# Susceptibility and Proximity of Schools to Potential Landslides in Agusan Del Sur: A Geospatial Analysis

Sheila Kylene A. Tawas[1*]; Ma. Shella R. Millan[2]

[1*]Surigao Del Sur State University, Main Campus, College of Teacher Education, Tandag City, Surigao Del Sur, Philippines.

[1*]skyarreza@yahoo.com

[2]Surigao Del Sur State University, Main Campus, College of Teacher Education, Tandag City, Surigao Del Sur, Philippines.

[2]iya128@yahoo.com

**Abstract**

*This research study assessed the susceptibility and proximity of DepEd elementary and high schools in Agusan del Sur Province to landslide hazard. The study utilized data from the NOAH Project, of the Department of Science and Technology (DOST). Landslide hazard data are categorized into three susceptibility levels (Low=1, Medium=2, and High=3). Using geospatial techniques, the assessment reveals that out of 551 schools, 90 are within the landslide zones- an average of 5.44%. Out of the 90 schools 14 are on the high level of susceptibility. An average of 94.56% are proximate to the landslide zone, of which 770m is the closest distance and azimuth to the nearest potential hazard. The results of the study is expected to help policy makers and administrators in DepEd of Agusan del Sur in landslide hazard mitigation planning. The results can further give awareness and preparedness to LGU and NDRRMC in crafting precautionary measures for the lives of the school children and DepEd personnel.*

## 1. Introduction

Landslide is a universal term covering a wide variety of mass movement of rock, earth or debris downward in motion which is heavily influenced by gravity (Chalkias, et.al.,2014.) It is one of the major types of geohazards, that continues to result to environmental, social and economic losses despite the advances in technology (Mancini, et.al, 2010). There are many factors which can be considered in the landslide which includes the slope, elevation, annual precipitation and peak ground

acceleration (PGA) among the few factors. Landslides are a frequent occurrence in the Philippines due to the country's steep, mountainous, and rocky terrain (Eugenio et.al., 2016). In fact, Agusan del Sur has three identified hazards that could possibly be experienced by the province, which includes, floods, rain-induced landslide, and ground rupture.

Landslide susceptibility is the tendency of the landslide to occur in an specific area in the future. A landslide susceptibility map is a useful tool in predicting future impacts of hazards and assess the future potential risk. It is also valuable in crafting mitigation measures and for better visualization for the best suitable location of infrastructures like constructing a school. The schools, and school children are among the few who are exposed to this natural hazard (Shahabi, et.al.,2012). Safety and precaution are main concerns for inhabitants especially school children. Schools wherever they are located - need to be aware of the possibility of landslides in their locality. The possibility of landslide occurrence need to be addressed by school policy makers and officials (Belarga, et.al., 2015).

Since the beginning of 1970's geoscientists and engineering professionals in landslide susceptibility zonation have widely used the Geographic Information System (GIS) technology for both qualitative and quantitative methods for analysis. The aim of this paper was to produce a landslide susceptibility and proximity map for the location of DepEd schools in Agusan del Sur province. This study hopes to give insight as to providing policy and decision makers the information upon which to base their pronouncements regarding landslide hazard mitigation.

