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Land Cover Mapping of an Urbanized Volcano Using an Open Source Software: Taal, Philippines

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Abstract:- Despite the hazards, the population within active volcanic areas has been increasing. Urbanization in these areas result to changes in land cover and increase of communities at risk. Thus, an accurate understanding of land cover in volcanic areas is necessary. Satellite remote sensing and geographic information systems have been used for land cover mapping for resources and land use planning. However, there are not so much studies concentrating on volcanic areas, especially in the developing countries. High quality reference data also contribute to better classification. This study seeks to map the land cover of Taal volcanic area in Batangas province, Philippines. It is one of the Twelve Decade Volcanoes of the world having a reputation for being dangerous and worthy of study, and where the tourism industry has been progressing. LANDSAT 8 Operational Land Imager/Thermal Infrared Sensor 2016 satellite image and ground truth photos were utilized for the analysis. The International Geosphere-Biosphere Programme system was used to categorize the land cover types. The Maximum Likelihood Classification algorithm was facilitated for the classification and accuracies were also calculated. The percentage of land cover classes will be presented, focusing on the urban or built up areas and its proximity to the hazard zones of the volcano.

Keywords:- *Land Cover; Volcano; Urban; Open Source; Taal.*

I. INTRODUCTION

There are various disasters which can be attributed by hazards of volcanoes. Examples of these volcanic hazards are pyroclastic flows and surges caused by eruption, earthquakes, landslides, tsunamis and mudflows. Despite these hazards, the population in active and potentially active volcanoes increases have been increasing. Around ten to twenty percent of the world's population live within active and potentially active volcanoes [11]. The growth of population being exposed to volcanic hazards is an integral driver in increased disaster occurrences [9].

Land cover maps and urban and built-up area monitoring is a tool for various purposes in terms of environmental management such as not only for land use planning in disaster prone areas. If the land area and locations of urban areas are included in hazard prone areas. Land Use and Land Cover (LULC) as a tool to plan land use which can help mitigate potential disasters to people [4]. Land cover maps may take time to make and local communities lack the capacity to create and analyze these maps. Open source softwares for geoinformation science have been beneficial in terms of environmental science studies as these are not only free of charge but are also open for enhancement or development by various researchers. Updated land cover maps can be done by local governments and communities through the satellite images which can be downloaded for free and the utilization of open source software to process and analyze these images.

Given the necessity to produce land cover maps amid limited resources, this study attempts to detect the urbanized areas in a volcanic area using satellite images and open source softwares.

II. MATERIALS AND METHODS

A. Study Area

The area to be studied is in Taal volcanic area (Fig. 1) in Batangas province, Republic of the Philippines. It is the second most active volcano in the country and one of the 12 Decade Volcanoes of the world cited by the International Association of Volcanology and Chemistry of the Earth's Interior [12]. The Decade volcanoes are those listed by the organizations which are needed to be studied because of their large eruptions in the past and high proximity to populated areas. Taal's eruptive history can be seen in Table 1, while its eruption sources can be seen in Fig. 2.

Taal volcanic area is also a very popular place for tourism as hiking, fishing, sightseeing, malls and amusement parks as it is just two hours away from Metro Manila, the country's capital. The area is also a popular site for residential villages and condominiums [13]. The Taal volcanic island is where the main crater is located is centered by a lake formed by the Taal caldera where it has forty-seven eruptive centers [10].

B. Data Collection

Level 1 satellite images from Landsat 8 OLI (Operational Land Imager) and TIRS (Thermal Infrared Sensor) were acquired for year 2016/04/03 from the United States Geological Survey's Earth Explorer repository. Five hundred (500) points from ground truth photos taken from a field visit in 2016 September and 2017 February at the Taal volcanic area. Visual interpretation was also done by referring to Google Earth. A total of 1147 polygons were used as reference data where 62% or 709 polygons were used as training data and 38% or 438 polygons as testing data.

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C. Data Analysis

The images were processed and the classification and accuracy assessment were performed using the Semi-automatic Classification Plugin or SACP [3] in Quantum GIS, an open source software. For a more accurate location of the ground truth photos, the coordinates were adjusted through the Site-based dataset for Assessment of Changing land cover by the Japan Aerospace Exploration Agency version 2 or SACLA-J, (available at https://eorc-jaxa.jp/lulc/SACLAJ/grefs/search_data). The points were referred in order to create polygons by the region growing algorithm in SACP. Stratified random sampling was done to select the training data, where at least 100 polygons were made for water, vegetation and barren categories. As the study focuses on the growth of urban areas, 200 polygons were created as training data for urban and built-up. Classification was performed by Maximum Likelihood Classification algorithm available in the plug-in. Accuracy assessment was determined by Producer's and User's Accuracies and Kappa coefficient also available in the plug-in. These algorithms are being used commonly for land cover mapping and classification.

