Visual Exploration of Spatial-Temporal Dynamics of Air Quality Using Volunteered Geographic Information: A Study Case of Pm 2.5 in Minneapolis, U.S.

Zain Ul Abdin Siyal, Ying Song

ABSTRACT:

The pervasive concern of air pollution in urban areas poses a substantial environmental and public health challenge. Understanding the intricate connections between human mobility, local climates, and social environment is pivotal in comprehending the dynamics of air quality within any geographic location. The increasing availability of volunteered geographic information (VGI) and open data portals provide real-time and historical air quality monitoring data that are accessible to the public. This study presents a meticulous spatial-temporal analysis of air quality dynamics utilizing the VGI, using PM 2.5 data collected by Purple Air in the Minneapolis metropolitan area as a study case. The study explores the seasonal, daily, and hourly variations of the air quality index (AQI) and relates the patterns to a few key factors such as the Social Vulnerability Index (SVI), proximity to transport networks, and weather conditions. The methodology follows a systematic process that begins with developing Python scripts to automate the Extract, Transform, Load (ETL) process from query Purple Air data from the server to organize the extracted spatial-temporal data. A crucial step in this process is data cleaning to ensure data integrity, which identifies and removes sensors with abnormal readings such as consistently much higher values than nearby sensors. Given the clean data, the study then examines the relationship between air quality and urban environments. First, considering the potential impacts of traffic on air quality, the study calculates the linear correlations between the PM 2.5 values recorded by the sensors and their distances to roads of various types. The analysis reveals a minimal positive correlation for municipal roads (0.0702), a slightly weaker negative correlation for county roads (-0.0509), and an even weaker negative correlation for interstate roads (-0.0103). The study continues with the Social Vulnerable Index (SVI) and reveals a coefficient of 0.0574 that is not significant. These suggest that the road proximity and SVI do not have a significant impact on the air quality. The study further investigates the impact of abnormal weather events, including heavy rainfalls, forest fires, and snowfalls, that may have an immediate influence on air quality. To control other factors, we compare air quality data before and after each event and compare the spatial-temporal patterns using data collected during the same season. The study reveals the significant impact of severe weather events on PM2.5 that surpasses the influence of the static geographical context of the sensors. In sum, the study concludes by providing nuanced insights into the spatial-temporal dynamics of air quality in Minneapolis, emphasizing the influence of meteorological factors and suggesting tailored management strategies for informed policy decisions. Moreover, the study creates a visual exploration workflow that is transferable and scalable, allowing for the seamless repetition of the analysis using VGI from various sources and providing a foundation for similar investigations in different geographic settings.

KEYWORDS: *air quality, Volunteer Geographic Information, data manipulation and analysis, spatial-temporal dynamics, human mobility, meteorological factors*

Zain Ul Abdin Siyal, Graduate Student, Department of Geography, Environment & Society, University of Minnesota, Twin Cities, USA

Ying Song, Professor, Department of Geography, Environment & Society, University of Minnesota, Twin Cities, USA