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Two Decades of Geo-hazards Risk Early Warning Based on Meteorological Factors in China and New Research Advances

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Abstract: China is one of the countries most severely affected by geo-hazards in the world. China's geological conditions are complex and diverse, and geo-hazards are widely distributed. Rainfall serves as the primary triggering factor for these disasters. Since the launch of the geo-hazards early warning based on meteorological factors in 2003, it has played an important supporting role in geo-hazard prevention and reduction. This paper reviews the 20-year development of China's geo-hazards risk early warning based on meteorological factors, highlighting advances in technology, methodology, and disaster prevention effectiveness. It further presents recent progress in machine learning based early warning methods using big data and artificial intelligence. From the model construction process of training sample-set construction, sample learning and training, model parameter optimization, model preservation, warning output, and so on, a method for constructing a regional landslide early warning model based on machine learning was systematically proposed.

Keywords: ***Geo-hazards, Early warning model, Development process, Machine learning.***

Introduction

China is one of the countries most severely affected by geo-hazards worldwide. The country has complex and diverse geological conditions, and geo-hazards are widely distributed, and rainfall plays a dominant role in triggering these disasters. Since the launch of geo-hazards risk early warning based on meteorological factors in 2003, the system has played a vital role in disaster prevention and mitigation. Over the past two decades, national and provincial authorities have continuously improved monitoring, forecasting, and early warning mechanisms. A comprehensive multi-level operational framework has been established, covering the national, provincial, municipal, and county levels.

In recent years, traditional regional landslide early warning models have faced limitations. Complex triggering mechanisms, insufficient data, and the lack of advanced data-driven methods have constrained their accuracy and reduced spatial refinement. To address these challenges, machine learning techniques have been introduced into the regional landslide early warning systems. These methods integrate geological, environmental, and meteorological data to build models with improved accuracy and generalization. They offer new directions for refined and adaptive early warning of rainfall-induced geo-hazards.

20 years of early warning for China regional Geohazards

The early warning process is divided into three stages: initiation and promotion (2003-2009), deepening cooperation (2010-2017) and reforming and upgrading (2018-2022). With 24-hour early warning work as the main content, progress in prediction, forecasting, and early warning has gradually been established, forming a relatively complete early warning system (Figure 1).

Three sets of early warning model technology and method systems have gradually been formed, including the critical precipitation threshold model, the threshold model based on geo-hazards risk, and the dynamic early warning model, with relevant industry standards released.

The warning time scale is mainly 24 hours, and has developed to medium- and long-term scales, such as 72-hour forecasts. In more than 8 provinces, early warnings in some cities and counties have included 3-hour short-term impending warnings, gradually forming a system to support short-term warning responses, medium-term prevention and long-term planning. The awareness of multi-party disaster prevention has been continuously enhanced. After receiving early warning information, the cases of strengthened inspection, investigation and organized personnel evacuation for successful risk aversion have been increasing, and the results of disaster prevention and reduction have been remarkable.

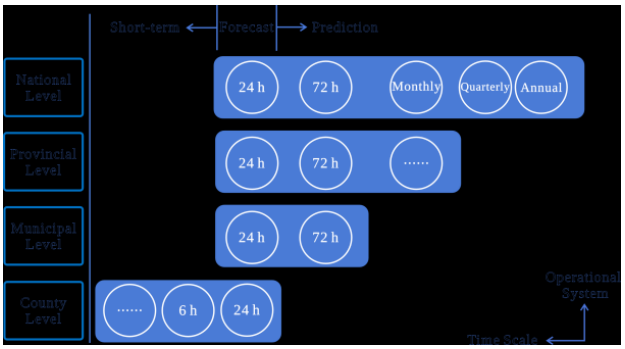

Figure 1, Schematic diagram of early warning and forecasting system.

Research on a regional landslide early-warning model based on machine learning

① The construction process of the training sample-set is shown in Figure 2, which mainly includes three steps: geological environment and rainfall factor feature library construction; positive and negative sample sampling; sample feature attribute extraction.

