

RISK ASSESSMENT AND MAPPING FOR CANLAON VOLCANO, PHILIPPINES

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KEY WORDS: Hazards, Risk, Mapping, Volcanoes, Disaster, GIS, Spatial, Method

ABSTRACT:

Risk assessment and mapping for Canlaon Volcano, Philippines is reported in this paper. Volcanic hazards in Canlaon Volcano affect the lives and properties within the vicinity. Thus, risk is present as a result of the relationship between the hazards and the human and non-human elements. The volcanic hazards considered were pyroclastic flow, lava flow and lahar. The risk of these hazards to two main factors was investigated, namely, to lives and to infrastructure and/or utility. Using the risk equation from the United Nations International Strategy for Disaster Reduction (Risk = Hazard x Vulnerability), actual computation of the risk values was made. The parameters in the equation were given numerical values. Numerical values for each hazard were assigned using the descriptive category of high, medium and low. The vulnerability parameter was given numerical values from the socio-economic data according to the presence, or absence, of population and infrastructure/utility factors. Having numerical values assigned to them, the hazard and vulnerability factors could then be multiplied to obtain the risk values. The ranking of the areas according to the hazard and vulnerability parameters was used to map out the volcanic risks for Canlaon Volcano. A total of 12 risk maps were produced covering up to the municipal and city level of mapping: one map for each of the two factors (lives; infrastructure and/or utility) and a combination of the two with respect to 1) each one of the volcanic hazards considered; and 2) the combination of all the three hazards.

1. INTRODUCTION

The concept of risk involves the presence of 1) danger or hazard; and 2) human and non-human elements being affected by the hazard itself or its consequence. If there exists a relationship between these two then there is a risk that can be discussed (Quiambao, 2006; ISDR Secretariat, 2004).

This principle is still being used and followed in this particular risk mapping activity. There is a hazard endangering an area and there is also something (human and/or non-human) present in the area, or some factor at risk in the area, which interacts with the hazard present. In this particular scenario, the idea of risk could be discussed.

In a paper by Alberico I., et al, the protocol used to map out risk in the area was to "intersect hazard areas with highly urbanized areas." This is valid for lives/people being in danger from the hazards as well as for the presence of property or productive capacity in the area. If there are no human beings in the area where there is a hazard, it does not necessarily mean that risk for that area is no longer considerable. In the definition of risk, as a matter of fact, the vulnerability factor pointing out to the presence of property or productive capacity would likewise subject an area to risk even without human beings in the area.

1.1 Calculation Explained

The risk equation used by the United Nations International Strategy for Disaster Reduction (UN/ISDR) is the one followed in this paper, i.e.,

$$\text{Risk} = \text{Hazard} \times \text{Vulnerability} \quad (1)$$

where Hazard = probability of occurrence of a given area being affected by some harmful or dangerous event within a given period of time

Vulnerability = proportion of the lives, property or productive capacity threatened likely to be in a given hazardous event; degree of damage resulting from the hazard

In order to obtain numerical values from this equation, which can then be used to map out the "risk" in the area, it is necessary to assign or calculate the numerical values for each of the parameters "hazard" and "vulnerability." Thus, the "hazard" value can be multiplied to the "vulnerability" value which will give a number for the "risk" value in a particular area.

1.2 Study Area

Canlaon Volcano in Negros Oriental Province, Philippines is the volcano being studied in this paper. This is a continuous research study by the author with previous output like generalized risk maps for Canlaon. Previously, purely geospatial analysis was done involving intersection of hazards with areas where utilities and socio-economic parameters, such as population, are known to exist (Quiambao, 2006). The study area (Figure 1) covers an extent from approximately 10°10'N to 10°40'N latitude and approximately 122° 47' E to 123° 24' E longitude.

1.3 Data Used

The following data were used:

1. Topographic, geologic, and hazard maps of Canlaon Volcano, available in digital environment (Canvas

and Mapinfo software/format); by the Philippine Institute of Volcanology and Seismology (PHIVOLCS) dated February 2000; made using the National Mapping and Resource Information Authority (NAMRIA) 1:50,000 topographic maps dated 1950s with additional data on the city, municipal and barangay boundaries coming from the local municipal/city planning offices as of March 1999 and National Statistics Office as of 2002;

2. Infrastructure, utilities and other social and economic data from the 1997 Socio-Economic Profile of Negros Occidental Province; and
3. 2000 and 2007 Population Census Data from the National Statistics Office, Philippines.

