Study on debris flow risk monitoring and Early Warning in Nujiang Prefecture, Yunnan Province, China

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Abstract. Debris flow is the mainly the geological disasters in Nujiang Prefecture, while precipitation is the trigger of it, how to implement debris flow forecast based on precipitation monitoring data or forecast data is a hot issue in current debris flow disaster research field. Because of the special geomorphology in Nujiang Prefecture, due to the influence of human activities, geological disasters occur frequently, severely affect the local economic development. As a demonstration area of geological disaster monitoring and early warning in Yunnan Province, to build a well-developed geological disaster warning system, it is very important to spread it to other parts of Yunnan province. Based on the analysis of the current situation of geological disasters in Nujiang Prefecture, adopt appropriate monitoring method and calculation method to select the primary sites for debris flow monitoring and early warning in the Nu River basin for research.

1. Introduction

Nujiang Prefecture and Honghe Prefecture in Yunnan Province have similar geological environment features, high mountains and steep slopes, and strong tectonic activities [1]. In recent years, geological disasters occur frequently in these two regions, constantly threatening the stability of the population and the society in the region. Therefore, Yunnan Provincial Department of Natural Resources takes Honghe Prefecture and Nujiang Prefecture as demonstration areas for geological disaster monitoring and early warning for demonstration area. To meet the needs of decision support for geological disaster early warning and emergency command in the demonstration area, how to draw lessons from the relevant technology and thinking of the big data, while ensuring the processing and analysis efficiency of geological disaster data, comprehensive utilization of spatial data and attribute data of geological hazards in demonstration area, to establish a set of perfect method of geological disaster warning system, it is an urgent problem to be in the advance of geological disaster early warning in Honghe Prefecture and Nujiang Prefecture at present stage.

The geological disaster monitoring and early warning project in Yunnan province has been piloted in the upper reaches of the Nu River since 2012, the geological disaster monitoring and warning equipment has been installed in Lijiang Prefecture, Qujing City, Zhaotong City, Honghe Prefecture, Nujiang Prefecture, Diqing Prefecture Dehong Prefecture Respectively, the professional monitoring
and warning network for geological disasters covers 34 counties (districts) in 7 prefectures (cities). At present, 1,807 sets of equipment have been installed and put into operation, realizing the dynamic monitoring of 170 important hidden spots of geological disasters include 141 mud-rock flows and 29 landslides.

2. Overview of the Research Area
Nujiang Lisu Autonomous Prefecture, located in the Northwest of Yunnan Province (figure 1), is a World Natural Heritage site of Three Parallel Rivers. Its geographical coordinates are 98°09′- 99°39′E, 25°33′-28°23′N. includes 1 city, 3 counties, a total of 29 townships. First highest elevation is 5128 meters, the lowest elevation is 738 meters, the relative height difference of 4390 meters, is a typical mountain ravines, the general terrain is higher in the north and lower in the south. Within the area there is Dandanglika Mountains, Gaoligong mountains, Biluo Snow Mountain, Yunling Mountain, and fast-flowing rivers include Nu River, Lancang River, Dulong River which from west to east and joint distribution, form the deep cutting mountain ravines Nujiang fracture Deep and large faults and secondary faults such as Lancang River fault and Biluo Snow Mountain fault are well developed, resulting in rock extrusion deformation, joint and fracture developed, integrity of rock mass destruction, reduced slope stability, and provided favorable conditions for the formation of slope geological disasters [2].

Figure 1. Location map of Nujiang Prefecture

There are 2018 all kinds of geological disaster points and Hidden troubles in Nu River basin, including 1076 landslide, 395 debris flow, 427 unstable slope. In recent years, frequent debris flow cause serious losses. For example, 1:30 a.m on August 18th, 2010, Massive flash floods and
mud-rock flows happened in Dongyue River in Puladi Villages of Gongshan County in Nujiang Prefecture. Debris flows crush into Nu River, caused the Nu River to be temporarily blocked, the water level above the accumulation body rises 6 meters, the water level drops tills landslide dam levee, but still 3 meters higher than the original water level. By August 26th, the disaster had affected 11,212 people in Gongshan County, resulting in 37 deaths, 53 missing, 9 seriously injured, 30 lightly injured, and 3,282 displaced people. The Dongyuegu iron ore dressing plant of Yujin Company was destroyed by mudslides, and infrastructure such as transportation, electricity and communications were severely damaged, resulting in a direct economic loss of 140 million yuan [3].

