Research on flash flood disaster warning index: Case study of Luoning County

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Abstract. The intensification of global climate change, the increase in extreme weather, and the frequent occurrence of heavy rains have led to frequent flash flood disasters. The flash floods are fast, the time of convergence is short, and the destructive power is strong, making it difficult to predict prevention, which poses a huge threat to the lives and property of the people living in the hilly areas. Therefore, it is extremely urgent to carry out flash flood disaster prevention and early warning. Taking the three natural villages in Luoning County of Henan Province as an example, we carried out the determination of early warning period of flash flood disaster and calculation of early warning index. The research results can provide scientific support for local flash flood disaster warning work and reduce the loss of people and property caused by flash flood disasters.

1. Introduction

Due to global climate change, flash flood disasters occur frequently. According to data released by the International Meteorological Organization, flash floods have become the top natural disasters in more than 100 countries around the world, accounting for 75.5% of the total statistics[1]. Flash floods not only cause devastating damage to the infrastructure of the hills, but also pose a great threat to the lives of the people. This has become a prominent problem in the current disaster prevention and mitigation work, and is one of the important constraints to the sustainable economic and social development of the hilly area[2].

Due to the complex topography of the basin and the large river channel, the convergence time of heavy rainfall in the flood season is relatively short, which results in the flash flood have the characteristics of fierce momentum, fast flow rate, large destructive power and sudden burst. Therefore, the prediction and the prevention of flash floods are more difficult[3]. With the increasingly severe flash flood prevention and mitigation situation, flash flood early warning has become one of the main countermeasures usually taken at home and abroad[4]. Among them, rainfall early warning is the most important early warning method for flash floods disasters. Based on this, this paper studies the critical rainfall index and their determination methods for small river basins.

2. Analysis of early warning index

2.1 Determination of the warning period

The early warning period refers to the typical rainfall duration used in the rainfall warning indicator, which is an important component of the rainfall warning index[5]. The early warning period is closely
related to the upstream catchment area size of disaster prevention object, rainfall intensity, watershed shape and its topography, vegetation, soil water content and other factors.

(1) The longest period is determined: the convergence time of the upstream catchment area of each disaster prevention object is taken as the longest period.

(2) The typical period is determined: The short duration (such as 60 minutes, 180 minutes, etc.) that is smaller than the convergence time is used as the early warning period. Generally, two to three typical early warning periods are selected.

(3) Comprehensive determination: According to the torrential rain, the characteristics of the underlying surface and the historical flash flood conditions, combined with the river valley shape, the rising rate of flood, the transfer time and the population affected by the disaster prevention object, we determine each typical warning period for each disaster prevention object.

2.2 Consideration of water content in the basin

Consideration of the water content in the basin soil is the deduction for calculating the critical rainfall. According to the different soil water content in the early stage, three typical scenarios are designed, which are dry soil (Pa=0.2Wm), general (Pa=0.5Wm) and relatively wet (Pa=0.8Wm). Where, Wm is the maximum water content of the soil and Pa is the current soil water content. In this study, the flash flood early warning rainfall indexes under these three soil water storage capacities are considered.

2.3 Calculation method of early warning index

The calculation of the flash flood warning index mainly includes the following items.

(1) According to the measured data of the section, the critical flow corresponding to the channel near the disaster prevention object and the disaster-prone water level is calculated.

(2) According to the selected calculation period, the corresponding initial rainfall value is selected, and the appropriate design rain type is selected. The rainfall of each rain time step is calculated and calculated, and the corresponding net rain is calculated as the initial input condition of the model trial calculation.

(3) The test algorithm is used to calculate the flood process at the early warning location. When the calculated peak flow is close to the critical flow of the early warning location, the rainfall is the critical rainfall for that period, which is the immediately evacuating warning indicator.

(4) Considering the evacuation and transfer time of the masses to deal with flash flood disasters, combined with the location of the disaster prevention targets and the surrounding environment, we determine the preparing evacuating warning indicator by reducing the immediately the immediately evacuating warning indicator.

3. Case study of Luoning County

3.1 Overview of the study area

Luoning County is located in the west of Henan Province. The total area of the county is 2,306 km², the hills are 135.4 km², and the plains are 15 km². The area of the hills accounts for 99.5% of the county's land area. Luoning County is a warm temperate continental monsoon climate. Due to the influence of monsoon circulation, precipitation varies greatly with the seasons. Summer precipitation accounts for 55.7% of the whole year. Heavy rains occur frequently. The domestic rainstorm has the characteristics of concentration, large quantity and short duration. Due to the complex geology and geomorphology of the area and the impact of human activities, flash flood disasters occur frequently.
3.2 Determination of the warning period

This study takes three natural villages as examples, including the Goukou Village, Sanyizhai Village and Er’zu. The early warning indexes of three villages are analyzed and the warning period setting is shown in Table 1.
Table 1. Setting of the warning period

| Number | Disaster prevention object (natural village) | Confluence time | Early warning period          |
|--------|---------------------------------------------|-----------------|--------------------------------|
| 1      | Goukou Village                              | 4 hours         | 1 hour, 2 hours, 3 hours, 4 hours |
| 2      | Sanyizhai Village                           | 3 hours         | 1 hour, 2 hours, 3 hours       |
| 3      | Er’zu                                       | 2 hours         | 1 hour, 2 hours, 3 hours       |

3.3 Consideration of soil water content

According to the Handbook for the Design of Storm Floods in the Medium and Small River Basins of Henan Province, the comprehensive loss of runoff in Luoning County is about 3~8 mm/h and Wm=50mm. At the same time, different soil types also affect the amount of infiltration loss. The rainfall deduction settings considering soil moisture content are shown in Table 2.