Year	**Eruption source**	**Eruption type**	**Volcano Explosivity Index (VEI)**	**Hazard type(s)**	**Volume of ejecta (1 x 106 m^3)**	**Ashfall thickness**	**Affected areas**	**Human impacts**
1731	Pira-piraso	Phreatomagmatic	2	Base surge, tephra fall, bombs, tsunami	-	-	Taal volcano island	Undetermined
1749	Main crater	Violent, phreatomagmatic	4	Tephra fall, base surge, projectiles, tsunami, acid rain, shock waves, subsidence	50-100	-	Taal volcano island, lakeshore towns (Taal, Sala & Tanauan)	Undertermined
1754	Main crater (southern flank)	Very violent, phreatomagmatic	4	Tephra fall and projectiles, ash fall, base surge, tsunami, fissures, shock waves, acid rain	150	100 cm in 400 km^2 area; 110 cm – 16 km SW of crater	Taal volcano island, lakeshore towns (Taal, Lipa, Sala & Tanauan)	12 casualties
1911	Main crater	Violent, phreatic	3	Tephra fall and projectiles, ash fall, base surge, tsunami, acid rain, shock waves, fissuring and subsidence	80	25 cm in 230 km^2 area	Taal volcano island, Talisay and other lakeshore towns	1,335 casualties
1965	Mt. Tabaro	Violent, phreatomagmatic	4	Tephra fall and projectiles, ash fall, base surge, acid rain, tsunami, shock waves	40	25 cm	Taal volcano island, Talisay and other lakeshore towns	200 casualties
1968-1969	Mt. Tabaro	Phreatomagmatic	3	Tephra fall and projectiles	-	-	Taal volcano island	-

Table 1:- Taal's Major Eruptions Since 1700s [5][7][11]