## 1.1. Objectives of the Study

1. To determine the susceptibility levels of DepEd (Department of Education) schools in Agusan del Sur to landslides;
2. To calculate the distance and angular bearing of schools to the nearest potential landslide;
3. To determine the number and percentage of schools that are within or at some distance to the nearest potential landslides.
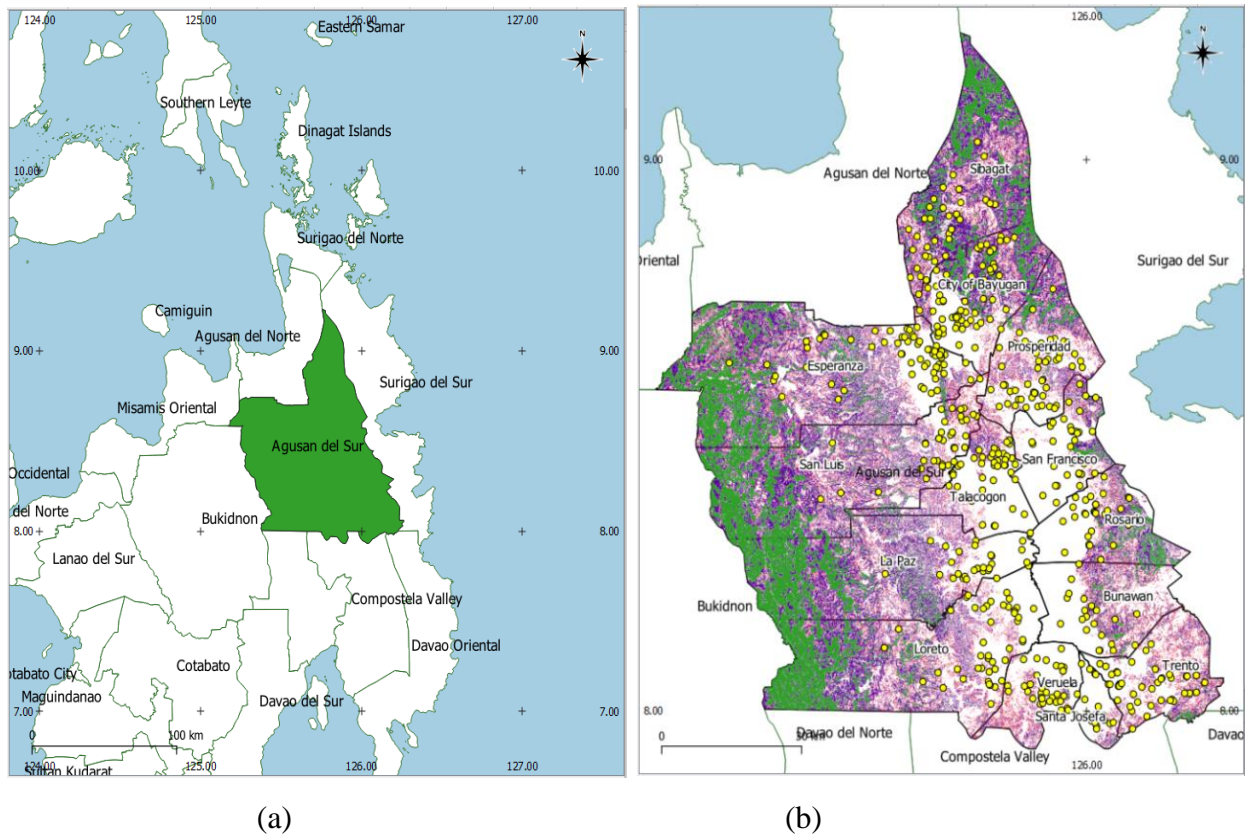
## 1.2. Study Area

The study was focused on landslide susceptibility and proximity mapping of the DepEd (Department of Education) schools in Agusan del Sur (Fig.1). The province consists of 13 municipalities and one city: Bayugan City, Bunawan, Esperanza, La Paz, Loreto, Prosperidad,

Rosario, San Francisco, San Luis, Santa Josefa, Sibagat, Talacogon, Trento and Veruela. Agusan del Sur covers a land area of 9,989.52 km2 making it the fourth largest province in the country.Most of the areas has a flat and rolling topography suitable for agriculture, industry, and forestry. The municipalities of Loreto, La Paz, Esperanza, and San Luis are the four largest municipalities in land area comprising almost 60% of the province's total land area. Santa Josefa and Talacogon, also river towns have the smallest land area. Forestland constitutes 76% of the total land area or 6, 872.5 km2 while the alienable and disposable constitutes about 24% or 2,137.5 km2. Present land use, however showed that settlements and commercial areas already occupy some of the forestland.

With the population increasing at the rate of 1.61 percent annually, there is a greater demand for lands to be utilized for the establishment of schools. Therefore, mapping the schools DepEd schools susceptibility to landslide, their hazard potential and their angle bearing and proximity to the nearest landslide zone is crucial as the data in this study may guide the DepEd policy makers, LGU's and NDRRMC in formulating mitigation and preventive measures.

Figure 1 - (a) Location of Study Area (b) and Geographic Distribution of DepEd Schools in Agusan de Sur (Yellow Dots)



(a)

(b)

## 2. Methodology

In order to accomplish the landslide susceptibility analysis in the study area, spatial analysis tools were implemented using the QGIS (version 3.8) software. The GIS data sets of landslides data were derived from NOAH (Nationwide Operational Assessment of Hazards) simulation from 5-meter IFSAR- derived digital terrain model. The NOAH hazard maps show unstable slopes and propagation extent. Hazard maps do not include deep-seated complex landslides and extremely long run-out debris avalanche.

