THE POTENTIAL RISK AND DISTRIBUTION OF FLOOD WATERLOG ON CROPLAND IN THE MIDDLE-LOWER REACH OF YANGTZE RIVER IN CHINA

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ABSTRACT: The floods waterlog on crop and farmland induced by heavy rainfall is one of the primary natural disasters and has resulted in large number of food losses across the world. Flood submerge crops in whole plants or part of the plants for long time, leading to the insufficiencies of oxygen in plant roots and lodging, resulting in decrease in production. In China, the average 9.42×10^6 ha of croplands were suffered by flood waterlog every year with more than 1000 tons loss of food, while more than 55% of them occurred in the middle-lower reach of Yangtze River. With the increase in extreme rainfall events in future's climate change, it is very important to map the potential risk areas of flood waterlog induces by heavy rainfall to select the flood resistant cultivars and manage the farmlands. In this paper, based on the data sets from 74 meteorological stations in southeastern China during the periods of 1961 to 2008, the times of day of heavy rainfall that the daily precipitation were more than 50 mm, the largest daily precipitation of every stations, the largest continual precipitation of every stations and the probable distribution region of a heavy rainfall process were statistically analyzed and mapped by the GIS methods. And then, the fine resolution DEM extracted from the Yangtze River watershed and the vector land use map were add to analyze the potential sinking areas using the Hydrology Model according to different probabilities of heavy rainfall (P = 1%, 2% and 10%). The results showed that the times of rainstorm and the largest daily precipitation, the largest continual precipitation and the spatial distribution of a rainstorm process distributed in the middle-lower reach of Yangtze River with the distribution center area from Wuhan to Jiujiang. The potential risk cropland areas suffering severe and moderate flooding waterlog would be 650 (P=1%), 430 (P=2%), and 270 (P=10%) $\times10^4$ ha respectively, approximately accounting for 28, 18 and 11% of the cropland areas in study area. The severe, moderate and slight flood waterlog area would be submerged cropland in 1.5 to 3.5 m, 1.0 to 2.5 m and 0.5 to 1.5 m respectively.

KEY WORDS: Flood Waterlog, Cropland, Rainstorm, Yangtze River, China

1. INTRODUCTION

The floods waterlog on crop and farmland induced by rainstorm is one of the primary natural disasters and has resulted in large number of food losses across the world. Flood converged by runoff which derives from a heavy rainfall or consecutive days of rainfall synchronously combined runoff from upper reaches submerge crops in whole plants or part of the plants for long time, leading to the insufficiencies of oxygen in plant roots and lodging, resulting in decrease in production.

In China, the average area of 9.42×10^6 ha of cropland were suffered by floods waterlog every year with more than 1000 tons loss of food, while more than 55% of them occurred in the middle-lower reach of Yangtze River (Bian et al., 2012). Thus, controlling and preventing from flooding are the crucial work in every year flood season during April to October in these areas. A large number of studies were conducted to research the characteristics of rainstorm (Wang et al., 2012; Sun et al., 1998; Feng et al., 1998; Zai et al., 2005), the distribution of flood disasters (Li et al., 1996; Zhang et al., 2001; Yu et al., 2006), the risk assessment (Bian et al., 2011) and the mechanism of flood waterlog (Zheng et al., 2013). With the likely increase in extreme rainfall events in future's climate change, there would be more frequent times of rainstorms and more dangerous statues of flood and waterlog in the flood-prone areas in China. However, the potential risk and distribution of floods waterlog on cropland caused by likely increased heavy rainstorms in future are not distinct. It is very important to map the potential risk areas of floods waterlog in different intensities of rainstorms and select the flood resistant cultivars and manage the crops in farmlands under the background of climate change. The goal of this study was (1) to exam the characteristics of heavy rainstorms in middle-lower reach of Yangtze River since 1960s; (2) to determine the precipitation of heavy rainstorms in different frequencies of heavy rainstorms and maximal consecutive rainfall, and (3) to map the risk areas in different frequencies of heavy rainstorms or maximal consecutive rainfall and their submerged depth.

