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EARLY WARNING SYSTEMS FOR LANDSLIDES

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ABSTRACT

Early warning systems are important in the disaster prevention of natural hazards such as landslides. Warnings about slope instability can alert communities who are prone to landslides and allow time for the evacuation of those in danger. There are many different methods of monitoring the deformation of slopes, such as Community Slope SAFE approach to Acoustic Emission monitoring (CSS AE), the SIGMA warning system and ground-based radar interferometry, which can all be used as early warning systems for landslides. The implementation of these Early Warning Systems in frequent landslide locations would help to decrease the number of fatalities from landslides worldwide, as although there are some agencies (e.g. Federal and state agencies in the US) that currently issue warnings, they cannot provide continuous support or expand services to all areas due to their limited resources.

***KEYWORDS**: Early, Warning, Systems, Landslides*

INTRODUCTION

Landslides represent one of the world's highest fatalities from major natural hazards, with 14% of total casualties worldwide being due to slope failure between the years of 1971-1975(Varnes et al. 1984). This statistic has decreased over the years, partly due to the increasing global population, yet landslides were still recorded to have caused a total of 55,997 people killed worldwide from only 4862 landslides between the period of January 2004 to December 2016 (Froude et al. 2018). There are many natural causes for landslides, some due to volcanic eruptions or some simply down to the rock and earth being too weak or fractured; however, other causes are from such activities as agriculture and construction which have been found to increase the risk of a landslide. This is due to some unnatural activities such as deforestation, excavation or water leakage involved with construction and agriculture which leads to the destabilization of slopes.

Thus, due to the severity of the impact landslides have on a multitude of communities, research has been done into how they could be prevented and into methods of warning vulnerable communities about an impending landslide. There are several widely used early warning systems; the Community Slope SAFE Acoustic Emission monitoring (CSS AE), the SIGMA warning system and ground-based radar interferometry, which will all be discussed in this report. The CSS AE warning system works on the basis "Acoustic emissions are elastic stress waves generated by deformation" (Dixon et al. 2018), thus the sensors can detect the deformation of a slope via measuring the acoustic emission from the materials placed either side of the tube attached to the sensor, and thus send a warning to the appropriate authorities. The SIGMA warning system, however, does not physically measure the slope deformation but "combines rainfall forecasts with hourly rainfall measurements recorded by an automated regional network of pluviometers." (Lagomarsino et al. 2013), then compares these figures with several thresholds which correspond to increasing levels of rainstorm severity to associated to a warning level. Contrastingly, the ground-based radar interferometry monitors ground displacements, using a ground-based radar system with "a 2–3-m-long linear rail on which two antennas move with millimetric steps is used to form a synthetic aperture." (Casagli et al. 2010) to detect a possible slope displacement, which, if detected will be used to warn the appropriate authorities of the forthcoming landslide before it occurs.

CRITIQUE

The academic journal article about the creation of the CSS AE early warning landslide system for low-income and middle-income countries (Dixon et al. 2018) has a broad range of references from many other publications, which it uses in support of the acoustic emission early warning system being one of the most effective and cost efficient instruments for determining landslides and warning of them to the community. In total, the journal article has made thirty-six references to other publications, however, eight of these references made are to publications written by one of the same authors who wrote this journal article, thus could be discounted as they are simply making use of their own work.

This journal article has been cited seven times; however, in three of these instances it was cited by two of its own authors in their other journal articles. This number of citations is around the average, when compared to other academic journal articles written about same topic (early warning systems for landslides) and released at a similar time to this article. Thus, evidencing that the article has not been ignored by other researchers in this area, as some other journal articles have made use of it in their publications, although, due to its relatively recent release date, there have not been many other authors who have chosen to make use of it as yet.

The information presented in the journal article is valid and reliable with a multitude of references showing that all the statistics considered have been gathered from credible sources, researchers or organisations working in the same field as the authors to this article. However, as mentioned above, some of the sources referenced in this academic journal article have also been written by some of the authors as this article. This does suggest that there may have been some bias in the use of some of the resources for the journal article (due to some of the authors perhaps prioritising their own work over that of other researchers), but this may be due to circumstances. The suggestion of bias could be negated by the lack of credible research in this field, requiring the authors to have to make use of their own credible research in order to demonstrate the need for this device effectively.

The information the journal article provides appears to be accurate, with excellent presentation of the proposed early warning system. The results are clearly displayed via graphs demonstrating the extent of the research that went into the development of this early warning system, with multiple tests of the device having been conducted with differing features on the device to finely tune the sensitivity appropriately. The diagrams in the journal article help the reader to visualise exactly how the device will be used in practice and provides a clearer understanding of the inner workings of the acoustic emission system. They also explain how differing diameters of tubes can provide more sensitive readings of a slope's instability.