Table 2. Rainfall deduction considering soil moisture content

| Disaster prevention object (natural village) | Goukou Village | Sanyizhai Village | Er’zu |
|---------------------------------------------|----------------|-------------------|-------|
| Watery state time interval (h)              | 1 2 3 4 1 2 3 2 |                   |       |
| Wet Initial loss (mm)                       | 5 5 5 5 5 5 5 5 |                   |       |
| steady infiltration (mm)                    | 3 3 3 3 3 3 3 3 |                   |       |
| General Initial loss (mm)                   | 8 8 8 8 8 8 8 8 |                   |       |
| steady infiltration (mm)                    | 3 3 3 3 3 3 3 3 |                   |       |
| Dryer Initial loss (mm)                     | 12 12 12 12 12 12 12 12 |               |       |
| steady infiltration (mm)                    | 3 3 3 3 3 3 3 3 |                   |       |

3.4 Critical flow calculation

Based on the measured cross-section data, the Manning formula was used to calculate the critical flow rate corresponding to the disaster water level for each natural village (Table 3).

Table 3. Critical flow of disaster prevention objects

| Disaster prevention object (natural village) | Disaster level (m) | Comprehensiv e ratio (%) | river channel rough rate | Critical flow (m³/s) |
|---------------------------------------------|--------------------|--------------------------|--------------------------|---------------------|
| Goukou Village                              | 552.22             | 17.47                    | 0.032                    | 204.0               |
| Sanyizhai Village                           | 421.24             | 16.54                    | 0.031                    | 182.0               |
| Er’zu                                       | 630.77             | 28.38                    | 0.034                    | 137.3               |

3.5 Result

3.5.1 Critical rainfall

The critical rainfall of different natural forests under different early warning periods was calculated by trial algorithm (Table 4).

Table 4. Critical rainfall of disaster prevention objects
### Comprehensive determination of rainfall warning index

**Considering the factors such as river valley shape, flood rising rate and early warning response time** of the rivers where the disaster prevention objects are located, we comprehensively determine the rainfall warning index for the preparing evacuating and immediately evacuating on the basis of the critical rainfall. Since the critical rainfall is calculated from the flood of the corresponding flow level of the disaster-causing water level, the critical rainfall is considered to be an immediately evacuating indicator. For the preparing evacuating indicator, it is a comprehensive “reduction” process of preparing evacuating time and the flood process line based on critical rainfall.

| Location                  | Event Type | Rainfall Intensity | Time (hours) | Confluence Time (hours) |
|---------------------------|------------|--------------------|--------------|-------------------------|
| **Er’zu**                 | 0.20Wm     | 1                  | 87           | 93                      |
|                           |            |                    | 3            | 103                     |
|                           | 0.50Wm     | 1                  | 83           | 89                      |
|                           |            |                    | 3            | 99                      |
|                           | 0.80Wm     | 1                  | 80           | 86                      |
|                           |            |                    | 3            | 96                      |
|                           | 0.20Wm     | 1                  | 71           | 78                      |
|                           |            |                    | 2            | 87                      |
|                           |            |                    | 3            | 91                      |
| **Goukou Village**        | 0.50Wm     | 1                  | 67           | 74                      |
|                           |            |                    | 2            | 83                      |
|                           |            |                    | 3            | 87                      |
|                           | 0.80Wm     | 1                  | 64           | 71                      |
|                           |            |                    | 2            | 80                      |
|                           |            |                    | 3            | 84                      |
|                           | 0.20Wm     | 1                  | 54           | 59                      |
|                           |            |                    | 2            | 66                      |
| **Sanyizhai Village**     | 0.50Wm     | 1                  | 50           | 55                      |
|                           |            |                    | 2            | 62                      |
|                           | 0.80Wm     | 1                  | 47           | 52                      |
|                           |            |                    | 2            | 59                      |
4. Conclusion
This study discussed the basic methods for calculating the early warning index of flash flood disasters, including the determination of early warning periods, the consideration of water content in the basin, and the calculation of early warning index. Taking the three natural villages in Luoning County of
Henan Province as an example, we calculated the early warning index of flash flood disasters, and obtained the warnings for the preparing evacuating of different early warning periods and the immediately evacuating of rainfall, which could provide support for local flash flood disaster prevention, early warning and the work of disaster prevention and mitigation.

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