2. MATERIAL AND METHODOLOGY

2.1 Study Area

The study area (111-118˚E, 27-32˚N), covering parts of Hubei, Hunan Jiangxi, and Anhui province with the total area of $34.9 \times 10^4 km^2$ is located in the middle-lower reach of Yangtze River, where the river course across the center from west to east and receive three anabranches, naming Xiang river, Han river and Gan river and two lakes of Dongting and Poyang. Over the both sides of river course and lakes, there are plains with the elevation from 20 to 40 meters above the see level and hills with the elevation from 40 to more than 500 m (Figure 1). Forest land, Grass land, Cropland and Marsh are distributed over the area (Figure 2). In the period from April to October of every year, the heavy rainfall poured down and the flood water converge into the rivers and lakes, causing the overflow and serious floods waterlog.

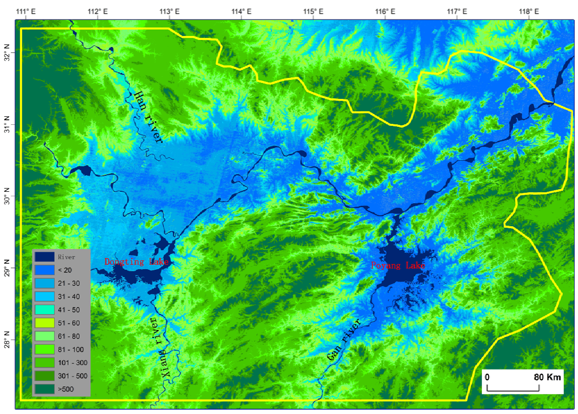

Figure 1: The study area and DEM in middle-lower reach of Yangtze River, China.

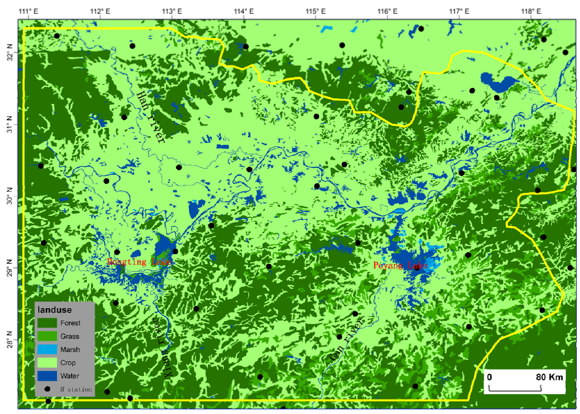

Figure 2: The land use and the meteorological stations of study area in middle-lower reach of Yangtze River, China.

2.2 Data and Processing

We collected three types of data: Digital Elevation Model (DEM) in scales of 1:250000 and 30 meters of contour interval, the land use vector map attributing forest, grass, crop, marsh and water body, and the daily precipitation over the year from 1961 to 2008 of 73 meteorological stations over covering the study area (Figure 2).

We use the daily precipitation time series data to generate the parameters of each station in the period of 1961 to 2012. The parameters are the maximum heavy rainfall intensity (mm day-1), number of days of heavy rainfall (the heavy rainfall defined as daily precipitation more than 50 mm), the number of days in different daily rainfall classification (50-59, 60-69,70-79, 80-89, 90-99, 100-109, 110-119, 120-129, 130-139, 140-149, 150-159, 160-199, 200-250, and more than 250 mm), and the maximum continuous precipitation. Based on these parameters, we obtained the spatial distribution of heavy rainfall intensity, heavy rainfall times and the maximum continuous-days precipitation using the Inverse Distance Weighted interpolation. We calculated the times of day of different heavy rainfall classification and the total times of day, and then calculated the frequency and accumulative frequency to obtain the heavy rainfall frequency accumulation curve. According to this curve, the storm intensity in different frequency (p = 1, 2, and 10 %,) obtained. In order to determine the flow director and calculate the flow accumulation, we refined the DEM from 30 m of contour interval to 2 m in the elevation range from 20 to 40 m.

Based on the heavy rainfall intensity in different frequency and the maximum continuous precipitation, we calculated the runoff in different rainfall intensity after 24 hours of a heavy rainfall and a continuous-days rainfall. And then, based on the water budget inflow from upper reaches and outflow through the given section, the potential submerged areas were mapped according to the DEM. The processing work was carried out on ARC Map 9.3 and MS Office.

3. RESULTS

3.1 The Spatial Characteristics of Heavy Rainfall in Study Area

During the period of 1961 to 2008, the times of days of heavy rainfall were more than 150 days with average of 3.1 days per year in study area. Of them, there were more than 200 days of heavy rainfall in most part and the maximum were 349 and 419 days at Lu Mountain and Huang mountain station respectively (Figure 3), indicating the prone areas of heavy rainfall along with the course of Yangtze River, and Lu Mountain and Huang Mountain were the center of heavy rainfall in study area.

