PHILIPPINE VOLCANIC HAZARDS: A MODIFIED APPROACH OF THE VPI30 CALCULATION USING GIS EXTRACTION TOOLS AND SENTINEL-2 IMAGERY DATA

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Abstract

The Volcano Population Index at 30 kilometers (VPI30) is a key metric used in the National Volcano Threat Assessment (NVTA) to estimate the population at risk within a 30-kilometer radius of an active volcano. This metric is especially important to the Philippines which is home to more than 300 volcanoes, 24 of which are active. To support research and development on the mitigation of volcanic-related disasters, the Philippine Institute of Volcanology and Seismology (PHIVOLCS) uses a modified version of the VPI30 to fit the Philippines setting. The current Philippine VPI30 methodology assumes uniform distribution across barangay (village) boundaries. This study aims to improve the existing methods through the use of high-resolution Sentinel-2 satellite imagery and geospatial analysis techniques. This is investigated to enhance understanding of the population distribution which is especially important in rural areas where households are generally observed to be clustered. Using land classification models, the built-area pixels within village boundaries intersecting the 30-kilometer buffer zone are identified. These built-area pixels will be proxies for human settlement and population. The ratio of built-area pixels inside the buffer zone to the total built-area pixels for each village is then calculated, the result is multiplied by the village population to get a more refined estimate of population distribution. Using this modified VPI30 methodology, a representative village yielded at least a 70% decrease in calculated exposed population. While the method marks an improvement in identifying exposed populations, it has some limitations. The reliance on broad land classifications, such as "built areas," can impact precision, particularly in distinguishing between residential and non-residential structures. Future work will focus on refining land classification models to better identify housing clusters and validate consistency when applied to multiple villages.

Background

Volcanism in the Philippines can be attributed to its complex tectonic setting. The archipelago lies at the convergence of the Philippine Sea Plate, Eurasian Plate, and Indo-Australian Plate, creating subduction zones such as the Manila Trench and the Philippine Trench[1]. These subduction processes are the main catalysts for magma generation in the region as oceanic plates descend into the mantle, triggering partial melting and magma production.

The Philippine National Volcano Threat Assessment is a hazard and exposure matrix to create a threat ranking for active volcanoes in the Philippines. The Volcano Population Index at 30 km (VPI30) is a factor that calculates ground-based population as one of the exposure matrices.[5]

30 km is chosen for several reasons:

- It catches proximal population distributions in all regions
- For VEI 4-5 eruptions, which is the worst case for most systems, pyroclastic flow has a small (~5%) chance to exceed 30 km from the vent.
- For eruptions ≥ VEI 4, there is an 80% chance of tephra fall accumulation to exceed 10cm at 30 km downwind

The 30 km radius is a compromise radius that identifies the greatest extent of volcanic hazards (volcanic ash & pyroclastic flows) while also considering the most likely scenarios during an eruption.[2]

Figure 1. Active Volcanoes of the Philippines – black box showing the study area

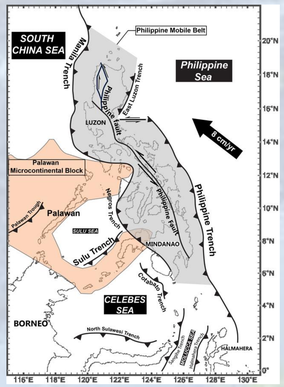

Figure 2. Map showing the tectonic setting of the Philippines[1]

Methods

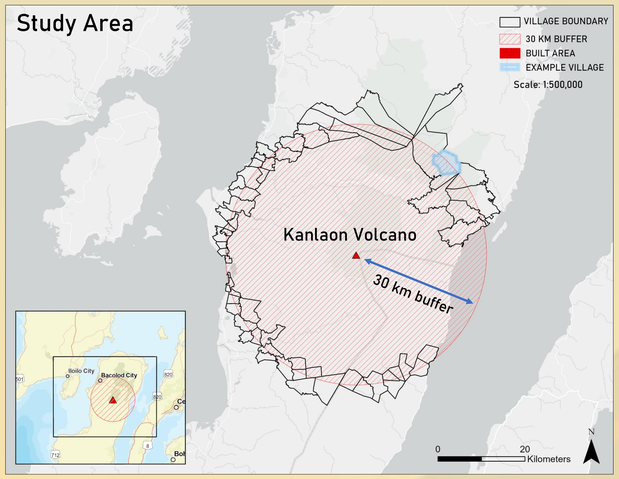

Figure 3. Study area containing the 62 villages that are partially within the VPI30. Villages fully within 30 km are disregarded as 100% of their population is within the 30 km buffer

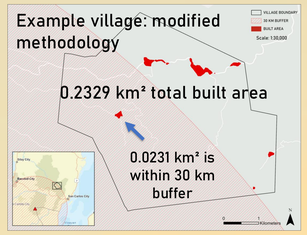

Figure 4. Modified methodology assumes that the population is distributed across only the built area polygons

