactions to the Yangtze River flood will be described and two typical environmental policies will be discussed. The final part is the "discussion part", which explores other agencies' criticism on Chinese Government's environmental policies and discussion on age-old controversies on the relationship between forest and flood. In the "conclusion" part, Chinese Government's policy will be justified based on what has been discovered in this study.

2. YANGTZE RIVER

2.1 OVERVIEW OF YANGTZE RIVER AND ITS RIVER BASIN

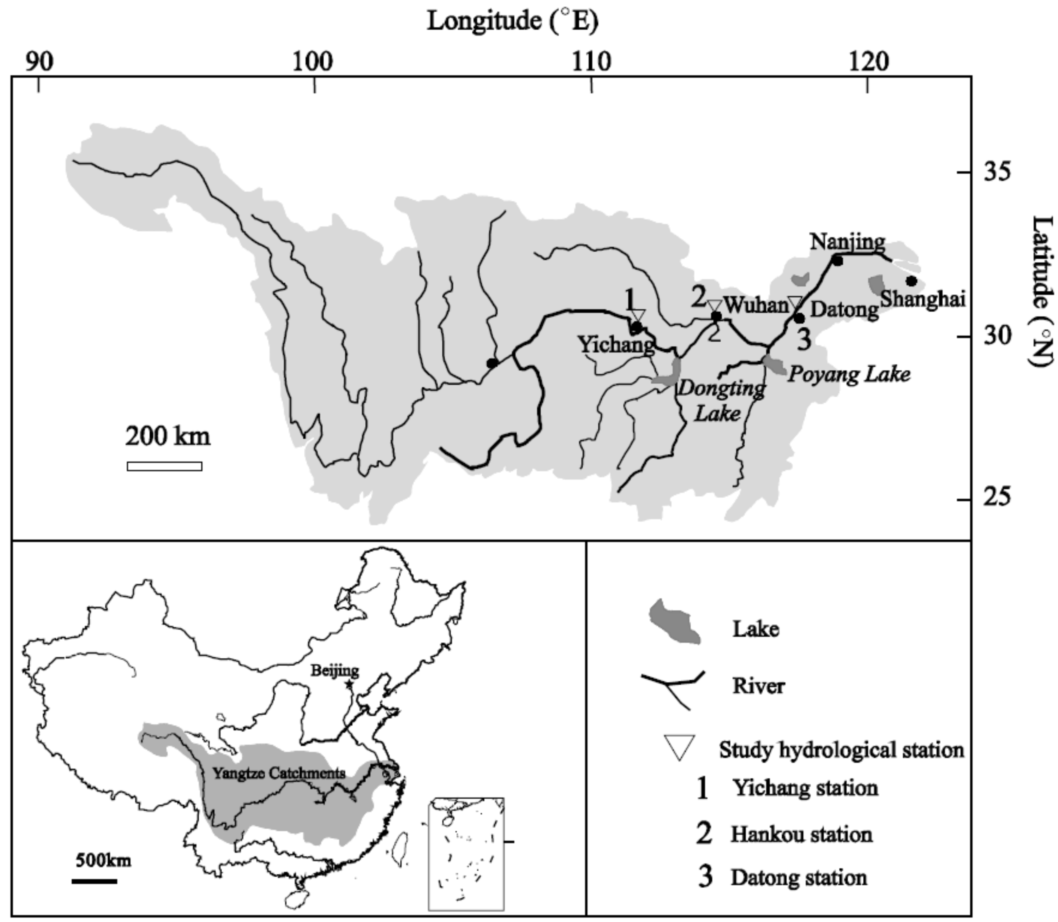

Figure 1: Graph showing Yangtze River basin and the location of three study hydrologic stations to measure the trends of annual maximum water level and stream flow during the past 130 years. Source: (Zhang, et al., 2006)

Yangtze River is the longest river in Asia as well as the third longest one in the world. Yangtze River rises from Kunlun Mountain at an elevation of 4 900m (roughly 16 000 ft) and flows to the outlet in eastern China with a total span of 6 300km (Qian, 2003). The main channel of Yangtze River flows through 11 provinces right across China (Qian, 2003). The size of the river basin is roughly 1.8 million km^2 which accounts for 18.75% of China's land area (Qian, 2003). This huge river basin is also the birthplace of one of the earliest civilizations. Nowadays, there are about

0.6 billion people living in Yangtze basin (45 percent of China's total population) (Zhou, 2003). This basin produces 42 percent of China's GDP and it is also one of the most developed regions in China with 43 percent of this country's fixed investment (Qian & Glantz, 2005). Therefore, Yangtze River basin is an extremely important area for the economic, cultural and social development for China (Zhou, 2003).

Flood hazard in the middle and lower reaches of Yangtze watershed system is the striking factor that affects people's livelihood. There are two factors contributing to the stable stage of Yangtze River. The first one is rich vegetation cover. Intensely forested areas with good ground vegetation cover in the upper reaches can reduce the direct impact of water moving on ground. The other factor is large lake area. Lakes with adequate storage capacity can temporarily store overland flows in Yangtze River watershed. However, Yangtze River was continuously flooding after 800AD as people began to build dams in flood plain and embankments around lakes. Lakes were filled due to agricultural activities. In fact, the most dramatic logging activities were recorded after 1949 with forest coverage decreasing from 30%-40% in 1949 to about 10% in the late 1990s (Qian, 2003). Few trees were found in the upper reaches of Yangtze River, even in uninhabited regions. Soil erosion increased with the increasing deforestation, resulting in increasing amount of sediments deposit in river pathways and lakes in this watershed.

The most recent flood in Yangtze River was recorded in 1998. After that, Chinese government forbid developing agriculture in area with slope bigger than 25 percent and tried to turn area that was already farm land into forest land according to "Environmental Protection Law"，"Forest Law" and "Soil and Water Conservation Ordinance" and imposed a logging ban as well.

2.2 HYDRO-CLIMATE REGIME OF YANGTZE BASIN

According to numerous Chinese and international literature, mean annual runoff in the outlet is approximately 951.3 billion km^3 (Zhang et al., 2006). The mean values of the main water components in Yangtze River basin are listed as followings: precipitation (1100mm), evaporation (605mm) and runoff (550mm) (Mikhailov et al., 2001). The annual runoff coefficient in Yangtze basin is about 0.5(Mikhailov et al., 2001).