The maximal heavy rainfall intensity was more than 200 mm/day, with two larger center of heavy rainfall intensity of more than 250 mm/day. There were more than 3 peak values of heavy rainfall intensity with 360, 351, and 328 mm/day at Huangshi, Lu Mountain and Huang Mountain station respectively (Figure 4). The largest belt of higher heavy rainfall intensity was accounted for half part of the study area locating north-south orientation.

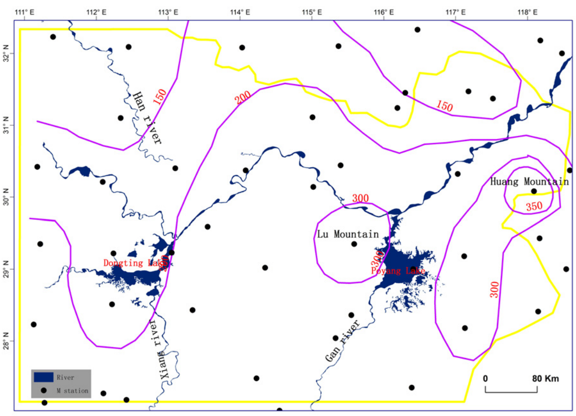

Figure 3: The distribution of times (days) of heavy rainfall during 1961 to 2008.

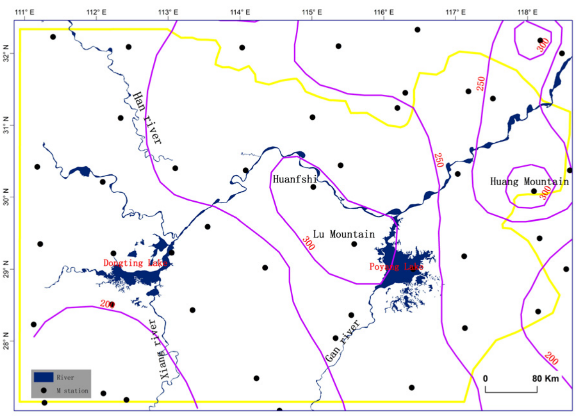

Figure 4: The distribution of maximal heavy rainfall intensity (mm/day) in study.

Continuous rainfall for many days is another reason inducing flood waterlog in study area. During the period of 1961 to 2008, the maximal continuous precipitation was more than 400 mm for average 10 days, and in larger area was more than 600 mm (Figure 5). The 3 peak values of continuous precipitation were 1051 mm at Lu Mountain station for 9 days, 872 mm at Huang Mountain station for 11 days and 945 mm at Guixi station for 15 days.

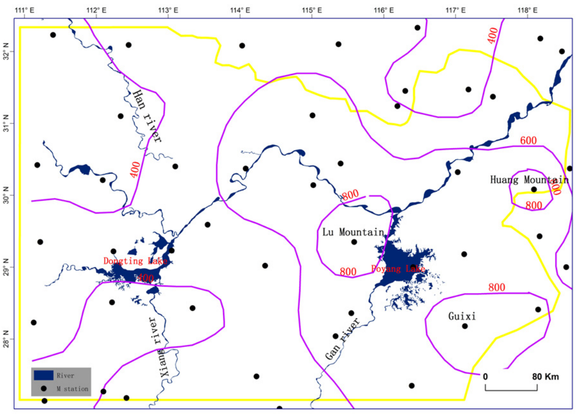

Figure 5: The distribution of the maximal continuous precipitation for average 10 days (mm).

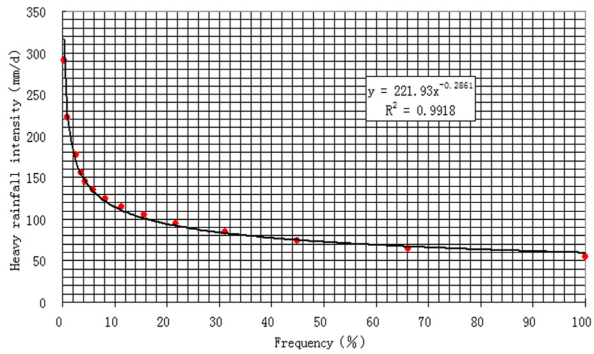

Figure 6: The heavy rainfall frequency accumulation curve.

