A REVIEW OF AN EARLY-WARNING TECHNIQUE OF FLASH FLOOD AND DEBRIS FLOW DISASTER

Zhou Jinxing[A], *Wang Yan*[A] *and Liu Yijun*[B]
[A] Research Institute of Forestry, Chinese Academy of Forestry, Beijing, 100091
[B] College of Resource and Environment, Southwest Agriculture University, Chongqing, 410716

Abstract
Early-warning techniques for flash flood and debris flow disaster is always taken as an important aspect in the field of disaster prevention and reduction in mountainous areas worldwide. This paper indicates that space forecasting, time forecasting and a system of early-warning techniques are major branches of forecasting, which are analysed and summarised on the basis of current research and investigation in China and abroad. Researchers from China and elsewhere are now focused on establishing regression models of the quantity and strength of rain when debris flow occur. There are slight differences between such researchers in selecting the parameters of rain rate and the number of effective rain days. At the end of this review, we have provided an outlook on the development of early-warning techniques for flash floods and debris flows disaster in the future.

Additional Keywords: Flash flood and debris flow disaster, early-warning technique, review

Introduction
There are a lot of disputes over the precise definition of flash floods and debris flow disasters. We considered a flash flood is a flood from the river (rivulet or torrent) in mountainous areas. Debris flow includes a mix of solid and liquid materials, occurring on vales and slope. Debris flow is also taken to include the blending of gas, water and soil (relaxed solid) from hyper-concentrated flows in mountainous areas.

Flash flood and debris flow disasters are usually considered as a bane to human beings and social economic systems, but not all flash floods and debris flows result in disaster, particularly in sparsely populated high mountainous region. Many developed countries try to alleviate losses caused by flash floods and debris flows but still cannot avoid this kind of disaster completely. In China, with big mountainous areas and a large population, flash flood and debris flow disasters can result in serious losses, with significant effects on economic development.

Because of the serious dangers and complicated cause and effect factors, flash flood and debris flow disasters cannot easily be brought under control. Residents in dangerous regions can get warning information in time and take measures in advance to avoid loss. Early-warning techniques are valid, feasible and realistic in protecting life and property of people in dangerous mountain areas. With the development of the UN's activity in reducing impacts of disasters, China should be doing its contribution in respect of reducing disaster impacts, particularly in the mountain areas, by using advanced science and technology to estimate and distinguish risk, identifying high risk slopes in ditches, forecasting disaster ranges and measuring the period to flash flood and debris flow after the incident of rainfall. Only through these methods will the risk of flash flooding and debris flow be precisely forecasted. Early-warning techniques for flash flood and debris flow disasters are always a topical point in China and abroad. There are many achievements in the technique at present, including space-forecasting technique, time-forecasting technique and early-warning system.

Space Forecasting Technique
The space-forecasting technique of flash flood and debris flow is a measure of the danger in a region and district, achieved by compartmentalizing flash flood and debris flow ditch, evaluating the danger level and undertaking hazard zone mapping.

Present condition in area outside of China
Currently, international experts generally accept the measure of torrent classification and hazardous zone index by Austrian scientist Oliches, which is scientific and feasible. By analysing danger level and degree of flash flood or debris flow disaster in ditch or alluvium, red zone, yellow zone and white zone are classified in order that government and people may take measures to control the disaster. Its main technique is to investigate and adopt sample to analyze the concrete ditch or torrent, namely adopting 9 indexes and 51 concrete factors to obtain the danger index. Japan is also one of the previous countries in studying early-warning technique of flash flood and debris flow. Japanese scientists established different kinds of danger range forecasting models of debris flow, by