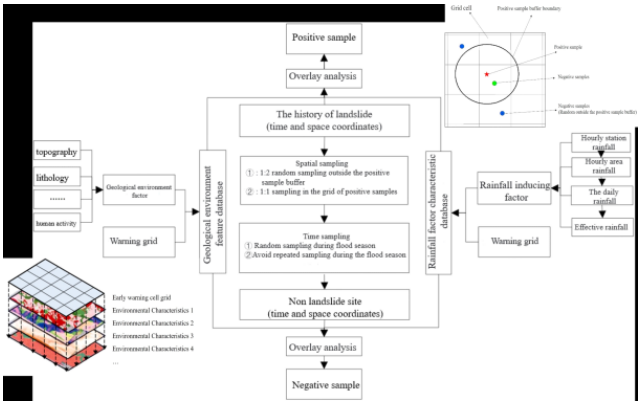

Figure 2, Distribution map of geological disaster points in Fujian Province.

② Six machine learning algorithms, including Random Forest, Artificial Neural Network, K-Nearest Neighbor, Logistic Regression, Support Vector Machine, and Decision Tree were compared to evaluate model performance. The Random Forest algorithm achieved the highest accuracy (92.3%) and demonstrated the strongest generalization capability (AUC = 0.955: Figure 3). ③ Compared with the traditional statistical model, the new model achieved a sixfold or equal improvement in hit rate, while the landslide density in the early-warning area was 1.6-1.7 times higher, indicating significantly enhanced accuracy and a reduced false alarm area (Figure 4).

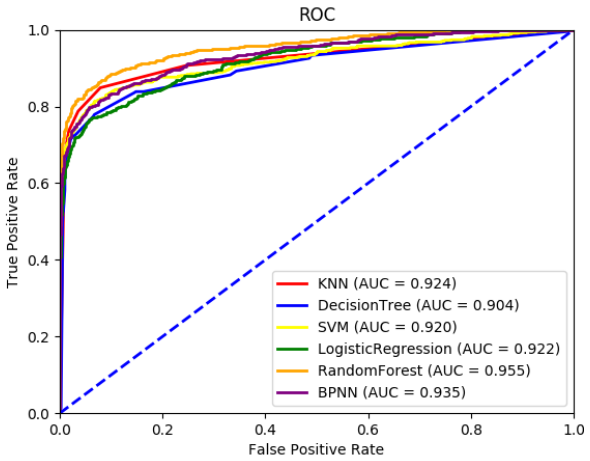

Figure 3, Comparison of ROC and AUC of six machine learning early-warning models.

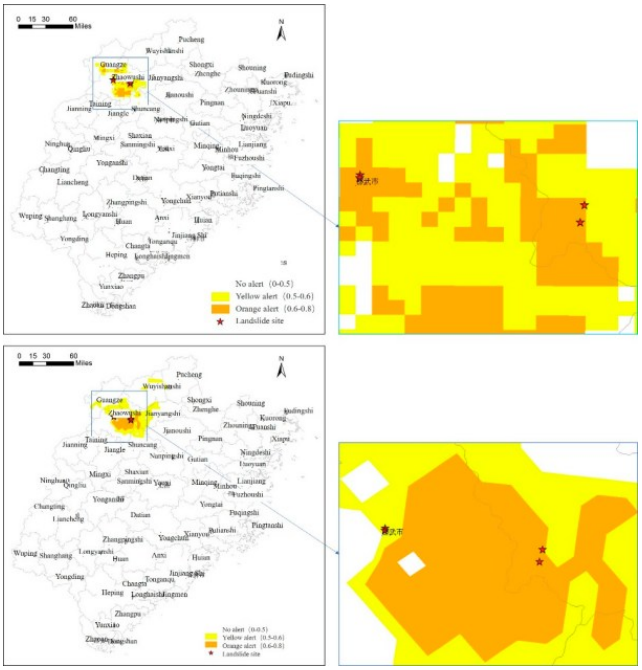

Figure 4, Comparison of early-warning results of different models on 28 June 2021 (above: early-warning results of Random Forest model; below: explicit statistical model warning results).