There were three attributes identified in this study:
(1)LH = 1: Build only with continuous monitoring;
(2)LH= 2: Build only with slope protection and intervention, and continuous monitoring;
(3)LH= 3:No dwelling zone.

Using the geospatial processing tools, Philippine provincial and municipal boundary data sets were added to the QGIS software. The Agusan del Sur boundary was clipped from the Philippine boundary. Landslide and schools data sets were added. Calculation of the landslide area was done through GIS - based overlay functions. The landslide susceptibility map (Fig.2) of the DepEd schools was created by combining landslide susceptibility values by means of GIS overlay analysis.

**Computation on the Distance and Bearing of School to the Nearest Potential Landslide**

The distance and bearing of school to nearest landslide (LH=1) has the following definitions:
SD= School ID Number
D = Distance (m) to the nearest potential landslide
LH =1 landslide area (shown by straight dotted line.
A= angle (degree) measured clockwise from vertical line pointing north (=0) to the line pointing to the nearest LH=1 landslide.
Definitions are similar for LH= 2,3.

Figure 2 - Computation on the Distance and Bearing of Schools to the Nearest Potential Landslide (Schools in Black Dots)
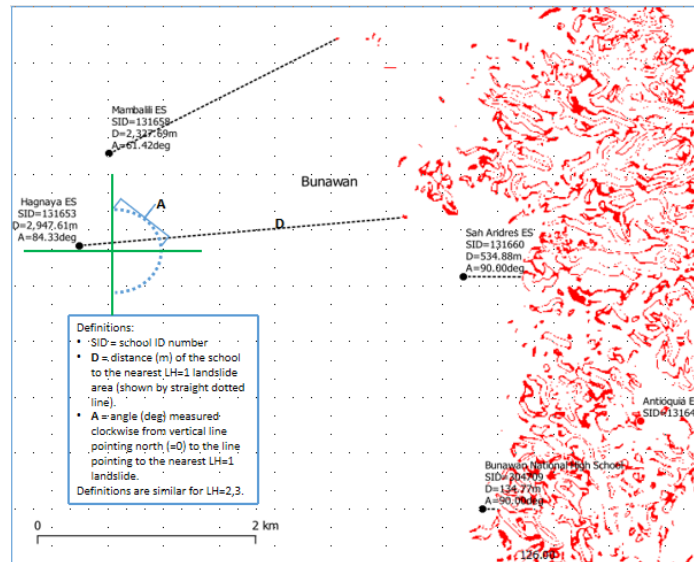


## 3. Results and Discussion

### 3.1 Schools in Low Susceptibility (LH=1)

The output of landslide susceptibility map for Low Susceptibility LH=1 shows that 27 (4.9%) of the schools are on the potential hazard of LH=1, while 524 (95.1%) are not on LH=1 (Fig.2).The name of the DepEd schools prone to LH=1 are listed in Table 1.

Table 1 - DepEd Schools Prone to Low Susceptibility LH=1

| School ID | Name of the Schools | Municipality |
|---|---|---|
| 131778 | Las Navas Elementary School | Prosperidad |
| 131729 | Linatawan Primary School | Loreto |
| 131871 | Keoya Elementay School | Sibagat |
| 131794 | Inagawan Learning Center | Prosperidad |
| 131895 | Anitap Elementary School | Veruela |
| 131875 | Magsaysay Elementary School | Sibagat |
| 131633 | Montevista Elementary School | City of Bayugan |
| 132016 | San Roque Elementary School | Trento |
| 131647 | Agpan Elementary School | Bunawan |
| 131640 | San Juan Elementary School | City of Bayugan |
| 131680 | Langag Elementary School | Esperanza |
| 131648 | Antiquia Elementary School | Bunawan |
| 131707 | Nato Elementary School | Esperanza |
| 131683 | New Gingoog Elementary School | Esperanza |
| 317421 | Johnson National High School | Loreto |
| 317414 | Hawilian National High School | Esperanza |
| 317446 | San Vicente National High School | Loreto |
| 131946 | Don Pedro Primary School | San Luis |
| 131973 | DOP BALIT IP School (IPA) | San Luis |
| 131965 | Santiago Elementary School | San Luis |
| 131964 | San Pedro Elementary School | San Luis |
| 132007 | Pangyan Elementary School | Trento |
| 131972 | Cebuna Elementary School | Talacogon |
| 212030 | Cogonon Elementary School | Trento |
| 212022 | Upper Consuelo II Elementary School | Bunawan |
| 131722 | Ilang-Ilang Elementary School | Loreto |
| 131720 | Don Flaviano I Elementary School | Loreto |

