PENGEMBANGAN MODEL POLA DISTRIBUSI ECENG GONDOK DI WADUK CIRATA BERDASARKAN HIDRODINAMIKA ARUS DAN KUALITAS AIR DALAM RANGKA PENGELOLAAN TUMBUHAN INVASIF UNTUK KETAHANAN KESEHATAN EKOSISTEM WADUK

Program Riset Unggulan ITB 2026

Ketua: Yadi Suryadi[1] | Tim peneliti :

Indratmo [1]; Eka Oktariyanto Nugroho [1]; Arno Adi Kuntoro [1]; Mohammad Farid [1]; Abdul Kadir Alhamid [1]; Widodo [1]; Mayrina Firdayati[1]; Dian Rosleine[1]; Akbar Rizaldi[1]; Azmeri[2]; Entin Hidayah[3]; Anom Herudjito[4]; Ressky Octa Pratama[5]; Regina Dio Oriandra[1]; Roni Farfian[1]; Cipta Riyana[1]; Ken Wiralino Taredja[1]; Muhammad Fadli Fauzi[1]; Nurul Hasanah[1]; Hanif Syafrian Purnama[1]

[1]Institut Teknologi Bandung; [2]Universitas Syiah Kuala; [3]Universitas Jember; [4]Perum Jasa Tirta II; [5]PT PLN Nusantara Power UP Cirata

Abstrak

Eceng gondok merupakan tumbuhan invasif yang berpotensi mengganggu fungsi ekologis dan operasional Waduk Cirata. Penelitian ini mengintegrasikan klasifikasi tutupan perairan berbasis citra Sentinel-2 Level-2A menggunakan *Google Earth Engine* (GEE) dan algoritma *Random Forest* dengan simulasi hidrodinamika dua dimensi MIKE 21 FM untuk mengevaluasi keterkaitan spasial distribusi eceng gondok dan karakteristik kecepatan arus. Analisis dilakukan pada dua periode terpilih, yaitu 14–21 Agustus 2024 (kemarau) dan 21–28 Februari 2025 (hujan), masing-masing menggunakan input angin STA 19 dan STA 22 sehingga menghasilkan empat skenario simulasi. Peta distribusi eceng gondok tanggal 21 Agustus 2024 dan 27 Februari 2025 diintegrasikan dengan hasil simulasi arus melalui analisis overlay pada domain bersama. Hasil menunjukkan bahwa 54,87–66,99% luas eceng gondok valid pada keempat skenario beririsan secara spasial dengan zona kecepatan arus ≤ 0,005 m/s. Perbedaan proporsi antarskenario memperlihatkan sensitivitas hasil analisis terhadap variasi input angin dan kondisi hidrodinamika pada periode pengamatan. Pendekatan ini menyediakan informasi spasial sebagai dasar awal identifikasi lokasi prioritas pemantauan eceng gondok, dengan interpretasi yang dibatasi pada asosiasi spasial, bukan hubungan sebab-akibat.

Kata kunci: eceng gondok; Sentinel-2; RF; MIKE 21 FM

Pendahuluan

Waduk Cirata merupakan infrastruktur sumber daya air multifungsi yang mendukung pembangkitan listrik, kegiatan perikanan, dan fungsi ekologis perairan. Keberadaan eceng gondok (*Eichhornia Crassipes*) dalam jumlah besar berpotensi mengganggu pemanfaatan waduk melalui penutupan permukaan air, hambatan aktivitas operasional, dan peningkatan kebutuhan pengendalian tumbuhan invasif.