Yangtze River originates in the central part of the Plateau of Tibet at an elevation exceeding 5500m (Guo-Liang et al., 1994). It is indicated that there is significant positive correlation between snow cover in the plateau and the water flow of the upper-middle reach of Yangtze River during the flood season (from August to September) in the following year (Guo-Liang et al., 1994).

The hydrologic regime is dominated by the monsoon climate in the middle-lower reaches (Mikhailov et al., 2001). Maximum amounts of precipitation were recorded mainly from May to October. Three gauge stations, Yichang station, Hankou station and Datong station, were set up to represent the upper, middle and lower reaches of Yangtze River. According to data from the Wuhan (Hankou) hydrological station, water runoff is most dramatic from May to October. More specifically, water runoff in the middle reach of Yangtze River is distributed as following within a year: 3.1% (January), 3.1% (February), 4.3% (March), 4.3% (April), 8.5% (May), 10.9% (June), 13.6% July, 15.6% (August), 13.2% (September), 11.7% (October), 7.8% (November) and 3.9% (December) (Mikhailov et al., 2001). Similarly, water runoff from the Daton Hydrologic station showed that 71.1% of the precipitation comes from the wet season (May-

October) and the dry season (November-April) is only responsible for 28.3% of the annual runoff (Mikhailov et al., 2001).

Overall, snow dominates the hydro-climate in the upper-middle reach of Yangtze River and monsoon climate dominates the middle-lower reaches.

2.3 Vegetation Coverage Reduction (especially forest coverage)

Historically, forest coverage in Yangtze River basin was about 60-85% (Wei, 1999). People began utilizing forest land in Yangtze River basin in 800AD. In 1949, forest coverage decreased to 30-40% (Qian, 2003). In fact, the most dramatic deforestation activities happened after 1949 with forest coverage reducing to 22% in 1957 (Wei, 1999). As indicated in table 1, forest coverage reduced by more than half over the period from 1957 to 1986 and in 1986, only 10% of Yangtze drainage area was covered by forest. More specifically, 53 counties located in the main tributaries of Yangtze River, such as Tuo River, Pei River and JiaLin River, have less than 3% forest coverage, within which 19 counties only have forest coverage which is less than 1% (Wei, 1999). Furthermore, 85% of the original vegetation in this watershed has been lost (Qian, 2003), resulting in increasing rate of soil erosion, land slide, and flood.

Table 1: Changes in forest coverage in Yangtze River basin from 1957 to 1986 Source: (Yin&Li, 2001)

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

Human practices in the management of catchment in Yangtze River basin have been criticized as the main cause of increasing flood events in this area. Figure 2 shows the fact over the short period from 1980 to 1990, woodland and grassland reduced by 0.97% and 3.33%, which are 3,310km^2 and 12,260km^2 in area (Wu et al., 2008). Reduction in woodland and grassland is believed to be mainly caused by land reclamation and degradation to unused land. In fact, increases in cultivated land area and decreases in forest area are the most manifest land use/cover change in Yangtze Basin.

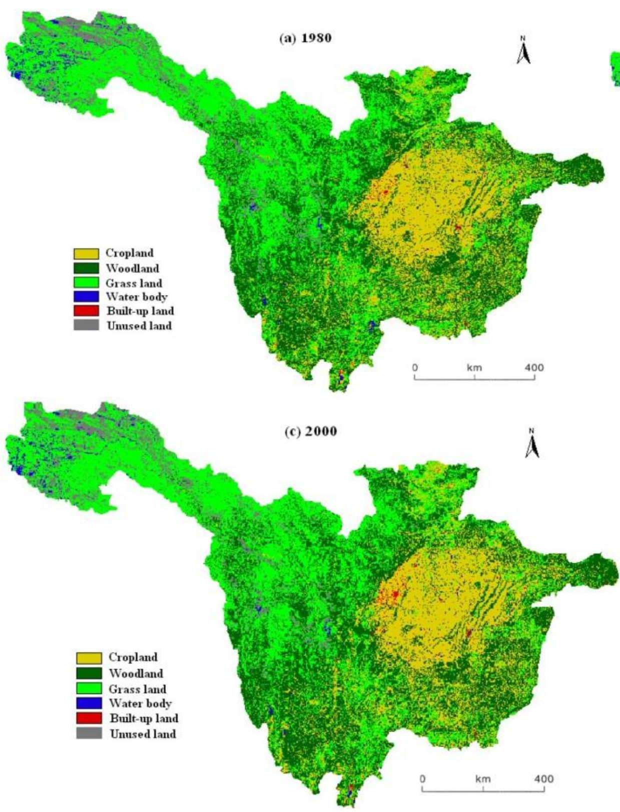

Figure 2: Changes in forest land cover during the period: 1980-1990-2000. Source: (Wu, et al., 2008).

For example, YiLiang County, which was located in the upper reach of Yangtze watershed (Yunnan Province), experienced the most dramatic land use/coverage change (LUCC) in the past few decades. The cultivated land increased from 64060.6 ha in 1960 to 79997.1 ha in 2000, suggesting that cultivated land increased by 24.88% (Wu et al., 2008). The largest proportion of the new cultivated land was sloping field which has greater impact on the environment. Also, over the same period of time, the county's forest area decreased from 145,045.1 ha to 128,921.1 ha with a decreasing rate of 11.12% (Wu et al., 2008). As indicated in figure 3, some agriculture land was converted back into forest; however, the rate of conversion from agriculture to forest land is much lower than the rate of the opposite direction.