MAIN BODY

As mentioned briefly above in this essay, the CSS AE warning system is the one of the most cost-efficient early warning systems, thus can be implemented in more areas at risk from landslides due to its low cost. This makes the CSS AE system extremely beneficial, as by being widely used this could greatly reduce the global fatalities from landslides, as it will allow more vulnerable people to escape an impending landslide. The CSS AE system works by monitoring the acoustic emission of the slope near continuously with a "monitoring period of 15 to 30 min" (Dixon et al. 2018) via the backfill the steel tube is imbedded into. The system has a predetermined voltage threshold, which once passed will lead to an alert message being sent to the appropriate authorities within the area. This early warning system is very sustainable in its design, as it allows excavated materials to be reused when installing the device as backfill, this limiting both the cost involved when installing the system and minimising use of carbon as materials do not have to be imported to the site. This the system is also sustainable due to being powered by a solar panel placed on the roof on the exterior covering of the device, enabling it to work without being located near a source of power, thus improving its utility as it can be placed in more remote locations.

Another early warning system mentioned prior, is the SIGMA warning system. This system does not physically measure the deformation of a slope but uses a "decisional algorithm based on the overcoming of statistical rainfall thresholds" (Martelloni et al. 2012). The rainfall thresholds were created by constructing sigma curves based on precipitation over a given time interval. The next step was then to select the most appropriate sigma curves for use in the SIGMA warning system; this was done by using both an optimization algorithm and daily model outputs for occurring landslides which lead to identification of the σ curves that reduce the surpassing of thresholds for days in which landslides were not reported. This is then used in combination with data about hourly rainfall and forecasts to determine whether a landslide is occurring. This result is displayed on a four-tiered alert scale with level 0, being no landslide is expected, level 1, landslides may occur, level 2, landslides are expected and level 3, where public authorities should be alerted. This alert system has been updated, to be able to implement a warning level for different sections of an area allowing it to provide a better, more accurate level of early warnings, not just a general overview of possible landslides. This system constantly improves over time, as at first it greatly underestimated the number of landslides which would occur, due to the data the algorithm had been provided being from years when few landslides had occurred, thus making it and ineffective warning system, although since then it has obviously improved due to collating more data, and thus is now an effective warning system.

The last early warning system for earthquakes is the ground-based radar interferometry system (GB-InSAR). This system uses a radar instruments to detect slope displacement with millimetric accuracy. This method of detecting slope displacement is used over satellite-based detection due to having a significantly higher image acquisition rate and thus is able acquire data about a singular slope in considerably shorter time intervals. This speed in data acquisition will in turn lead to an earlier warning of a landslide, thus enabling action to be taken sooner for those vulnerable. Due to the high measuring rate of the GB-InSAR, there is the ability to use a large set of images for averaging and provide displacement measurements with a very high spatial resolution “2 × 2 m at 1-km range” (Casagli et al. 2010), which is the same as that from the satellite, over a few square kilometers. The GB-InSAR is also better suited to operating with steep slopes, as it can do this when satellites are unsuccessful to obtain images of these areas and thus unable to detect a slope displacement, making the GB-InSAR a better early warning system than the satellite based radar systems. As previously mentioned, the GB-InSAR features a 3m long rail with two antennas that moves along this using a “continuous-wave step-frequency radar” (Casagli et al. 2010) and microwave transceiver to observe a predetermined section of a slope in order to determine a surface deformation.

CONCLUSION

Therefore, all three of the systems discussed prior are valid options for use in the early warning for landslides, with each solving the problem of detecting landslides in a unique way. However, these systems are not perfect, with each having flaws to the design, or merely not meeting the exact specifications proposed for them. This can be seen with the CSS AE system, as it is the updated version of the old ALARMS system for detecting slope deformation, as this was deemed to not be affordable. The SIGMA system also requires some improvements, as at the moment, the system does not take into consideration, how rainstorms can vary spatially and thus the algorithm is incomplete. Also, the results from the algorithm are factual, however they are investigated by authorities using their own judgements, thus the system in not completely objective, perhaps leading to action not being appropriately taken. Thus, the systems used for analysing whether a landslide will occur and providing an early warning to those vulnerable, are functional and effective in determining slope deformation and providing a lifesaving warning. The CSS AE system is affordable and thus can be widely distributed, this suggests this system is a more efficient way of monitoring slopes at risk than the GB-InSAR. This is due to the GB-InSAR requiring more experience to operate it, whereas the CSS AE system is self-sustained, and requires minimal interference from those involved to accomplish its purpose. However, the GB-InSAR and the CSS AE monitoring system, still are more beneficial than the SIGMA system as these both actively monitor slopes, whereas the SIGMA system merely makes inferences based on other data collected and does not determine whether a specific slope will deform.

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