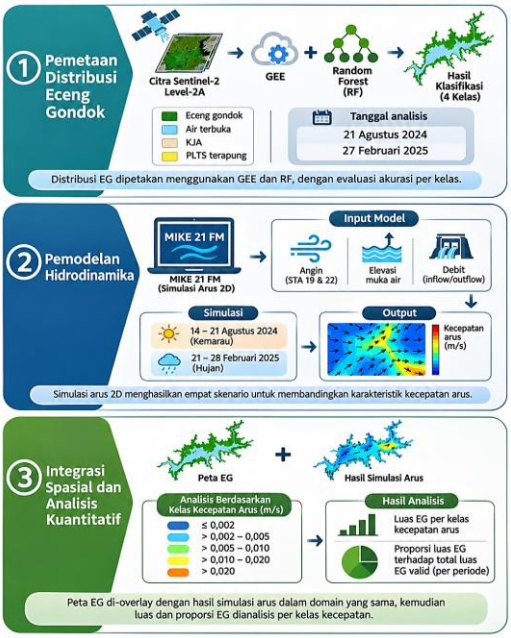
Distribusi eceng gondok berkaitan dengan interaksi berbagai faktor lingkungan, termasuk kondisi hidrodinamika perairan. Pemetaan berbasis citra satelit mampu mengidentifikasi lokasi dan luas tutupan eceng gondok, tetapi belum memberikan informasi mengenai karakteristik kecepatan arus pada area yang teridentifikasi. Sebaliknya, pemodelan hidrodinamika menggambarkan kondisi pergerakan air, tetapi tidak secara langsung menunjukkan distribusi aktual eceng gondok.

Oleh karena itu, integrasi penginderaan jauh dan pemodelan hidrodinamika diperlukan untuk mengevaluasi hubungan spasial antara tutupan eceng gondok dan kelas kecepatan arus. Penggunaan dua periode pengamatan serta dua sumber data angin memungkinkan perbandingan hasil analisis pada kondisi simulasi yang berbeda. Tujuan penelitian yang disajikan:

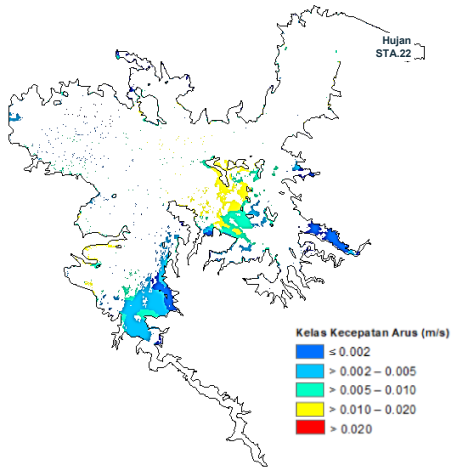
1. Mengidentifikasi distribusi spasial eceng gondok menggunakan citra Sentinel-2 dan algoritma Random Forest.
2. Menganalisis karakteristik kecepatan arus Waduk Cirata melalui simulasi MIKE 21 FM pada dua periode dan dua skenario input angin.
3. Mengevaluasi distribusi luas eceng gondok berdasarkan kelas kecepatan arus sebagai dasar awal identifikasi lokasi prioritas pemantauan.

Penelitian secara keseluruhan mencakup distribusi eceng gondok, hidrodinamika, dan kualitas air. Poster ini berfokus pada integrasi distribusi eceng gondok dan kecepatan arus, sedangkan hasil analisis kualitas air belum disajikan secara kuantitatif.

Metode Penelitian

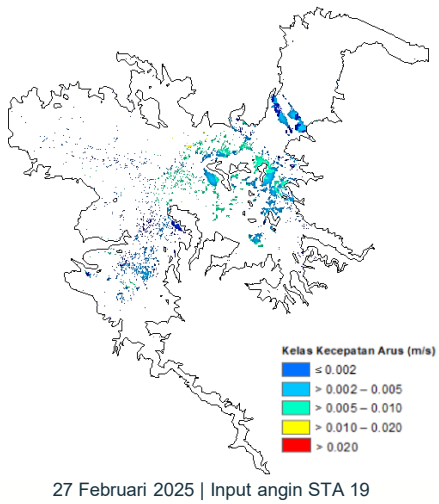


OVERLAY ECENG GONDOK–ARUS | KEMARAU



21 Agustus 2024 | Input angin STA 19

OVERLAY ECENG GONDOK–ARUS | HUJAN



27 Februari 2025 | Input angin STA 19

Peta overlay menunjukkan irisan spasial eceng gondok dengan kelas kecepatan arus pada dua periode pengamatan menggunakan input angin STA 19. Hasil STA 22 disajikan dalam grafik empat skenario sebagai pembanding. Analisis pada domain bersama memungkinkan perbandingan spasial yang konsisten, dengan tetap mempertimbangkan perbedaan waktu citra dan keluaran model.

