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Landslide Early Warning System Based on Multi Sensors and Artificial Internet of Things (AIoT) : A Review

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ABTRACT

Landslides occur due to shifting soil, flooding, and rainfall with high intensity of rain resulting in excessive water content in the ground. It takes a system that can acquire data in the field to predict the occurrence of landslides. Slope condition analysis is an analysis that must be carried out to find out how fast and appropriate action must be taken if the slope collapses or landslides. This study focuses on developing an effective Landslides Early Warning System (LEWS) that provides real-time information. In the literature study to understand some of the methods used based on previous research. This survey follows the steps by conducting a research question (RQ), then searching and observing previous research from the journal database. Based on ten articles, this study concludes that currently, there are various types of people who use Machine Learning taken from GIS Maps, use geosensors to detect ground shifts, detect rain to anticipate landslides on mountain slopes, and use Lo-Ra radio to transmit information on ground displacement. Based on the literature review that has been carried out, a LEWS system design using multiple sensors and the Artificial Internet of Things (IoT) can be developed.

Kata Kunci: Landslides, Early Warning System, Real-time, IoT, Information

1. INTRODUCTION

Landslides result from different geodynamic processes and represent an essential type of geohazard, causing economic and social losses by damaging infrastructure and buildings (Prakasam et al., 2021). Various factors cause landslides, soil geological conditions, geomechanics, soil weathering, rainfall, and soil moisture. Variations in these factors influence the occurrence of landslides (Ali et al., 2018). Landslide is one of the disasters that can cause a lot of damage. The damage caused does not only have a direct impact, such as damage to public facilities, agricultural land, and casualties (Khaled & Mcheick, 2019). Landslides hurt the community because they can cause material losses and loss of life; for example, landslides can cause vehicles to be buried by the ground, causing fatalities. There is no information about road conditions when the car passes (Pham et al., 2019).

High rainfall usually triggers landslides in highland areas. The disaster is still not getting treatment or prevention effectively (Piciullo et al., 2017). People who live in landslide-prone areas do not receive an early notification so that they can save themselves and materials that can be threatened when a landslide occurs. Early warning of landslides is needed to minimize casualties or losses for the community (Lin et al., 2022; Su, 2022) .

The use of the Early Warning System (EWS) to detect landslides can be installed on mountain slopes that tend to shift soil (Anh Bui et al., 2019). The tool will work in the event of land shifting and will provide signals and notifications to residents. The community will very much need the existence of EWS as a real-time source of information for the effective prevention and management of landslides (Gamperl et al., 2021).

Based on this, the authors are interested in conducting research literature studies and designing a system that the community can use as an early warning system for landslides. The design of the tool is in the form of a Landslide Early Warning System Disasters Based on Multi sensors and Artificial Internet of Things (AIoT); this tool will provide convenience for the public to access information about soil conditions on mountain slopes because this tool is equipped with the Internet of Things (IoT). IoT can be accessed on smartphones. The development of this EWS uses multi-sensors that can predict the occurrence of soil from various factors such as soil shift, soil moisture, and rainfall.

2. METHOD

2.1 Systematic Literature Review (SLR)

Systematic Literature Review (SLR) is one of the methods for conducting a review of previous interrelated research. SLR is one of the standard methods so that the following research process can be re-done by other people with almost the same results. SLR is secondary research to find out, evaluate, evaluate, consolidate and collect information from the main study results related to the research topic (Kitchenham & Brereton, 2013). SLR is part

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of the survey process on research topics based on the desired keywords, with the survey object being the result of research that has been published in online journals. This systematic process will result in gaps that can become opportunities and challenges for further investigation. This paper focuses on a survey related to Early Detection of Landslide Disasters Based on Multi sensors and the Artificial Internet of Things (AIoT). The primary purpose of this literature study is to look at trends in IoT implementation for Early Detection of Landslide Disasters, models, or Early Warning System Methods, and the factors that make landslides. To obtain complete survey results, this research was conducted using research results published in several popular international journals such as IEEE, DOAJ, ScienceDirect, and Scopus, which were limited from 2015 – to 2022. The SLR consists of several stages, namely determining the research question or Research Question (RQ), then selecting the appropriate research, collecting research-related data according to the paper being studied, analyzing and describing the findings. Thus, in principle, SLR aims to answer RQ related to research topics by knowing the beginning, evaluating and analyzing research results.

Determination of research questions or Research Questions (RQ) can be done by conducting an initial overview related to research topics. The purpose of determining RQ is to maintain the focus and direction of research so that the collection of references and data related to the study can be regular and more accessible. In addition, the importance of the initial analysis to determine RQ is to sharpen the keywords in the search for previous research. Here is the RQ on this study, presented in table 1.

Table 1. Table Research Questions

ID	Questions	Motivation
RQ1	What are the factors that cause landslides?	Identify some of the factors that cause landslides.
RQ2	How to detect early the occurrence of landslides so that they can provide information in realtime	How to detect early the occurrence of landslides so that they can provide information in realtime

2.2 Search Result

Searching for papers in the database of popular international journals was carried out from April 1 to April 6. Articles related to the study were obtained using keywords ("**Early Warning System Landslides**" or "**Landslides Detection**") and ("**Internet of Things for Landslides**"). When finding papers related as data sources, filtering using *inclusion and exclusion criteria is* carried out, these criteria aim to make it easier to extract information from the papers found. The existence of restrictions based on particular criteria can sharpen the research process. It also aims to increase time efficiency in the analysis stage.

