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Integrating Sentinel-2 NDVI and Web GIS for Rice Vegetation Monitoring

Beny Riswanto[1*], Kusnana[2], Nursetianti[3], Agus Sudarmanto[4], Syaiful Akbar Rizy Mubarok[5]
[1,2,3,4,5]Universitas Komputama, Indonesia
[1*]benyriswanto@gmail.com, [2]nanakusnana999@gmail.com, [3]nursetiaa24mail@gmail.com,
[4]syaifulakbar873@gmail.com, [5]kukukganyon@gmail.com

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***Corresponding Author**

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ABSTRACT

Monitoring rice vegetation across agricultural plots requires accessible spatial information. Satellite-derived vegetation indices provide periodic observations, while Web Geographic Information Systems (Web GIS) present spatial data through interactive maps. This study develops a Web GIS integrating Sentinel-2-derived Normalized Difference Vegetation Index (NDVI) data to support rice vegetation monitoring in Negarajati Village, Cimanggu District, Cilacap Regency, Indonesia. The study used processed monthly NDVI values from ten sampling locations (P1–P10) covering May–September 2026. Descriptive statistics were calculated to summarise monthly NDVI values and their variation. The Web GIS was developed using Laravel, PostgreSQL with PostGIS for spatial data management, and LeafletJS for map visualisation. The application was deployed in a web-hosting environment to provide browser-based access. The monthly mean NDVI values were 0.159538 in May, 0.270014 in June, 0.491593 in July, 0.621865 in August, and 0.571092 in September. The mean increased from May to August before declining in September. The Web GIS presents monthly NDVI information and sampling-point attributes through an interactive map, enabling users to explore the processed spatial dataset. The developed Web GIS provides an integrated platform for presenting Sentinel-2-derived NDVI information for village-scale rice vegetation monitoring. The monthly values describe variation in the processed dataset but do not independently confirm crop growth stages or field health. Further work should document image-processing procedures and include field validation to strengthen interpretation.

INTRODUCTION

Rice is a strategic commodity for food security, making periodic observation of crop conditions an important part of agricultural land management. At the local level, rice crops are often monitored through direct field observation. Although field visits can provide information about actual conditions, they require time and labour when the cultivated area contains many plots. Visual observation also does not automatically produce structured spatial information that shows how vegetation conditions differ from one location to another. Limited spatial information can therefore make it difficult to identify local variation and use it to guide more targeted land management. The original manuscript also notes that limited monitoring personnel relative to the area and number of agricultural plots can constrain regular monitoring (Sugiarto et al., 2024).

Studies have used Sentinel-2-derived NDVI to examine rice vegetation dynamics, nitrogen content, and growth stages(Afifah et al., 2025), while other research has combined Sentinel-2 and unmanned aerial vehicle imagery to analyse rice growth stages (Tian et al., 2023).

Satellite-derived indices alone do not fully address the challenge of communicating analysis to local users. Image-processing outputs may require specialised tools and knowledge, leaving a gap between technical remote-sensing data and information that can be readily explored by non-specialists(Soriano-González et al., 2022). Web-based Geographic Information Systems (Web GIS) can help address this gap by combining geospatial layers and descriptive attributes in an interactive map. Previous work has demonstrated the use of Web GIS for agricultural monitoring and land management (Sugiarto et al., 2024). In this context, a spatial database can associate vegetation-index measurements with mapped agricultural areas, while a web interface can make the results available without requiring every user to operate remote-sensing software(Sheng et al., 2025).

The research gap addressed in this study is the integration of satellite-derived vegetation information, spatial data management, and web-based visualisation within a village-scale monitoring workflow. The proposed system combines Sentinel-2 imagery and NDVI analysis with PostgreSQL/PostGIS for spatial data management and Laravel with LeafletJS for interactive map visualisation(Sudiana et al., 2025). Its intended contribution is not a new vegetation index, but a practical information workflow that transforms satellite analysis into location-based information that can be explored by local users. Field comparison is also included in the planned workflow so that NDVI interpretation is not treated as a standalone diagnosis of crop health.