Hasil dan Pembahasan

Proporsi Eceng Gondok pada Arus ≤ 0,005 m/s



Pada periode kemarau, proporsi eceng gondok yang beririsan dengan zona arus ≤0,005 m/s mencapai 54,87% (STA 19) dan 56,39% (STA 22), sedangkan pada periode hujan mencapai 66,99% dan 60,21%. Luas eceng gondok valid pada domain bersama masing-masing sebesar 632,52 ha dan 963,46 ha. Perbedaan antar-STA menunjukkan sensitivitas hasil overlay terhadap variasi input angin, sedangkan perbedaan antarperiode mencerminkan variasi kondisi hidrodinamika pada dua waktu pengamatan. Dominasi irisan spasial dengan zona arus rendah tidak membuktikan hubungan sebab-akibat.

Kesimpulan

Integrasi klasifikasi Sentinel-2 dan pemodelan MIKE 21 FM menghasilkan informasi spasial mengenai distribusi eceng gondok pada berbagai kelas kecepatan arus di Waduk Cirata. Analisis empat skenario memungkinkan evaluasi perbedaan hasil berdasarkan periode pengamatan dan sumber input angin, sehingga memperkuat interpretasi hidrodinamika secara komparatif.

Informasi spasial tersebut dapat digunakan sebagai dasar awal identifikasi lokasi prioritas pemantauan dan pemeriksaan lapangan eceng gondok, khususnya pada area yang beririsan dengan zona arus rendah. Namun, rekomendasi pengelolaan operasional masih memerlukan validasi hidrodinamika, integrasi kualitas air, serta pengamatan temporal yang lebih luas.

Analisis terbatas pada dua periode simulasi terpilih sehingga belum mewakili karakteristik musiman secara keseluruhan. Validasi hidrodinamika, kesesuaian waktu citra–model, dan integrasi kualitas air masih diperlukan untuk memperkuat rekomendasi pengelolaan.

DEVELOPMENT OF A MODEL FOR THE DISTRIBUTION PATTERNS OF WATER HYACINTH IN CIRATA RESERVOIR BASED ON CURRENT HYDRODYNAMICS AND WATER QUALITY IN SUPPORT OF INVASIVE SPECIES MANAGEMENT FOR THE ECOLOGICAL HEALTH AND RESILIENCE OF THE RESERVOIR ECOSYSTEM

ITB's 2026 Flagship Research Program

Research Team Leader: Yadi Suryadi[1] | Research team:

Indratmo[1]; Eka Oktariyanto Nugroho[1]; Arno Adi Kuntoro[1]; Mohammad Farid[1]; Abdul Kadir Alhamid[1]; Widodo[1]; Mayrina Firdayati[1]; Dian Rosleine[1]; Akbar Rizaldi[1]; Azmeri[2]; Entin Hidayah[3]; Anom Herudjito[4]; Ressky Octa Pratama[5]; Regina Dio Oriandra[1]; Roni Farfian[1]; Cipta Riyana[1]; Ken Wiralino Taredja[1]; Muhammad Fadli Fauzi[1]; Nurul Hasanah[1]; Hanif Syafrian Purnama[1]