When finding papers related as data sources, filtering using *inclusion and exclusion criteria is* carried out, these criteria make it easier to extract information from the papers found. The existence of restrictions based on special criteria can sharpen the research process. It is also aimed at increasing time efficiency in the analysis stage. Table 2 presents *inclusion and exclusion criteria*

Table 2. *Inclusion dan Exclusion Criteria.*

CRITERIA	
Inclusion Criteria	• I1 - Research papers related to trends, Early Warning System Landslides • I2 - English papers • I3 - Papers with Full-text access • I4 - Published papers 2015 - 2022
Exclusion Criteria	• E1 – The same research paper from a database of different journals • E2 - Research results in the form of books, white papers, publications, conference reviews • E3 – Papers unrelated to the Early Warning System Landslide • E4 – Survey paper or systematic review related to early warning system landslides

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Restrictions on papers to be explored, by applying particular criteria (inclusion and exclusion), aim to obtain the amount of information related to the research topic. Search results that are still temporary can be added again if, after screening, some sources are still not significantly associated with the issue of problems and research questions. In the last stage, in the form of the final study, the articles obtained as many as 10 overall, the discussion in each paper is reviewed and analyzed. The results of the analysis are then mapped to answer each research question.

At the systematic stage of review, additional filters can be given to improve the study results, based on published journals' indexes. The journal index shows the reputation of the research results. This aims to increase satisfaction and confidence in the quality done. Reputable journals have passed reviews by experts in their respective fields.

Table 3. Filtering Process Results

No.	Publication	Number of Articles
1.	Journal Q1	2
2.	Journal Q2	5
3.	Reputable International	1
4.	Conferences	2
Total		10

3. RESULT AND ANALYSIS

Early warning systems are an essential part of community preparedness mechanisms, as warnings can be an important key factor linking the stages of preparedness and emergency response (Prakasam et al., 2021). Theoretically, if an early warning is delivered on time, then an event that can cause a devastating disaster can be minimized the negative impact (Gamperl et al., 2021).

The early warning system is a series of techniques to notify the emergence of natural events, which can be disasters or other natural signs. Early warning to the community of catastrophe is the act of providing information with language that is easily digested by the community (Anh Bui et al., 2019). In critical circumstances, in general, an early warning that delivers information is realized in the form of sirens, *kentongan*, and so on.

3.1 Early Warning System Landslides

Based on the results of the library review, several research areas discuss early waning landslide disaster systems. Some of these studies use different methods. Research that has been studied uses several indicators to beat the occurrence of landslides (Ali et al., 2018). Use the EDUMAP method to analyze the performance of regional early warning models by considering fixed warning zones to issue alerts. The method consists of three consecutive steps: identification and analysis of landslide events and warnings (E) of the available databases, definition, and calculation of the duration matrix (DuMa), and evaluation of the performance of early warning models (P) through performance criteria and indicators. So the method developed is called EDUMAP (Piciullo et al., 2017).

Solutions using time series analysis methods and dynamic hybrid landslide prediction models can achieve accurate landslide displacement predictions, effectively reducing the risk to communities affected by landslides. This method can be applied in other landslide areas by detecting land transfer in a particular area (Lin et al., 2022). The use of sensors that can detect soil shifts can also be applied as an Early Warning System; one of the studies used geosensors to detect soil shifts. Geosensors associated with LO-RA. The geosensor has a tilt sensor to test the ground movement (Gamperl et al., 2021).

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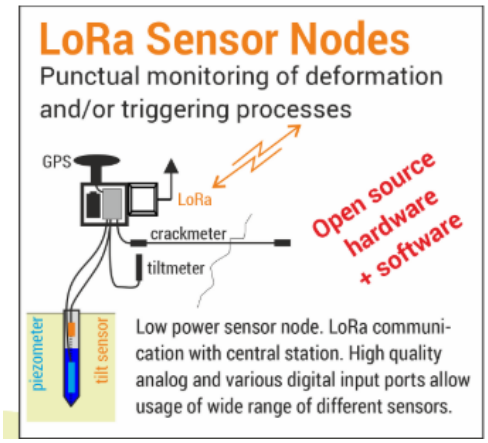

Figure 1. Measurement Concept for the LoRa Sensor Nodes (Gamperl et al., 2021)

The thing that is often the cause of landslides is high rainfall. Sloping areas will be affected when rainfall is high. Therefore, it is necessary to develop a system to overcome early warning signs of land movement during heavy rain. In addition, it can also be calibrated to predict flooding in significant rivers based on rainfall intensity (Prakasam et al., 2021).

Based on the research studied, the critical thing is that the exchange of information is indispensable for people in their daily lives. Disaster-prone environments require an information system to prevent fatalities and material casualties. Applying a sound communication system in a disaster-prone climate is fortunate to design or choose more effective technology to operate in emergency conditions (Khaled & Mcheick, 2019).