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This study aims to develop a Web GIS based on Sentinel-2 imagery and NDVI to map variation in rice vegetation conditions and provide spatial information for agricultural land monitoring in Negarajati Village, Cimanggu District, Cilacap Regency, Indonesia. Specifically, it connects image preparation, vegetation-index calculation, spatial data management, and interactive web visualisation in one system. The research questions are how Sentinel-2-derived NDVI can be used to represent the spatial variation of rice vegetation in the study area and how the resulting information can be integrated and visualised through a Web GIS(Muchsin et al., 2022) . The intended contribution is a locally accessible, data-oriented approach to agricultural monitoring. Final claims about system performance and the agreement between NDVI and field conditions must be based on completed testing and validation .

LITERATURE REVIEW

The Normalized Difference Vegetation Index is a spectral indicator derived from red and near-infrared reflectance and is widely used to observe vegetation variation over time (Afifah et al., 2025).

A second strand of related work concerns the delivery of agricultural spatial information. Developed a Web GIS application for monitoring agricultural activities in Indonesia. Building on this broader approach, the present system uses PostgreSQL/PostGIS to associate spatial features with vegetation-index attributes and uses Laravel and LeafletJS to serve and display the information in an interactive browser-based map (Zhao et al., 2024) The focus of this study is the integration of monthly satellite-derived vegetation information, sampling-point attributes, and web-based visualisation in a village-scale workflow. The contribution is an application and information workflow rather than a new vegetation index or a validated crop-health classification method(Hisyam et al., 2022).

METHOD

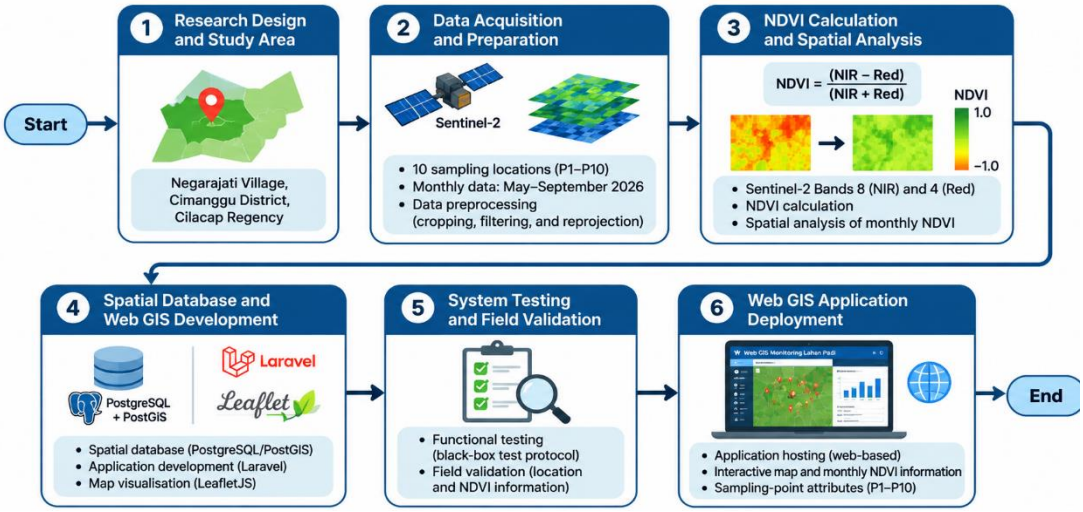


Figure 1. Research Workflow

Figure 1 illustrates the research workflow, which consists of five main stages, beginning with the identification of the research design and study area, followed by data acquisition and preparation, NDVI calculation and spatial analysis, spatial database integration and Web GIS development, and system testing. The processed monthly NDVI data from ten sampling locations were integrated into the spatial database and presented through an interactive Web GIS application. The application was subsequently deployed in a web-hosting environment to provide browser-based access to monthly vegetation information and sampling-point attributes. Each stage is described in the following subsections.