## 3.2. Schools in Medium Susceptibility (LH=2)

The results of the medium susceptibility LH=2 map (Fig.2) shows that there are 49 school or (8.89%) of the total schools are susceptible to LH=2, while 502 school or (91.11%) are not on the LH=2 but have the potential bearing and distance to LH=2,

Table 2 - DepEd Schools Prone to Medium Susceptibility LH=2

| School ID | Name of the Schools | Municipality |
|---|---|---|
| 131944 | Datu Sandigan Elementary School | San Luis |
| 131704 | Duangan Elementary School | Esperanza |
| 317424 | Duangan National High School | Esperanza |
| 131598 | Gethsemane Elementary School | City of Bayugan |
| 131674 | Gulbunon Elementary School | Esperanza |
| 131599 | Hamogaway Elementary School | City of Bayugan |
| 212014 | J.A. Morales Elementary School | Rosario |
| 131795 | Jose U. Cortes Elementary School | San Francisco |
| 131656 | Kalingayan Elementary School | Bunawan |
| 131872 | Kolambugan Elementary School | Sibagat |
| 131901 | Limot Elementary School | Veruela |
| 131840 | Locac Elementary School | San Francisco |
| 131631 | Mahayag Elementary School | San Luis |
| 131710 | Makalindang Primary School | Esperanza |
| 131705 | Maliwanag Elementary School | Esperanza |
| 131823 | Marfil Elementary School | Rosario |
| 131605 | Mt.Olive Elementary School | City of Bayugan |
| 212008 | New Israel Elementary School | Trento |

## 3.3. Schools in High Susceptibility (LH=3)

The output of schools prone to high susceptibility of landslide LH=3 covers 14 schools (2.54%) of the total schools proximate to LH=3 is 537 (97.46%).

Table 3 - DepEd Schools Prone to High Susceptibility LH=3

| School ID | Name of the Schools | Municipality |
|---|---|---|
| 212026 | Balonbon Elementary School | Sibagat |
| 131671 | Calabuan Elementary School | Esperanza |
| 131836 | Das-agan Elementary School | San Francisco |
| 131796 | La Purisima Elementary School | Prosperidad |
| 131603 | Magkiangkang Elementary School | City of Bayugan |
| 131734 | Mansungad Primary School | Loreto |
| 131824 | Masabong Primary School | Rosario |
| 131634 | Mt. Ararat Elementary School | City of Bayugan |
| 131622 | New Bohol Elementary School | City of Bayugan |
| 131860 | San Isidro Elementary School | San Francisco |
| 131882 | San Isidro I Elementary School | Sibagat |
| 131663 | Tagbayangabang Elementary School | Bunawan |
| 131892 | Villangit Elementary School | Sibagat |
| 131614 | Wilderness Elementary School | City of Bayugan |

## 3.4. Comparison of Schools at Various Landslide Susceptibility Levels

Table 4 - Number and Percentage of DepEd Schools in Agusan Del Sur Susceptible to Landslide Hazard

| LH (Susceptibility) | On- LH | % On- LH |
|---|---|---|
| LH = 1 (Low) | 27 | 4.90 |
| LH= 2 (Medium) | 49 | 8.89 |
| LH = 3 (High) | 14 | 2.54 |
| **Total** | **90** | **16.33** |

The schools susceptible to LH=1 has a total of 27 (4.90%), LH=2 is 49 (8.89%) while LH=3 is 14 (2.54%). While the schools tasked id to educate the youth, it is also one essential that the children are safe while they are in school. Knowing the hazard a school is prone to allows the administration to seek for possible mitigation plans, and strategies to foster safe and meaningful learning.

