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Application of traditional manual measurements and remote sensing technologies in monitoring natural disasters

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Abstract. Natural disasters have occurred frequently worldwide. Some manual measurements and remote sensing technologies are widely believed to be effective and convenient in hazard monitoring. This study illustrates the causes and impacts of three natural disasters including floods, wildfires and earthquakes, and analyzes the application of traditional and remote sensing technologies in monitoring these natural disasters. In flood monitoring, traditional tools include meteorological and hydrological detection facilities and equipment could obtain rainfall and water level. Remote sensing technologies could extract water bodies and make disaster evaluation. In wildfire monitoring, traditional tools include the standard equipment of urban fire departments, portable pumps, tank trucks, and earth-moving equipment. Remote sensing technologies could be applied to fuel mapping and fire estimates. In earthquake monitoring, traditional tools include seismic measurement, crustal deformation observation, geomagnetic measurement, telluric observation, gravity observation, in-situ stress observation, and groundwater dynamic observation. Remote sensing technologies could help monitor through house images and thermal data. Remote sensing technologies bring natural disaster monitoring systems a great revolution, both in data acquisition and processing methods.

Keywords: natural disasters, remote sensing technology, floods, wildfires, earthquake.

1. Introduction

For a long time, natural disasters have been causing damage to human society. According to Munich Re Group, global losses from natural disasters reached $210 billion in 2020. Besides, over 4 billion people have been affected from 2000 to 2019, nearly a billion more than in the previous 2 decades. As a result, natural hazards are of the major concern in society. However, its governance and impact are often complicated due to different causes and locations. In order to develop disaster response guidelines, it needs to monitor natural disasters first.

Traditionally, monitoring methods mainly rely on manual measurements such as fire patrol. Regarding technology, remote sensing (RS) technologies are widely believed to be effective and convenient in hazard monitoring. People can easily use the data from earth observation satellite or UAVs to quickly obtain the damage caused by natural disasters. Then, combine the multi-sensor RS data and the different digital image processing methods with GIS technology to develop both a short-time approach forecasting system and emergency monitoring. For a specific disaster, through the processing of multi-remote sensing data and the observation information of meteorological satellites, RS

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technology can provide important support for weather analysis, environmental monitoring, climate monitoring, resource assessment and disaster warning. When the disaster is over, we can also get an accurate post-disaster damage report after the spatial and temporal variation analysis. Last but most important, with the comprehensive analysis and statistical analysis method of GIS, people need to do more to prevent the next disaster. Therefore, this study aims to illustrate the theories of the typical RS technologies and their application in monitoring three natural disaster cases: floods, wildfires and earthquakes.

2. Application of remote sensing technologies in floods

2.1. Background of flood disaster

2.1.1. Cause of floods. There are many reasons for floods. Flood is the phenomenon that the flow of water or the level of water in rivers, lakes and oceans increases sharply due to heavy rain, melting snow, melting ice and dam-break. The disaster always occurs when the water overflow. Natural processes such as hurricanes, weather systems and snowmelt can cause floods. Other floods following tsunamis and coastal surges have natural causes like earthquakes in the seabed and high tides attributed to the pull of the moon [1].

Human activities are also a major cause of floods. For example, soil erosion is more and more serious in the development and construction processing, as many people are cutting down increasing trees, the capability of flood discharge is weakened. For many developing countries, inadequate drainage in some urban areas cannot match urbanization. Unplanned urban layout also has been considered as an important factor in flooding in those countries.

Furthermore, human activity can indirectly cause flooding through climate change. Global warming cause icebergs to melt and sea levels to rise. For each degree rise in temperature, the amount of saturated water vapor in the air increases by 7 percent. However, there is only a 2-3% increase in the intensity of evaporation at the surface for each degree of temperature rise. So it takes more time to evaporate, allowing the amount of water vapor in the air to reach the level of rainfall. Rising sea levels also lead to larger water areas, longer rainy seasons and more frequent flooding.

2.1.2. Impacts of floods. Flood disaster is the most common natural disaster with destructive force. When a flood happens, it always kills people, inundates the farmland, destroys crops, and destroys man-made facilities. As a common disaster, many floods cause no damage. However, the maximum damage of the flood is incalculable. From July 17 to 23, 2021, a severe flood disaster occurred in the central Chinese province of Henan, causing a total of 14.786 million people affected by the disaster, 398 people died or went missing due to the floods, and the direct economic losses amount to 12.06 billion yuan.

Changes in climate, land use, infrastructure and demographics are closely related to flood hazards, increasing the severity, duration and frequency of destructive floods, with global flood losses estimated at US $651 billion between 2000 and 2019.

