Evaluasi dan Optimasi Performa Estimasi Hujan Multi-Satelit Berbasis *Google Earth Engine* dengan Data Penakar Hujan Observasi di Wilayah Sulawesi Selatan

Evaluation and Performance Optimization of Google Earth Engine-Based Multi-Satellite Rainfall Estimation Using Observation Rain Gauge Data over the South Sulawesi Region

Abstract

Precipitation plays a crucial role in human life, especially in the hydrological cycle. Rainfall data are essential for understanding regional climate and weather patterns. However, observational rainfall data in Indonesia, particularly in South Sulawesi, remains limited in spatial coverage and quantity. Remote sensing, especially satellite and weather radar, has significantly aided atmospheric studies. Google Earth Engine (GEE), a cloud-based computing platform, provides a valuable tool for storing, processing, and visualizing spatial and temporal data, including rainfall estimation from satellite sources. This study evaluates the performance of four multi-satellite rainfall estimations (CHIRPS, GSMAP, GPM-IMERG, and PERSIANN-CDR) available on GEE before and after calibration using ground-based rainfall data from the Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG) over the South Sulawesi region during 2018-2023. The original multi-satellite data showed significant spatial and quantitative discrepancies compared to observational data. Among the original multi-satellites, CHIRPS was most similar to the observed rainfall patterns, while GPM-IMERG had the highest coefficient of determination but tended to overestimate rainfall. Calibration using Geographical Differential Analysis (GDA) successfully improved the accuracy of all multi-satellite rainfall estimates, as evidenced by a reduction in bias by 94%, 98%, and 100%, a decrease in RMSE by 47%, 38%, and 24%, and an increase in RSQ values by 63%, 82%, and 89% at annual, monthly, and daily scales, respectively. After calibration, PERSIANN-CDR presents superior spatial distribution and performance across various time scales and rainfall intensities. Analysis of elevation and rainfall intensity revealed that multi-satellite rainfall estimates were sensitive to changes in elevation and rainfall intensity. Detection indicators such as POD, which increased by 14-43%, FAR, which decreased by 11-28%, and CSI, which improved by 25-62%, also demonstrated enhancements in calibrated multi-satellites for light to extreme rainfall events. This study highlights the importance of calibration in improving the accuracy of satellite-based rainfall products, supporting better decision-making in water resources management and hydrometeorological disaster risk mitigation.

Keywords: *rainfall, multi-satellite, Google Earth Engine, calibration, accuracy.*

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Intisari

Hujan memainkan peran vital bagi kehidupan manusia, terutama dalam siklus hidrologi. Data hujan penting untuk memahami karakteristik cuaca dan iklim di suatu wilayah. Namun, ketersediaan data hujan observasi di Indonesia yang masih terbatas sebaran dan jumlahnya, tak terkecuali di Sulawesi Selatan. Sistem penginderaan jauh sangat membantu untuk studi atmosfer, khususnya satelit dan radar cuaca. Adanya sistem komputasi awan Google Earth Engine (GEE) dapat dimanfaatkan sebagai basis data, pengolahan, bahkan visualisasi data spasial dan temporal, termasuk estimasi hujan yang bersumber dari data satelit. Penelitian ini mengevaluasi performa empat estimasi curah hujan multi-satelit (CHIRPS, GSMAP, GPM-IMERG, dan PERSIANN-CDR) yang tersedia di GEE sebelum dan sesudah proses kalibrasi dengan menggabungkan data curah hujan BMKG dari penakar hujan *in situ* di wilayah Sulawesi Selatan selama 2018-2023. Data multi-satelit *original* menunjukkan perbedaan spasial dan kuantitatif yang signifikan dibandingkan dengan data hujan observasi (OBS), di mana CHIRPS memiliki kesamaan paling mendekati dengan peta hujan yang diamati, sementara GPM memiliki nilai koefisien determinasi (RSQ) tertinggi tetapi cenderung overestimasi curah hujan. Kalibrasi menggunakan teknik *Geographical Differential Analysis* (GDA) berhasil meningkatkan akurasi semua estimasi curah hujan multi-satelit, terlihat dari pengurangan bias 94%, 98%, dan 100%, penurunan RMSE sebesar 47%, 38%, dan 24%, dan peningkatan nilai RSQ 63%, 82%, dan 89% pada skala tahunan, bulanan, dan harian. Setelah kalibrasi, PERSIANN-CDR menyajikan distribusi spasial dan performa yang paling unggul di berbagai skala waktu dan intensitas hujan. Analisis terhadap elevasi dan intensitas hujan menunjukkan bahwa estimasi multi-satelit memiliki sensitivitas terhadap perubahan elevasi dan intensitas hujan. Indikator deteksi seperti POD yang meningkat 14-43%, FAR yang menurun 11-28%, dan CSI yang meningkat 25-62% menunjukkan perbaikan pada multi-satelit terkalibrasi mulai dari hujan ringan hingga ekstrem. Penelitian ini menegaskan pentingnya kalibrasi untuk meningkatkan keakuratan produk curah hujan berbasis satelit, untuk mendukung pengambilan keputusan yang lebih baik dalam pengelolaan sumber daya air dan mitigasi risiko bencana hidrometeorologi.

Kata kunci: hujan, multi-satelit, Google Earth Engine, kalibrasi, akurasi.