Research Design and Study Area

This study follows a geospatial system-development workflow that combines satellite-image processing, spatial analysis, spatial database design, and Web GIS implementation. The study area is Negarajati Village, Cimanggu District, Cilacap Regency, Central Java, Indonesia. The objective is to represent spatial variation in rice vegetation and present the resulting information through an interactive web map.

Data Acquisition and Preparation

The study dataset contains ten sampling locations (P1–P10) and monthly NDVI values for May–September 2026. Image preparation and spatial inspection were conducted using geographic information system tools (Jiang et al., 2024).

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NDVI Calculation and Spatial Analysis

For Sentinel-2 imagery, NDVI is conventionally calculated from near-infrared (Band 8) and red (Band 4) reflectance using Equation (1) (Zhang et al., 2025) :

$$NDVI = (NIR - Red) / (NIR + Red) \quad (1)$$

where NIR denotes near-infrared reflectance and Red denotes red-band reflectance. The resulting NDVI values are linked to their geographic positions and analysed to describe the spatial distribution of vegetation-index values across the rice-growing area. In this study, NDVI is treated as an initial indicator of vegetation conditions. Interpretation should account for phenological stage, water conditions, image acquisition timing, and other environmental influences. The specific thresholds used to classify NDVI into categories are not supplied in the source manuscript and should not be inserted until the authors confirm the classification scheme.

Spatial Database and Web GIS Development

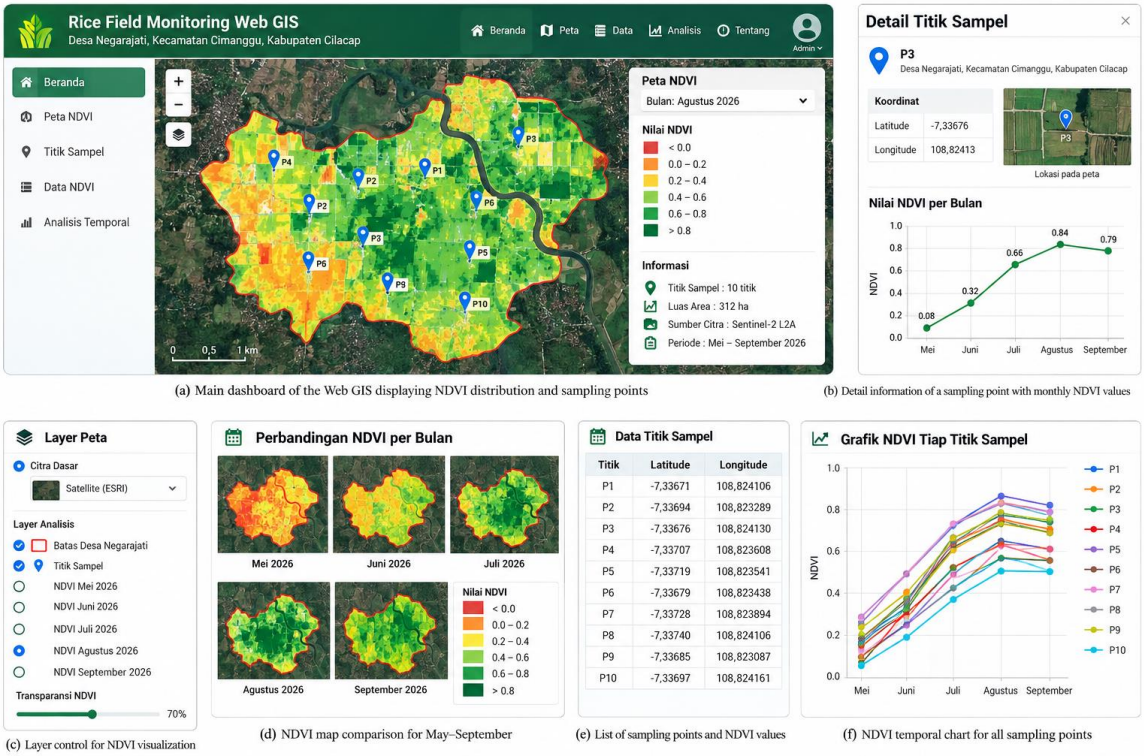
The Web GIS application was developed using Laravel for application logic (Laravel, n.d.), PostgreSQL/PostGIS for spatial-data management (PostGIS Project Steering Committee, n.d.), and LeafletJS for interactive map visualisation (Ni et al., 2021)

