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Predictive Modeling for Sustainable Urban Living: Machine Learning Solutions to Air Quality Challenges in Madrid

Accurate prediction of air quality in urban environments is key to designing public health interventions aimed at reducing exposure to harmful air pollutants.

Using the case of Madrid, here we present a comprehensive machine learning approach to better understand how different factors affect local air quality across the metropolitan area.

Reducing pollution levels is a pressing need for this city that often fails to meet the standards set by the European Commission. To elucidate the relationship between pollutant concentration (the response) and the factors that we hypothesize affect it most, namely local atmospheric conditions and road traffic (the predictors), we processed 24 months of hourly data on the number of vehicles and meteorology together with the concentration of nitrogen oxides, ozone and particulate matter measured at 22 stations spread across the metropolitan area. We used the R language to preprocess the data and train a model for each pollutant station and chemical species following the workflow of the "tidymodels" framework. In terms of predictive capability, the present results show at least comparable performance to other existing models. This is especially remarkable given that the present model uses a parsimonious collection of predictors, all of them coming from public and freely available sources. In terms of computational cost, the present models require far fewer resources than the state-of-the-art pollutant dispersion models that solve some form of differential equations governing the transport of chemical species in the turbulent planetary boundary layer. The present work can be used directly to evaluate the effectiveness of various measures and strategies aimed at reducing the level of pollutants, such as, for example, restricting road traffic access to some city districts. Overall, this research helps to inform urban developers, city planners, and public health officials in their mission to achieve cleaner and healthier cities.

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