Through the study of the statistical calculations and spatialization treatment of the collected data, a preliminary analysis was conducted on temperature, humidity, rainfall, disasters present situation of Nujiang Prefecture, the analysis results show that the temperature is higher from May to September, there are two flood season in Gongshan County and Fugong County, while there is a flood season in Lanping County and Lushui County. The rainfall is concentrated in June to September in Nujiang Prefecture. LanPing County is recurrent area of geological hazards, followed by Lushui County, geological hazards occur in Fugong County is least of all, a high incidence of geological disasters from July to September, landslide and debris flow are the most important geological hazards in Nujiang Prefecture which happen the most and causes the most damage, they should be the focus of monitoring and defence.

3. Purpose and significance of the research
In recent years, because of the influence of the human engineering activities and natural factors, the incidence of geological disasters has obvious increasing trend than in the past, so the government and State investment in geological disasters increases year by year, especially in prevention and prediction of geological hazards, this is extremely important to the social development and guarantee the people's livelihood. At the present stage, the rapid development of artificial intelligence and information technology provides convenience for people's basic necessities of life, at the same time, the range of application is wider, especially in GIS (Geographic Information System) related technology in the application of geological disaster is increasing. How to organically combined Artificial intelligence and information technology with geological hazard prediction, this is a question that all sectors of society are thinking about, because it can not only improve the reliability and credibility of the government, more important is the economic losses and human casualties caused by disasters can be mitigated through early prevention [4] (figure 2).

4. Monitoring methods and contents
Implement the investigation of the rule of geological disaster combined with early warning forecast system construction, through field monitoring and simulation methods, find out the regional geological disaster formation conditions and characteristics to carry out regional geological hazard assessment, to explore the mechanism of geological hazards, to master the critical value of rainfall induced geological hazard under different background conditions[5][6]; Combined with the rain forecast of the meteorological department of the demonstration area, using monitoring data from mountain torrent mudslide level, disconnected wireless warning system, landslide fracture telescopic instrument, landslide warning telescopic instrument and pulviograph to carry out early warning and forecast of geological disasters in demonstration areas, then promote and apply in other areas of Yunnan Province.

The Nu River basin is characterized by great topographic fluctuations, complex geological conditions, and great changes in the formation conditions and characteristics of geological disasters. It
is difficult to identify these changes from regional regions due to huge workload, large regional differences in climate, strong randomness of rainfall, so accurate monitoring and early warning of geological hazards is difficult.

Figure 2. The direct economic losses caused by geological disasters in Nujiang Prefecture

4.1. Monitoring method

(1) flow calculation of debris flow

According to the research of Chinese scientists on debris flow gullies along Dongchuan and Cheng-Kun railway, the formula of debris flow based on the principle of rain-flood method is presented [7]:

\[ Q_c = (1 + \phi)Q_p \cdot D_c \]

In the formula:

- \( Q_c \) —— Peak flow of debris flow interface \((\text{m}^3/\text{s})\)
- \( Q_p \) —— Design peak flow of the storm \((\text{m}^3/\text{s})\)
- \( \phi \) —— Sediment correction factor of debris flow

\[ \phi = \frac{(\gamma_c - \gamma_w)}{(\gamma_H - \gamma_c)} \]

(2) Frequency of debris flow under storm flood

According to the formula of debris flow frequency under storm flood recommended in the appendix of the prevention for exploration and control projects of debris flow disaster(DZ/T 0220-2006)
\[ R = K_1 \left( \frac{H_{24}}{H_{24D}} + \frac{H_1}{H_{1D}} = \frac{H_{1/6}}{H_{1/6D}} \right) \]

In the formula:

- \( K_1 \) —— There is a correction factor for previous rainfall;
- \( H_{24} \) —— Maximum 24-hour rainfall;
- \( H_{24D} \) —— Maximum 24-hour rainfall limit for possible debris flow;
- \( H_1 \) —— Maximum 1-hour rainfall;
- \( H_{1D} \) —— Maximum 1-hour rainfall limit for possible debris flow;
- \( H_{1/6} \) —— Maximum 10-minute rainfall;
- \( H_{1/6D} \) —— Maximum 10-minute rainfall limit for possible debris flow.

The statistical analysis results are given according to the prevention for exploration and control projects of debris flow disaster.

- \( R < 3.1 \), Security rainfall regime;
- \( R \geq 3.1 \), debris flow disaster may occur;
- \( R = 3.1 \sim 4.2 \), Debris flow probability is less than 0.2;
- \( R = 4.2 \sim 10 \), Debris flow probability is between 0.2 and 0.8;
- \( R \geq 10 \), Debris flow probability is more than 0.8.