2.1.3. Traditional flood monitoring technologies. From ancient times, building reservoirs to store natural water has been another popular method of flood control. Around 2650 BC, Egypt built the Sadd El Kafara Dam on the Wadi Garawi River, creating a reservoir for flood control. Of course, there are other ways of doing this. Dujiangyan, located in Chengdu, is a grand water conservancy project originally constructed around 256 BC in the Qin dynasty, Then it has been modified and expanded over thousands of years. Dujiangyan uses natural topographic and hydrological features to solve problems of diverting water for irrigation, draining sediment, flood control, and flow control without the use of dams [2]. In general, the core idea of flood control is dredging and plugging through engineering.

In modern times, people have paid great attention to the study of flood control and disaster reduction and the research on emergency management decision-making. Since the 1960s, non-engineering measures, which include floodplain management, flood forecasting and warning, and flood prevention programs, have been promoted worldwide.

With the further development of nature, floods have the potential to cause even more terrible disasters. To find the best method for flood management under different conditions, flood monitoring seems to be the basis of all measures. As traditional flood monitoring mainly uses meteorological and hydrological detection facilities and equipment to obtain meteorological and hydrological observation data such as rainfall and water level. It is difficult and costly to operate and maintain, and unable to reflect the occurrence of flood disasters objectively and comprehensively.

2.2. Application of remote sensing technologies in monitoring floods

With the development of RS technology, modern flood disaster monitoring can offer a comprehensive understanding of every flood disaster wherever and whenever, which greatly benefits flood disaster control. This part mainly discusses its application in water body extraction and disaster evaluation.

2.2.1. Water body extraction. After satellites and drones offer us images not available through traditional methods, the first nut for us to check is to extract information about water bodies. There are many methods to apply, such as single-band threshold, ratio, vegetation index, water index, and object-oriented methods. After practical application, the water index method has a good effect on water extraction. Radar data has the characteristics of penetrating clouds and rain and can work all day. However, radar data could be affected by terrain, which means that sometimes would misjudge the shadow as water body for mountainous areas. Terrain data are needed as auxiliary data when applying radar data for water extraction.

In July 2021, a severe flood disaster took place in Henan Province, China. Use Sentinel-1 imagery to extract water body through threshold method. The result of water body extraction is shown in Figure 1.

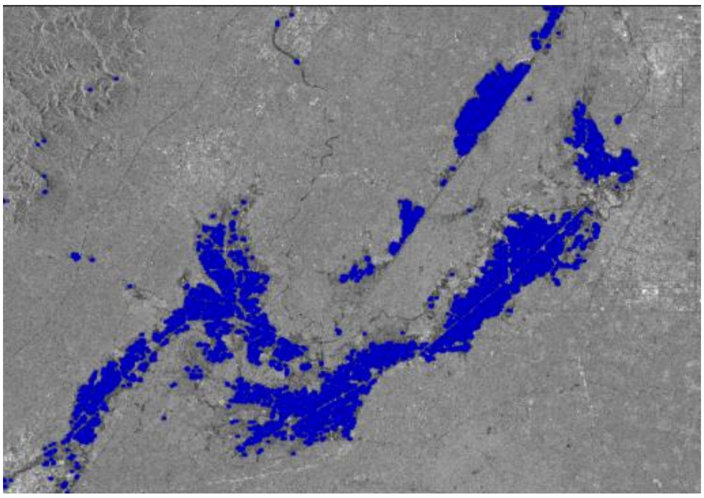

Figure 1. Sentinel-1 image, Henan, China, blue part shows water body.

2.2.2. *Disaster evaluation.* When floods happen, the water body in disaster areas has different inundations. Compare the water body extracted from the image after the flood disaster with which extracted from the RS image before the flood disaster to obtain the changing part of the water body.

As the inundation area includes previously land areas, to get more detailed information, take maximum likelihood classification (MLC) as an example. It assumes that a multivariate normal distribution can describe each spectral class. Therefore, MCL takes advantage of both the mean vectors and the multivariate spreads of each class, and can identify those elongated classes [3]. After convert the covering image into a shape file, carry out the further editing of the images by visual interpretation

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of the flooded areas. The topographic maps are intersected with the accumulated shape file of the inundated area to extract different types of info-layers for damage assessment [4].

