

Participatory Noise Mapping Using GIS in Community Barrio Obrero Oeste, Caño Martín Peña Special Planning District

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Abstract

This study investigates urban noise pollution in Barrio Obrero Oeste, San Juan, Puerto Rico, using Geographic Information Systems (GIS) and participatory noise mapping. Noise pollution is a significant environmental and public health concern, particularly in densely populated urban areas. Using the NIOSH Sound Level Meter App, 81 noise samples were collected to analyze equivalent continuous sound levels (LAeq) and maximum sound levels (Lmax). The study identifies transportation corridors, air traffic, and mixed-use zoning as primary contributors to noise pollution. Kernel density analysis highlights noise hotspots exceeding regulatory thresholds set by Puerto Rico's Environmental Quality Board. Findings demonstrate that participatory noise mapping is a cost-effective approach for environmental monitoring. This research provides insights into land-use zoning impacts on noise pollution, emphasizing the need for community-driven solutions and sustainable urban planning.

Introduction

Noise pollution is a critical urban environmental issue, with significant public health implications, including sleep disturbances, cognitive impairments, and cardiovascular diseases [1]. In densely populated communities, excessive noise exposure often stems from transportation corridors, industrial activities, and mixed-use zoning, leading to chronic noise stress among residents. Barrio Obrero Oeste, located within the Caño Martín Peña Special Planning District (CMPSPD), is particularly vulnerable to high noise levels due to its proximity to major highways, a train station, and an international airport (Figure 1).