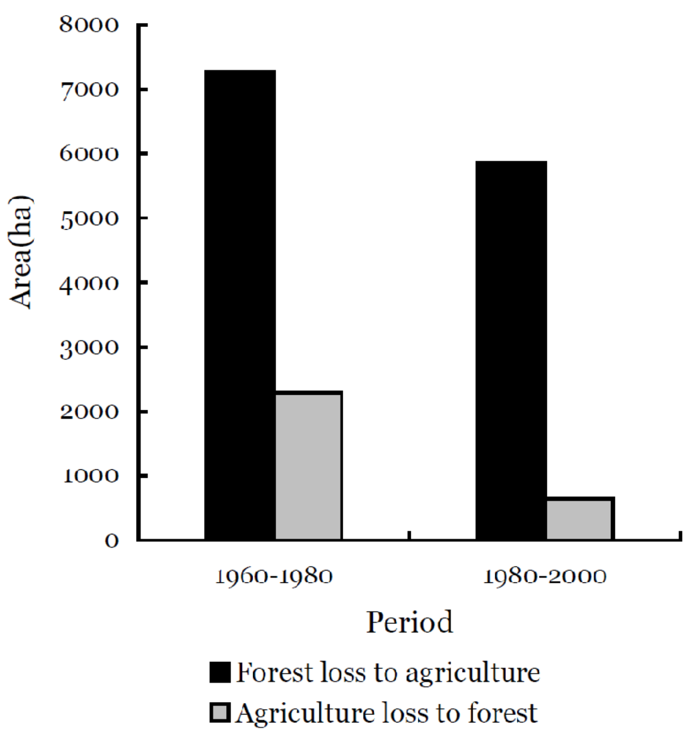

Figure 3, land conversion between forest and agriculture land in Yiliang County. Source: (Wu et al., 2008)

Deforestation increases soil erosion and decreases water retention ability of the surface soil. For example, ChongQing is located in the upper reaches of Yangtze River and ChongQing Municipal

Government estimated that $4.33*10^6$ha of land adjacent to the Yangtze watershed is under severe erosion, which produces about 46 tons of sediments per ha. Such dramatic amount of sediment is distributed in reservoirs, lakes, river networks and main channels of the Yangtze River (Zong & Chen, 2000). Sedimentation decreases lake size and narrows river channel which contributes to the higher incidence of overland flow and flood events under extreme conditions.

2.4 SHRINKAGE OF LAKE AREA AND WATER VOLUME STORED IN LAKES

River-lake systems are important in controlling flood responses to regional and global change. However, since the beginning of the 20th century, cultivation of marshlands and land reclamation of the lakes have resulted in decreasing lake areas in most lakes in Yangtze River basin (Zong & Chen, 2000). Dongting Lake and Poyang Lake are the largest lakes located in the right bank of the lower reaches of Yangtze River. They regulate the water runoff and accumulate a considerable amount of water during flood periods (Mikhailov et al., 2001). These lakes have experienced similar patterns of change in the past few decades, and DongTing Lake will be discussed as a typical example.

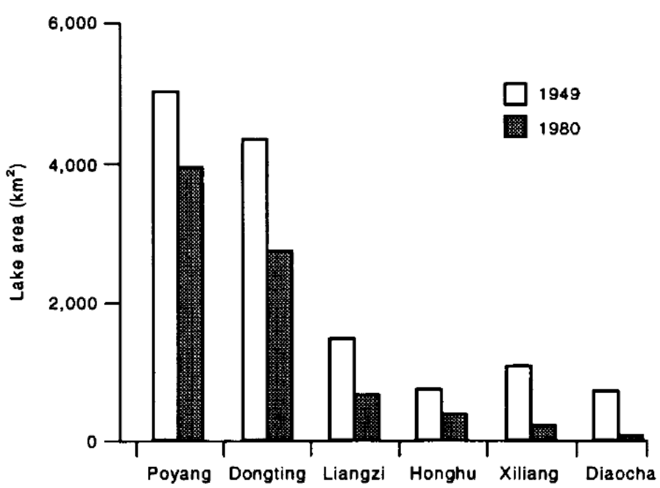

Figure 4 Changes in surface areas in these six major lakes in the middle Yangtze River basin indicating the impact of land reclamation taken place between 1949 and 1980. Source: (Zong & Chen, 2000)

Historical images have indicated that DongTing Lake has greatly reduced in size in the past few decades. From figure 5, it is striking that the lake area has reduced about two thirds from 1930s to 1980s and from table 2, the decrease in surface lake area can be calculated to be about 44.90%, which is almost half of the historical lake area. The main cause for decreasing area in DongTing Lake is intensified human activities in this area. The lake margins are heavily reclaimed for the purpose of agriculture and the upper and middle reaches of Yangtze River experienced dramatic deforestation (Du et al., 2001). Deforestation in the upper and middle reaches of this watershed system increases sedimentation in lakes in the lower reaches which is another cause for decreasing size in Dongting Lake. The result is that, during dry season, this lake narrows to a river channel but it also expands a lot during wet season (Du et al., 2001). Figure 6 also indicates that 1998 Yangtze River flood has inundated a large area adjacent to DongTing Lake which was estimated to be around $>4.4*10^4$ ha (Du et al., 2001).