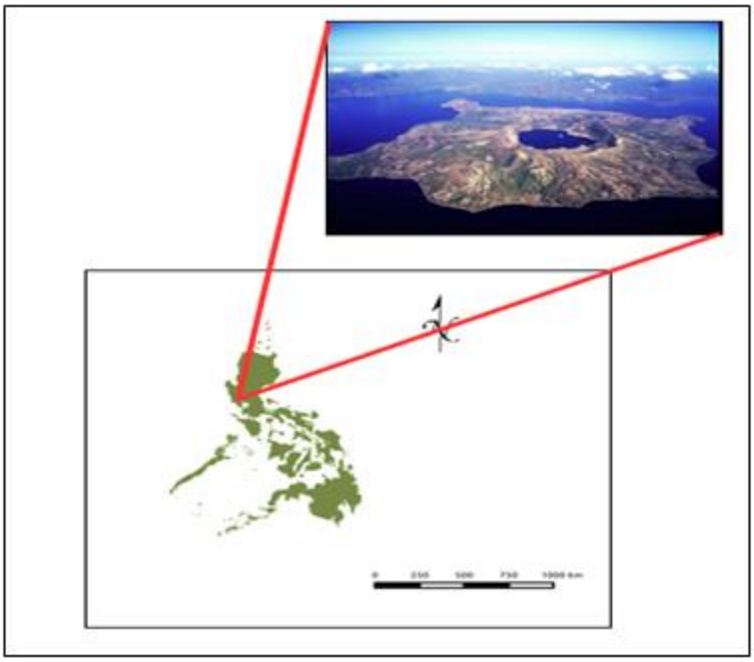

Fig 1:- Taal volcanic island

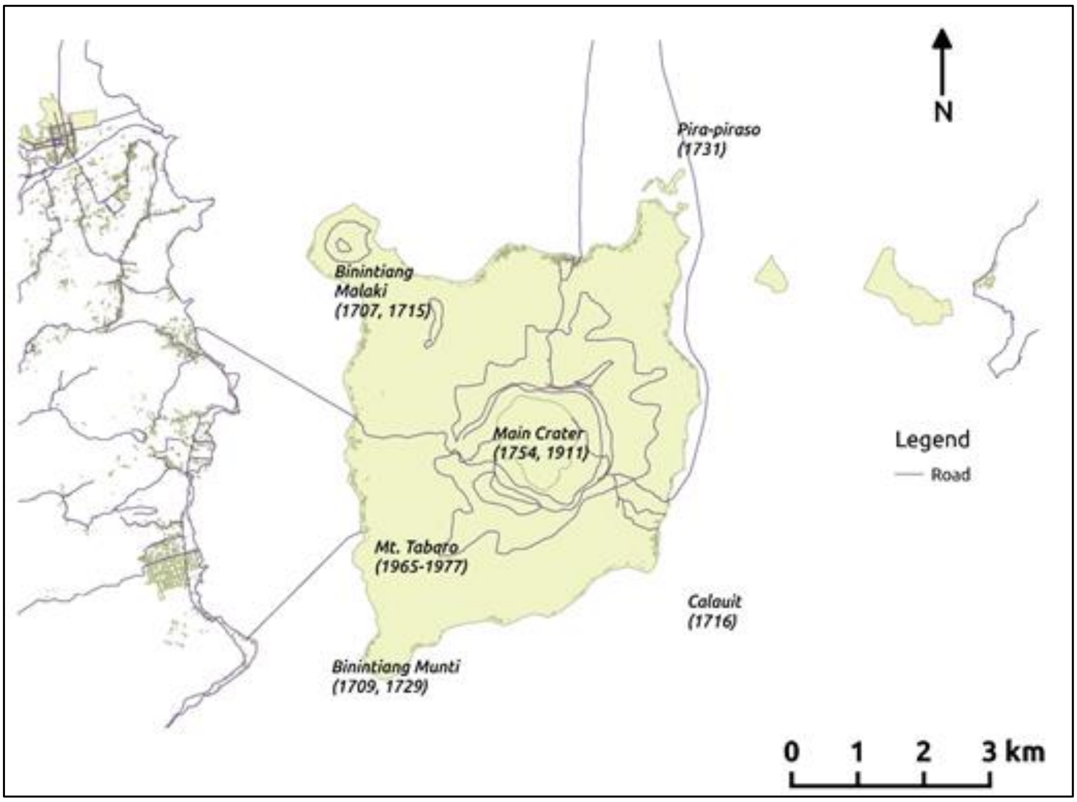

Fig 2:- Taal eruption sources

For simplicity, the classification types were reduced to four classes, namely Water, Vegetation, Urban and Built-up and Barren. The Vegetation category includes forest, grassland, cropland and shrubland categories. Clouds and shadows were also extracted in the creation of training data and described as null data or "0" category.

III. RESULTS AND DISCUSSION

A. Land Cover Map

The classified land cover map is shown in Fig. 3. The results of the classification in Table 2. revealed that the vegetation category has the largest coverage in the area with 365 km^2 or 33.54%, while the urban and built-up area is the second category with 21.83%. It covered 238 km^2 of land area. Next to urban and built-up is water with 20.36%

covering a land area of 222 km^2. The barren category covers 17.92% with a land area of 195.165 km^2. As seen on the map, there are urban and built-up areas in the volcano island specifically at the edges of the crater, and the island and caldera shores.

B. Accuracy Assessment

The accuracy assessment of the map can be seen in Table 3. The overall accuracy of the map is 98.35% with a Kappa coefficient of 0.915. The producer's accuracy for water and vegetation are the highest at 98.99% and 98.64% with Kappa coefficients of 0.99 and 0.98. The producer's accuracy for urban and built-up category is at 86.54% with a Kappa coefficient of 0.83%.

The producer's accuracy for barren is at 89.5 % with a Kappa coefficient of 0.74 %. The presence of urban and built-up areas where also confirmed during the ground truth field visit in 2016 September.

The urban areas identified in the volcano island and surrounding lakeshores and the upper part of the caldera are evidences of the growing tourism industry in the area. The volcanic island has become a residential area and most of the people who live here are doing jobs related to tourism such as horse guides and food and souvenir sellers. Urbanization over the years can also be seen by comparing from NAMRIA's 1999 and 2010 land cover maps. These urbanized areas however are prone to volcanic hazards as identified in the PHIVOLCS' maps for volcanic hazards [6] such as pyroclastic flow and ballistic projectiles. In this case, people such as residents and tourists that are near or within hazard areas are at risks of volcanic disasters which may lead to injuries or death.

The volcanic island is identified as a Permanent Danger Zone even though there is no Alert Level as sudden eruptions may occur. This means that there should be no permanent inhabitants in the area. However, as identified in the map and the field visit, there are urban areas present there. As asked during an interview, relocation has always been an option but the implementation is difficult. In this case, continuous monitoring of urban and built-up areas can be done through the use of open source softwares which are already available. In addition to the urban and built-up land cover, population census data monitoring must be needed. Most importantly, there is a need to have stricter land use planning as it contributes in not allowing development of buildings and houses in hazardous areas and planning for evacuation [1][8].

