

INTISARI

Ketergantungan terhadap energi fosil mendorong kebutuhan akan sumber energi terbarukan yang berkelanjutan, salah satunya energi surya. Akurasi estimasi radiasi matahari sangat bergantung pada ketelitian model topografi yang digunakan. Penelitian ini bertujuan untuk: (1) menganalisis perbedaan karakteristik spasial antara *Digital Elevation Model* hasil akuisisi *Unmanned Aerial Vehicle (UAV)* dan Digital Elevation Model Nasional (DEMNAS) dalam estimasi radiasi matahari, (2) menganalisis pengaruh kuantitatif parameter topografi terhadap hasil estimasi radiasi matahari, dan (3) membandingkan tingkat akurasi estimasi iradiasi sesaat dari kedua model terhadap hasil pengukuran lapangan.

Pemodelan radiasi dilakukan menggunakan algoritma *Area Solar Radiation* (Fu & Rich, 2000) yang menghitung total energi radiasi berdasarkan posisi matahari, orientasi lereng, bayangan topografi, dan faktor pandang langit. Algoritma ini mengintegrasikan komponen radiasi langsung, radiasi difus, dan radiasi pantulan pada setiap piksel model elevasi. Parameter atmosfer diasumsikan konstan, sehingga perbedaan hasil estimasi ditentukan sepenuhnya oleh karakteristik spasial DEM. Pengukuran lapangan dilakukan menggunakan *Solar Power Meter* SM206 pada 40 titik pengamatan yang tersebar berdasarkan empat kelas penutup lahan: permukiman, sawah, kebun, dan lahan terbuka.

Hasil penelitian menunjukkan bahwa DEM UAV menghasilkan hubungan spasial yang lebih kuat terhadap data lapangan dengan nilai koefisien determinasi $R^2 = 0,6567$, sedangkan DEMNAS memiliki nilai $R^2 = 0,1807$. Variabel *slope* dan elevasi berpengaruh signifikan terhadap iradiasi sesaat, menunjukkan sensitivitas tinggi terhadap variasi topografi mikro. Namun, hasil uji akurasi menunjukkan bahwa DEMNAS memiliki nilai kesalahan rata-rata lebih kecil ($RMSE = 147,88 \text{ W/m}^2$) dibanding DEM UAV ($RMSE = 190,45 \text{ W/m}^2$), terutama pada wilayah datar.

Penelitian ini menyimpulkan bahwa perbedaan resolusi spasial model elevasi digital secara signifikan memengaruhi estimasi radiasi matahari. DEM UAV unggul dalam ketepatan pola spasial dan kemampuan menangkap variasi lokal, sedangkan DEMNAS unggul dalam stabilitas numerik dan representasi nilai rata-rata. Oleh karena itu, pemilihan model elevasi sebaiknya disesuaikan dengan karakteristik wilayah: DEM UAV untuk area kompleks vertikal dan analisis tapak, sedangkan DEMNAS untuk area datar dan analisis skala regional wilayah.

Kata kunci: Radiasi matahari, DEM multiskala, DEM UAV, DEMNAS, regresi linear berganda, irradiasi, energi terbarukan

ABSTRACT

Dependence on fossil fuels has driven the need for sustainable renewable energy sources, one of which is solar energy. The accuracy of solar radiation estimation strongly depends on the precision of the topographic model used. This study aims to: (1) analyze the spatial characteristic differences between the Digital Elevation Model derived from Unmanned Aerial Vehicle (UAV) acquisition and the National Digital Elevation Model (DEMNAS) in solar radiation estimation; (2) analyze the quantitative influence of topographic parameters on the estimated solar radiation results; and (3) compare the accuracy level of instantaneous irradiance estimation from both models against field measurement data.

Solar radiation modeling was conducted using the Area Solar Radiation algorithm (Fu & Rich, 2000), which calculates the total solar energy based on solar position, slope orientation, topographic shading, and sky-view factors. The algorithm integrates the components of direct, diffuse, and reflected radiation for each DEM pixel. Atmospheric parameters were assumed to be constant, so that the estimation differences were entirely determined by the spatial characteristics of the DEM. Field measurements were carried out using a Solar Power Meter SM206 at 40 observation points distributed across four land-cover classes: settlement, rice field, plantation, and open land.

The results showed that the UAV-derived DEM produced a stronger spatial correlation with field data, with a coefficient of determination of $R^2 = 0.6567$, while DEMNAS had a lower correlation of $R^2 = 0.1807$. The slope and elevation variables significantly influenced instantaneous irradiance, indicating high sensitivity to micro-topographic variation. However, the accuracy assessment revealed that DEMNAS had a lower average error (RMSE = 147.88 W/m²) compared to the UAV DEM (RMSE = 190.45 W/m²), particularly in flat terrain areas.

This study concludes that the difference in spatial resolution between digital elevation models significantly affects solar radiation estimation. The UAV DEM performed better in capturing spatial patterns and local variations, while DEMNAS demonstrated greater numerical stability and consistency in representing mean irradiance values. Therefore, the selection of elevation models should be adjusted to the topographic characteristics of the study area: UAV DEMs are preferable for complex vertical terrains and site-scale analyses, whereas DEMNAS is more suitable for flat regions and regional-scale assessments.

Keywords: Solar radiation, multi-scale DEM, UAV DEM, DEMNAS, multiple linear regression, irradiance, renewable energy.