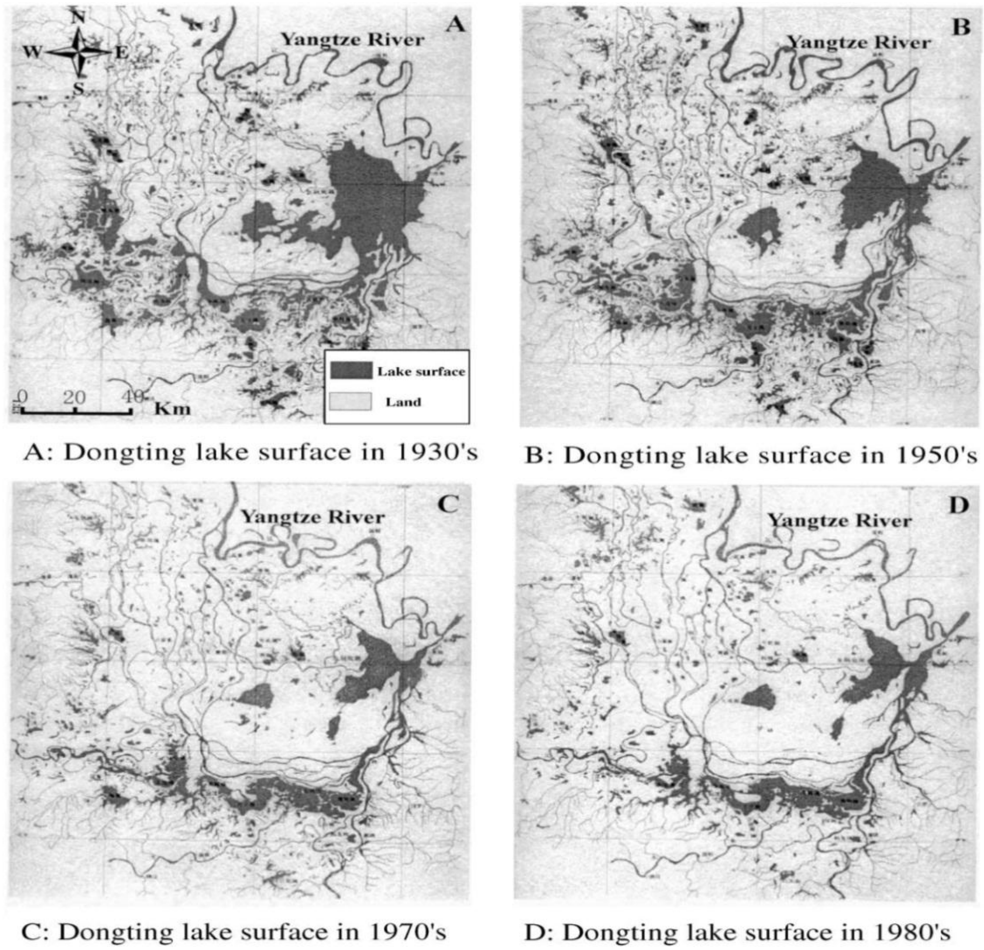

Figure 5: Area changes in DongTing Lake in the 1930s, 1950s, 1970s and 1980s based on bathymetry investigation. (Du et al., 2001)

Table 2: Changes of surface area in DongTing Lake (Du et al., 2001)

Dongting Lake decadal area changes

Lake time	Eastern Dongting Lake area (km^2)	Southern Dongting Lake area (km^2)	Western Dongting Lake area (km^2)
1930s	1454	626	294
1950s	861	707	517
1970s	587	589	312
1980s	551	561	196

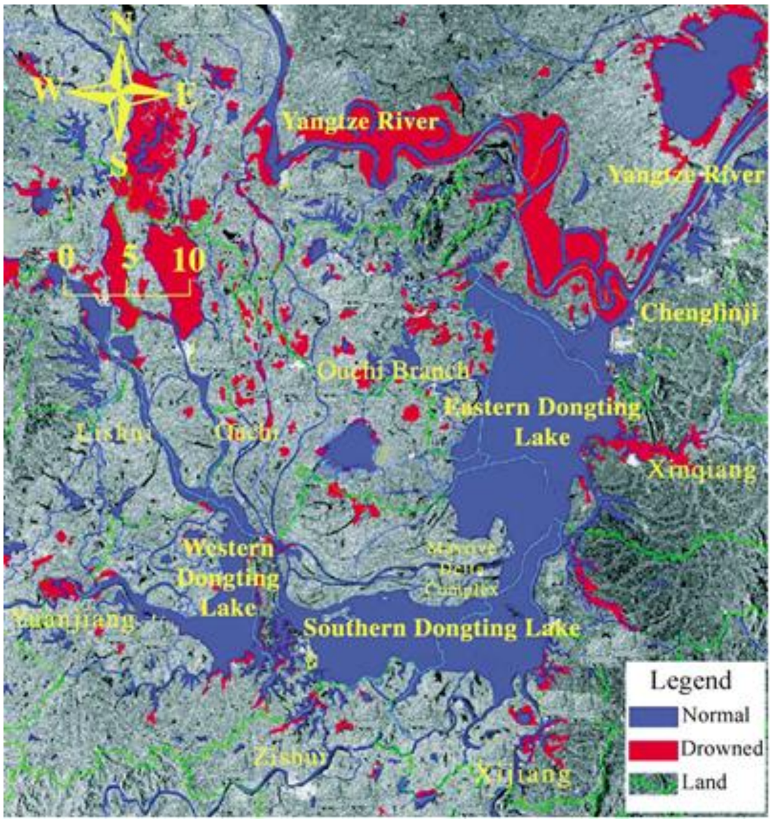

Figure 6: Satellite image indicating flood areas in 1998 Yangtze River flood. (Du et al., 2001)

3. 1998 YANGTZE RIVER FLOOD

In summer of 1998, the whole Yangtze River basin experienced the worst flood in the past 44 years after the big flood in 1954. The primary cause of this flood was the severe rainfall during this period of time (Hays, 2011). In fact, as early as winter in 1997, rainfall intensity was already abnormal in Yangtze River basin. Figure 7.1 and figure 7.2 show the excessive rainfall intensity in the upper and lower reaches of Yangtze River which exceeded the cautionary historical levels.