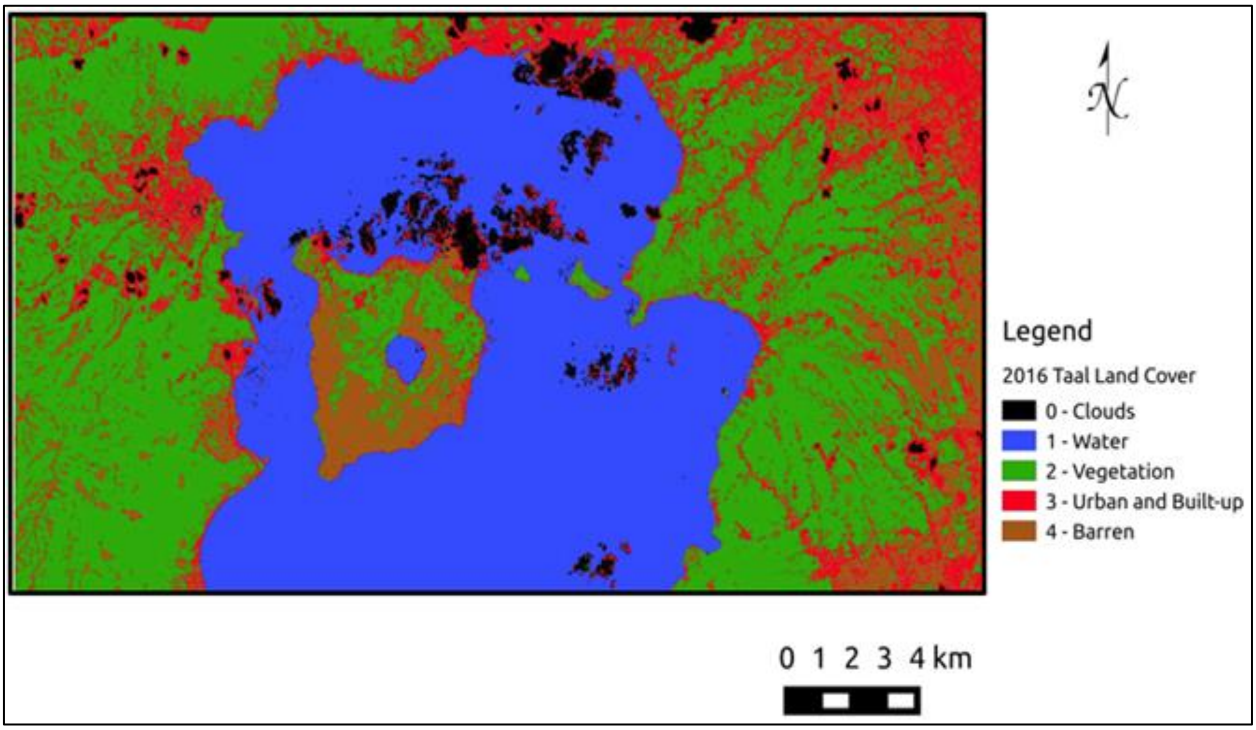

Fig 3:- Taal land cover classification map 2016

Class ID	Class Name	Pixel sum	Percentage (%)	Area (km^2)
0	Clouds	76878	6.35 %	69.190
1	Water	246325	20.36 %	221.692
2	Vegetation	405826	33.54 %	365.243
3	Urban and Built-Up	264121	21.83 %	237.708
4	Barren	216850	17.92 %	195.165

Table 2:- Classification Results

Class ID	Class Name	Producer's Accuracy	User's Accuracy	Kappa hat
0	Clouds	Nan	0.0%	0.0
1	Water	98.99%	99.98%	0.99
2	Vegetation	98.64%	98.31%	0.98
3	Urban and Built-Up	86.54%	83.32%	0.83
4	Barren	89.50%	75.49%	0.74
OVERALL Accuracy = 98.35%				
Kappa hat = 0.915				

Table 3:- Accuracy Assessment

The findings also show how important mitigation by education and preparedness must be intensified especially about the people's ideas on what the hazards are, what harm they can these do and what they need to do.

IV. CONCLUSION

The 2016 Land Cover of Taal volcanic area was mapped using LANDSAT 8 OLI-TIRS and open source software QGIS. The presence of urban and built-up areas in hazardous zones was identified. The utilization of free datasets and software may be useful for developing countries. Higher resolution satellite images and classifiers. Change detection analysis of the urban and built-up areas from the past years up to the present is also suggested for future studies.

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