The measurement function of GIS tools can be used to measure the width and length of water surface. Combined with topographic data, data such as inundated water volume and submerged water depth can be estimated, and important data such as the width of the breach can also be calculated. The impact assessment mainly estimates the number and spatial distribution of affected bodies such as residential areas (counties, towns and villages), houses, population, cultivated land and communication lines within the inundation range. In the assessment of disaster degree, the number and spatial distribution of affected bodies with different loss degrees are calculated. In the assessment of economic loss, the value of loss is expressed in monetary form. The selection of different assessment levels mainly depends on the data status and the assessment time requirements.

3. Application of remote sensing technologies in wildfires

3.1. Background of wildfires

3.1.1. Cause of wildfires. Generally speaking, wildfires can be divided into three types: surface fire, canopy fire, and underground fire. The first factor of mountain fires is natural factors. According to statistics, there are more fires in spring than in summer because of dry weather and lack of moisture. Dry weather will increase the risk of forest fires. Natural causes such as high temperature, drought and other weather caused by relatively high ground temperature, easy to cause the spontaneous combustion, resulting in forest fires; another factor is that summer thunderstorms are easy to cause "lightning fire", also easy to trigger forest fires; volcanic eruptions and other factors can also work. In addition to natural factors, more than 90 percent of the fires in the world are caused by people, and in China, man-made factors cause more than 98 percent of forest fires. Apart from arson, the main causes of fire caused by negligence are violations and carelessness. Human activities can also cause fires, such as burning paper, land, carrying fire, intentional arson.

3.1.2. Impacts of wildfires. Wildfires can result in three major hazards. The first is environmental harm, and the most obvious is burning trees or other plant resources. The forest has a long growth cycle, and the larger the forest is, the harder it is to recover. Wildfires can damage the soil, reduce the water retention and permeability of the soil, causing swamp. Fire can also destroy the environment on which wild animals live, or even burn animals. Burning mount fire releases large amounts of carbon dioxide, likely increasing the greenhouse effect and leading to more intense global warming.

Secondly, the economic impact of mountain fires should not be ignored. The loss includes tourists, plant resources, current assets (forest by-products, agricultural and animal husbandry products, inventory, etc.), and firefighting cost.

Thirdly, mountain fires kill more than a thousand people worldwide each year. Fire smoke and dust lead to air pollution, easy-to-form smoke, and long-term inhalation can bring threats to people's health. Anaerobic environment on fire can also cause breathing disorders, loss of reason, convulsions, and even suffocation death.

In the last year, there were 529 wildfires all over the world. Although many of them can easily be put out, many still cause great disasters. For example, wildfires that began in late 2019 and lasted for over 7 months had swept across about 20% of Australia's land mass, displacing tens of thousands of people and decimating 100,000 of Australia's wildlife, wiping out at least 34 species. The report estimates a $5 billion loss in health and property damage from the wildfires.

3.1.3. Traditional wildfire monitoring technologies. To prevent wildfires, if everyone has the consciousness of preventing fire, most wildfires can be prevented in advance. However, it needs the government and the people work together. But accidents happen anyway, people still need to fight against wildfire. Tools for fighting wildfires range from the standard equipment of urban fire

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departments to portable pumps, tank trucks, and earth-moving equipment, and firefighters often have an important responsibility [5]. New types of fire-fighting equipment are constantly used, too.

Every little source of the fire has the potential to start a fire, but it is hard for people to control all fire sources in the wild by themselves.

3.2. Application of remote sensing technologies in monitoring wildfires

Set up hill fire monitoring points, make use of intelligent video monitoring and satellite monitoring, give full play to RS's advantages; it is easy to monitor key forest areas around the clock. This part mainly discuss fuel mapping and fire estimates.

3.2.1. Fuel mapping. Due to the origin of wildfires, the control and management of combustibles are critical for improving current fire prevention system. Fuel maps are essential for spatially computing fire hazards and assessing fire risk by their use in models simulating fire growth and intensity across a landscape [6]. RS techniques provide a new method to obtain data on fuel through satellite, with comprehensive spatial coverage and sufficient temporal resolution, this method symbolizes the trend of development.

To map fuels, we can combine various approaches include field reconnaissance, gradient modeling, direct-mapping and indirect-mapping methods. Based on RS image, the classification and identification of fuel types is the key step for all these methods. Bobbe et al. (2001) have described ways to make vegetation maps and summarized the application of RS data for mapping [7]. Then on the basis of forest fire occurrence and fire behavior forecast demand, according to experimental zone of Joe, irrigation, grass and other types of fuel type, develop a classification system; Characteristic band selection, PCA processing and feature extraction etc. methods are adopted to carry out the operations.

