

## Dinamika Spasial dan Temporal PM2.5 di Pulau Jawa = Spatial and Temporal Dynamics of PM2.5 in Java Island

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### Abstrak

Permasalahan polusi udara PM2.5 di Pulau Jawa semakin meningkat seiring dengan pertumbuhan aktivitas industri. Penelitian ini bertujuan menganalisis distribusi spasial-temporal PM2.5 dan kontribusi sektor industri menggunakan model Random Forest Regression berbasis data observasi dan citra satelit. Metodologi penelitian meliputi pengembangan model prediksi, analisis pola sebaran, dan evaluasi dampak industri dengan pendekatan wilayah buffer cluster. Hasil model menunjukkan kinerja yang baik untuk estimasi konsentrasi PM2.5, dengan nilai  $R^2$  dari data pelatihan mencapai 0.86 (RMSE = 6.24) dan  $R^2$  dari data pengujian sebesar 0.552. Meskipun terdapat indikasi overfitting, model tetap menunjukkan kemampuan prediksi yang baik untuk estimasi konsentrasi PM2.5 dalam rentang yang moderat. Analisis temporal mengidentifikasi dua puncak konsentrasi (27,6 g/m<sup>3</sup> September-Oktober 2019; 27,9 g/m<sup>3</sup> Oktober-November 2023) dengan pola musiman yang konsisten: terendah pada DJF (18-20 g/m<sup>3</sup>) dan tertinggi pada SON (25-27 g/m<sup>3</sup>). Secara spasial, konsentrasi tertinggi (35-45 g/m<sup>3</sup>) di kawasan industri dan perkotaan. Analisis wilayah mengidentifikasi empat kluster utama: Cilegon-Tangerang (32,45 g/m<sup>3</sup>; 33 KI, 10 PLTU), Bekasi-Karawang (27,64 g/m<sup>3</sup>; 45 KI, 10 PLTU), Semarang (26,41 g/m<sup>3</sup>; 14 KI, 1 PLTU), dan Surabaya (27,83 g/m<sup>3</sup>; 20 KI, 3 PLTU), menunjukkan gradien konsentrasi industri yang menurun dari barat ke timur Pulau Jawa. Penelitian ini menggarisbawahi pentingnya pendekatan terpadu dalam pengendalian pencemaran udara dengan mempertimbangkan variasi spasial-temporal dan kontribusi sektor industri.

.....The problem of PM2.5 air pollution in Java is increasing along with the growth of industrial activities. This study aims to analyze the spatial-temporal distribution of PM2.5 and the contribution of the industrial sector using the Random Forest Regression model based on observational data and satellite imagery. The research methodology includes developing a prediction model, analyzing distribution patterns, and evaluating the impact of industry with a buffer cluster region approach. The results model showed good performance for PM2.5 concentration estimation, with the  $R^2$  value of the training data reaching 0.86 (RMSE = 6.24) and the  $R^2$  of the testing data of 0.552. Although there are indications of overfitting, the model still shows applicable predictive ability for PM2.5 concentration estimation within a moderate range. Temporal analysis identified two concentration peaks (27.6 g/m<sup>3</sup> September-October 2019; 27.9 g/m<sup>3</sup> October-November 2023) with consistent seasonal patterns: lowest in DJF (18-20 g/m<sup>3</sup>) and highest in SON (25-27 g/m<sup>3</sup>). Spatially, the highest concentrations (35-45 g/m<sup>3</sup>) were concentrated in industrial and urban areas. The region analysis identified four main clusters: Cilegon-Tangerang (32.45 g/m<sup>3</sup>; 33 KIs, 10 PLTUs), Bekasi-Karawang (27.64 g/m<sup>3</sup>; 45 KIs, 10 PLTUs), Semarang (26.41 g/m<sup>3</sup>; 14 KIs, 1 PLTU), and Surabaya (27.83 g/m<sup>3</sup>; 20 KIs, 3 PLTUs), showing a decreasing industrial concentration gradient from west to east of Java Island. This study underscores the importance of an integrated approach in air pollution control by considering spatial-temporal variations and the contribution of the industrial sector.