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Sonic Justice and Tree Equity: Exploring Spatial Correlations between Aviation-Related Noise, Demographics, and Tree Canopy

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Abstract

The intricate relationship between aviation-related noise pollution, demographic factors, and tree canopy cover can hold significant implications for targeted interventions promoting environmental equity, sonic justice, and sustainable urban development. This study offers a geospatial exploration of these interconnections within the continental United States by employing National Transportation Noise Pollution data from the United States Department of Transportation alongside tree canopy cover from the United States Geological Survey's National Land Cover Database and demographic data from the American Community Survey in a correlation analysis. Our analysis reveals stark disparities in noise exposure levels, notably underscoring that low-income and predominantly Hispanic neighborhood shoulder a disproportionate burden of aviation-related noise. Moreover, a correlation between aviation-related noise pollution and low tree canopy cover suggests a potential avenue for utilizing nature as a buffer against heightened noise levels. However, recognizing the delicate equilibrium between fostering a thriving tree canopy and ensuring aviation safety highlights a need for innovative urban planning solutions capable of simultaneously addressing sonic injustice and tree inequity.

1. Introduction

Aviation-related noise pollution is a concerning issue. The sound of jet engines and of aircraft taking off and landing can cause elevated noise levels that disturb wildlife habitats and ecosystems (Alquezar & Macedo, 2019). However, the impacts of excessive aviation-related noise are not just felt by local ecosystems. Nearby human communities can also suffer from detrimental health impacts due to heightened exposure (Basner et al., 2017). The impacts of noise pollution on human health have been extensively documented. Individuals living near airports can suffer from disturbed sleep patterns, heightened stress levels, impaired cognitive function, and increased risks of cardiovascular disease and elevated blood pressure (Basner et al., 2017; Kaltenbach et al., 2008). Disadvantaged communities, such as those mostly comprised by racial and ethnic minority groups and low-income residents, experience a disproportionate share of noise-exposure impacts, which can be exacerbated by challenges in healthcare access and housing mobility (Collins et al., 2020; Penman-Aguilar, 2016).

In the United States, health inequity is tied to race, ethnicity and income, among other variables. Discriminatory policies and limited financial opportunity relate to high rates of chronic diseases and low life expectancy among historically marginalized populations (Penman-Aguilar, 2016). However, nature can play an important role in reducing these health issues, and, thus, increasing the quality of life of disadvantaged communities.

Nature, with its numerous benefits, plays a vital role in promoting positive mental and physical health by acting as a buffer against noise (Ow & Ghosh, 2017). Trees can play a crucial role in reducing noise pollution through their dense foliage, including leaves, branches and trunks, which act as natural barriers that absorb and deflect sound waves. However, the distribution of trees is often unequal, a phenomenon known as tree inequity, leading to disparities in tree canopy cover, especially in urban areas (Riley & Gardiner, 2020). This inequality disproportionately affects low-income neighborhoods and communities of color, exacerbating environmental disparities and potentially leaving residents in these areas more susceptible to the adverse effects of noise pollution (Riley & Gardiner, 2020). Consequently, urban greening not only promotes overall urban well-being but also addresses sonic injustice (i.e., the disproportionate exposure of disadvantaged communities, such as low-income residents and racial and ethnic minorities) to noise pollution (Collins et al., 2020).

While studies have established that socioeconomically vulnerable groups face heightened exposure to noise pollution, further research is necessary to comprehensively understand the specific contributions of various noise sources, such as aviation-related noise, to these disparities (Collins et al., 2020; Trudeau et al., 2023). Additionally, if considering trees as a nature-based solution to combat noise, it is essential to grasp the interconnected dynamics between tree canopy cover, distinct noise sources, and demographic factors including income, race, and ethnicity.

To our knowledge, no study has assessed the combined relationship between aviation-related noise, tree canopy cover, and population demographics. Thus, this study aims to assess the spatial correlation between aviation-related noise pollution, tree canopy cover, income, race and ethnicity to gain a better understanding of the relationships between these variables altogether. Through a spatial analysis, we answered the following question: Is there a significant correlation between aviation-related noise pollution, tree canopy cover, and the income, race and ethnicity of residents living near airports? We hypothesized a positive significant relationship between high aviation-related noise pollution, low tree canopy cover, and high percentages of low-income residents and racial and ethnic minorities.