Chaocha forest farm, in the north-east of China, is a high-fire risk area. Figure 2 shows a fuel map of this area.

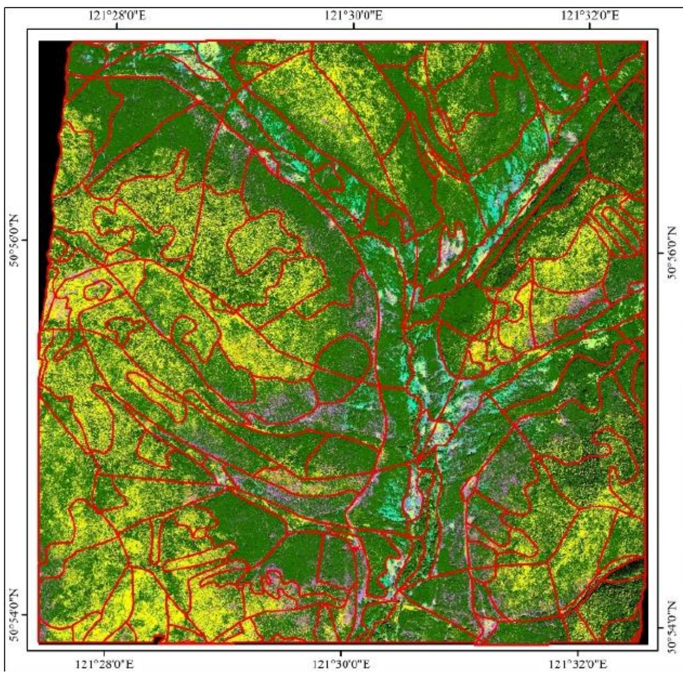

Figure 2. Distribution of and fuel types in Chaocha forest farm.

3.2.2. Fire estimates As an important basis for monitoring, fire estimates could help people plan for wildfires in advance. Combined with the advantage of RS technology and field reconnaissance, many methods could be used to estimate. Fire estimates based on FCCS need to obtain the arbor, shrub and

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herb, litter in the study area, the humus and so on many parameters, to get the comprehensive data parameters, the method relys on RS to obtain more forest parameters, such as using laser radar data to obtain the forest vegetation vertical parameters, through RS means to improve the ability to get forest parameters. And finally, it suggests putting forward technical support for scientific wildfire prevention and fighting.

4. Application of remote sensing technologies in earthquake

4.1. Background of earthquake

4.1.1. Cause of earthquake. The cause of the earthquake is an important subject in seismology, which include the theory of continental drift, the spreading of the sea floor, and the theory of plate tectonics, which is generally recognized by the academic community. The concept of "plate" was firstly introduced by Wilson in 1965. In 1968, Saville LePicon divided the global lithosphere into six plates, African, American, Pacific, Indian Ocean, Eurasian and Antarctic plates. The junction of plates and plates is the zone of active crustal activity and the zone of volcanic and earthquake concentration.

4.1.2. Impacts of earthquake. Earthquake is one of the most dangerous natural disasters in the world. The direct causes include the destruction of buildings and structures, such as building collapse, bridge broken, dam cracking, rail deformation; Ground damage, such as ground cracks and water spraying sand; The destruction of natural objects such as mountains and landslides. Damage in coastal areas are often caused by tsunamis or undersea earthquakes. In addition, in some large earthquakes, ground light burns people and animals.

Indirectly, earthquakes often cause serious casualties, fire, flood, toxic gas leakage, bacteria and radioactive material spread, and even tsunamis, landslides, collapses, cracks and other secondary disasters.

4.1.3. Earthquake monitoring technologies. As a destructive and unpredictable natural disaster, it is hard for people to take precautions against earthquakes in advance. But most earthquake-prone areas, such as Japan, where the average number of earthquakes is more than 1500 per year, have a perfect earthquake-proof system. In Japan, people are well educated about emergency response, first-aid kits, emergency wifi, and disaster prevention manual are available to everyone. And all buildings The building have good earthquake resistance by shockproof design and materials.

At present, the main means and methods used in earthquake monitoring are as follows: seismic measurement, crustal deformation observation, geomagnetic measurement, telluric observation, gravity observation, in-situ stress observation, and groundwater dynamic observation.

4.2. Application of remote sensing technologies in earthquake

In earthquake monitoring, remote sensing technology provides reliable pre-earthquake prediction through comprehensive observation, accurate disaster assessment during the earthquake and systematic guidance for post-earthquake recovery. This part mainly discusses house RS image recognition and thermal data.