System Testing and Field Validation

A functional black-box test protocol was defined for access to the hosted application, page navigation, map rendering, monthly NDVI display, sampling-point information, and monthly summaries. For each scenario, the expected behaviour is specified in Table 3. The observed-result column must be completed from actual test records before the manuscript claims that a function passed. Field validation of the NDVI values and formal usability, performance, or security testing are not documented in the current dataset(Namazi et al., 2023) .

RESULT

The monthly NDVI values from ten sampling locations (P1–P10) were summarised for May–September 2026. The mean increased from 0.159538 in May to 0.621865 in August, then declined to 0.571092 in September. The minimum, maximum, and standard deviation values indicate variation among the ten locations in each month(Muchsin et al., 2022) . These are descriptive patterns in the processed dataset; without the corresponding acquisition metadata and field observations, they should not be interpreted as proof of a particular crop-growth stage or crop-health condition(Chen et al., 2024) . The monthly values and sampling-point attributes are presented through the hosted Web GIS.



(a) Main dashboard of the Web GIS displaying NDVI distribution and sampling points

(b) Detail information of a sampling point with monthly NDVI values

(c) Layer control for NDVI visualization

(d) NDVI map comparison for May–September

(e) List of sampling points and NDVI values

(f) NDVI temporal chart for all sampling points

Figure 2. Hosted Web GIS interface for rice-field NDVI monitoring in Negarajati Village.

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Figure 2 illustrates the main interface and visualization features of the developed Web GIS for rice-field NDVI monitoring in Negarajati Village. As shown in Figure 2(a), the main dashboard presents the spatial distribution of NDVI values across the study area, including the locations of ten sampling points (P1–P10). Figure 2(b) displays detailed information for a selected sampling point, including its geographic coordinates and monthly NDVI values. The layer control panel in Figure 2(c) allows users to manage the visibility of spatial layers and select the available monthly NDVI data. Furthermore, Figure 2(d) provides a visual comparison of NDVI distribution from May to September 2026, enabling users to explore monthly variations in vegetation-index values. Figure 2(e) presents the sampling-point attributes, including geographic coordinates and monthly NDVI measurements, while Figure 2(f) displays the temporal variation of NDVI values across all ten sampling locations. These visualization features integrate spatial distribution, sampling-point information, and temporal data within a single web-based platform, supporting the exploration of processed NDVI information for agricultural monitoring.

Data provenance. The values in this manuscript are reported as processed results from the original study data for ten sampling locations across May–September 2026. To make the analysis reproducible, the final submission should identify the source imagery, acquisition dates, processing software and settings, cloud masking procedure, sampling-point extraction method, and any classification thresholds actually used.

Table 1. Monthly NDVI values for ten sampling locations (May–September 2026).

Point	Latitude	Longitude	May	June	July	August	September
P1	-7.33671	108.824106	0.172983	0.160000	0.350000	0.557419	0.497419
P2	-7.33694	108.823289	0.178329	0.322439	0.522531	0.643270	0.585716
P3	-7.33676	108.824130	0.080000	0.228257	0.440034	0.500000	0.420000
P4	-7.33707	108.823608	0.219540	0.313942	0.513282	0.765881	0.673723
P5	-7.33719	108.823541	0.260000	0.327881	0.620000	0.772375	0.543406
P6	-7.33679	108.823438	0.147394	0.288998	0.526572	0.657483	0.655686
P7	-7.33728	108.823894	0.137280	0.305352	0.516611	0.714814	0.574112
P8	-7.33740	108.824106	0.116934	0.184587	0.350000	0.500000	0.678183
P9	-7.33685	108.823087	0.188972	0.380000	0.620000	0.607405	0.560108
P10	-7.33697	108.824161	0.093950	0.188683	0.456901	0.500000	0.522569