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Abstract

Water hyacinth is an invasive plant that has the potential to disrupt the ecological and operational functions of the Cirata Reservoir. This study integrates water surface cover classification based on Sentinel-2 Level-2A imagery using Google Earth Engine (GEE) and the Random Forest algorithm with two-dimensional MIKE 21 FM hydrodynamic simulations to evaluate the spatial relationship between water hyacinth distribution and current velocity characteristics. The analysis was conducted for two selected periods: August 14–21, 2024 (dry season) and February 21–28, 2025 (rainy season), each using wind data from STA 19 and STA 22, resulting in four simulation scenarios. The water hyacinth distribution maps dated August 21, 2024, and February 27, 2025, were integrated with the current simulation results through overlay analysis on a common domain. The results showed that 54.87–66.99% of the valid water hyacinth area across all four scenarios spatially overlapped with zones where current velocity was ≤ 0.005 m/s. Differences in proportions across scenarios demonstrate the sensitivity of the analysis results to variations in wind inputs and hydrodynamic conditions during the observation period. This approach provides spatial information as a preliminary basis for identifying priority locations for water hyacinth monitoring, with interpretations limited to spatial associations rather than cause-and-effect relationships.

Keywords: water hyacinth; Sentinel-2; RF; MIKE 21 FM

Introduction

The Cirata Reservoir is a multifunctional water resource infrastructure that supports electricity generation, fisheries, and the ecological functions of the water body. The presence of water hyacinth (Eichhornia crassipes) in large quantities has the potential to disrupt the reservoir's use by covering the water surface, hindering operational activities, and increasing the need for invasive plant control.

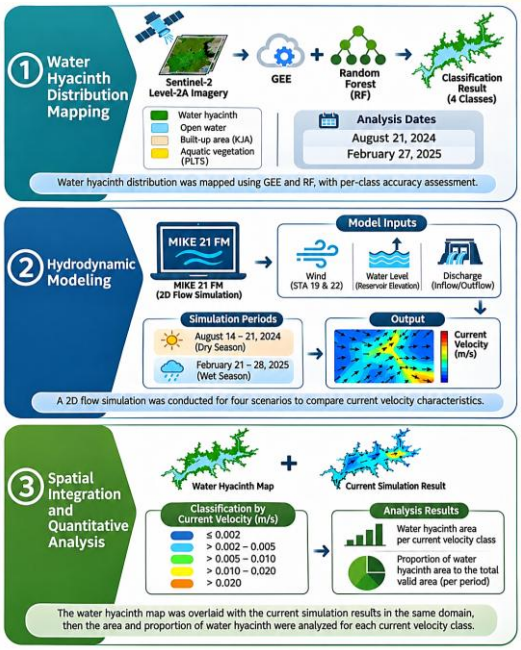
The distribution of water hyacinth is related to the interaction of various environmental factors, including the hydrodynamic conditions of the water body. Satellite image-based mapping can identify the location and extent of water hyacinth coverage but does not provide information on current velocity characteristics in the identified areas. Conversely, hydrodynamic modeling describes water movement conditions but does not directly show the actual distribution of water hyacinth.

Therefore, the integration of remote sensing and hydrodynamic modeling is necessary to evaluate the spatial relationship between water hyacinth coverage and current velocity classes. The use of two observation periods and two wind data sources allows for a comparison of analysis results under different simulation conditions. The objectives of this study are as follows:

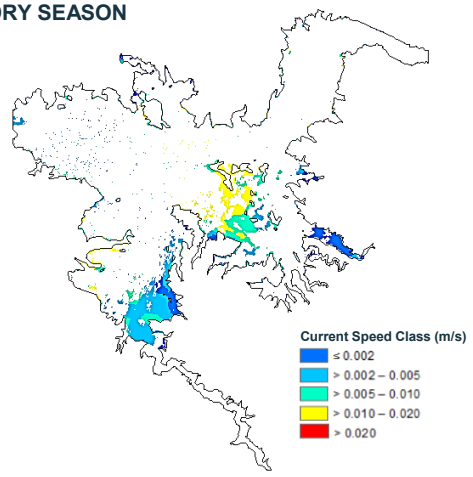
1. To identify the spatial distribution of water hyacinth using Sentinel-2 imagery and the Random Forest algorithm.
2. To analyze the flow velocity characteristics of Cirata Reservoir through MIKE 21 FM simulations across two periods and two wind input scenarios.
3. To evaluate the distribution of water hyacinth coverage based on current velocity classes as a preliminary basis for identifying priority monitoring locations.