studying the accumulated quantity and extent that debris flow rushed out. The scientists studied hazardous degree of debris flow and mainly focused on physiognomy condition, the form of debris flow and rain to make certain frequency of debris flow disaster. They include different factors, and each factor also involves several grades that give corresponding score, then probability that debris flow occurred is calculated and the statistic and the danger grades is obtained. Eldeen (1980) a Swedish scientist, mapped danger zones to forecast disaster type and grade. Take flood disaster as example, according to dangerous grades, 4 grades dangerous zone were classified in easy-occurred flood area, and each grade also consisted of 1-5 subzones, which would conclude the range of flood disaster. In addition, such as American and German, these countries also finished the hazard zone mapping. Though the countries all adopted synthetical index to classified dangerous zone, Austria has already reach to the extent the flash flood or debris flow disaster took place at each ditch or torrent, and other nations only different in which region would be occurred to disaster in large range. In fact, not all flash flood and debris flow ditches have been placed in dangerous area and occurred to disaster, so except Austria, other countries all demarcated hazardous zone in macroscopy. In spite, dangerous zone division and mapping contribute to space forecast of debris flow in large scale and has been used widely in disaster insurance, forecast and recourse, and so on.

Present conditions in China

There are many scholars domestic to research the space range demarcation of dangerous flash flood and debris flow zone, and this work began in 1985 and its main achievements are the disaster distribution and demarcation mapping of flash flood and debris flow in China, published in 1991. Analogously, discussing dangerous zone demarcation of Chinese flash flood and debris flow by Fang Bangxing and Liu Xilin, studying on dangerous degree demarcation of debris flow upriver at Yangtze river and dangerous analysis on debris flow disaster at province Liaoning. Three kinds among these research methods take on representative meaning.

The first method, the danger level of the whole debris flow ditch can be defined by risk degree analysis with composite index, basing on the judgement of debris flow ditch or non debris flow ditch. Tan Peiyan from Academy of Railway Sciences thought, according to math, physics and chemistry to grade, with 15 kinds index of judging debris flow ditch and dangerous level, total score exceed 85, for serious dangerous debris flow ditch, and from 63 to 87 for general danger ditch, from 33 to 63 for mild danger and under 33 for no danger ditch. District structure effect, plant cover of watershed, lithology effect quantity of relax materials among the ditch and slope grade of the ditch bank are quantified equally to value affect factors on debris flow, for it, without sufficient basis, so the author think it needs more research. For example, with 15 kinds indexes to district, different area adopts to different grade standard according to actual condition to improve accuracy in judging dangerous level of debris flow. As a whole, this method judging debris flow ditch is wide used currently in China. Investigating, judging and comparing 377 ditches along 11 railways, the result showed 85 percent judgements were unanimous, which attest to the method scientific and feasible.

The second method, the danger level of the different districts can be defined by investigating the risk degree and distribution density of debris flow ditch. The method includes 2 types, one is to grade by analyzing dangerous degree of debris flow ditch, and defining the danger level of whole debris flow ditch in the area. This type embodies the idea of debris flow demarcation, and reacts on forecasting disaster and making decision in macroscopy. At present, production usually is used at the county scale. Take Beijing as example, according to terrain and distribution density of debris flow ditch including 8 valued factors, Miyun county was divided into 5 grades dangerous zones by researching 20 debris flow ditches. Main technique was to divide 8 factors into 4 grades, and give a score for each grade, then add the grades of each factor to obtain dangerous level. So, above 144 for wondrous danger, from 108 to 144 for high danger, from 72 to 108 for notable danger, from 36 to 72 for possible danger, under 36 for no danger. At last, with different risk degree and distribution density of debris flow ditch,the area was divided into 4 grades dangerous zones and non dangerous zone. The other type is to value each unit in the whole region with the valued factor. For instance, Liu Xilin and his colleagues selected 8 indexes from 18 concrete indexes by correlative analysis in 10 countries and cities in province Yunnan. After synthetic analysis on the weight of each index, ten countries and cities was divided into 5 grades dangerous zones and non dangerous zone. This method is a feasible subarea method of flash flood and debris flow on large scale, because of 8 indexes' data collected easily and less workload. But, the author thinks this method gives the most weight of debris flow ditch density, it affects precision of subarea directly, so judgement and investigation in debris flow ditch should be strengthened.

