Rain Gauge System for Community-Based Disaster Risk Reduction Program in Northern Iloilo

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ABSTRACT

When Typhoon Yolanda (Haiyan) hit the area of Northern Iloilo, it brought so much devastation in the town of Concepcion. It prompted the College of Engineering, Central Philippine University to design and develop a rain gauge system for community-based disaster risk reduction program and an early warning system (EWS) for rain-induced landslides. The system was installed in eight (8) selected sites in the vicinity of the said town which were identified as landslide-prone areas. This system comprises of a self-emptying tipping bucket, strobe lights, alarm system, solar PV system, Bluetooth module, Android-based mobile unit, and the main control unit. The function and operations of the EWS were based on two factors: rain volume rate and soil absorption. Data were gathered from identified areas, and soil testing was conducted to determine the soil permeability. Three samples were taken from each site, and the highest permeability value was utilized to predict the possibility of a landslide occurrence. The result of the soil test was the basis of the EWS. The system was installed in the identified places, and final testing and evaluation were made to ensure its functionality. The rain gauge system for the prediction of a rain-induced landslide was successfully designed, developed and implemented.

Keywords: *early warning system (EWS), rain gauge system, risk reduction program*

Introduction

Strong winds and rain-induced landslides are two related hazards identified with typhoon prone areas and communities. Strong winds can destroy houses or topple down trees and electric posts. On the other hand, landslides can cause property damage, injury and even death. Rain induced landslides is prevalent and inevitable during rainy season cause by extreme weather conditions.

The factors contributed to an occurrence of landslide typically include: slope angle, climate, climate water content, vegetation, and geology. A number of elements will cause landslide, however, there were often triggers the movement of the soil. One of the major contributory factors is the prolonged rainfall that results in the elevation of pore pressure due to the water elevation difference as water flows from higher to lower elevation (Australian Government, 2016).

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The soil acts as a sponge to take up and retain water due to soil infiltration, percolation, permeability or hydraulic conductivity. Soil infiltration is the movement of water into soil, percolation is the downward movement of water within a soil. Water infiltrate and percolate the soil through pore space like conduit and serves as the storage of water (Australian Government, 2016).

Permeability is the ability of water to move and determine how far water will move through the soil in a given time. Soil complex property varies with location, soil type depth, soil moisture content and direction of flow. Permeability of soil was classified into very rapid to very slow. This classification determines how fast the water penetrates the soil. This natural disaster (typhoon) brought so much devastation in Concepcion, Iloilo that prompted the College of Engineering of Central Philippine University to design and develop a rain gauge system for community-based disaster risk reduction program and an early warning system (EWS) for rain-induced landslides.

Methodology

Table 1 shows the soil permeability classes. Infiltration and permeability is the manner by which water moves into and through soil. The water content can be determined by gravimetric (water/g soil) and volumetric (ml water/ml soil). But, the volumetric content is commonly used, since 1 gram of water is equal to 1 millilitre of water and can easily determine the weight and volume of water. The water content of soil at its saturation point is equal to the percent of porosity. Saturation is the soil content when all pores are filled with water, the soil water content after has been saturated and allowed to drain freely for about 24 - to - 48 hours is known as soil Field capacity (Wang, J., 2013).

Table 1
Soil Permeability Classes
* Saturated samples under constant water head of 1.27 cm.

Soil Permeability Cases	**Permeability rates***	
	cm/hour	cm/day
Very slow	Less than 0.13	Less than 3
Slow	0.13 - 0.3	3 – 12
Moderately slow	0.5 - 2.0	12 – 48
Moderate	2.0 - 6.3	48 – 151
Moderately rapid	6.3 - 12.7	151 – 305
Rapid	12.7 – 25	305 – 600
Very rapid	More than 25	More than 600

Water usually converted from a percentage volume basis to a depth of inches of water/foot of soil. Fine sandy loam, silt loam, and silty clay loam have the highest water holding capacity while coarse soil (sandy, loamy sand, and sandy loam) have the lowest water holding capacity, (Columbia Weather Systems, 2016) shown in Table 2.

