

## INTISARI

Permukiman perkotaan padat dengan dominasi bangunan semi permanen memiliki tingkat kerawanan kebakaran yang tinggi. Namun, pemetaan kerawanan kebakaran bangunan hingga saat ini masih didominasi oleh pendekatan deterministik berbasis skoring dan interpretasi visual, yang belum mampu merepresentasikan variasi karakter material bangunan, kepadatan skala mikro, serta keterjangkauan layanan pemadam secara spasial. Kondisi ini menuntut pengembangan pendekatan pemodelan yang lebih objektif, berbasis data, dan operasional. Penelitian ini bertujuan mengembangkan pemodelan spasial kerawanan kebakaran bangunan di kawasan permukiman padat Kota Banjarmasin melalui integrasi penginderaan jauh (PJ) resolusi sangat tinggi, Sistem Informasi Geografis (SIG), dan *machine learning*. Kerangka konseptual penelitian dibangun melalui dua pendekatan utama, yaitu pendekatan spektral-material untuk mengidentifikasi karakteristik fisik bangunan dan pendekatan spasial-operasional untuk mengevaluasi distribusi risiko serta jangkauan layanan pemadam kebakaran. Dalam kerangka ini, penginderaan jauh berperan dalam ekstraksi karakteristik permukaan melalui citra WorldView-3 (WV-3) tahun 2021 yang diproses hingga resolusi 0,5 m. Pendekatan spektral memungkinkan identifikasi indikator kerentanan struktural secara objektif melalui NDIOI (kombinasi NIR2-Blue) untuk mendeteksi atap seng korosi sebagai proksi bangunan semi permanen, serta NDBI untuk memetakan kepadatan kawasan terbangun pada skala objek atap. Selanjutnya, pemodelan spasial yang komprehensif mengintegrasikan variabel lingkungan dan operasional, meliputi *kernel density* kejadian kebakaran, *buffer* sungai, serta analisis *service area* pos pemadam berbasis jaringan jalan (0-10 menit). Pemodelan dilakukan menggunakan algoritma *Random Forest* melalui empat skenario pemodelan. Seluruh skenario menghasilkan akurasi di atas 90%, dengan model komprehensif menunjukkan performa paling stabil. Data kejadian kebakaran tahun 2020-2022 digunakan sebagai data latih-uji, sedangkan kejadian 2023-2025 dimanfaatkan sebagai validasi independen (*out-of-sample*). Hasil pemetaan menunjukkan bahwa Kecamatan Banjarmasin Tengah memiliki proporsi area rawan terbesar (28,8%), diikuti Banjarmasin Barat (19,6%), sementara Banjarmasin Utara relatif lebih rendah (11,8%). Penelitian ini berkontribusi melalui adaptasi NDIOI untuk konteks urban padat, formulasi NDBI resolusi sangat tinggi, pengembangan *framework* pemodelan multi-skenario berbasis *machine learning*, serta validasi multi-tahun berbasis kejadian nyata sebagai dasar mitigasi kebakaran berbasis bukti spasial.

**Kata kunci:** Pemodelan spasial kerawanan kebakaran, WorldView-3, NDIOI, NDBI, *machine learning*, *service area*.

## ABSTRACT

Dense urban settlements dominated by semi-permanent buildings exhibit a high level of fire vulnerability. However, urban building fire risk mapping has relied mainly on deterministic, score-based approaches and visual interpretation, which are insufficient to represent variations in building material characteristics, micro-scale density, and the spatial reach of fire service coverage. This limitation highlights the need for a more objective, data-driven, and operationally relevant modeling approach. This study aims to develop a spatial model of building fire vulnerability in dense residential areas of Banjarmasin City by integrating very-high-resolution remote sensing, Geographic Information Systems (GIS), and machine learning. The conceptual framework is structured around two complementary approaches: a spectral-material approach to identify physical building characteristics and a spatial-operational approach to evaluate risk distribution and fire service accessibility. Within this framework, remote sensing plays a key role in surface feature extraction using WorldView-3 (WV-3) imagery acquired in 2021 and processed to a final spatial resolution of 0.5 m. The spectral approach enables objective identification of structural vulnerability indicators through the Normalized Difference Iron Oxide Index (NDIOI), derived from the NIR2-Blue band combination to detect corroded metal roofs as a proxy for semi-permanent buildings, and the Normalized Difference Built-up Index (NDBI), which represents built-up density at the roof-object scale. Comprehensive spatial modeling further integrates environmental and operational variables, including kernel density of fire incidents, river buffering, and network-based analysis of fire station service areas (0-10-minute response times). Fire vulnerability modeling was implemented using the Random Forest algorithm across four predictor scenarios. All scenarios achieved classification accuracies exceeding 90%, with the comprehensive model demonstrating the most stable performance. Verified fire incident data from 2020-2022 were used for training and testing, while independent incidents from 2023-2025 served as out-of-sample validation. The resulting maps indicate that Central Banjarmasin has the highest proportion of high-risk areas (28.8%), followed by West Banjarmasin (19.6%), while North Banjarmasin exhibits a comparatively lower risk (11.8%). This research contributes through the adaptation of NDIOI for dense urban environments, the formulation of very-high-resolution NDBI, the development of a multi-scenario machine learning-based modeling framework, and multi-year empirical validation, providing a spatially explicit evidence base for urban fire risk mitigation.

**Keywords:** Spatial fire vulnerability modeling, WorldView-3, NDIOI, NDBI, machine learning, service area.