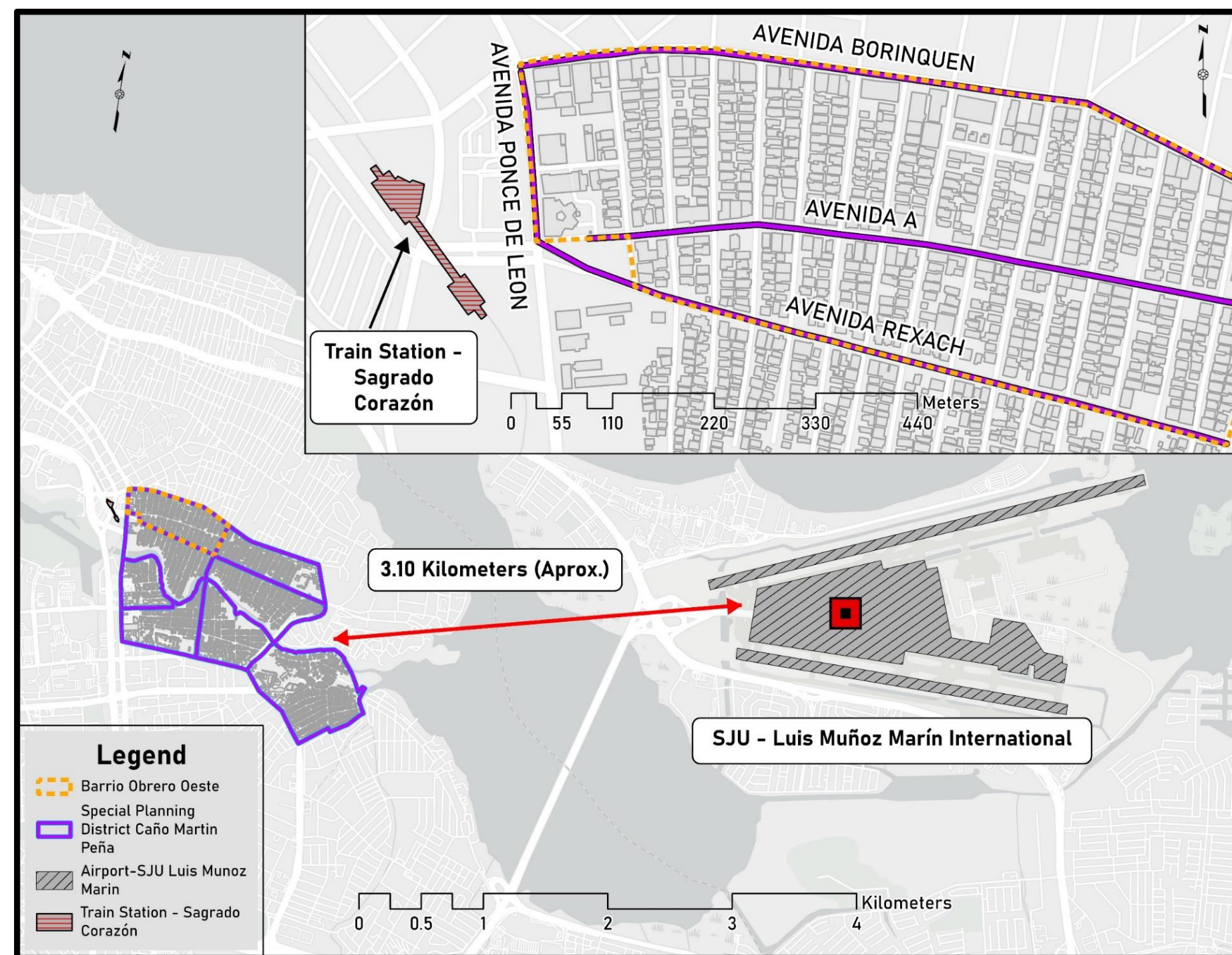


Figure 1: Map of Noise Pollution Sources such as Main Avenues & Transportation Infrastructure

The primary objective of this study is to analyze urban noise pollution using GIS-based participatory noise mapping to identify critical noise hotspots and examine the relationship between land-use zoning and noise pollution intensity. This research seeks to answer three fundamental questions: (1) What are the dominant sources of noise pollution? (2) How does zoning influence noise intensity? and (3) Can participatory noise mapping serve as a reliable, scalable tool for urban noise monitoring? By addressing these questions, this study contributes to sustainable urban planning, aligning with the United Nations Sustainable Development Goals (SDG 11: Sustainable Cities & SDG 3: Good Health & Well-being) [2][3].

Methodology

This study employs a participatory sensing approach integrated with Geographic Information Systems (GIS) to assess urban noise pollution in Barrio Obrero Oeste. The research was conducted through community-driven noise data collection, utilizing the NIOSH Sound Level Meter App on iOS devices. A total of 81 noise samples were collected from four key roads—Avenida Ponce de León, Avenida A, Avenida Rexach, and Avenida Borinquén—during a one-week diurnal period between 11:00 AM and 12:00 PM. The app recorded Equivalent Continuous Sound Levels (LAeq) and Maximum Sound Levels (Lmax), capturing both sustained and peak noise exposures. ArcGIS Field Maps was used to georeference each sample, ensuring spatial accuracy and enabling the integration of noise data into a GIS-based analytical framework.



Figure 2: NIOSH Sound Level Meter App (Left side) & TOPTES Decibel Level Meter (Right side)

To analyze spatial noise distribution, the study implemented an 80m x 80m grid-based spatial framework, ensuring systematic data collection and high-resolution noise mapping. Using Kernel Density Analysis, noise intensity clusters were identified, highlighting areas where noise exceeded regulatory thresholds set by Puerto Rico's Environmental Quality Board. Additionally, land-use zoning classifications were overlaid onto noise data to examine correlations between zoning regulations and noise exposure levels. The study aimed to determine how commercial, industrial, and residential zones are affected by noise pollution and to identify patterns in high-risk areas.

To enhance measurement reliability, a comparative validation study was conducted between the NIOSH Sound Level Meter App and the TOPTES Sound Meter (Figure 2), a calibrated external sound level device. The comparison revealed a measurement deviation range of ±0 to ±2.7 dB(A), confirming that the NIOSH app provides accurate and reliable noise measurements when properly calibrated. These calibration efforts ensured the integrity of the participatory noise mapping approach, reinforcing the viability of smartphone-based noise assessments as a scalable and cost-effective solution for urban noise monitoring.