3.2 The Intensity of Heavy Rainfall and The Potential Runoff

The heavy rainfall frequency accumulation curve in study area is showed on Figure 6. It presents a power function with the constant a = -0.2861 and R^2 = 0.9918. According to this frequency accumulation curve function, the heavy rainfall intensity in any frequency can be calculated. Here the heavy rainfall intensity in frequency of 1, 2 and 10% were 222, 182 and 115 mm/day. The frequency of 1, 2 and 10% were the rainfall reappearing period of one hundred, fifty and twenty years respectively.

The runoff coefficient is a parameter that is used in equations to determine the runoff and its peak amount in a drainage system. Based on the long term observation, research results suggested that the runoff coefficient in Yangtze River was 0.514 (Luo et al., 1992). According to this value, the potential value of runoff in different heavy rainfall intensity of 222, 182 and 115 mm/day were 114, 94 and 59 mm respectively over the study area. While the runoff transformed from the continuous precipitation of 400 and 600 mm for ten days were 205.6 and 308.4 mm in study area.

3.3 The Potential Impacted Area

After 24 hours of the heavy rainfall, the flood flow into the rivers and lakes, elevating the water level, and probably submerging the cropland. According to the budge of rainfall and runoff, the heavy rainfall in heavy rainfall intensity of 222, 182 and 115 mm/day would elevate averagely 2.1, 1.7 and 1.1 meters of the water level in river and lakes. While the continuous precipitation of 400 and 600 mm would elevate averagely 5.7 and 3.8 meters of the water level in river and lakes.

Based on the budge of flow and the DEM, we mapped the potential impacted area where the severe, moderate and slight waterlog area were be defined in which the severe, moderate and slight flood waterlog area would be submerged 1.5~3.5 m, 1.0 ~2.5 m and 0.5~1.5 m respectively.

The potential risk cropland areas suffering severe, moderate and slight flooding waterlog would be 650 (Figure 7, P=1%), 430 (Figure 8, P=2%), and 270 (Figure 9, P=10%) $\times 10^4$ ha respectively, approximately accounting for 28, 18 and 11% of the cropland areas in study area. While the potential risk cropland areas suffering severe and moderate flooding waterlog would be 732 and 103 $\times 10^4$ ha for continuous rainfall of 400 mm(Figure 10) and 835 and 137 $\times 10^4$ ha for continuous rainfall of 600 mm (Figure 11).

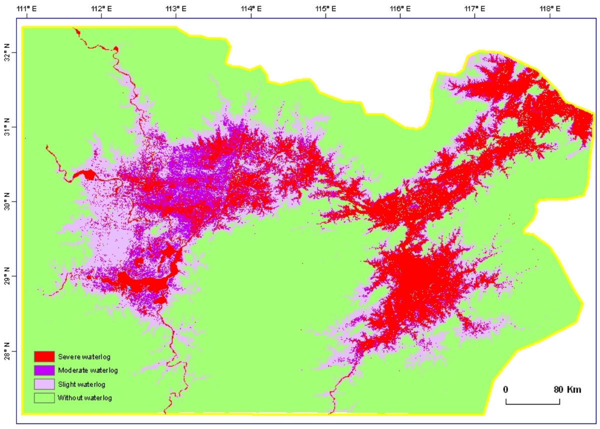

Figure 7: The potential risk areas suffering flooding waterlog in the rainstorm probability of 1%.

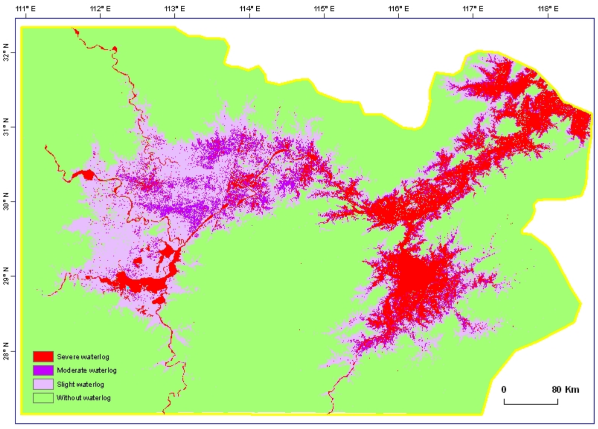

Figure 8: The potential risk areas suffering flooding waterlog in the rainstorm probability of 2%.

