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Pemodelan Transisi Lahan Perkotaan dan Faktor Sosial-Ekonomi serta Lingkungan di Metropolitan Yogyakarta: Pendekatan Survival Analysis dan Machine Learning
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INTISARI

Urbanisasi merupakan proses perubahan penggunaan lahan yang berlangsung cepat dan memengaruhi kondisi sosial-ekonomi maupun lingkungan. Di kawasan Kartamantul (Kabupaten Sleman, Kabupaten Bantul, dan Kota Yogyakarta), peningkatan ekspansi kawasan terbangun (*urban sprawl*) menuntut pendekatan yang tidak hanya mengidentifikasi lokasi urbanisasi, tetapi juga menjelaskan tahapan perkembangan kawasan urban. Penelitian ini bertujuan untuk menganalisis dinamika ekspansi urban di Kartamantul periode 2017–2024, mengidentifikasi faktor-faktor yang memengaruhi konversi lahan menjadi kawasan urban, serta menganalisis hubungan *Classified Urban Age* dengan indikator sosial-ekonomi dan lingkungan yang direpresentasikan oleh *Nighttime Light* (NTL) dan *Land Surface Temperature* (LST).

Penelitian menggunakan data ESRI Global Land Cover tahun 2017 dan 2024, VIIRS *Nighttime Light*, serta *Land Surface Temperature*. Faktor pengendali urbanisasi dianalisis menggunakan algoritma Random Survival Forest yang diinterpretasikan melalui *Variable Importance*, SHAP (*Shapley Additive Explanations*), *Partial Dependence Plot* (PDP), dan *Accumulated Local Effects* (ALE). *Classified Urban Age* ditentukan berdasarkan waktu terjadinya konversi lahan menjadi kawasan terbangun. Hubungan *Classified Urban Age* dengan NTL dan LST dianalisis menggunakan uji Kruskal–Wallis dan *pairwise* Wilcoxon karena data berdistribusi tidak normal.

Hasil penelitian menunjukkan bahwa luas kawasan urban meningkat sebesar 21,98%, dari 648,28 km² menjadi 790,79 km² selama periode 2017–2024. Pemetaan *urban transition hazard* menghasilkan nilai hazard ternormalisasi sebesar 0–98,77%, dengan wilayah berhazard tinggi terkonsentrasi di bagian selatan Kabupaten Bantul serta sebagian wilayah utara dan barat kawasan studi. Hasil pemodelan menunjukkan bahwa $elevation$, $distCity$, dan $Nightlight$ merupakan variabel dengan *Variable Importance* tertinggi, sedangkan interpretasi SHAP, PDP, dan ALE mengindikasikan hubungan non-linear antara variabel pengendali dan probabilitas transisi urban. *Classified Urban Age* juga menunjukkan hubungan yang signifikan dengan NTL dan LST ($p < 0,05$), yang mengindikasikan bahwa indikator tersebut mampu merepresentasikan tahapan perkembangan kawasan urban beserta implikasi sosial-ekonomi dan lingkungannya. Temuan ini berpotensi mendukung perencanaan wilayah dan pengelolaan lingkungan perkotaan yang lebih berkelanjutan.

Kata kunci: Transisi Urban*; Urban age; Random Survival Forest; Nighttime Light; Land Surface Temperature*

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ABSTRACT

Urbanization is a rapid land-use transformation process that significantly affects socio-economic and environmental conditions. In the Kartamantul region (Sleman Regency, Bantul Regency, and Yogyakarta City), the increasing expansion of built-up areas (*urban sprawl*) necessitates an approach that not only identifies where urbanization occurs but also characterizes the developmental stages of urban areas. This study aims to analyze urban expansion dynamics in Kartamantul during 2017–2024, identify the factors influencing land conversion into urban areas, and examine the relationship between *Classified Urban Age* and socio-economic and environmental indicators represented by *Nighttime Light* (NTL) and *Land Surface Temperature* (LST).

The study utilized ESRI Global Land Cover data for 2017 and 2024, VIIRS Nighttime Light data, and Land Surface Temperature data. Urbanization drivers were analyzed using the Random Survival Forest algorithm and interpreted through *Variable Importance*, *Shapley Additive Explanations* (SHAP), *Partial Dependence Plots* (PDP), and *Accumulated Local Effects* (ALE). *Classified Urban Age* was determined based on the timing of land conversion into built-up areas. The relationships between *Classified Urban Age* and both NTL and LST were evaluated using the Kruskal–Wallis test followed by pairwise Wilcoxon tests because the data were not normally distributed.

The results indicate that the urban area increased by 21.98%, from 648.28 km² to 790.79 km² between 2017 and 2024. The *urban transition hazard* map produced normalized hazard values ranging from 0% to 98.77%, with high-hazard zones concentrated in southern Bantul Regency and parts of the northern and western study area. The Random Survival Forest model identified elevation, distance to the city center (distCity), and Nightlight as the most influential predictors. SHAP, PDP, and ALE analyses further revealed non-linear relationships between the predictor variables and urban transition probability. In addition, *Classified Urban Age* showed significant relationships with both NTL and LST ($p < 0.05$), indicating that these indicators effectively represent different stages of urban development and their associated socio-economic and environmental characteristics. These findings demonstrate the potential of *Classified Urban Age* to support sustainable urban planning and environmental management.

Keywords: Urban transition; Urban age; Random Survival Forest; Nighttime Light; Land Surface Temperature