4.2.1. House Remote Sensing Image Recognition. The damage and collapse of buildings caused by the earthquake is an important cause of casualties and property losses. The application of emerging RS images to identify the seismic capacity of buildings can provide a basis for earthquake disaster risk pre-assessment [8]. Many scholars used high-resolution RS images of disaster areas before and after earthquakes to study the damage of buildings. Ji Shunping et al. used pixel compensation of shadows to reduce interference and realize the detection of building loss changes [9]. Yuan used CNN algorithm to extract buildings and achieved good results [10]. Multiscale image segmentation and U-Net model can also be used for building damage identification.

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By applying the results of RS image recognition of houses to earthquake disaster risk pre-assessment, the overall seismic capacity of houses in this region can be effectively grasped, the reliable data in earthquake disaster risk pre-assessment can be obtained, too.

4.2.2. Thermal data infrared RS technology. Satellite thermal infrared RS technology can compensate for the shortage of traditional methods with the advantages of large information range, fast data update, and spatio-temporal dynamic monitoring.

Natural phenomena and data availability stimulated the analysis of the long time series of thermal images in relation to earthquake hazards [11]. The first time Thermal images been used in seismic research was in ’80s [12]. Later, similar researches were carried out all over the world. Thermal data indicate the significant change in the Earth’s surface temperature and near-surface atmosphere layers, which is the key to earthquake monitoring and prediction. Due to many uncertain factors, such as the uncertainty about the emissivity and atmospheric profile, the accuracy is limited. Therefore, most scholars use surface luminance temperature to characterize thermal infrared radiation. Currently, the diathermy index method and the mean gradient method are commonly used thermal information extraction methods.

The Destructive Bam earthquake in Iran took place on 26 Dec 2003. Compared the background distribution of the surface temperature in common and five days before the earthquake. The anomaly could be found five days before the earthquake. The result is shown in Figure 3 [13].

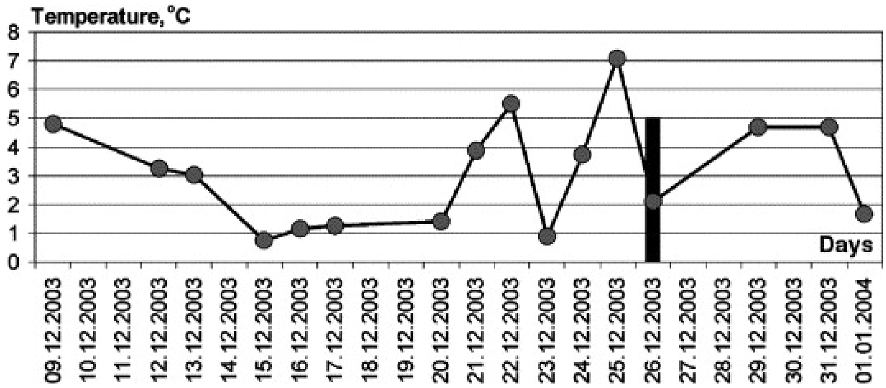

Figure 3. Thermal temperature in Bam, Iran. Column.

5. Discussion and prospects

RS has tremendous potential and boosts bright prospects in natural disaster monitoring. However, difficulties and challenges also exist. First, the integration of RS monitoring and other means is not enough. RS monitoring has some advantages, but sometimes there are limitations, such as being unable to see, not seeing clearly, and not being able to see accurately. Second, the lack of connection between satellite operation management and risk assessment leads to data redundancy and a lack of coexistence. In daily situations, the satellite operates the established mode and can obtain about 10000 remote sensing data daily. However, in emergencies, adverse weather and limited satellite capabilities can result in a shortage of data. Third, the development of intelligent production and knowledge services has been hindered, which has caused efficiency improvement to be blocked. Currently, many risk remote sensing monitoring related information platforms are still in the initial stage, and the product system needs further improvement.

6. Conclusion

This study focuses on floods, wildfires and earthquakes, and discusses the background of these natural disasters and the application of RS technologies in monitoring them.

In flood monitoring, RS could extract water bodies and make disaster evaluations, which makes up for the shortcoming of traditional methods such as high cost and low precision. In wildfires monitoring, RS could estimate disaster risk and conduct real-time monitoring and evaluation, reducing a lot of loss in wildfires compared with the traditional methods, which take a long time to react. In earthquake monitoring, RS has the advantage of a bigger view and multi-source data.

In general, RS brings natural disaster monitoring systems a great revolution, both in data acquisition and processing methods. However, the amalgamation of multifold subjects could suggest the future development of remote sensing application for natural disasters.

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