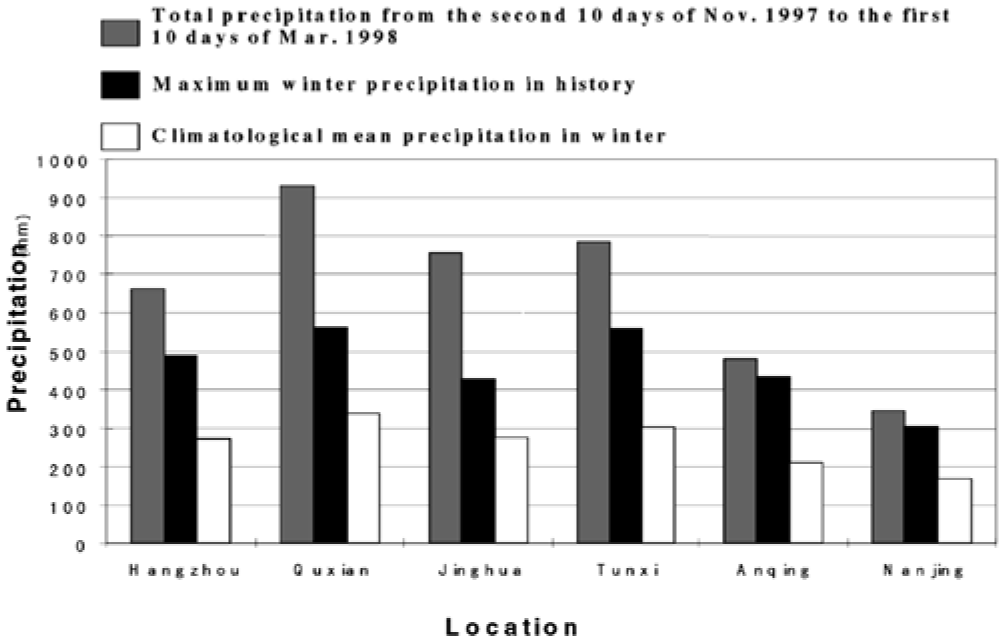

Figure 7.1 Comparison of the maximum winter precipitation and total precipitation from the second 10 days of Nov. 1997 to the first 10 days of Mar. 1998 in Hunan and Hubei Provinces which represent the upper reaches of Yangtze River. Source: (Qian & Glantz, 2005)

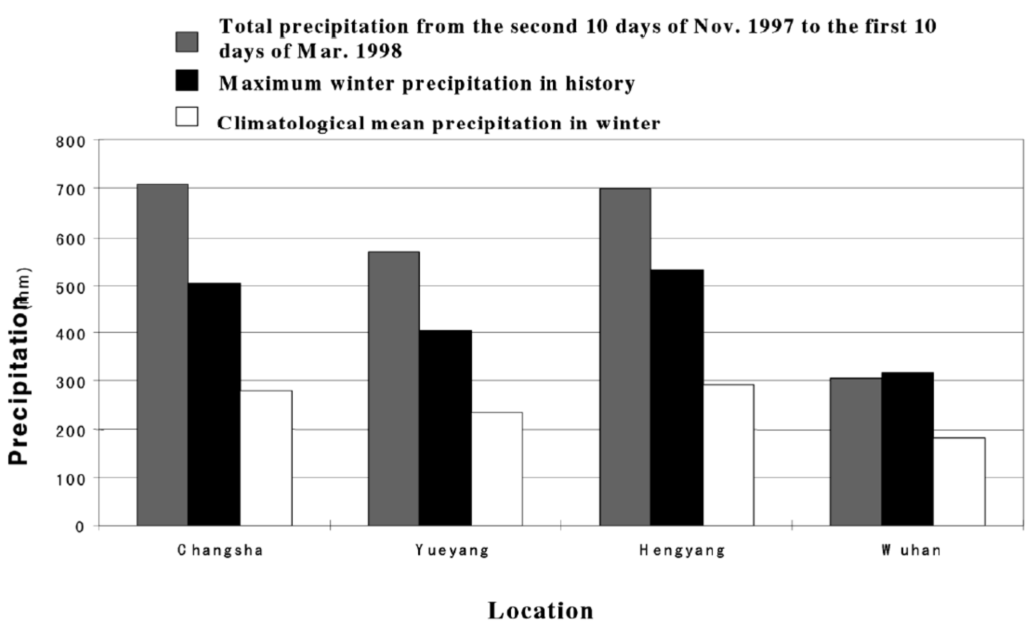

Figure 7.2 Comparison of the maximum winter precipitation and total precipitation from the second 10 days of Nov. 1997 to the first 10 days of Mar. 1998 in cities in the lower reaches of Yangtze River. Source: (Qian & Glantz, 2005)

A triggering factor for the 1998 big flood is that Yangtze River Watershed experienced an abnormal El Nino event in 1998. The subtropical high in the Northwestern Pacific at the beginning of the summer of 1998 was the strongest one on record. The convection bands stalled in the middle and lower reaches of Yangtze watershed and caused continuous precipitation in that area starting in mid-June (Qian & Glantz, 2005). This sub-trophic high-pressure system moved to northern China in July and the middle and lower reaches of Yangtze watersheds became rainless (Zong & Chen, 2000). Shortly after that, it moved back to the middle and lower basins for a second time and caused continuous, strong precipitation (Qian & Glantz, 2005). Strong rainstorms in DongTing Lake and PoYang Lake caused rapid increase in Yangtze River flow (1998 Yangtze River Flood (BaiDu)). Water from DongTing Lake, PoYang Lake and other small streams continuously flowed into Yangtze River. Water level in Yangtze rose suddenly which is the main cause of the great flood in the whole basin.

The 1998 Yangtze River flood can be divided into three phases. The first period is from mid-June to the end of June. Rainfall in this period was roughly twice higher than the average. In mid-June, total precipitation in Jiangxi, Hunan, Zhejiang, Guangxi and Fujian Provinces from June 12 to June 27 ranged from 200 to 500mm which was two to three times higher than the normal state. In northern part of this region (the area of these provinces), precipitation reached 600-900 mm and precipitation in some places even exceeded 1000mm (Qian & Glantz, 2005). It is quite abnormal that such high intensity of rainfall poured into the basin within such short period of time.

The second period is from July 20 to July 30. As the subtropical high reduced, the rainy area reduced and the rainy period was shorter with precipitation amounting from 90 to 300 mm on average (Qian & Glantz, 2005). However, as the water level was already pretty high in the former stage, continuous precipitation caused water level in Yangtze River basin to exceed the damage level.

The third period is from the beginning of August to the subsiding stage of this flood event. The monthly precipitation ranged from 150 to 250 mm and even more than 300mm in some areas (Qian & Glantz, 2005). Frequent precipitations lead to repeated occurrences of flood peaks. Water flooded into cities, villages and agricultural fields, causing catastrophic damage.

This flood only lasted for about three months; however, it was recorded as one of the most dramatic anthropological disasters in the 20th century. According to National Climatic Data Center (NCDC), which quoted damage of this flood from official Chinese government documents, this flood resulted in "3656 people dead, 14 million people homeless, 240 million people affected, 5 million houses destroyed, 12 million houses damaged, 25 million hectares of farmland flooded and $20 billion ($US) damages" (NCDC: Flooding in China, Summer 1998 , 1998).