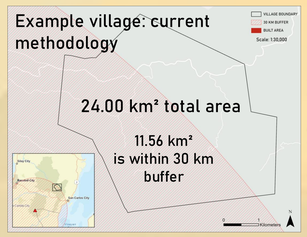

Figure 5. Current methodology assumes that the population is distributed across the entire village boundary [5]

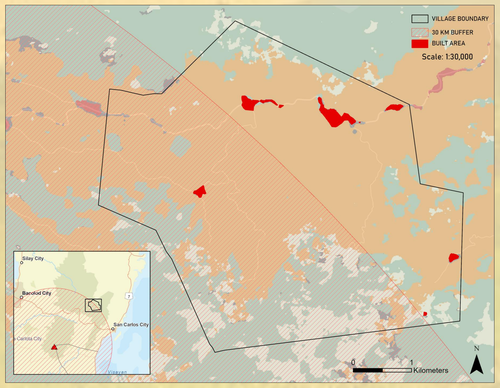

Figure 6. Sentinel -2 land classification data over the example village

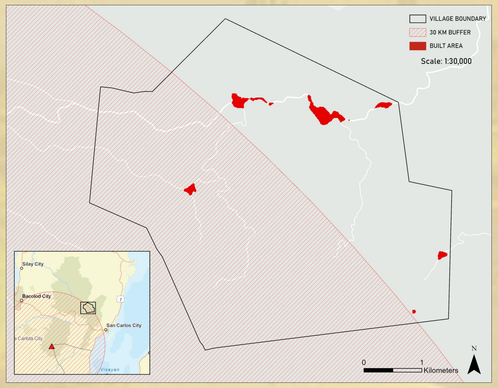

Figure 7. Extracted built area pixels over the example village

The first part of the analysis is extracting the pixels using the Extract by Mask tool in ArcGIS Pro. This is followed by using the Raster to Polygon tool and then the Clipping tool to finally identify the built area within the 30 km buffer.

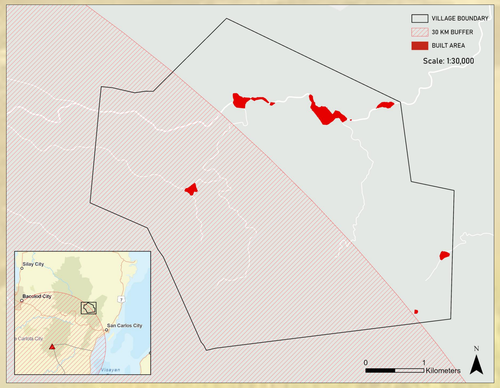

Figure 8. Identified built area polygons within the example village

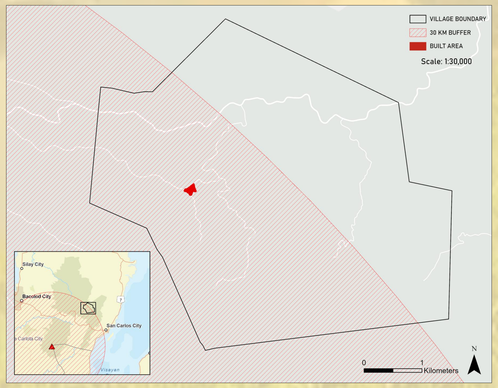

Figure 9. Clipped built area polygon within the 30 km buffer

The Raster to Polygon tool is used to avoid problems with consistency when clipping rasters. Using this tool also automatically calculates the shape area of all polygons generated

Results and Discussion

Methodology	Total Population villages partially within VPI30	Total Population excluding extended hazard zone
Original Calculation	245,258	951,213
Modified Calculation	184,485	890,457

- For 62 villages that are partially within the VPI30, as much as a **28%** difference (60,773) is computed using the modified methodology
- If the modified methodology is applied to all villages (235) within a 30 km radius of Kanlaon Volcano, there is a **7%** difference in the population of villages
- In some cases, when the modified methodology is used, as much as a **70%** decrease in population is observed in villages where village centers are outside the 30 km buffer
- The modified methodology adds precision to the current methodology by identifying population clusters through land classified built areas – this is especially important in the context of the National Volcanic Threat Assessment, as more precision in identifying population distributions can lead to improved efficiency of emergency action plans

Moving Forward

- The modified methodology is only as good as the resolution of the land classification data. In areas with dense vegetation cover, smaller housing clusters may be difficult to identify
- Coordination with Local Government Units for housing data and field verification of structures would provide a gauge for the accuracy of the methodology
- Explore other land classification datasets for comparison – NAMRIA (National Mapping and Resource Information Authority) Land Classification provides a good localized dataset for the Philippine setting
- Image classification to identify individual housing clusters is possible in ArcGIS Pro but is extremely limited to the resolution of satellite imagery and the strength of training polygons
- Automation of the GIS workflow is possible through ArcPy, a Python package built into ArcGIS Pro. Using scripts for the analysis speeds up the process and ensures workflow accuracy, especially when dealing with a large dataset

References

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Acknowledgements and Contact Information

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