4.2. Monitoring and warning equipment

(1) Automatic rainfall monitoring transmission warning instrument

Monitoring equipment must be established to monitor rainfall for rainstorm debris flow, in order to monitor rainfall (Precipitation in time period and continuously varying precipitation). When conditions permit, use advanced automatic monitoring equipment such as telemetry rainfall monitoring system, storm radar ultra-short-time monitoring system and meteorological satellite short-time monitoring system to Conduct rainfall monitoring.

(2) Debris flow acoustic monitoring wireless warning instrument

debris flow vibration monitoring warning, range 0-5 V, warning value 0-5 V, continuously adjustable

(3) Remote sensing monitoring

In view of the depth of mountains and valleys in the Nu River basin, reach above Liuku town is long and narrow mountain canyon landform, with the maximum relative height difference reaching more than 4,000 meters. With the development of ravines and valleys on both river sides, debris flow
hazards are serious. In recent years, debris flow disasters have occurred many times, causing heavy casualties and property losses. Due to upstream of debris flow gully depopulated zone (formation area) With high mountains and steep slopes, no road feasible, It's hard for ordinary people to climb the mountains., ground survey is extraordinary difficult; Fortunately Uav aerial remote sensing system has the characteristics of high resolution of real-time, strong mobile and flexible images, which can not only operate in high-risk areas, but also have a broad application prospect in the process of early warning on geological disaster monitoring and emergency rescue.

Before the main flood season(from March to May), uav aerial photography remote sensing is used to investigate and monitor monitoring early warning points, and high-resolution aerial photography image is used to identify debris flow and landslide, identify debris flow source, the scale, developmental stage and activity routines of the debris flow to screening and determination of monitoring points. The displacement of disaster point can be monitored by superposition measurement of orthophoto map with coordinate information. The short-period dynamic monitoring of the change of basic parameters of debris flow can be carried out by ground multispectral land photography and ground stereophotogrammetry.

4.3. Group survey mass prevention and simple monitoring
The construction project of geological disaster monitoring and early warning demonstration area in the upper reaches of The Nu River basin is a geological disaster monitoring and early warning project based on specialized monitoring means of debris flow. The group survey, mass prevention and simple monitoring in the demonstration area are not included in the consideration scope of this project. The existing landslide and debris flow monitoring sites listed as group monitoring objects should be mobilized to organize local residents to conduct simple monitoring, with combine the efforts of both professionals and the masses, and disaster prevention and Mitigation for all, so that the residents in disaster-stricken areas can understand that professional monitoring is only a supplement and enhancement of the group monitoring and prevention, which cannot replace the group monitoring and prevention.

5. Geological disaster warning level
Mechanism of the geological disasters is more complex than drought, floods and other natural disasters, it is not only a simple rainfall caused disaster, The occurrence of geological disasters is usually caused by the basic geological environment conditions and external forces, risk assessment mainly includes the geological hazards susceptibility based on the geological environment condition and based on the induction of timeliness.

The occurrence of geological hazards is not a random event, it is often accompanied by the early stage of the development of geological disasters, this is a gradual process, it can be found in historical disaster statistics, we found the occurrence of geological disasters mainly focus on June, July and August which is high rainfall season by statistics on historical disasters, and in the early stage of the geological disaster is often accompanied by continuous rainfall, which has a direct inducing effect on geological disasters. Therefore, rainfall is selected as the inducing factor of geological disasters, to express the possibility of geological disasters on the time dimension of the actual investigation in the historical process, we found that the in the early stage of geological disasters, such as landslide, debris flow and collapse, there is a heavy rainfall process in general, which indicates that the influence of rainfall on geological disasters often has hysteresis and the lag time has some regularity.
The following table shows primary point basic information of Debris flow monitoring and Warning in Nu River Basin.