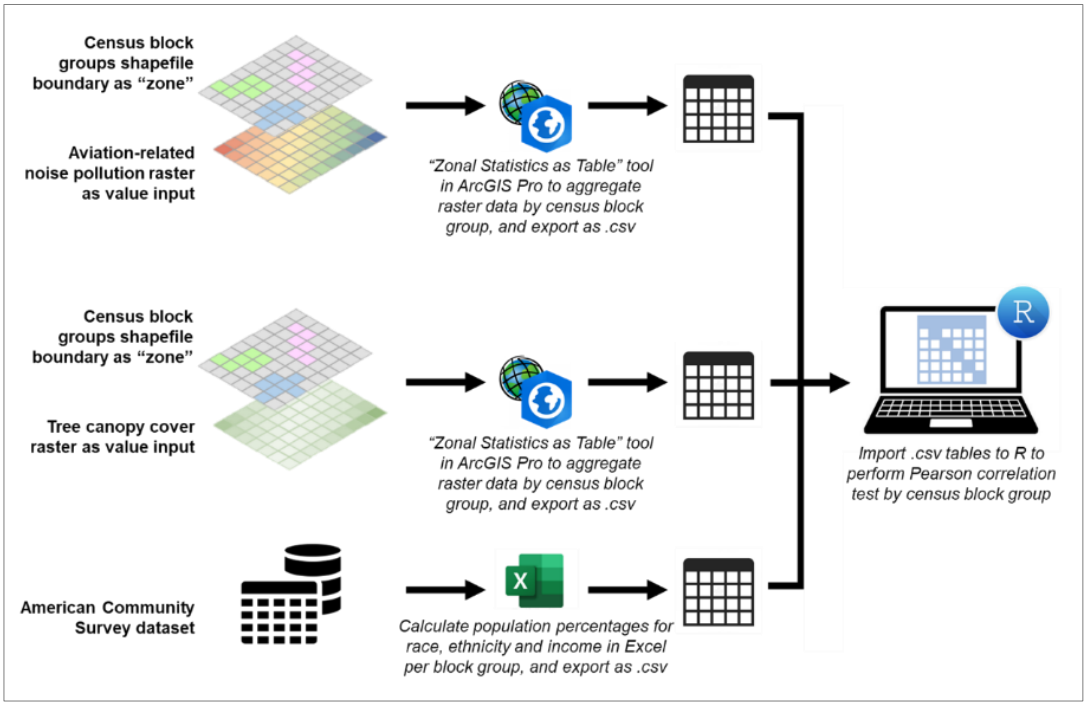
2. Data and Methods

This study accounts for all areas within the continental United States that have documented aviation-related noise pollution. Using ArcGIS Pro (Esri, 2023), we performed zone-based summary statistics to estimate mean exposure to aviation-related noise pollution (in decibels) by census block group, the smallest census denomination for the United States. Isolated values of aviation-related noise pollution were downloaded from the Department of Transportation's National Transportation Noise Pollution public database (United States Department of Transportation – Bureau of Transportation Statistics, 2022) (refer to Table 1 for data details).

Table 1. Data Inputs and Sources.

Description	Data Type	Year	Origin	Download Source
National Transportation Noise Pollution (aviation-related noise only)	Raster	2020	Department of Transportation	United States Department of Transportation – Bureau of Transportation Statistics, 2022
National Land Cover Database Tree Canopy Cover	Raster	2020	United States Forest Service	United States Geological Survey, 2023
Demographic variables (median household income, population by race, and population with Hispanic origin)	Tabular	2017-2021	American Community Survey 5-Year Data Release	Manson et al., 2023a
Census Block Groups	Polygon (Shapefile)	2020	United States Census Bureau	Manson et al., 2023b

A boundary layer for census block groups was downloaded from the open-data website IPUMS National Historical Geographic Information System (Manson et al., 2023a). In ArcGIS Pro, we also performed zone-based summary statistics of tree canopy cover to determine percent per census block group (United States Geological Survey, 2023). Mean aviation-related noise pollution and percent tree canopy were imported along with three demographic variables from the United States American Community Survey (2017-2021), median household income, percent of individuals not white, and percent of Hispanic or Latine individuals (Manson et al., 2023b), into the R statistical language (R Core Team, 2021) to perform a Pearson correlation test between all variables. Demographic data was preprocessed using Microsoft Excel (Microsoft Corporation, 2023). A detailed workflow diagram of our methodology is provided in Figure 1. Data inputs are listed in Table 1.