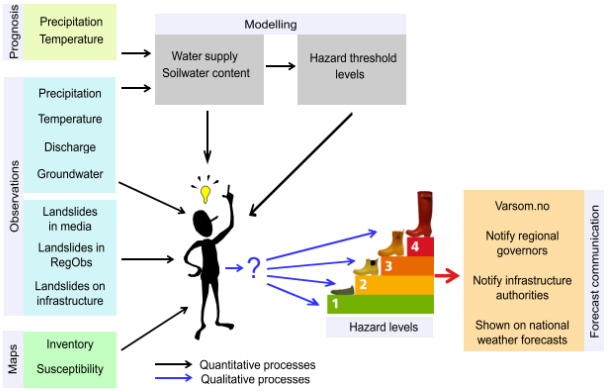

Figure 1. Organization of the landslide early warning system in Norway (Piciullo et al., 2017)

The construction of the landslide early warning system is expected to complement the community's existing knowledge to increase the community's preparedness. With the increase in community preparedness, it is hoped that the potential loss of life and property losses can be lowered. This system will also be a tool for regional managers to develop skills in disaster management, especially landslides. Early warning is carried out for quick and appropriate action to reduce the risk of disasters and prepare emergency response measures. So the emphasis is that disaster information readiness – especially landslide disasters – is needed that is timely and effective, which is managed and passed through institutions that are indeed competent and responsible so that the community can take actions that can reduce their risk of being exposed to losses that may be caused based on the information of the landslide disaster.

3.2 Design Landslide Early Warning System Disaster Bases on Multi Sensors and Artificial Internet of Things (AIoT)

Internet of Things (IoT) technology cannot prevent disasters, but it will be helpful in disaster preparedness, such as prediction and early warning. In IoT systems in landslide disaster management, sensors will be installed in places with the opportunity for disasters to occur by data from the GIS map (Ali et al., 2018); the sensor periodically sends data to the server for data fusion analysis. If the data matches the avalanche parameters based

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on the IoT system, an alert will be sent over the internet to the endpoint; a Smartphone integrated into the internet network.
Here is the hardware design from LEWS

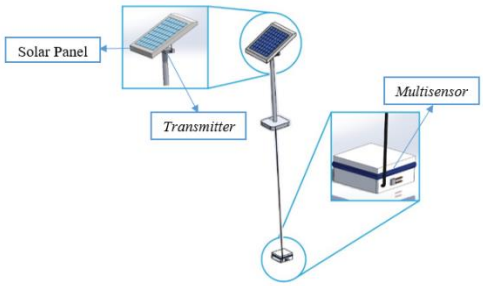

Figure 3. LEWS Hardware Design

The implementation of this tool is to detect sudden movements of soil, temperature, humidity, and soil pressure on the slopes of a mountain in the middle of a residential area. This tool uses a Telemetry system that on a server is integrated with the internet of things. This device allows sending information from the device to the information system that has been built in real-time.

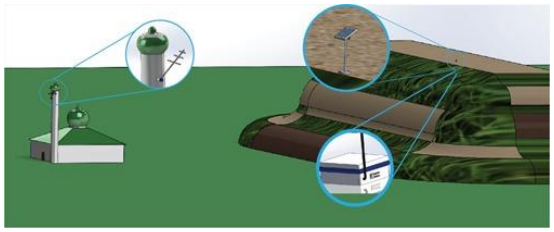

Figure 4. LEWS Application 3D Design

A data sending system will be placed on a mountain, and then a multisensor box will be planted into the ground to get more accurate parameters. The transmitter will read the data from the multisensor and then send the data to the receiver. The antenna is used to capture or receive signals from the transmitter and then forward them to the receiver in real-time. The receiver will receive and process the signal received from the transmitter through the antenna. The data receiving system will update the data in real-time so that the public can see any changes through the smartphone application. When the received data parameters exceed normal limits, the mosque siren will sound in the form of sound based on three warning categories.

4. CONCLUSION

The research identified several methods used in making LEWS that can provide accurate and real-time information to the community to reduce losses, both loss of life and material. This study uses a systematic literature review method by searching several popular journal databases. Based on the review results, it was concluded that the use of IoT is one of the most effective methods in creating a LEWS system. Easy operation and can provide fast information are one of the advantages possessed by the IoT system. The public cannot be separated from data in order to maintain safety from disaster hazards. Meanwhile, the current LEWS development model varies; some of which use Machine Learning taken from GIS maps, use geosensors to detect ground shifts, detect rainfall to anticipate landslides on mountain slopes, and use Lo-Ra radio to send state information ground shift.
Based on the literature review that has been carried out, a LEWS system design using multi-sensors and Artificial Internet of Things can be developed; this development can make the LEWS system more effective because data transmission is carried out by the telemetry system to the server and then updated to IoT so that cellular networks do not hamper data sometimes lost. Sensor data recorded will be updated in real-time which can be seen on the smartphone application of people living in landslide-prone areas. Warnings are not only via smartphones but this system is also designed to sound warning sirens in places of worship such as mosques.

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