4. Chinese government's reaction to 1998 Flood

Natural disasters in China drew Chinese government's attention on issues of deforestation. A series of programs have been developed to protect China's natural forests with the objectives of fundamentally curbing environmental degradation, conserving biodiversity, and promoting social and economic sustainable development.

4.1 Natural Forest Protection Program (NFPP)

Natural Forest Protection Program (NFPP) has been implemented by Chinese government as the world's largest ecological rehabilitation project to improve its fragile and precarious ecosystem conditions (Shen, et al., 2006).

The first stage of this program was from 1998 to 2000. The main objective in this stage was to reduce the amount of wood products produced from natural forests in this region and to strengthen the construction and protection of ecological forests. Logging in the upper reaches of Yangtze River and Yellow River is thoroughly banned and the amount of logs from the North-eastern China and Mongolian Province was modified and reduced. Displaced forestry workers were resettled. At the end of this stage (2000), the natural forests would get preliminary protection and restoration.

The second stage of NFPP ranges from 2000 to 2010. During this stage, the objective is to make a smooth transition from reliance on natural forests to reliance on plantations. Plantations become the main source of timber and forestry economy gets recovered and further developed.

The final stage is from 2000 to 2050. The goal is to restore natural forests fundamentally and the main wood supply comes from plantations. By that time, complete forestry ecosystem and a rational system of forestry will be established.

Altogether, NFPP covers 17 provinces and autonomous regions in China, including 414 counties or forest bureaus in the upper reaches of Yangtze River and 358 counties or forest bureaus in the middle reaches of Yellow River (Shen et al., 2006). There has been significant progress in this program. Wang and Innes (2007) noted that over 98 million ha of forest was under effective protection during the period from 1999 to 2007, which was a great success as it accounts for more than half of China's total forestland (155 million ha). In the Northeastern China and Inner Mongolia, forest production reduced from 18.24 million m^3 in 1997 to 10.99 million m^3 in 2006 and 0.67 million displaced workers have been resettled (Wang et al., 2007).

4.2 Sloping Land Conversion Program (SLCP) /Grain for Green Program (GFG)

China's Sloping Land Conversion Program (SLCP) was introduced in 1999 in response to a severe drought in Yellow River in 1997 and the 1998 Yangtze River flood (Bennett, 2008). It is the largest retirement plan among developing countries with the goal of converting 14.67 million hectares cropland with slopes of 25 degrees or greater to forests and the total budget for this program is about RMB 337 billion (over US$ 40 billion) (Xu et al., 2004). This program covers more than 2000 counties located in 25 provinces and it also enrolled roughly 15 million farmers.

This program is composed of two components: the first one is about converting sloping crop land into forest and the second one is about afforestation in barren mountains. Lands to be converted into forests also include those that have severe soil erosion with low production capacity.

SLCP is different from other conservation programs in China for the following reasons. The first reason is that this program is not only about conserving water and soil in ecologically fragile areas, but also restructuring rural economies, shifting farmers to engage in environmentally and ecologically friendly economic activities, such as livestock breeding and off-farm work. Farmers were compensated to plant trees rather than crop. Three types of compensations were offered, namely grain, cash and free seedlings (Uchida et al., 2005). Moreover, voluntarism is another characteristic that makes SLCP distinctive. Acting as core agents of project implementation, millions of households have been engaged in SLCP. Up till 2002, 15 million farmers participated in this program and it was estimated that 40-60 million rural households will be affected by this program (Xu et al., 2004).

SLCP has converted 8.8 million ha of cropland into forest and soil erosion has been reduced by 4.1 million ha (Wang et al., 2007), which is a great success for such an ambitious environmental reform. SLCP is also beneficial for restructuring industrial structure of agriculture. A variety of models which combine ecological and economic governance have been established after the application of SLCP. Some characteristic agriculture and forestry industries such as tea, bamboo, herbal medicine, orchard, etc. have provided diverse sources of farmers' income.

5. DISCUSSION

Though proposed with good intention and accepted by the public, Chinese government's environmental policies received criticisms from other agencies worldwide, which include Food and Agriculture Organisation and other public or private organizations. The core cause of these arguments is that the relationship between forest and flood is still controversial. A better study on this topic will help us understand whether Chinese government's environmental policies are appropriate or not.

5.1 FREQUENCY-PARING VS. CHRONOLOGICAL PAIRING

FAO (2005) and Hamilton (2008) support the contention that forest has no effect on large floods by making paired watershed studies. For example, Hamilton (2008) stated that:

"Hewlett (1982) reviewed the evidence from watershed research worldwide and reported that no cause and effect were demonstrated between forest cutting in the headwaters and floods in the lower basin. No conflicting information has been published since, more than 20 years later"

This line of reasoning is not valid. Alila et al. (2009) have illustrated for the first time that the outcomes of decades of paired watershed studies are erroneous as they use chronological pairing as a principle method in conducting research. Chronological pairing is the "principle method of analysis" to examine the effect of forest harvesting on peak flows in hydrology (Robinson et al., 2003, p. 89). Chronological pairing focuses on changes in magnitude between pre-harvesting and post-harvesting flood events when paired by equal meteorology. However, Alila et al. (2009) stated that using this prevailing method in studies of forest and flood "is not right, it is not even wrong". More specifically, Alila et al. (2010) claimed that chronological pairing "fails to account for physical changes in frequency of peak flows caused by harvesting". It means that decades of research on the relationship between harvesting and flood events is irrelevant as chronological pairing did not take into account the two most fundamental attributes of a flood event, namely magnitude and frequency simultaneously.

By incorporating the lost dimension of frequency into the science of forests and floods, Alila et al. (2009) have demonstrated that peak discharge shift upward by clear-cutting, forests have a dramatic effect on large floods (30 to 50 year events), and also that the larger the flood event the larger is the effect of forests on such event. Furthermore, a study made by Kuras et al., 2012 drew to the same conclusion that “contrary to the prevailing perception in forest hydrology, the effects of harvesting are found to increase with return period” (Kuras et al., 2012, p. 1)

5.2 Routing of peak flows

Hewlett (1982) stated that all paired watershed studies have demonstrated “no causes and effect between forest cutting in the headwaters and floods in the lower basin”. The key issue behind this statement is “flow routing”. As indicated in figure 8, peak flow magnitude is much lower in the outlet of a large basin compared to its headwaters because of desynchronization of peak flow magnitudes. Therefore, peak flows in the outlet are much lower than peak flows in the tributary. For example, peak flow in the tributary may increase 30% but peak flow in the outlet may not change much.