Results and Discussion

A. Noise Source Identification and Hotspots

The analysis of 81 noise samples revealed that transportation corridors and air traffic are the primary sources of noise pollution in Barrio Obrero Oeste. The highest noise levels were recorded along Avenida Borinquén and Avenida Rexach, both of which serve as major vehicular routes with significant commercial activity. Maximum noise levels (Lmax) in these areas frequently exceeded 90 dB(A), surpassing Puerto Rico's Environmental Quality Board noise thresholds for residential and commercial zones. The proximity of Luis Muñoz Marín International Airport further contributed to elevated noise levels, with both military and commercial aircraft affecting the area during landing approaches. These findings highlight that a combination of road traffic, transit hubs, and air traffic significantly increases noise exposure in the study area.

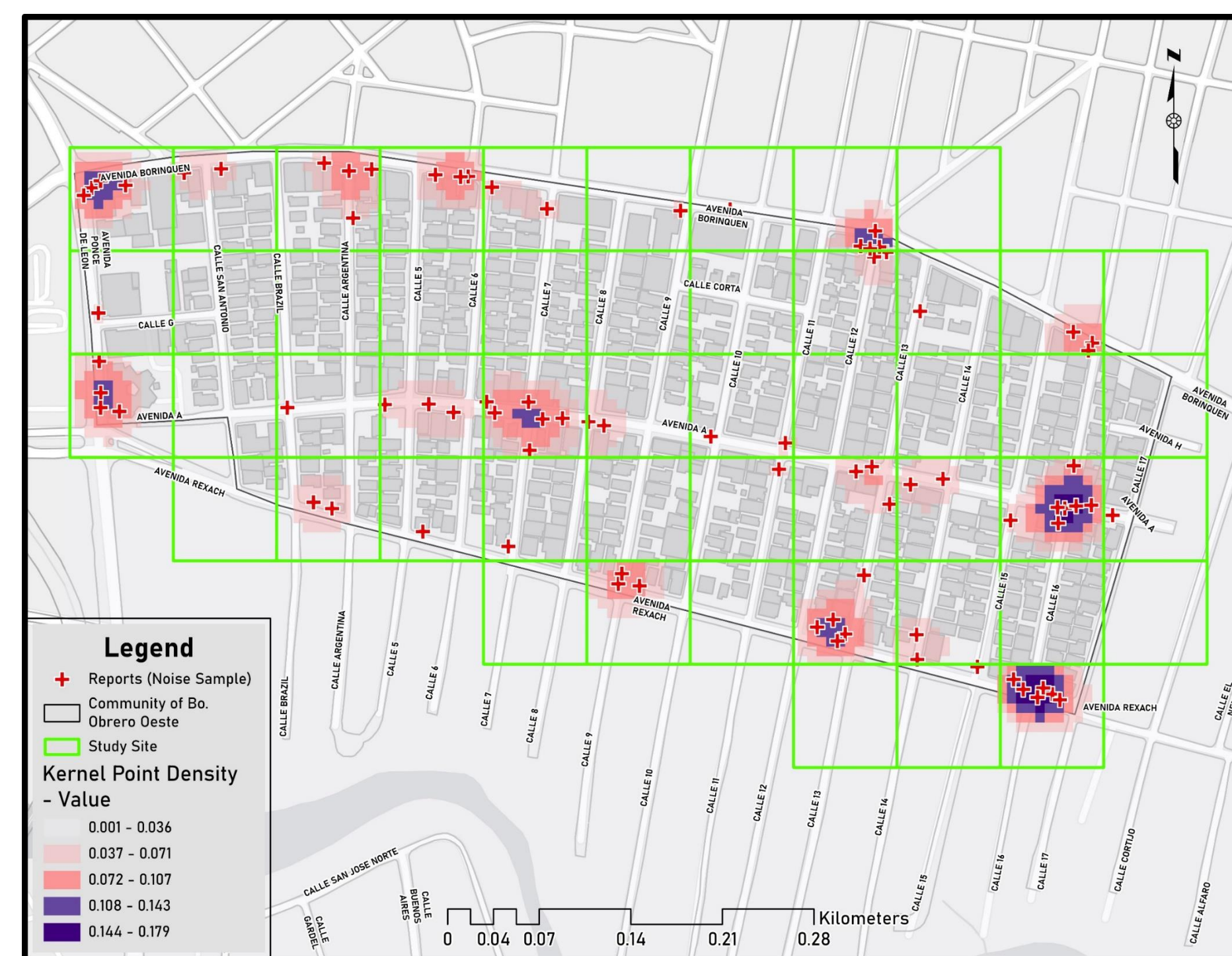


Figure 3: Kernel Point Density Map Report of the 81 Noise Samples

