Decision strategy for landslide event based on 4 parameters

P Herlambang¹, A Suharjono¹ and M Mukhlisin²

¹ Department of Electrical Engineering, Politeknik Negeri Semarang, Indonesia
² Department of Civil Engineering, Politeknik Negeri Semarang, Indonesia

*Email: pram84292@gmail.com

Abstract. Landslides are typically caused by heavy rain in some locations that have a certain slope of land compounded by deforestation or earthquakes. For instance, in 2018 there were 148 reported landslides in the Banjarneagara highlands, Indonesia. By using that fact, some research has been done. The research is about the indicator parameters of landslides by combining rain gauge sensors, soil moisture sensors, ground shift sensors and groundwater pressure sensors using Arduino Promini. The data from sensor is sent through LoRa Bee to the database server using NodeMCU ESP8266 which is connected to the Internet in real-time through access points. The data that has been sent to the server will be processed and displayed on the website. In this paper, the author devises an algorithm for analysing the data from each sensor to a decision-making strategy. The decision-making method for an early warning of landslides uses a decision tree that compares the measured parameters with a predetermined threshold of each sensor. After analysis and testing, this system is expected to provide early warning of the landslides quickly and accurately.

1. Introduction

In the last 10 years, landslides become a natural disaster that ranks high incidence in Indonesia. In the year 2019 the incidence of landslides in Indonesia was ranked second most incidents, with the number of events 550 times. The peak of the incident occurred in 2014 where 352 people died by the number of events 598. In addition to death victims, thousands of houses were damaged and 27,336 people were displaced. From the data, the provinces of Central Java and West Java were the largest compared to other provinces in Indonesia.

The occurrence of landslides is often caused due to high rainfall in locations that have a land slope of a certain value and compounded by deforestation or earthquakes. For example, in the year 2018 has been reported 148 times the mudslide occurs in the high-altitude area of Banjarneagara, Indonesia.

Noting this has been done research on indicator parameters will occur landslide by combining rainfall sensor[1], Soil humidity Sensor [2], [3], Soil shifting sensor [3] and a groundwater pressure sensor [2] using the Arduino Promini. The sensor Data is sent through LoRa Bee to the database server using the NodeMCU ESP8266 which is connected to the Internet utilizing the realtime access points. Data that has been sent to the server will be processed and displayed on the media website or the application on the smartphone. In this paper, authors devise algorithms to analyse the data that has been sent from each sensor to a decision-making strategy. The decision-making method for the early warning of landslides uses a Sugeno fuzzy algorithm that compares measured parameters with predefined threshold of each sensor. After analysis and testing, this system is expected to provide early warning of the landslides quickly and accurately.
2. Method
The research phase of the landslide monitoring system has been done before. Starting from designing the type of sensors used, testing sensors and wireless communication systems conducted on a laboratory scale. To strengthen the ability of the landslide monitoring system must be design decision making. The stages of this research can be seen in Figure 1. The decision-making method will use the Fuzzy Sugeno method. Input derived from rainfall sensors, ground moisture sensors, ground water pressure sensors and ground deformation sensors will be processed using the Fuzzy Sugeno to obtain output. The Output can be deployed via the media application on a smartphone, buzzer and website. Decision making using the fuzzy requires several processes until the output is formed according to the fuzzy calculations. The process is like fuzzification, rule creation, inference and defuzzification. In Figure 2, indicates that each sub-process on the fuzzy system has its relevance to the other, so the resulting sub-process will be an iper for the next sub-process until it becomes the final output of the system.

![Figure 1. Flowchart Research Roadmap](image1)

![Figure 2. Flowchart Fuzzy Design](image2)

3. Result and Discussion
The landslide monitoring system in the study consisted of 4 parameters. Parameters of rainfall, soil moisture, groundwater pressure and ground shifting. In general, this system can be seen in Figure 3.
Figure 3. Whole Design Landslide Monitoring System

The trigger of mudslide events in certain slope areas is generally precipitation [4]. Basically there are two types of rain trigger avalanche, namely heavy rain that reaches 70mm to 100mm per day and the rain is less heavy continuously for several hours until the day followed by heavy rain [5]. This certainly has different values for each region. In this system, rain is classified into 5 criteria, namely rain is very light, light, medium, dense and very dense (BMKG).

| Rain         | Cumulative Rainfall (mm)/24hours |
|--------------|----------------------------------|
| Very Light   | < 5                              |
| Light        | 5 – 20                           |
| Medium       | 21 – 50                          |
| Heavy        | 51 – 100                         |
| Very Heavy   | > 100                            |

In addition to rain, soil moisture can also be a parameter triggering the occurrence of landslides. This is because during and after the rain, some of the rainwater that reaches the surface of the slope infiltrate the ground while the other becomes the runoff of the surface. When the water infiltrates the slopes, the matric suction decreases as the soil moisture increases, then changes the soil structure, and reduces the friction and cohesive forces between the particles [6]. Large water content in the soil can be classified according to the 3.2 table.

| Soil  | Available Water Content in mm water depth per m soil depth (mm/m) |
|-------|-------------------------------------------------------------------|
| Sand  | 25 to 100                                                         |
| Loam  | 100 to 175                                                       |
| Clay  | 175 to 250                                                       |

Groundwater pressure can also affect slope stability or sloped ground [7]. Some post-mortem avalanche analysis by Nurly et al, (2006) at Air Laya, Indonesia showed that causes of slope failure were found due to cracks. The existence of deep cracks in the slopes will lead to a sharp increase in the
water pressure of pores as it allows the infiltration of rainwater into the soil and weakens the surrounding land.

Based on the character of each sensor that has the criteria, making decisions using the fuzzy algorithm can be done. Based on existing criteria, Fuzzification process can be done. After that, continued with the inference process. Inference is the process of merging multiple rules based on available data. In this fuzzy rule it will give the rules in the fuzzy system created using the command "IF" and "and" and generate the command "THEN".

4. Conclusion
Based on the discussion of each parameter, there are known criteria for conditions in the size of the specified value. This makes decision-making use of the Sugeno fuzzy algorithm to be performed. Sugeno's fuzzy logic on landslide early warning systems includes Fuzzification, inference and defuzzification which are capable of delivering warnings in the form of landslides, so that actions can be taken in accordance with the level of danger Detected. The next process of this research is conducting fuzzy logic testing, which is comparing between manual calculations and calculations of the system.

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