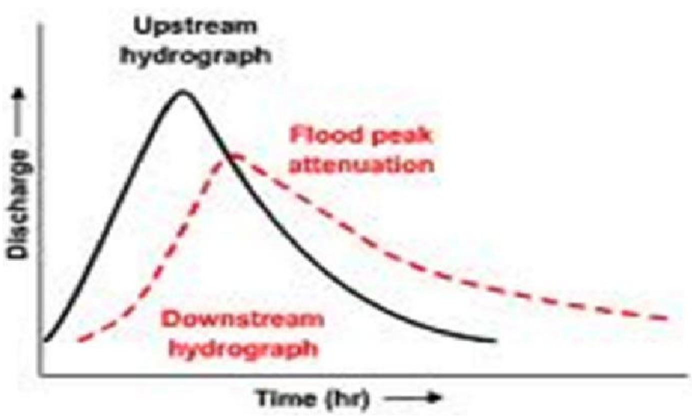

Figure 8 Hydrograph of peak flows in watershed headwater and outlet. Source: (Streamflow Routing: International Edition, 2010)

Many scientists invoke routing of peak flows which attenuate further downstream as the only mechanism that is related to the cumulative downstream flood effects (e.g. Hewlett, 1982; Grant et al., 2008). This line of reasoning about “flow routing” seems correct at the first glance; however, it “does not invoke the critically linked changes in flood frequency and therefore could be misleading” (Alila et al., 2009, p. 18). Flow routing is a direct consequence of reasoning from chronological pairing, so it does not invoke changes in flood frequency (Alila et al., 2009, p.18).

In fact, in large basin, downstream flooding is caused by increasing runoff volume as a result of harvesting in headwater as opposed to increases in peak flows. Hewlett and Helvey (1970) once warned that forest clearing increases not only the peak discharge, but also the total runoff volume. In frequency-paired studies, large watersheds have mildly sloped frequency curves and they are susceptible to greater changes in return period in response to changes in flow magnitude (Alila et al., 2009, p. 18). In other words, logging in headwaters will cause increase (small or big) in runoff volume in downstream watersheds, which will translate into large increase in flood return period and therefore intensifies flood events.

5.3 GEOMORPHOLOGY (SILTATION)

Van Dijk et al. (2009) argued that it was reasonable to identify silting up of the Yangtze River watershed as the main reason for increasing flood intensity. However, reduced forest cover is not the determining factor. This is “not just a semantic but also a practically important distinction” (Van Dijk et al., 2009, p.112). It indicates that deforestation does not necessarily increase the risk of flood as long as the soil is protected and settlements, roads and drains are well maintained.

Furthermore, it means that afforestation does not necessarily reduce flood risk if soil properties do not recover.

In fact, a direct and apparent effect of deforestation is increased siltation and sedimentation. The first reason is that there is dramatic disturbance to soil layer when trees were harvested. The only exception that harvesting has no effect on soil happens when trees are cut on site and they are removed manually. However, tractors or bull-dozers are heavily used in Yangtze River watershed to pull out trees. A study by Johns et al. (1996) indicated that harvesting of 2% of trees bigger than 10cm in diameter can result in damage to 26% of the remaining trees, resulting in canopy opening of 50%. Furthermore, logging roads cover around 10% of the forest area (Johns et al., 1996). Logged trees and forest roads expose soil to the rain where higher amount of sediments washed into adjacent water systems.

A direct result of logging is increased flow volume in the watershed channels. The reason is that removal of forest cover can result in decreased evapotranspiration and interception. Besides that, forest harvesting increases antecedent soil moisture as less evapotranspiration can result in more water being retained in soil mantle. Construction of roads can also increase flashiness of flood events. The fact that roads cause direct runoff from the compacted road surface and interception of subsurface flow by the road cut slopes also contributes to the total runoff. Even if logging in Yangtze River watershed is done in an environmentally friendly way, like helicopter logging, ground flow still increases as a result of logging. Increased flow volume and intensity tend to cause more erosion to river beds and banks. As a result, more sediment will be carried along channels. This is another source of siltation in downstream reaches of main streams and rivers.

As mentioned in the previous chapter, lake area in Yangtze River watershed decreased by approximately half compared to historical data. Siltation is an essential factor besides land reclamation that causes shrinkage of lake area. Logging also causes silting up of river bed and river bank. As a result, siltation has restricted channel capacity. Because of the reduced recharge ability, water level must rise to discharge the same amount of water. In short, siltation, which is mainly caused by increasing logging, increases flood level and had great contribution to the 1998 Yangtze River flood (Yin & Li, 2001).

5.4 REDUCTIONIST APPROACH

Some scientists continue to draw a "no evidence" of a relationship between forest and flood by using a reductionist line of reasoning. They examine how forest cover can affect each individual component of a hydrologic cycle such as interception, infiltration, transpiration, soil moisture storage, and flow and sediment routing one at a time (e.g. Van Dijk et al., 2009; Grant et al., 2008; Gilmour et al., 1987).

However, it is indefensible to analyse those flood generation factors separately. The reason is simple. Flood magnitude is generated by the integration of all those flood generation processes (factors) over the entire river basin and flood frequency is an integration of many flood events overtime. Therefore, reductionism examines the relationship between forest and flood at an inappropriate scale and identifies the wrong patterns. Ironically, "we are clever at devising explanations of what we see, we may think we understand the system when we have not even observed it correctly" (Wiens, 1989, p. 390).

Furthermore, this reductionist approach that examines the relationship between forest and flood at an inappropriate scale is deterministic (Jones & Grant, 1996, p. 972) as this method is based on the old chronological pairing method with equal storm input as opposed to equal frequency. Therefore, reductionist approach strips away statistical physics domain from research on the relationship between forest and flood (Yevjevich, 1974, p. 232). Yevjevich (1974, P. 238) has long warned that deterministic approach in hydrology: "Though idealized or simplified approaches in form of deterministic concepts and methods in hydrologic analysis and synthesis may be useful for understanding some parts of the general physics of processes, they most often represent significant deviations from the properties of the natural hydrologic processes and environments". Therefore, reductionist approach is inappropriate in analysing the relationship between forest and flood.