**Table 1.** primary point basic information of Debris flow monitoring and Warning in Nu River Basin

| No. | Name of the debris flow gully       | The main channel length(km) | Morphology of the gully | drainage area (km²) | grading forecasting | Notes                  |
|-----|-------------------------------------|-----------------------------|-------------------------|---------------------|---------------------|------------------------|
| 1   | Wangqi gully                        | 6.52                        | straight                | 9.5                 | III                 | mid-long-term          |
| 2   | Jimudou gully                       | 2.14                        | bend                    | 2.2                 | IV                  | mid-long-term          |
| 3   | Longpo river gully                  | 8.42                        | compound                | 18                  | III                 | mid-long-term          |
| 4   | The hill behind the cultural center gully | 0.85                     | straight                | 0.34                | III                 | mid-long-term          |
| 5   | Dandang River gully                 | 1.97                        | bend                    | 1.15                | II                  | in the near future     |
| 6   | Adudi gully                         | 1.14                        | straight                | 0.3                 | III                 | in the near future     |
| 7   | Cikaiqing gully                     | 4.36                        | compound                | 5.95                | I                   | in the near future     |
| 8   | Agala gully                         | 2.5                         | compound                | 1.66                | I                   | in the near future     |
| 9   | Wazanka gully                       | 1.82                        | straight                | 1.23                | II                  | in the near future     |
| 10  | Wangzanka gully                     | 1.19                        | straight                | 0.45                | IV                  | mid-long-term          |
| 11  | Niulangdang River gully             | 7.74                        | compound                | 14.5                | III                 | mid-long-term          |
| 12  | Galabo River gully                  | 23.34                       | compound                | 124.5               | II                  | in the near future     |
| 13  | Danzhu River gully                  | 17.14                       | bend                    | 115                 | II                  | in the near future     |
| 14  | Qilangdangluo River gully           | 5.79                        | straight                | 11.6                | III                 | mid-long-term          |
| 15  | XIyuwege River gully                | 10.58                       | bend                    | 28                  | III                 | mid-long-term          |
| 16  | Litoudi gully                       | 5.1                         | straight                | 9.5                 | IV                  | mid-long-term          |
| 17  | Lijibuluq gully                     | 2.3                         | straight                | 1.4                 | III                 | mid-long-term          |
| 18  | Dulongdi gully                      | 5.14                        | compound                | 8.5                 | III                 | mid-long-term          |
| 19  | Lazanyima River gully               | 6.95                        | compound                | 16.5                | III                 | mid-long-term          |
| 20  | Shangpa River gully                 | 11.86                       | compound                | 54                  | I                   | in the near future     |
| 21  | Zilijia River gully                 | 15.76                       | bend                    | 36.5                | I                   | in the near future     |
| 22  | Jinman River gully                  | 16.53                       | bend                    | 60                  | I                   | in the near future     |
| 23  | Gudeng River (Sezhong River) gully  | 11.78                       | bend                    | 24.7                | I                   | in the near future     |
| 24  | Weilizu gully                       | 16.03                       | compound                | 35                  | II                  | in the near future     |
| 25  | Denglongba gully (Tingming River)   | 30.25                       | bend                    | 18                  | I                   | in the near future     |
| 26  | Denggeng River gully                | 17.5                        | compound                | 72                  | III                 | mid-long-term          |
| 27  | Ayaluo River gully                  | 13.23                       | compound                | 36                  | III                 | mid-long-term          |
| 28  | Laogan River gully                  | 2.47                        | straight                | 5                   | I                   | in the near future     |
| 29  | Pailu Dam gully                     | 4.75                        | compound                | 5                   | I                   | in the near future     |
| 30  | Laimao gully                        | 9.98                        | bend                    | < 5                 | I                   | in the near future     |
| 31  | Shigang River gully (Including its tributary Sancha River) | 20.85 | straight | 18 | II | in the near future |

6. Conclusion
Intelligent monitoring equipment is the basic conditions for professional monitoring and early warning work, intelligent dynamic geological disaster monitoring data acquisition technique is to obtain
effective monitoring data support, monitoring equipment will also continue to be developed in this direction in the future. The process warning model can accurately judge the deformation development process of geological hazards, it played a reliable role in professional monitoring and early warning, the improvement of the early warning model will also further enhance the effect of the geological disaster early warning. Multi-source data collaborative warning is also the main development direction in the future. With the continuous improvement of monitoring and early warning technology, scientific and professional monitoring and early warning will eventually make greater contribution to human disaster prevention and reduction.

Nujiang Prefecture is the area where debris flow disaster occurs frequently, as the study area of debris flow warning research can provide reference for the local disaster prevention and mitigation work, reduce the loss caused by debris flow disasters. Due to the population distribution in Dulong River area of Gongshan county is small, and the geological conditions are relatively good, it may not trigger a debris flow even when it rains a lot, easy to cause an early warning null, but rainfall tends to be low in Lanping County, and Severe geological conditions in LanPing County, less rainfall could induce debris flow disasters, It is easy to cause omission forecast, if early warning and forecast models are established respectively combine the different in areas liable to geological disasters and population distribution area can make the results more precise.

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