Source: Adapted from Esri, 2023

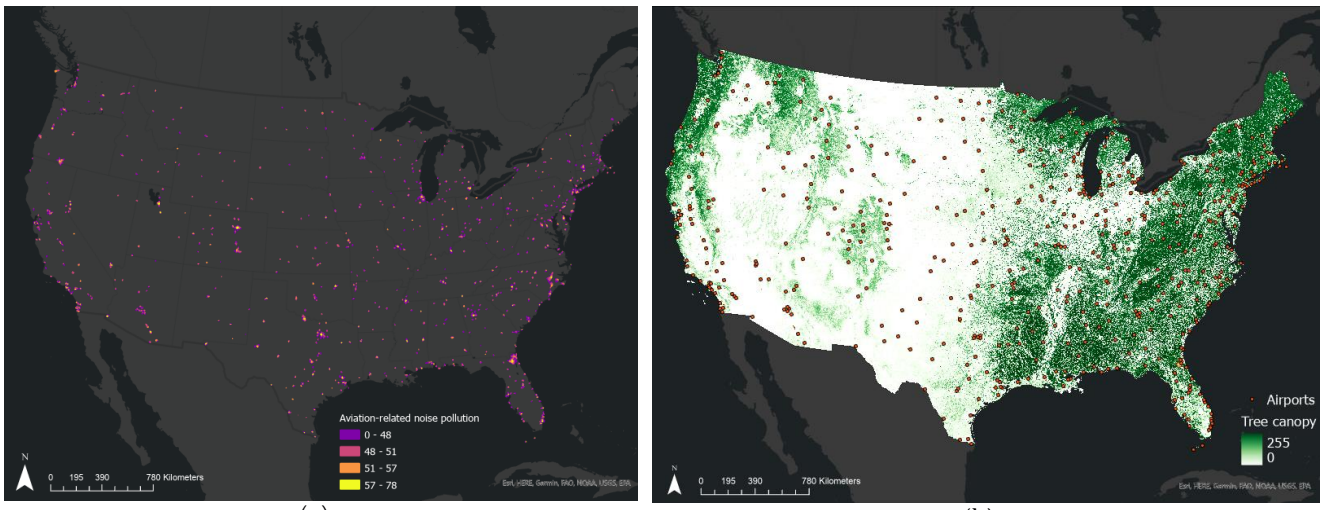
Figure 1. Processing and Analytical Workflow

3. Result and Discussion

3.1. Sonic Justice

The analysis of aviation-related noise pollution in relation to the demographic variables (median household income, percent not white, and percent Hispanic or Latine) revealed that lower-income neighborhoods exhibit higher levels of exposure in noise-polluted areas (Figure 3). Furthermore, despite there being an apparent negative correlation between high levels of aviation-related noise pollution and high percentages of non-white residents, we observed that aviation-related noise pollution also correlates positively with the percent of Hispanic residents (Figure 3).

The analysis of aviation-related noise pollution in relation to tree canopy revealed a significant negative correlation between the two (Figure 2 and 3). Areas with reduced tree canopy cover experience higher aviation-related noise pollution levels. Greater percentages of Hispanics correlated with both lower income and less tree canopy access (Figure 3). Thus, lower-income Hispanics are particularly exposed to greater levels of aviation-related noise while simultaneously lacking access to tree canopy cover.



(a) (b)

Source: *National Atlas of the United States, 2014*; *United States Department of Transportation – Bureau of Transportation Statistics, 2022; United States Geological Survey, 2023*

Figure 2. (a) Aviation-related Noise Pollution, and (b) Tree Canopy Cover in relation to Airports (for reference purposes)

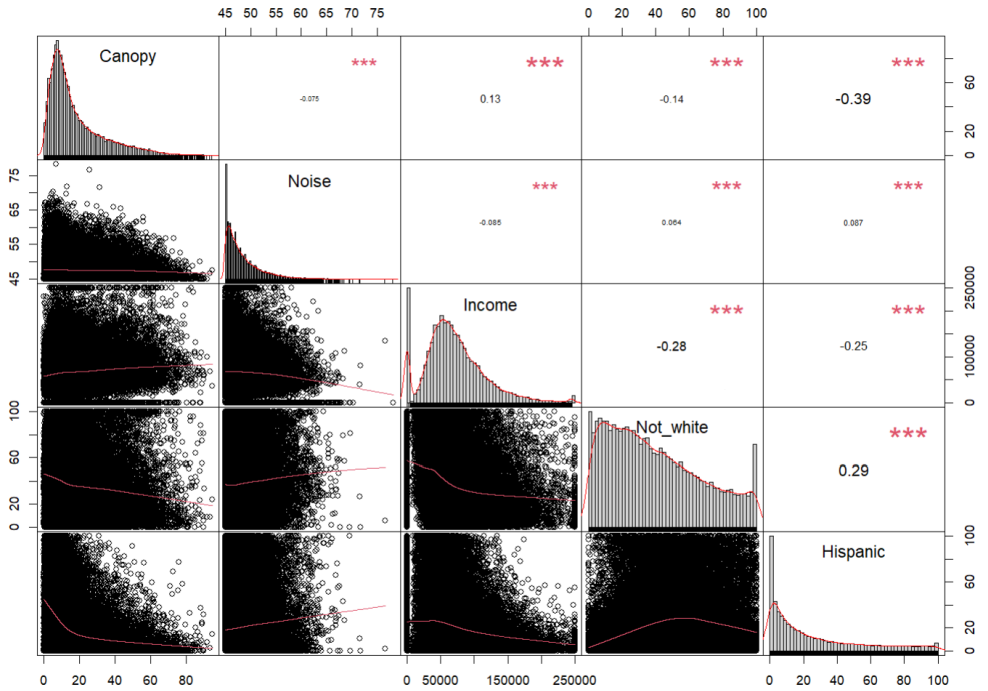


Figure 3. Variable distributions (on the diagonal), bivariate plots with fitted lines (below the diagonal), and correlation values with significance levels represented by asterisks (above the diagonal) for percent tree canopy ("canopy"), mean aviation-related noise pollution ("noise"), median household income ("income"), percent of residents not white ("not white"), and percent of residents who identify as Hispanic or Latine ("Hispanic").