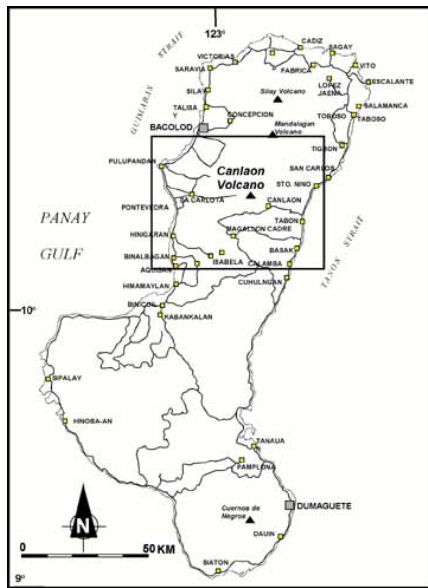


Figure 1. Canlaon Volcano and vicinity, Philippines

2. NUMERICAL CONSIDERATIONS

In order to use the risk equation from the UN/ISDR as a spatial parameter, it is imperative that the parameters in the equation have numerical values. The basic tenet followed was calculation of risk based on assigning/calculating numerical values to the parameters in the risk equation. To give numerical value or range for each parameter, the following points were considered.

2.1 Hazards Value Calculation

The following descriptions of hazards for the pyroclastic flow, lava flow and lahar are in use, based on the PHIVOLCS hazard maps:

Pyroclastic flow:

- 1) pyroclastic flow hazard

Lava flow:

- 1) High lava flow
- 2) Low lava flow

Lahar:

- 1) Areas highly prone to lahar
- 2) Prone to lahar

In assessing the areas likely to be affected by the hazards, it is appropriate to take into account the areas where the volcanic products have been emplaced. This is a spatial consideration of where the volcanic products have been deposited. Hence, the areas where there are lava flow deposit and pyroclastic flow deposits have likewise been noted and included under the respective hazard category.

Based on the hazard description and emplacement of the deposits, the following hazard areas were considered:

- 1) pyroclastic flow hazard
- 2) pyroclastic deposit including debris avalanche deposit, fluvial deposit
- 3) high lava flow
- 4) low lava flow
- 5) lava flow deposit
- 6) potential lahar pathways/areas highly prone to lahar
- 7) prone to lahar

High, medium and low terminologies could be used to describe each category of hazard areas as described above. Consequently, a numerical value of 3, 2 and 1 could be used for each of the category high, medium and low, respectively, in which the highest value being given to the most dangerous category of hazard.

Thus, in order to give numerical values for each hazard area, and in order to be able to use this in the risk equation, the following representation was used:

Numerical value	Category of hazard area	Hazard area
3	High	Pyroclastic flow hazard High lava flow Potential lahar pathways/ areas highly prone to lahar
2	Medium	Pyroclastic deposit including debris avalanche deposit, and fluvial deposit Low lava flow Prone to lahar
1	Low	Low lava flow

Table 1. Hazard representation and categorization

2.2 Vulnerability Value Calculation

The risk equation in use includes the vulnerability factor. As defined in the ISDR documents, the vulnerability factor represents the proportion of the lives, property or productive capacity threatened likely to be in a given hazardous event.

The available socio-economic factors that can be used for the calculation of volcanic risk in the Canlaon Volcano area were population number and the presence of infrastructures and utilities in the area. The infrastructure and utility data was taken from the 1997 Socio-Economic Profile of the Negros Province while the population data was taken from the 2000 and 2007 National Census Data of the National Statistics Office.

In the discussion of vulnerability to the hazards, two socio-economic factors were considered: vulnerability of **lives** and vulnerability of **infrastructure/utility**.