Table 1 presents the monthly NDVI values recorded at ten sampling locations (P1–P10) from May to September 2026. The results show variations in NDVI values across the sampling locations and observation periods. In May, the values ranged from 0.080000 to 0.260000, while in June they ranged from 0.160000 to 0.380000. The NDVI values generally increased in July, with a range of 0.350000 to 0.620000, and reached higher values in August, ranging from 0.500000 to 0.772375. In September, the values ranged from 0.420000 to 0.678183, indicating a decrease in several sampling locations compared with August. The highest recorded value was 0.772375 at sampling point P5 in August, whereas the lowest value was 0.080000 at sampling point P3 in May. These results indicate spatial and temporal variations in the processed NDVI dataset, providing a basis for examining vegetation-index distribution across the study area.

Table 2. Descriptive statistics of monthly NDVI values.

Month	Mean NDVI	Minimum	Maximum	Standard deviation
May	0.159538	0.080000	0.260000	0.055955
June	0.270014	0.160000	0.380000	0.074156
July	0.491593	0.350000	0.620000	0.094406
August	0.621865	0.500000	0.772375	0.106810
September	0.571092	0.420000	0.678183	0.082245

Table 2 presents the descriptive statistics of monthly NDVI values calculated from ten sampling locations between May and September 2026. The results indicate an increase in the monthly mean NDVI from 0.159538 in May to 0.270014 in June, 0.491593 in July, and 0.621865 in August. In September, the mean decreased to 0.571092. The maximum NDVI value was also recorded in August (0.772375), while the minimum value was 0.080000 in May. Regarding data variability, the standard deviation increased from 0.055955 in May to 0.106810 in August, indicating greater variation among sampling locations during August. It subsequently decreased to 0.082245 in September. These descriptive statistics demonstrate temporal changes in the mean NDVI and variations in the distribution of values across the sampling locations. The results provide a quantitative summary of the processed dataset without independently establishing the actual health conditions or growth stages of rice vegetation.

The monthly mean values calculated from the ten locations are 0.159538 in May, 0.270014 in June, 0.491593 in July, 0.621865 in August, and 0.571092 in September. The mean rises through August and decreases in September. This describes the dataset only; interpretation in terms of rice growth or field condition requires acquisition-date information, consistent preprocessing, and comparison with field observations.

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Functional Testing Results

Table 3. Functional Testing Results

ID	Function tested	Test procedure	Expected result	Observed result
T1	Hosted application access	Open the deployed application URL in a web browser.	The application landing page loads and is accessible.	The application landing page loaded successfully and was accessible through a web browser.
T2	Page navigation	Open the main navigation items used by the application.	The selected page or section opens without an application error.	All selected navigation items opened their corresponding pages without errors.
T3	Map rendering	Open the map page and inspect the base map and study layers.	The map and configured spatial layers are displayed.	The base map and configured spatial layers were displayed correctly.
T4	Monthly NDVI display	Select or view the available monthly NDVI information.	The selected month's NDVI information is displayed correctly.	Monthly NDVI information was displayed according to the selected observation period.
T5	Sampling-point information	Select a sampling point on the map.	The corresponding point attributes are displayed.	Sampling-point attributes were displayed correctly when a location was selected.
T6	Monthly summary display	Open the section containing monthly descriptive statistics.	The monthly summary values are displayed and correspond to the dataset table.	Monthly descriptive statistics were displayed according to the processed dataset

Table 3 presents the functional testing results of the deployed Web GIS application using a black-box testing approach. The evaluation covers six main functional aspects, including hosted application access, page navigation, map rendering, monthly NDVI display, sampling-point information, and monthly summary statistics. Each test scenario was designed to examine whether the implemented functions operated according to their expected behaviour. The testing process involved accessing the application through a web browser, navigating between application sections, inspecting the map and spatial layers, viewing monthly NDVI information, selecting sampling locations, and examining the displayed statistical summaries. These tests provide an assessment of the application's functional performance in its deployed environment and help identify whether the main features operate as intended.