3.2. Discussion

Our study provided valuable insights into the relationships between aviation-related noise pollution, demographic factors, and tree canopy cover across the continental United States at the census block-group level. The analysis revealed the existence of disparities, as block groups that are predominantly low-income and Hispanic disproportionately bear the greatest burden of aviation-related noise pollution while exhibiting low

tree canopy access. This is consistent with other studies, which have documented the association of disadvantaged communities with greater noise exposure and with low tree canopy access, separately (Collins et al., 2020; Riley & Gardiner, 2020; Trudeau et al., 2023). Although confounding variables are expected, our findings underscore the critical need to understand how intersecting marginalized identities experience multiple environmental challenges simultaneously and unevenly (in this case, being of Hispanic origin and having a lower income level and experiencing both high exposure to aviation-related noise pollution and low tree canopy access.

The analysis of aviation-related noise pollution in relation to tree canopy revealed a significant negative correlation between the two, suggesting that tree canopy cover could be used as a mitigation strategy. Other studies have extensively documented the role that trees play in reducing noise pollution (Ow & Ghosh, 2017), even demonstrating how nature can reduce airport noise while promoting many ecosystem services (Korol et al., 2018). Despite the contributions of nature in buffering against noise, the presence of a tall and dense tree canopy also poses a concern to aviation safety due to reduced visibility for pilots and increased bird habitat that could lead to a greater chance of bird strikes (Metz et al., 2020; Mobini & Sabzehparvar, 2022). This juxtaposition highlights a need for establishing best practices that promote vegetation growth without compromising aviation safety. Knowing best practices for aviation safety standards in this context could support the use of nature-based solutions in mitigating aviation-related noise pollution.

Our findings suggest that there is a potential for urban forestry interventions to address both noise pollution and tree canopy disparities simultaneously through strategic tree plantings. However, the delicate balance between promoting tree canopy cover and ensuring aviation safety cannot be overlooked. While tall trees contribute positively to noise reduction and overall environmental well-being (Korol et al., 2018; Ow & Ghosh, 2017), they introduce risks for pilots during takeoff and landing (Metz et al., 2020; Mobini & Sabzehparvar, 2022). This translates into a challenge for urban planning that requires further research to explore the application of strategic tree placement and species selection near airports to find a balance between an abundant and equitable tree canopy and aviation safety.

4. Conclusion

The goal of our study was to provide key insights into the intricate connections between aviation-related noise pollution, demographic factors, and tree canopy cover to guide interventions for environmental equity, sonic justice, and sustainable urban development. Our analysis highlighted a disproportionate impact on socio-economically vulnerable populations, particularly those of Hispanic origin and with lower income levels. It emphasized the need for nature-centric mitigation strategies, especially in block groups with low income or predominantly Hispanic populations experiencing excessive noise pollution. However, the correlation between higher noise exposure and lower tree canopy also indicated the potential role of nature as a mitigation strategy, prompting further research to identify the delicate balance between promoting sonic justice and ensuring aviation safety.

Based on the key insight of this study, we suggest exploring any of the following as means to better capturing the intricate connections between aviation-related noise pollution, demographic factors, and tree canopy cover: (1) Identifying tree species and placement patterns ideal for optimizing tree canopy cover for noise reduction without increasing aviation hazards; (2) Applying temporal analyses to observe the relationship between aviation-related noise pollution, demographic dynamics, and tree canopy cover over time; (3) Assessing mental and physical health impacts from aviation-related noise exposure and tree canopy access for a more holistic understanding of tradeoffs; (4) Assessing the perspectives of residents affected by aviation-related noise to inform community-driven solutions that promote sonic justice and tree equity simultaneously; (5) By exploring these avenues of research, future studies could lead to a comprehensive understanding of the intricate relationships between aviation-related noise, demographics, and tree canopy, guiding the development of effective strategies that balance environmental, social, and safety considerations for sustainable urban development.

5. Acknowledgment

All data sources and software used, with exception of ArcGIS Pro and Microsoft Excel, are open source and publicly accessible. Access to ArcGIS Pro and Microsoft Excel was obtained through institutional affiliation of the authors.

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