## 3.5. Proximate Distance of Schools to LH (Meters)

Table 5 - Proximate distance of DepEd Schools in Agusan Del Sur Susceptible to Landslide Hazard

| Variable | LH =1 (Low) | LH =2 (Medium) | LH =3(High) |
|---|---|---|---|
| Coefficient of variation | 1.70 | 1.59 | 1.04 |
| Count | 524.00 | 502.00 | 537.00 |
| Maximum value | 5550.46 | 7398.12 | 9967.61 |
| Mean value | 425.60 | 59.30 | 1287.29 |
| Median value | 158.05 | 268.22 | 902.55 |
| Minimum value | 0.43 | 0.33 | 1.05 |
| Standard deviation | 721.40 | 952.37 | 1337.60 |

Figure 3 - Landslide Susceptibility Map for DepEd Schools in Agusan del Sur Province (a) LH-1, (b) LH- 2, and (c) LH-3. ( (The red dots are schools on the ; LH=1, 2 and 3 while the black dots are schools not prone to LH=1,2 and 3)



(a)

(b)

(c)
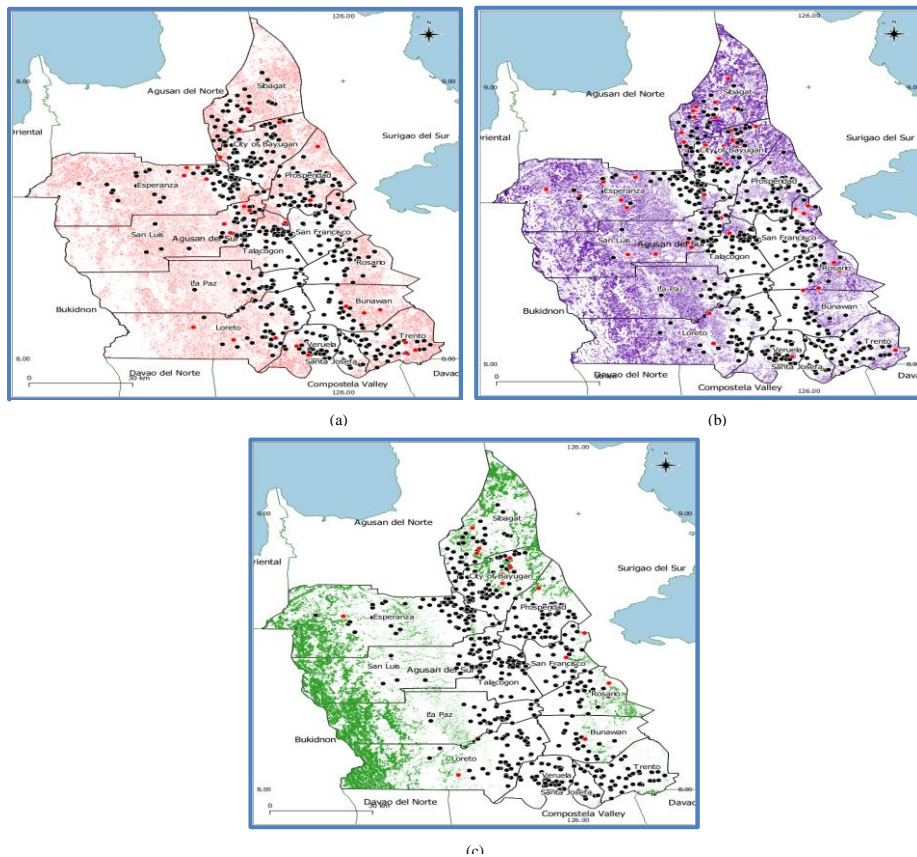
## 4. Conclusions

The study assessed the susceptibility and proximity of schools to potential landslide hazard within LH= 1,2,3. A total of 30 out 551 schools in Agusan del Sur (or 5.44%) are susceptible to landslides. While, 521 of the 551 schools (or 94.56%) are at some distance from LH=1,2,3. The average distance of schools (not within the landslide area) to the nearest landslide hazard is 770 m.

Ideally, schools need to be situated outside landslide hazard zones (LH=1,2,3). School infrastructure within LH=1,2,3 need to be conservatively designed based on highest landslide susceptibility (LH=3).

School decision makers need to take heed to avoid possible risk to these schools prone to danger in the province of Agusan del Sur. The result of this study will further strengthen school preparedness, and seek for possible mitigation efforts in the areas of safety, security and emergency management. The school administrators in collaboration with the LGU's and NDRRMC can help reduce injuries and loss of lives through careful analysis of disaster risk, establishment of early warning systems, drill and training for emergency response strategies. Through this collaborative effort, many lives will be saved from the fatal impacts of hazards.

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