2.2.1 Vulnerability of Lives: Based on the PHIVOLCS Canlaon Volcano Hazards Maps, 6 cities and 13 municipalities around the volcano, for a total of 19, were considered/mapped out. These are the following:

- 1) Bacolod City
- 2) Bago City
- 3) Binalbagan
- 4) Canlaon City
- 5) Guihulngan
- 6) Himamaylan City
- 7) Hinigaran
- 8) Isabela
- 9) La Carlota City
- 10) La Castellana
- 11) Moises Padilla
- 12) Murcia
- 13) Pontevedra
- 14) Pulupandan
- 15) Salvador Benedicto
- 16) San Carlos City
- 17) San Enrique
- 18) Valladolid
- 19) Vallehermoso

From the 2000 and 2007 Population Census data, the number of people for all of the 19 municipalities was added up. Calculation of the percentage of each municipality/city with respect to the total population was then obtained. This percentage gives the ranking of each municipality/city in terms of which one has the highest number of people to be affected. The highest value of the rank was given to the area with the most number of people to be affected.

A single-step increase in the percentage value was used for its corresponding rank value. Thus, percentage values of 1 to 2 were given a rank of 1; 3 to 4 percentage were given a rank of 2; and so on with the last rank value of 6 given to percentage 11 and above. The higher the rank value, the higher the vulnerability factor.

From the rank values obtained by calculating the percentage of each municipality/city with respect to the total population of the 19 municipalities/cities, these numbers give numerical value to the factor “vulnerability of lives” in the risk equation.

2.2.2 Vulnerability of Infrastructure/Utility: Aside from lives, property is another parameter considered to be threatened when there is a hazardous event. The infrastructure present, as well as the utilities available in the area, was considered. From the Socio-Economic Profile of the Negros Province, these properties were tabulated and a listing for each municipality/city concerned was made.

The infrastructures and utilities available in the municipalities and cities concerned include the following:

- 1) bridges
- 2) ports (private and public)
- 3) airport
- 4) hospital/health center
- 5) road system
- 6) school
- 7) fire fighting facility
- 8) telecommunication infrastructure

From the listing per municipality/city, one point was given for each infrastructure and utility present. The total points for each

municipality/city was then summed up and ranked from lowest to the highest value. This gives the value for the factor “vulnerability to infrastructure/utility” in the risk equation. Ranking of the total infrastructure/utility for each municipality/city was made. The highest rank was given to the municipality/city where there is the most number of infrastructure/utility present.

A single-step increase in the total infrastructure/utility value was given for its corresponding rank. These rank values were used for the “vulnerability of infrastructure and utility” factor in the risk equation.

3. CALCULATION OF RISK

We take from the risk equation being used, equation (1), the “risk” factor as a number denoting the product of “hazard” and “vulnerability.” We take the factors “hazard” and “vulnerability” as ranks of each one. Particularly, vulnerability can be calculated for possible 1) lives lost; and 2) infrastructure/facility damaged/lost. Hence, for each type of hazard, two risk values can be calculated: one, for possible risk to human lives lost and/or injured; and two, for possible risk to infrastructure/utility damaged/lost.

3.1 Equations to be Used for the Calculation of Risk

These are the equations to be considered:

- 1) Risk to lives possibly lost or injured

$$R_L = H \times V_L \quad (2)$$

where R_L = risk to lives
 V_L = vulnerability to lives
 H = hazard

- 2) Risk to infrastructure/utility possibly lost or damaged

$$R_I = H \times V_I \quad (3)$$

where R_I = risk to infrastructure/utility
 V_I = vulnerability to infrastructure/utility
 H = hazard

- 3) Total risk

$$R_T = R_L + R_I \quad (4)$$

The numerical values or range for hazard and vulnerability are the rankings of each.

For hazard, high, medium and low hazards were given the rankings of 3, 2, and 1 respectively.

For vulnerability of lives, the percentage populations with respect to the total population for each municipality/city were ranked and numerical values of 1 to 6 were obtained, the highest value of which belongs to the most populous area (most number of people will be affected.)

For vulnerability of infrastructure/utility, one point was given for each facility found in every municipality/city and these were summed up. Ranking of the sums was obtained getting values from 1 to 5. The area with the most number of facilities that can be damaged or lost got the highest rank value.