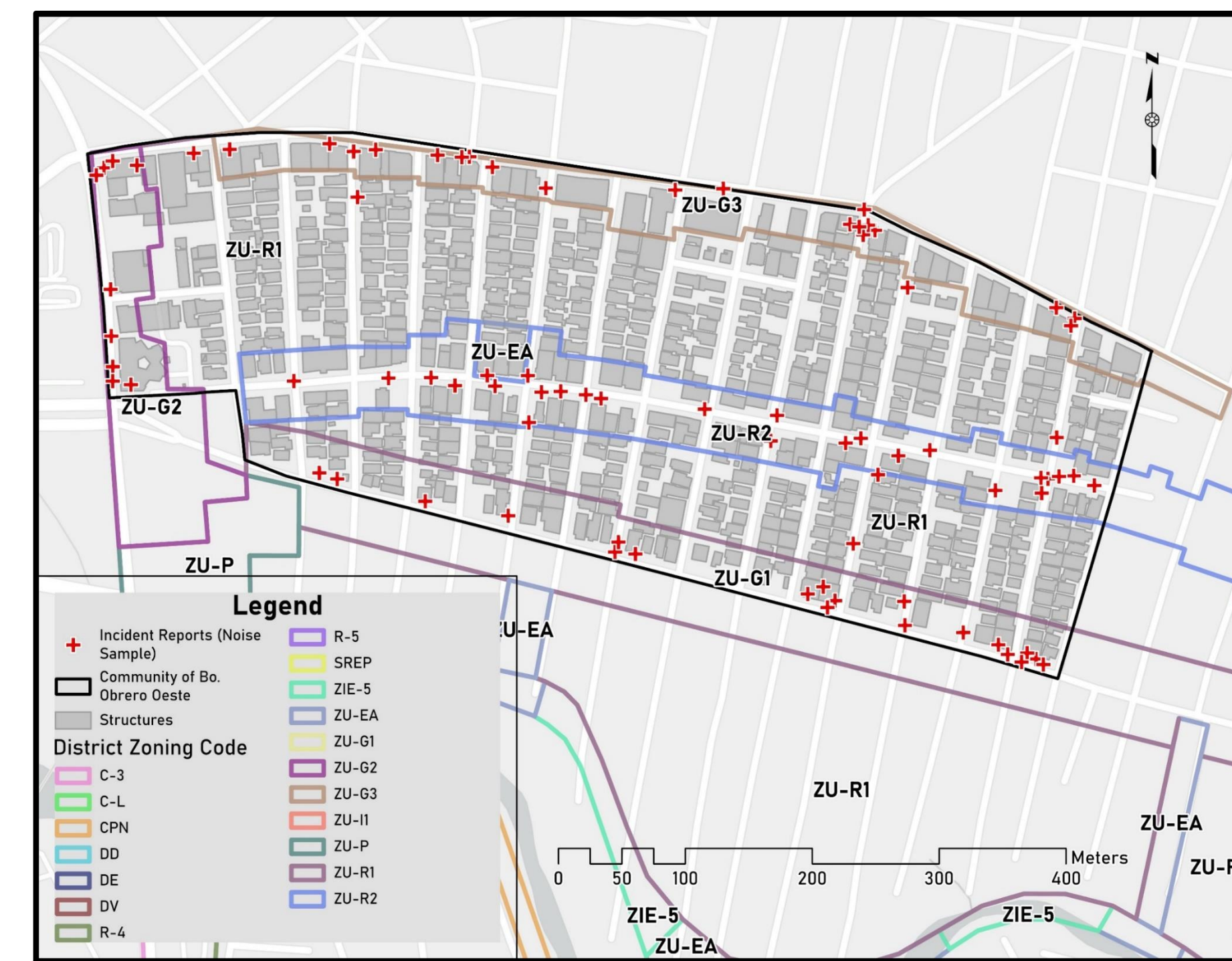


Figure 4: Zoning Districts in Bo. Obrero Oeste Map & the Spatial Distribution of the 81 Noise Samples

B. Zoning and Noise Exposure Correlation

Spatial analysis through Kernel Density Mapping (Figure 3) identified significant noise concentration clusters, predominantly in mixed-use and commercial zones (ZU-G1, ZU-G2). These areas (Figure 4), characterized by heavy vehicular flow and pedestrian activity, exhibited consistent LAeq values between 80.1–90.3 dB(A). However, residential zones (ZU-R2) recorded the highest noise sensitivity, with 25 incidents where noise exceeded acceptable limits, suggesting that residents in these areas experience prolonged exposure to high-decibel environments. The study found a strong correlation between zoning classifications and noise intensity, emphasizing the need for stricter urban planning policies to mitigate noise pollution in mixed-use zones adjacent to residential areas.