The third method is to classify torrent by selecting certain index and adopting different dangerous zone model to divide the whole ditch into dangerous zone and more dangerous zone. For example, Wang Lixian classified 228 ditches in Beijing region with synthetic exponential method by selecting 6 indexes and 24 factors. Main judgement standard is synthetic exponent, above 3.0 for strong destroyed debris flow ditch, from 2.7 to 3.0 for desolated debris flow ditch, from 1.9 to 2.7 for high density flood, under 1.9 for general flood. The analyzed result showed Beijing had 24 for strong destroyed ditches, 249 for desolate ditches, 986 for high sand flood and 1021 for general. The flood peak runoff and velocity of each flash flood or debris flow were calculated to divide and mapping dangerous zone, combining with dangerous zone model. This method's prominent characteristic is to investigate each potential flash flood or debris flow disaster ditch and map different type torrent. So the forecast about flash flood and debris flow would be veracious and scientific obviously, though the most workload among above mentioned. At present, some advanced methods are put forward, such as information management system about torrent classification and dangerous zone mapping, numerical simulation and neural network technology, etc to make off dangerous debris flow ditch, which will lessen workload.

Time Forecasting Technique

In fact, time forecasting technique is about to forecast what time the flash flood and debris flow happen. It includes medium to long term forecast and real-time forecast.

Medium to long term forecasting technique

From C.M.Fulanst's idea, the method is mainly to forecast the trend of flash flood and debris flow by researching its frequency and period, analyzing historical statistical data and information. The result that the sum add two neighboring time interval of the flash flood and debris flow disaster divides total times occurred in the ditch in past, then subtract 1, is used to make sure the period and activity of flash flood and debris flow disaster. For instance, by researching the period of flash flood and debris flow in Beijing region, Cui Zhijiu concluded that there must be flash flood with debris flow every 8 years. According to the period and frequency, Beijing mountainous area was divided into two kinds, namely serious debris flow occurred ditch and general debris flow occurred ditch.

Real-time forecasting technique

This method can alleviate and avoid the lose of flash flood and debris flow disaster by studying the rule of rainstorm, flash flood and debris flow disaster and early-warning in time. Real-time forecasting technique of flash flood can be forecasted with hydro-meteorological and runoff model. On April, 1980, International Hydrological Science Institute and WMO held a seminar on international hydrological forecasting at Oxford, Britain. At the conference, there were 16 papers about real-time forecasting technique from 46. Real-time forecasting technique on rainstorm and debris flow meets with more and more recognition. Its main technique lies in collecting and analyzing precipitation to make sure critical precipitation and spring precipitation. Of course, some researchers also make certain critical rainfall by studying the developed mechanism of debris flow and rainfall process equation, such as runoff process, rain process and groundwater seepage. To sum up, at present, among the real-time forecasting technique of the debris flow, critical precipitation and rainfall analysis, man observation and equipment monitor are more studied. Forecasting model have the statistical regress model and developed mechanism model. Main methods include the mathematical statistics method, grey system theory, neural network and 3S techniques.

Critical precipitation and rainfall analytic method: According to the analysis on historical precipitation condition in debris flow ditch, combining with its form condition, with regression, statistical analysis, grey forecast, neural network and intelligent model, etc, critical precipitation is made sure. According to weather forecast, real-time rainfall condition and critical precipitation or forecast model, the possibility occurred to flash flood and debris flow is made certain.

Man observation method: When rainstorm come forth up on the upriver, observers immediately look over the collapse condition on slope and the flood in ditch. If there is big collapse and more and more runoff, or the flood turnoff suddenly, it should be done that transmitting early warn.

Equipment monitor method: Disposing touched or untouched instrument in ditch or dangerous zone, when they monitor serious collapse or flash flood and debris flow, the apparatus will alarm to catchment area. For Kang Zhicheng as example, he put ultrasonic hydro-probe in mud of debris flow ditch to monitor and forecast based on initialization. Another example, Che Jingri monitored under-audio of debris flow by alterant sensor named DT-1 type.