3.2 Tables of Risk Calculation

For each area (municipality or city) around Canlaon Volcano, the corresponding “hazard” value/ranking and “vulnerability” value/ranking were calculated. The “risk” value for each area could then be derived. These “risk” values were ranked accordingly, from lowest to highest value. Areas having “0” value of risk are areas where there were no hazard as indicated in the PHIVOLCS hazard maps, and thus, no value for risk was calculated. Permutation of the parameters in the risk equation leads to the generation of a total of 12 risk maps.

Below are the tables showing the ranking of “risk” to the three risk factors considered (lives, infrastructure/utility, and both) with respect to the volcanic hazard factors considered (pyroclastic flow, lava flow, lahar and all three).

Municipality/City	Ranking of risk to lives due to		
	PF	LF	LAHAR
Bacolod City	0	0	0
Bago City	5	5	5
Binalbagan	2	0	3
Canlaon City	3	3	3
Guihulngan	0	0	0
Himamaylan City	0	0	0
Hinigaran	3	0	4
Isabela	2	0	3
La Carlota City	3	3	3
La Castellana	3	3	3
Moises Padilla	1	2	2
Murcia	2	1	0
Pontevedra	2	0	3
Pulupandan	0	0	1
Salvador Benedicto	0	0	0
San Carlos City	4	4	0
San Enrique	0	0	2
Valladolid	0	0	0
Vallehermoso	0	0	0

Table 2. Risk to lives due to volcanic hazards

Municipality/City	Ranking of risk to infrastructure/utility due to		
	PF	LF	LAHAR
Bacolod City	0	0	0
Bago City	5	5	5
Binalbagan	1	0	2
Canlaon City	2	2	2
Guihulngan	0	0	0
Himamaylan City	0	0	0
Hinigaran	2	0	3
Isabela	1	0	2
La Carlota City	3	3	3
La Castellana	4	4	4
Moises Padilla	1	2	2
Murcia	2	1	0
Pontevedra	1	0	2

Municipality/City	Ranking of risk to infrastructure/utility due to		
	PF	LF	LAHAR
Pulupandan	0	0	1
Salvador Benedicto	0	0	0
San Carlos City	4	4	0
San Enrique	0	0	2
Valladolid	0	0	0
Vallehermoso	0	0	0

Table 3. Risk to infrastructure/utility due to volcanic hazards

Municipality/City	Ranking of risk to both lives and infrastructure/utility due to		
	PF	LF	LAHAR
Bacolod City	0	0	0
Bago City	8	7	6
Binalbagan	2	0	3
Canlaon City	4	3	3
Guihulngan	0	0	0
Himamaylan City	0	0	0
Hinigaran	4	0	5
Isabela	2	0	3
La Carlota City	5	4	4
La Castellana	6	5	5
Moises Padilla	1	2	2
Murcia	3	1	0
Pontevedra	2	0	3
Pulupandan	0	0	1
Salvador Benedicto	0	0	0
San Carlos City	7	6	0
San Enrique	0	0	2
Valladolid	0	0	0
Vallehermoso	0	0	0

Table 3. Risk to lives and infrastructure/utility due to volcanic hazards

Municipality/City	Ranking of risk due to all hazards to		
	Lives	Infrastructure /Utility	Both
Bacolod City	0	0	0
Bago City	9	11	11
Binalbagan	5	4	4
Canlaon City	7	7	7
Guihulngan	0	0	0
Himamaylan City	0	0	0
Hinigaran	6	5	6
Isabela	5	4	4
La Carlota City	7	9	8
La Castellana	7	10	10
Moises Padilla	4	6	5
Murcia	3	3	3
Pontevedra	5	4	4
Pulupandan	1	1	1
Salvador Benedicto	0	0	0
San Carlos City	8	8	9
San Enrique	2	2	2
Valladolid	0	0	0
Vallehermoso	0	0	0

Table 4. Risk due to the three volcanic hazards

4. MAP GENERATION

Shown in the risk tables are the risk values for each city/municipality around Canlaon Volcano based on numerical-value assignment to the hazard present and to the vulnerability of lives and infrastructure/utility present. The risk values obtained ranged from the highest possible value to zero for each category. No definite high value could then be generalized for all types of hazards nor for a specific factor vulnerable to the hazard (lives or infrastructure/utility). However, a zero value can be obtained for an area with no apparent hazard present according to PHIVOLCS hazard map. A ranking of zero value was assigned to areas where there is no hazard present.