The overall study covers water hyacinth distribution, hydrodynamics, and water quality. This poster focuses on the integration of water hyacinth distribution and current velocity, while the results of the water quality analysis have not yet been presented quantitatively.

Research Method

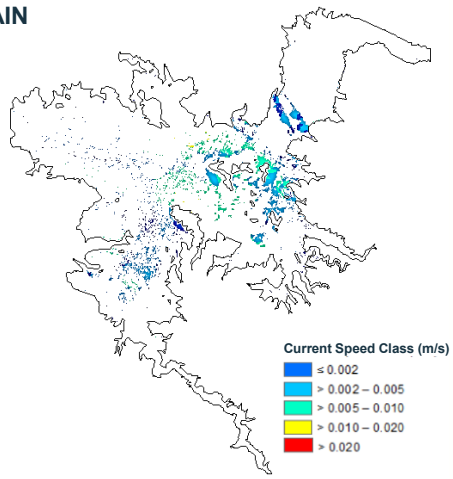


ECENG GONDOK–CURRENT OVERLAY | DRY SEASON



August 21, 2024 | Wind data from STA 19

ECENG GONDOK OVERLAY–CURRENT | RAIN

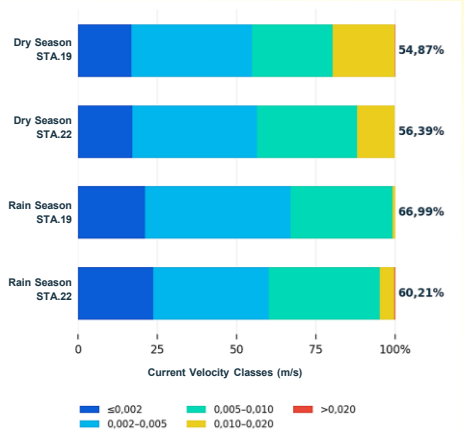


February 27, 2025 | Wind data from STA 19

The overlay map shows spatial slices of water hyacinth distribution overlaid with current velocity classes for two observation periods using wind data from STA 19. Results from STA 22 are presented in four scenario graphs for comparison. Analysis within a common domain allows for consistent spatial comparisons, while accounting for differences in image and model output timing.

Discussion & Result

Proportion of Water Hyacinth in Currents ≤ 0.005 m/s



During the dry season, the proportion of water hyacinth overlapping with current zones ≤0.005 m/s reached 54.87% (STA 19) and 56.39% (STA 22), while during the rainy season it reached 66.99% and 60.21%. The valid water hyacinth areas in the respective shared domains were 632.52 ha and 963.46 ha. Differences between STAs indicate the sensitivity of the overlay results to variations in wind input, while differences between periods reflect variations in hydrodynamic conditions at the two observation times. The predominance of spatial overlaps with low current zones does not prove a cause-and-effect relationship.

Conclusion

The integration of Sentinel-2 classification and MIKE 21 FM modeling provides spatial information on the distribution of water hyacinth across various current velocity classes in Cirata Reservoir. Analysis of four scenarios allows for an evaluation of differences in results based on observation periods and wind input sources, thereby strengthening the comparative interpretation of hydrodynamics.

This spatial information can serve as a preliminary basis for identifying priority locations for water hyacinth monitoring and field inspections, particularly in areas overlapping with low-current zones. However, recommendations for operational management still require hydrodynamic validation, integration of water quality data, and broader temporal observations.

The analysis is limited to two selected simulation periods and therefore does not yet represent the overall seasonal characteristics. Hydrodynamic validation, image–model temporal alignment, and water quality integration are still needed to strengthen management recommendations.