Man observation and equipment monitor methods have been applied in practice in spite of not much literature and data. For instance, 76 times coasted debris flow disaster were forecasted successfully and protected life and property by water and soil conservation bureau of Yangtze River committee from 1990 to 1997. There more papers on critical precipitation and rainfall analysis. For Chen Jingwu, by analyzing actual water conservancy data, concluded critical rainfall discriminant that the debris flow formed and broke out, then made into forecasting map. As far as constituting rainfall density and effective precipitation combined discriminant, most domestic researchers adopt to linear regress to constitute linear equation, none but different parameter of rainfall density and efficient precipitation. In the 70's, Chen Jingwu used one day's rainfall before the debris flow broke out and intraday rainfall as efficient precipitation and selected 10 minutes rainfall density to constitute linear equation. Wang Lixian adopted previous 3 days or 5 days or 15 days rainfall and intraday rainfall to constitute regress model, and researched the result of debris flow disaster with non-linear neural network model. Japanese researcher also constituted forecasting model with intraday rainfall and previous 1 hour rainfall density. It can be used to make sure critical rainfall line and refuge alarming line and protract forecasting map. Most representative models include linear regress model y=ax+b and exponential model y=ax.

Early-Warning Systems

Abroad research concerning early-warning system of flash flood and debris flow, primarily is to establish sensor to receive frequency and extent signal of flash flood and debris flow, then constitute early-warning system with advanced transmission technique. As early as 40's, the former Soviet Union developed the research about characteristic and mechanism of debris flow. In look for refuge system to debris flow disaster, in end of 70's, before the debris flow break out, setting sensor in ditch and adopting non-wire and wire cable to transmit the simulant frequency and extent signal of debris flow to downriver control station for disposal and judgement ahead. So before the debris flow takes place, transmitting alarm to residents and department in ditch can avoid or lessen the lose of life and property. Japan is placed in lead position in the aspect of early-warning system of debris flow and hold more advanced instrument equipments. They adopt high mud position checking wire, touched mud position checking wire, vibrating sensor and special wire cable for delivering passage. Now, Japan has began to establish early-warning system in a concrete ditch or neighboring several ditches on a small scale. By analyzing rainfall data in upriver area, making sure critical rainfall and critical rainfall alarming borderline to portract forecasting map. Rainfall computer sensor and RS instrument collect real-time rainfall data ,then compute and compare and distinguish, two methods above mentioned are adopted more aboard, the former must overcome the interference of earthquake etc, the latter must establish more rainfall sensors in the same ditch.

The research on early-warning system of our country mainly is railway system and Chinese Science Academy (CSA). Railway Structure Institute, Railway Science Academy, made sure critical rainfall and critical line of disaster and established sensor form and so on, by disposing and collecting and analyzing rain data before debris flow disaster. Dongchuan debris flow monitor station by CSA has constituted early-warning system with telemetric rainfall equipment and telemetric under-audio siren by computer collecting and coordinating data and establishing forecasting model of debris flow.

Specially, in current mountain area in our country, undeveloped transportation and more residents in flash flood and debris flow ditch and lagged communication method all baffled from the found of early-warning system. Now, China and Austria cooperated item AB by Beijing city science and technology committee, special subject 5---early-warning system research of flash flood and debris flow in Beijing mountainous area, will forecast and deliver information and form a excellent early-warning system, with advanced data transmission equipment, such as telephone and network, by early-warning model of flash flood and debris flow based on torrent classification and dangerous zone mapping and combining with meteorologic data. Its main characteristic is gathering more information and making the data management and search and model analysis and information announced, in integral whole, mainly including data transmission rapidly and data renew rapidly and simply and feasibility and maneuverability etc. Railway department also apply GIS, Visual FoxPro terrace to develop early-warning system of flash flood and debris flow. According to the railway test between Chendu and Kunming, the result showed well.

Prospects for the Development of an Early-Warning Technique in the Future

There are range of methods available to develop early warning systems include traditional statistical regression, grey forecasting, neural network forecasting, and intelligence forecasting. Forecasting critical rainfall intensities and quantities is most important. Historical statistical and actual data should be combined with accurate meteorological forecasts to identify risk. Combining manual observations, automatic monitoring systems and the forecasting system automatically will improve predictive abilities. Traditional real-time reconnaissance at specific locations will assist in confirming the predictive capabilities of the system. Considering the range of topographic and climatic conditions, high efficiency early-warning systems will need to incorporate a range of advanced data transferal methods and combine a range of advanced techniques (eg. meteorological forecast, radar technique, forecasting model, equipment monitor, network and data transmission by satellite).

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