Color assignment to areas was used in mapping the volcanic risks calculated in Canlaon volcano area. Risk values were ranked accordingly and the ranking was indicated by a varying color shade. Increasing rank value showed an increasing risk value with the zero rank indicating a “no risk” value. A variation of color from light to dark indicates an increasing risk to the area with no color (white) for no risk zone (zero value). The map showing the risk to both lives and infrastructure and/or utility with respect to all hazards is in Figure 2.

5. CONCLUSION

Volcanic risks for Canlaon Volcano were calculated using the definition of “risk” from the United Nations International Strategy for Disaster Reduction (UN/ISDR). The parameters “hazard” and “vulnerability” were either calculated and/or assigned values/ranked based on the principle that the highest value was given to the area where the “most” of the factor prevailed – most dangerous category of hazard; most number of people to be affected; and most number of infrastructure/utility present. The product of “hazard” and “vulnerability” gives the “risk” values for each municipality with the higher value indicating greater risk for the area. The municipalities were then mapped out using an increasing shade of color. Thus, monochromatic color shading was used to map out the volcanic risk values for the 19 municipalities around Canlaon Volcano. The maps generated were risk maps to lives, infrastructure/utility and/or a combination of both with respect to the hazards – pyroclastic flow, lava flow, lahar, and a combination of the three. Twelve risk maps were produced with the various permutations of the parameters. These 12 risk maps are as follows:

- 1) Risk to lives with respect to pyroclastic flow
- 2) Risk to lives with respect to lava flow
- 3) Risk to lives with respect to lahar
- 4) Risk to lives with respect to all hazards
- 5) Risk to infrastructure and/or utility with respect to pyroclastic flow
- 6) Risk to infrastructure and/or utility with respect to lava flow
- 7) Risk to infrastructure and/or utility with respect to lahar
- 8) Risk to infrastructure and/or utility with respect to all hazards
- 9) Risk to both lives and infrastructure and/or utility with respect to pyroclastic flow
- 10) Risk to both lives and infrastructure and/or utility with respect to lava flow
- 11) Risk to both lives and infrastructure and/or utility with respect to lahar

- 12) Risk to both lives and infrastructure and/or utility with respect to all hazards

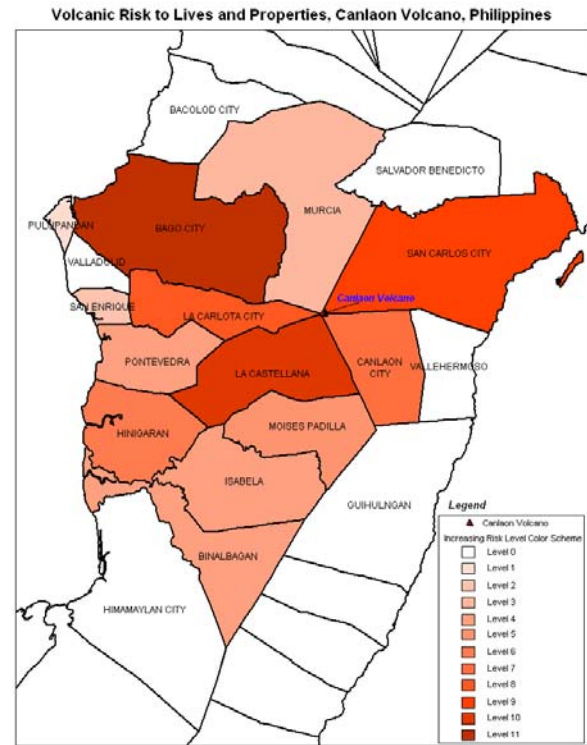


Figure 2. Risk map for both lives and properties due to all three volcanic hazards, Canlaon Volcano and vicinity, Philippines

In an environment devoid of an operational GIS hard- and software, and cash-strapped for almost all other related expenses but has technical manpower equipped with the fundamental knowledge on the subject matter, volcanic risk assessment was successfully completed. This risk assessment procedure can provide answers to the questions such as what type of volcanic hazard is going to affect which area and what socio-economic parameter will be affected and where.

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Detailed explanation of the risk calculation and the print out of all the risk maps generated are included in the interactive presentation.