Table 2

Soil Texture classes

Texture Class	Water Holding Capacity, inches/foot
Coarse Sand	0.25 - 0.75
Fine Sand	0.75 - 1.00
Loamy Sand	1.10 - 1.20
Sandy Loam	1.25 - 1.40
Fine Sandy Loam	1.50 - 2.00
Silt Loam	2.00 - 2.50
Silty Clay Loam	1.80 - 2.00
Silty Clay	1.50 - 1.70
Clay	1.20 - 1.50

With these given parameters of the soil, predictions of the rain-induced landslide are possible and providing a state of the art early warning system is a must to mitigate the effects of these natural calamities.

There are many early warning systems developed related to this system. The Intelligent Soil Monitoring and Control System for Forecasting and Enhancement of the Community Based Rain Induced Geologic Hazard (Yu Fan-Chieh, 2006). Method of forecasting stability of soil slope under condition of raining (Maneesha, R. V. & Vidyapeetham, A.V., 2012) and the Infinite Slope Safety Analysis System According to a Rain Fall Saturation Depth Ration Capable of Reinforcing Landslide Prediction Ability (Wu Chae1, B.G., Lee, J.H.,& Park H.J. Choi, J. (2014).

This system utilized soil characteristics and complex soil features to predict the occurrence of landslide. To further enhance the early warning and mitigation system, the rain volume flow rate and the permeability must be considered. The localized procedure in determining the soil sample characteristics must be done for further development and improvement of the system, before there were no existing systems that could do early warning and mitigation forecasts for possible disasters to ensure safety for the community and save lives.

The system shown in Figure 1, composed of the following: self-emptying tipping bucket, strobe lights, alarm, solar PV system, main control unit. The control unit composed of the following: microcontroller unit (MCU), blue tooth module, LED display, driver and relay circuit, Solar PV module, charge controller and the battery.

The system operation starts with the detection of rainfall volume from the rain gauge using the tipping bucket. The bucket is designed to tip every five (5) milliliters of water. The volume is then recorded in the microcontroller that processes the data on the soil permeability of the area to determine the saturation level of the soil. When the saturation level reaches an alarm level, the microprocessor will turn on the alarm intermittently every five (5) minutes. When the saturation level reaches critical level, the alarm will be turned on continuously. The alarm is in the form of strobe lights and a horn. An LED display and an application program for smartphone are developed so that the saturation level can be viewed in real time using

Bluetooth connectivity. To ensure uninterruptible power, the EWS is designed using solar PV system as its main power source. (Maxwell Scientific Organization, 2015)

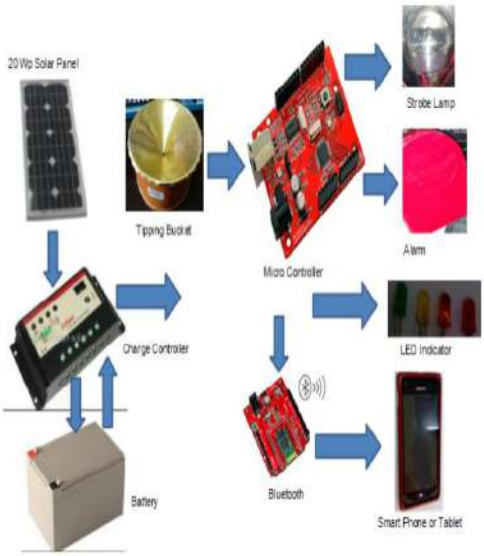

Figure 1. Block Diagram of the Rain Gauge System

Data gathered from the specific location and soil testing was done to determine the soil characteristics specifically its permeability, k(cm/sec). There were eight (8) selected sites in the vicinity of Concepcion Iloilo identified as landslide prone areas; Malangabang, Loong, Nipa, Macatunao (Balabago),Polopina, Salvacion, Bagongon and Bacjawan Norte. The identification of these areas was done by the local National Risk Reduction Management Council (NDRRMC) of Concepcion.

Three soil samples were taken from each location. The soil samples were taken at approximately one-meter depth to ensure that actual soil characteristics of the area are accurate. The samples were taken from the upper, middle, and lower elevation of the area. The soil samples were brought to a soil-testing laboratory to determine its characteristics specifically its permeability k (cm/s).