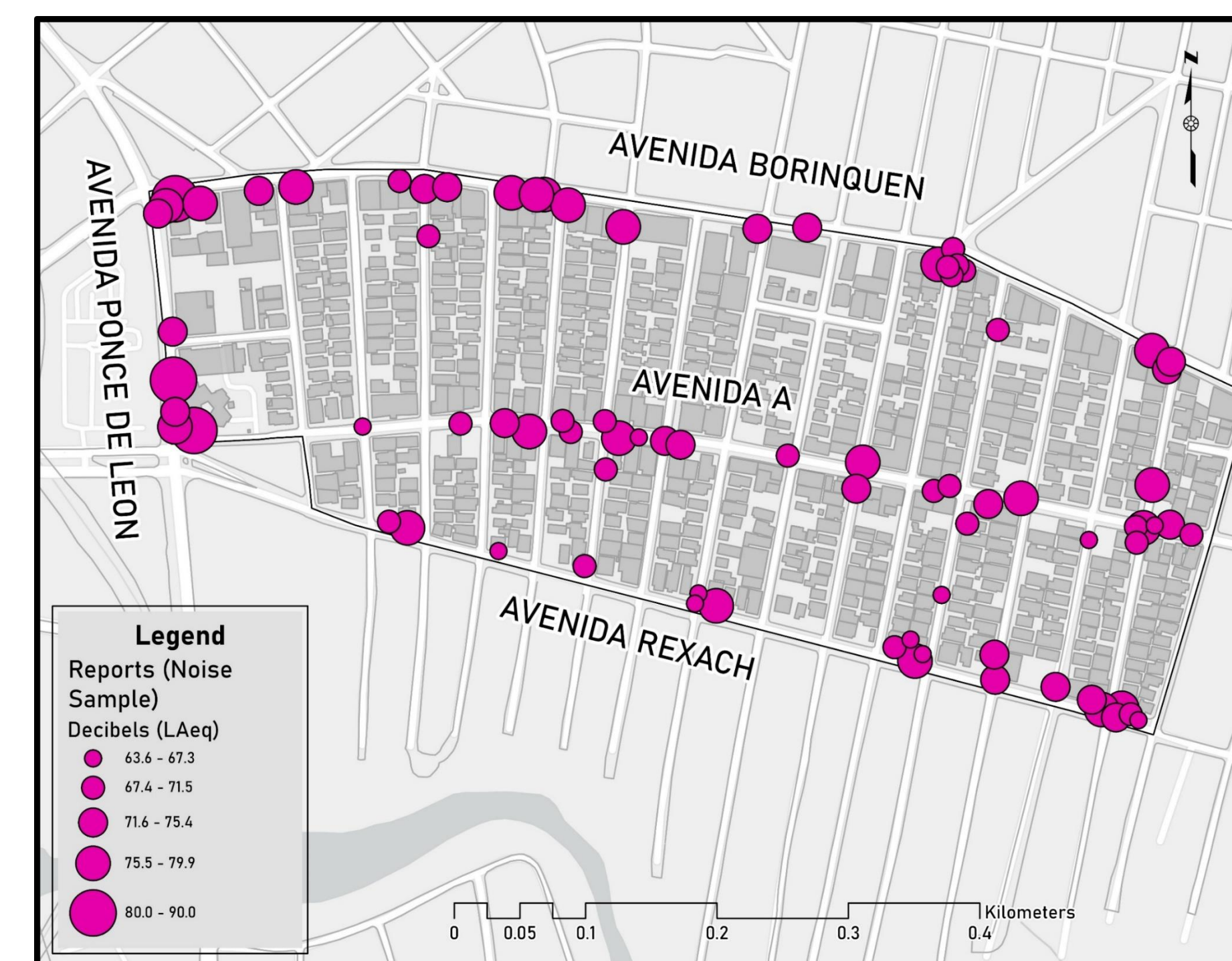


Figure 5: LAeq Exposure Analyzed from the 81 Reports

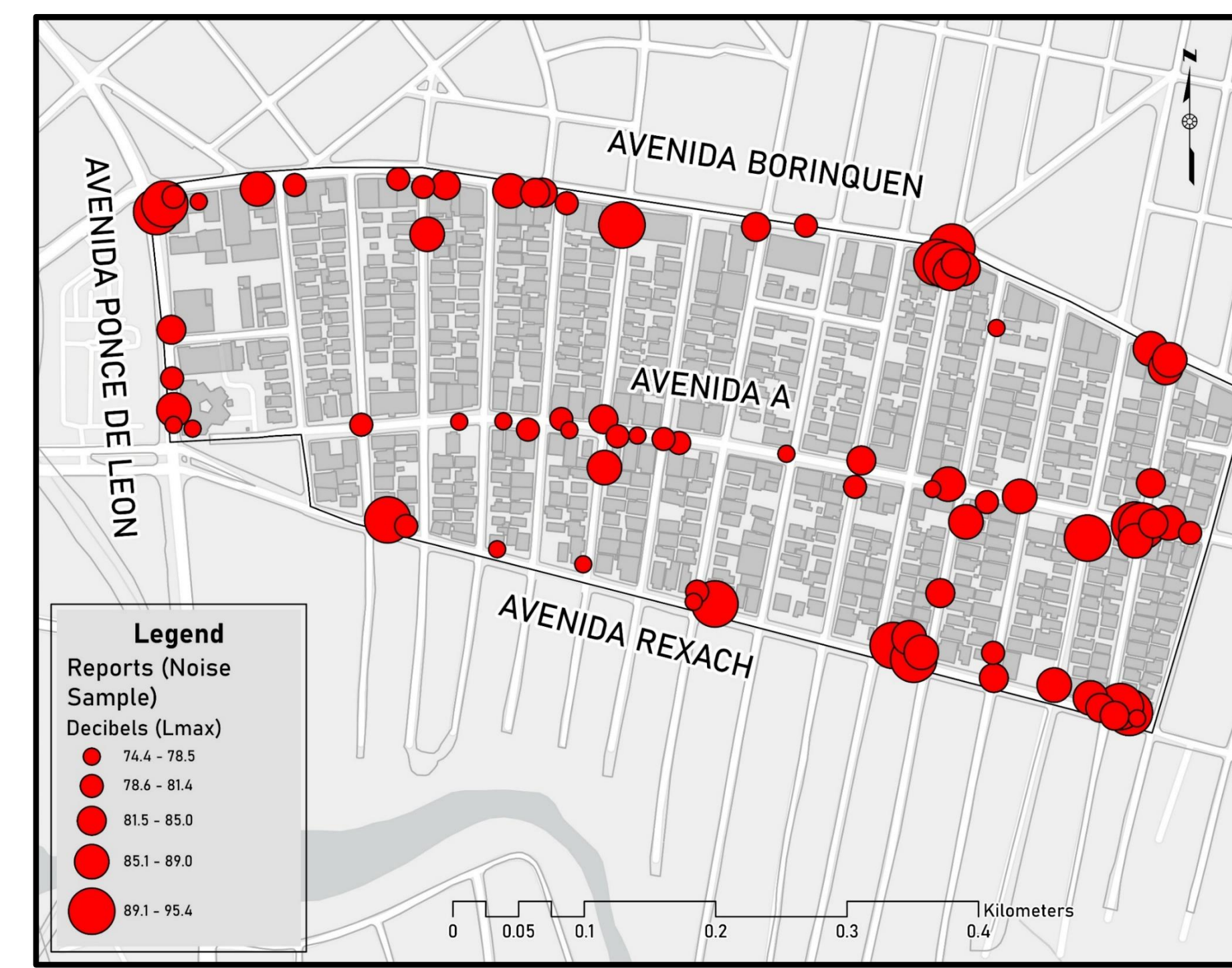


Figure 6: Lmax Exposure Analyzed from the 81 Reports

C. Noise Peaks and Public Health Implications

Further analysis of LAeq (Figure 5) and Lmax events (Figure 6) revealed that short-term noise spikes exceeded 90 dB(A) in multiple locations, particularly near high-traffic intersections, public transit stops, and commercial areas. These noise peaks were predominantly attributed to bus traffic, heavy vehicles, and aircraft flyovers, contributing to intermittent but significant noise disturbances. Comparative studies on urban noise pollution indicate that exposure to such noise levels over time may contribute to long-term health risks, including stress-related disorders and cardiovascular diseases [1][2]. These results reinforce the need for tailored noise mitigation strategies, including sound barriers, optimized traffic management, and stricter zoning regulations to minimize noise exposure in high-risk residential areas.

Conclusions & Future Work

A. Key Findings and Contributions