DISCUSSION

System Functionality and Web GIS Integration

The deployed Web GIS combines spatial-data management, interactive mapping, monthly NDVI presentation, and sampling-point information in a browser-based interface. Laravel supports application logic, PostgreSQL/PostGIS manages spatial information, and LeafletJS provides map interaction. Deployment makes the application accessible through a browser. These implementation details describe the system architecture; they do not independently establish the accuracy of the NDVI values or the agronomic validity of the mapped vegetation conditions.

Interpreting the NDVI Time Series

NDVI describes variation in red and near-infrared reflectance and can support temporal or spatial comparison of vegetation. It is not, by itself, a complete diagnosis of rice-plant health. Differences between monthly observations may be associated with crop growth stage, water management, acquisition timing, cloud or atmospheric effects, and mixed pixels. Comparisons should therefore use documented acquisition dates and consistent preprocessing. In this manuscript, the reported monthly values are treated as processed study results, as specified by the study data record. The temporal pattern should not be attributed to a specific agronomic cause without further supporting metadata and field observations.

Comparison with Related Studies

(Afifah et al., 2025) examined rice-growth dynamics using Sentinel-2-derived NDVI and considered environmental influences. (Sugiarto et al., 2024) Described a Web GIS for monitoring agricultural activities in Indonesia. These studies represent complementary strands of the present work: satellite-based vegetation information and web-based presentation of agricultural spatial data. The current system focuses on integrating monthly index information and sampling-point attributes in a village-scale Web GIS. The comparison is qualitative; this manuscript does not establish quantitative superiority over previous systems because no comparative performance or usability measurements are reported.

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The comparison concerns study focus and system purpose rather than quantitative performance. The manuscript reports the system's implementation and the descriptive statistics of the retained dataset; it does not report field-validated NDVI accuracy or measured usability.

Relationship to Previous Studies and Contribution

The contribution is the integration of spatial-data management, map-based exploration, monthly index presentation, and sampling-point information in a village-scale Web GIS workflow. This is a system-development contribution and does not establish the accuracy of NDVI values or superiority over other monitoring systems.

Practical Implications and Deployment Status

The hosted Web GIS can provide browser-based access to processed spatial information for village-level users, agricultural officers, and researchers. The interactive map, monthly NDVI views, and sampling-point details reduce the need to open desktop GIS software for basic exploration. The practical value of the application depends on reliable hosting, understandable map legends, and clear documentation of the NDVI-processing workflow(Ardiansyah et al., 2023) .

Limitations and Further Work

The current manuscript reports processed NDVI values and describes the deployed Web GIS, but complete processing metadata are needed for reproducibility. The prepared functional test cases also require observed outcomes to be entered from actual tests. These checks do not replace field validation of vegetation conditions or formal usability, performance, and security assessments. Further work should document source-image metadata and preprocessing, compare selected locations with field observations, and evaluate the hosted system using recorded functional and usability measures.

CONCLUSION

This study developed and deployed a Web GIS for presenting processed NDVI data from rice fields in Negarajati Village. Built with Laravel, PostgreSQL/PostGIS, and LeafletJS, the application provides an interactive map, monthly index views, and sampling-point information. The retained dataset shows monthly mean NDVI increasing from May through August and decreasing in September. This is a descriptive result and does not, on its own, confirm a particular crop-growth stage or field-health condition. Before submission, the functional test table should be completed from actual observations, and the image-processing workflow should be documented sufficiently for reproducibility. Field validation and further usability, performance, and security evaluation are recommended.

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