The profile of the area was also considered and data regarding inclination angle and existing vegetation was noted. Other relevant parameters such as GPS coordinates, existing cellular phone signal, and history of landslide occurrences were also noted. These data are necessary for the design and development of the control and data acquisition system of the rain gauge.

Results

Figure 2 shows the main unit of the system housed in a water proof metal box. On the front panel are two light emitting diodes (LED) that serve as the communication status indicator for Bluetooth connection. The six (LED) with colors of green, yellow, orange and red represent the warning system level.

Figure 2. Main Unit of the EWS

Table 3 shows the result of the soil testing of the eight identified locations. Out of the eight locations, and three samples from each site, the highest soil permeability was registered in barangay Macatunao with the value of 0.0747 cm/sec while the lowest was in barangay Loong with the value of 0.0015 cm/sec. The result shows that the higher the permeability value of the soil, the higher is the probability of rain-induced landslide occurrence.

However, the prediction of the landslide occurrences does not only depend on the soil permeability, but also on the profile of the area.

Table 3

Soil Test Result

Barangay	**Permeability Values, k (cm/sec)**					
	I (UPPER)		**II(MIDDLE)**		**III (LOWER)**	
Bacjawan Norte	0.0037	0.0056	0.0028	0.0042	0.0252	0.0378
Bagongon	0.0092	0.0138	0.0022	0.0033	0.0035	0.0053
Loong	0.0015	0.0023	0.0073	0.0110	0.0055	0.0083
Macatunao (Balabago)	0.0332	0.0498	0.0498	0.0747	0.0016	0.0024
Malangabang	0.0035	0.0053	0.0047	0.0071	0.0042	0.0063
Nipa	0.032	0.0486	0.0485	0.0728	0.0034	0.0051
Polopina	0.008	0.0120	0.0281	0.0422	0.0071	0.0107
Salvacion	0.0074	0.0111	0.0054	0.0081	0.0039	0.0059

Table 4 shows the sample profile of Barangay Salvacion. The sample profile in Table 4 includes GPS coordinates, existing cellular phone signal in the area, the slope or grade of the area, history of landslide gathered from an interview with the residents and the type of vegetation in the area. These data were considered in the design and development of the control system for the EWS.

Table 4

Sample Project Site Profile

Rain Gauge Location	Brgy. Salvacion, Concepcion, Iloilo		
GPS Coordinates	N 11°14.798’, E 123°12.566’		
Cell Phone Signal	Smart	Globe	Sun Cellular
Slope	67˚		
History of Landslide	Yes	No	
Vegetation	Barren	Grass/Shrubs	Trees

The rain gauge uses two data in giving of warning: the rate of rainfall and soil absorption. This data are correlated to the soil permeability found in Table I. If the rainfall rate together with the reciprocal of the permeability is high, then a warning is given. With the consideration of the site profile and factor of safety, the warning is given before the critical rainfall rate happens.

Another factor for warning is the water penetration depth in the soil. There were four indicated levels: first level for a depth of penetration less than one meter; second level for a depth greater than one meter but less than 1.5 meter; third level (warning level) for a depth level greater than 1.5 meters, but less than 2 meters; and fourth level (critical level) for a depth greater than 2 meters. The volume rate of penetration is calculated based on the permeability of the soil and the rainfall rate. Depth penetration is defined by the equation:

$$Depth = permeability\left(k, \frac{cm}{sec}\right) x\ rainfallrate(cm) x\ 60$$

The fourth level of critical level will activate only if the depth is greater than 2 meters. During this time, both strobe lights and horn will turn "ON" mode. This alarm is repeatedly sound for 10 minutes. The strobe lights will continuously be in the "ON" within the 24 hours even after the rain stops.

Conclusion

The rain gauge system for the prediction of a rain-induced landslide was successfully designed, developed, and implemented. It was installed in the eight (8) selected barangays of Concepcion, Iloilo. It was developed locally with the required specifications needed in the implementation and installation of the system.

The system was tested and functioned as expected and is already in use by the community in the selected site/location. It is recommended that for the prediction of possible landslide occurrences, further study on the effect of vegetation and slope of each site must be done.

Also, in order for the system to be reliable, maintenance of the system is required at least twice a year, mainly before the start and the end of the rainy season. Replacement of the sensor every six month is required for the reliability of sensing and measurement of rainfall.

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