5.5 LARGE VS. SMALL WATERSHED

Another argument against logging ban in China is that scientists believe forests do have effect on mitigating the magnitude of flood events; however, "reforestation to prevent or reduce floods is effective at only local scale with a few hundred hectares" (Hamilton & FAO, 2008). Similarly, Andersson and Plermkamon (2001) stated that no detectible water balance changes were found at the end of the rainy season in a large river basin that is about 12 100km^2 though forest coverage has reduced from 80% to 27% due to commercial logging. To date, studies in larger basins have not usually found any changes after deforestation of up to 50% of the catchment, and where changes did occur; these were not directly attributed to deforestation (Van Dijk et al., 2009, p.112). Furthermore, an FAO report presented by Day and Evening (2005, p.7) stated that effect of flooding tend to average out in basins larger than 50 000 hectares (50km^2).

These arguments about catchment size are misleading as they ignore the effect of changing catchment size on frequency of flood events. The fact is that for larger catchment, the flood frequency curve is mildly sloped, which means that in comparison with small catchments, these catchments are more sensitive to changes in flood events (a small increase in flood magnitude may result in dramatic change in flood frequency) (Alila et al., 2009, p.18).

Furthermore, afforestation shifts the flood frequency curve down which decreases the flood intensity. Figure 9 is cited from a study by N.S. Reynard, et al. (2001, p.356). This graph compares the impact of land use change scenarios, namely increased forest, increased urban and climate change only, on Severn watershed in middle England with a catchment area of 9 895km^2. As can be seen from this graph, afforestation shifts the frequency curve up down compared to the baseline scenario. For example, flood intensity for a 17-year event decreases from roughly 700m^3/s to about 650m^3/s. For floods with the same intensity, afforestation will increase flood return period, which makes flood events with certain magnitude less frequent. For example, floods with an intensity of roughly 600 m^3/s increase their return period from about 5 years (baseline) to about 10 years (afforestation). For floods with greater magnitude, changes in return period are even greater. In comparison to the 600 m^3/s event, floods with an intensity of 700m^3/s increase return period from about 18 years (baseline) to about 100 years (afforestation).

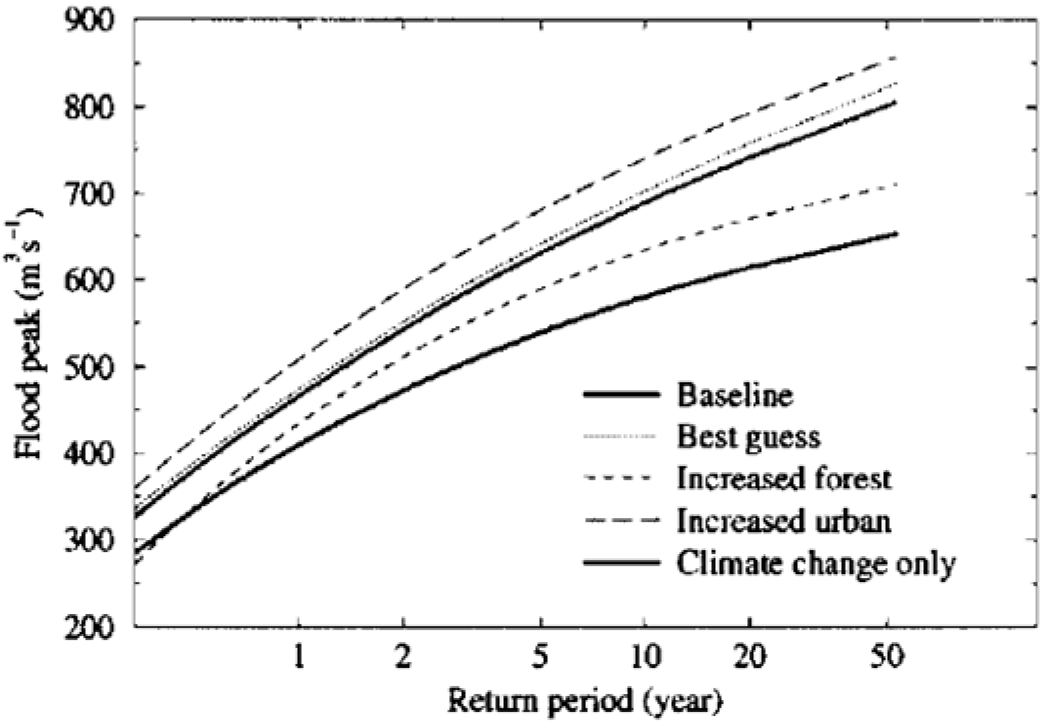

Figure 9 Effects of land use change scenarios on flood frequency curves for Severn. Source: (N.S. Reynard, et al., 2001)

Overall, mildly sloped flood frequency curves in big catchment are more sensitive to changes in the magnitude of peak flows and deforestation in large catchment can result in increase in flood magnitude and return period simultaneously. For a large catchment like Yangtze River watershed, flood frequency curve is quite sensitive to changes in flood intensity. Logging in that watershed can have a big effect on flood events.

6. CONCLUSION

Yangtze River Watershed has heavy load for the development of the national economy. Irrational human development and utilization of this watershed has resulted in severe environmental problems. Though the relationship between forest and flood is tenuous, we can safely make a conclusion based on discussion above that forest and flood are closely related to each other and logging does have huge impact on flood event, be it flood intensity or flood frequency. Chinese Government's environmental policies are appropriate when facing a devastating natural disaster like 1998 Yangtze River Flood. It is true that logging ban does influence employment, economic development and social well-being, but Chinese Government has already taken corresponding actions to resettle forestry workers and gradually shift wood supply from natural forests to wood plantations and from imports. Though in the short-term logging ban can influence social well-being, it has many long-term benefits, including offering good opportunities for flood control and a better living environment.

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