2A.5 - Uncovering the Drivers of Urban Air Pollution Using Spatial Machine Learning for Improved Analysis and Forecasting

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Abstract

Air pollution remains a complex challenge with far-reaching implications for public health and well-being, not only in low-income countries, but also in middle- and high-income ones. The impacts of air pollution go beyond human health, as it can cause reduced crop yields, decreased biodiversity, and damage to physical infrastructure. Some pollutants, such as carbon dioxide (CO_2), also contribute to climate change. In many cities, air pollution levels exceed World Health Organization (WHO) guidelines, calling for new and innovative approaches to better understand the sources and drivers of air pollutants. Although this hazard affects both urban and rural residents, the former are particularly vulnerable due to higher population densities, higher traffic volumes, slower ventilation due to urban form, and increased industrial and commercial activities that contribute to higher emissions. In this study, we leveraged machine learning with spatial analysis to predict and analyze critical air pollutants, including particulate matter ($PM_{2.5}$), nitrogen oxides (NO_x), sulfur dioxide (SO_2), ozone (O_3), and elemental carbon (EC), in urban settings. The analyses are also designed to identify the drivers of air pollution, as well as to quantify the spatial extent of the effect of several urban features on air quality. In particular, we combined machine learning (Gradient Boosting Regression, GBR) and spatial analysis, with New York City as a demonstration site. We analyze the interplay between urban characteristics and weather patterns, showing that the former control the concentrations of pollutants linked to traffic, while the latter exerts stronger influence over other pollutants. Urban characteristics are shown to act over spatial scales of 500×500 m, which is thus the footprint needed to effectively capture the impact of urban form and function. The spatial predictive model, needing only meteorological and urban inputs, achieves promising results with errors ranging from 6 to 32 percent. Our findings highlight the interacting roles of urban characteristics and weather conditions, and can inform urban planning, design, and policy.

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