This study demonstrates that transportation infrastructure, air traffic, and mixed-use zoning are the primary drivers of noise pollution in Barrio Obrero Oeste. The highest noise levels were recorded along major roads and commercial zones, with Lmax values frequently exceeding 90 dB(A), surpassing Puerto Rico's Environmental Quality Board noise thresholds. The Kernel Density Analysis identified clusters of high-intensity noise exposure, particularly in areas where residential zones (ZU-R2) are adjacent to mixed-use and commercial zones (ZU-G1, ZU-G2). These findings highlight the disproportionate impact of urban noise pollution on residential communities, reinforcing the importance of urban planning strategies that consider noise reduction measures in land-use policies.

B. Participatory Noise Mapping as a Viable Tool

The results validate the effectiveness of GIS-integrated participatory noise mapping as a cost-effective and scalable approach for urban noise assessment. By leveraging smartphone-based noise measurements, this study demonstrates that community-driven noise monitoring can provide valuable high-resolution noise exposure data, filling critical gaps in traditional noise assessment methods. The calibration study between the NIOSH Sound Level Meter App and the TOPTES Sound Meter confirmed the accuracy of participatory noise data collection, with measurement deviations of ±0 to ±2.7 dB(A). This reinforces the viability of smartphone-based participatory mapping as a low-cost solution for large-scale environmental noise assessments, particularly in resource-limited urban settings.

C. Policy Implications and Future Directions

The findings underscore the urgent need for policy interventions to mitigate noise pollution in high-risk residential areas. Implementing sound barriers, regulating commercial zoning expansions, and improving traffic management strategies could help reduce noise exposure levels in densely populated areas. Additionally, integrating real-time noise sensors and expanding participatory noise monitoring efforts could provide more comprehensive long-term noise exposure assessments. Future work should focus on replicating this study in other urban communities, particularly in the CMPSPD, to evaluate noise pollution variations and develop scalable mitigation strategies.

Acknowledgements

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