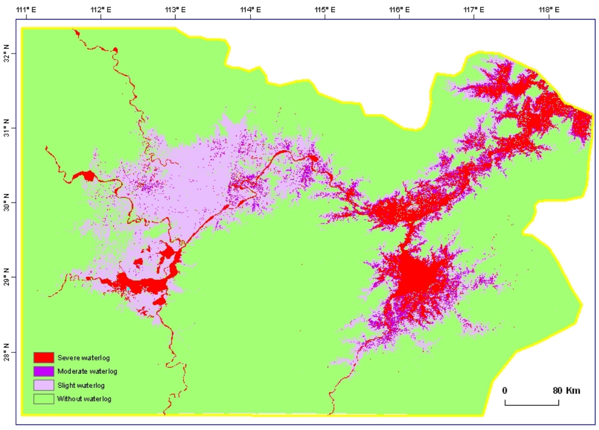

Figure 9: The potential risk areas suffering flooding waterlog in the rainstorm probability of 10%.

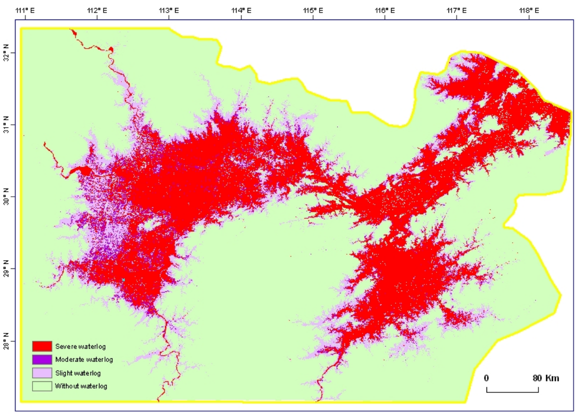

Figure 10: The potential risk areas suffering flooding waterlog in the continuous rainfall of 400 mm.

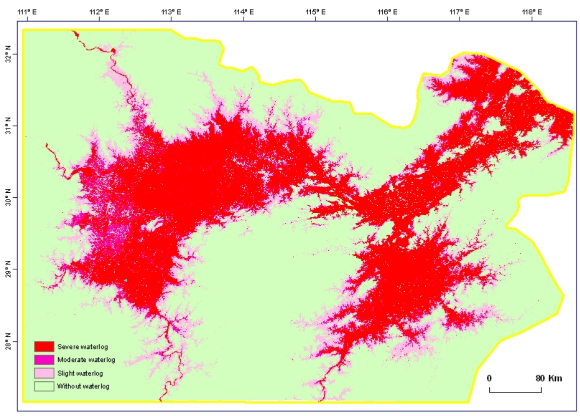

Figure 11: The potential risk areas suffering flooding waterlog in the continuous rainfall of 600 mm.

4. DISCUSSION AND CONCLUSION

Along with the course of Yangtze River, there is the flood plain Characterized by flat and marshy landform.

The severe heavy rainfall converged into the river and lakes, caused the higher water levels and submerged the cropland. Although without considering the flood flowed from upper reach of Yangtze River and neglecting the flood control conditions, we can still get some conclusions.

(1) There were the prone areas of heavy rainfall in part of area of Hubei, Hunanm, Jiangxi and Anhui province along with the course of Yangtze River.

(2) The heavy rainfall intensity in frequency of 1, 2 and 10% were 222, 182 and 115 mm/day, which present the rainfall reappearing period of one hundred, fifty and twenty years respectively.

(3) The potential risk cropland areas suffering severe, moderate and slight flooding waterlog would be 650 (P=1%), 430 (P=2%), and 270 (P=10%) $\times 10^4$ ha respectively, approximately accounting for 28, 18 and 11% of the cropland areas in study area. While the potential risk cropland areas suffering severe and moderate flooding waterlog would be 732 and 103 $\times 10^4$ ha for continuous rainfall of 400 mm and 835 and 137 $\times 10^4$ ha for continuous rainfall of 600 mm.

(4) The severe, moderate and slight flood waterlog area would be submerged cropland in 1.5 ~ 3.5 m, 1.0 ~2.5 m and 0.5~1.5 m respectively.

5. ACKNOWLEDGEMENT

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