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Original research article

Geoinformatics-Based Spatial Evaluation of Durian Cultivation in Chanthaburi, Thailand

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ABSTRACT

Sustainable management of high-value perennial crops under climate variability requires reliable spatial tools to assess productivity and constraints. This study used geoinformatics to analyze spatial and temporal variability in durian orchard performance across Chanthaburi province, Thailand, a major production area in Southeast Asia. Multitemporal Sentinel-2 imagery (2022-2025) provided the Normalized Difference Vegetation Index (NDVI), which was integrated with yield per rai and rainfall data from ten districts. NDVI showed a strong positive correlation with yield ($r = 0.74$, $p < 0.01$), confirming its reliability as a proxy for crop vigor and productivity. Rainfall had a moderate correlation with NDVI ($r = 0.61$) and a weaker one with yield ($r = 0.48$). The robust NDVI-yield relationship supports its use in practical yield estimation models when combined with environmental and management factors. These results demonstrate the value of remote sensing for mapping high and low yield zones, enabling precision orchard management, resource optimization, and climate resilience. Overall, the integrated geospatial framework highlights the potential of Earth observation technologies to enhance sustainable orchard practices and advance food security, climate adaptation, and environmental stewardship.

Keywords: Chanthaburi; Durian cultivation; Geoinformatics; GIS; NDVI

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1. Introduction

Durian (Durio zibethinus) is one of the most economically significant fruit crops in Southeast Asia, particularly in Thailand, where it serves as a major export commodity and a vital income source for farmers. Among Thailand's durian producing regions, the province of Chanthaburi stands out as the "Durian Capital of Thailand" due to its favorable agroecological conditions, including a tropical monsoon climate, fertile soils, and established cultivation systems [1]. Despite these advantages, spatial variability in durian productivity persists across the region. This variability arises from a complex interplay of natural factors such as topography, soil characteristics, and uneven rainfall patterns, as well as anthropogenic influences including land use transformation, unsustainable cultivation practices, and increased exposure to climate-related risks [2-4]. As productivity becomes increasingly sensitive to environmental stressors, there is a critical need for more precise, scalable, and data driven approaches for orchard management [5]. Importantly, this research also contributes to broader global sustainability initiatives. In alignment with the United Nations Sustainable Development Goals (SDGs), it addresses multiple interconnected targets. It supports Goal 2 Zero Hunger by improving the efficiency of food production systems through spatial productivity assessment. By identifying underperforming areas and guiding better land use decisions, this study promotes sustainable agricultural intensification. Additionally, it supports Goal 13 Climate Action by evaluating the influence of climate variability, particularly changes in rainfall on crop vigor and productivity, thereby contributing to climate resilient agriculture. Lastly, it advances Goal 15 Life on Land by promoting responsible monitoring and sustainable management of agricultural land through the use of Earth observation technologies that support long term environmental stewardship. In this context, geoinformatics technologies, particularly Geographic Information Systems (GIS) and satellite-based remote sensing (RS), have become essential tools in modern agricultural planning and decision making. These technologies allow researchers and stakeholders to monitor vegetation conditions, assess land use suitability, and optimize input efficiency [6, 7]. Among these tools, the Normalized Difference Vegetation Index (NDVI) is a widely adopted spectral index used to evaluate plant health, biomass distribution, photosynthetic activity, and canopy vigor using reflectance in the red and near-infrared wavelengths [8-10].

In this study, Sentinel-2 satellite imagery with high temporal and spatial resolution was employed to generate multi-temporal NDVI datasets for the years 2022 to 2025. These datasets, including multi-temporal NDVI, official yield records, and meteorological data, were jointly analyzed to assess spatial variability of durian orchards in Chanthaburi. NDVI served as a proxy for vegetation vigor and was used to estimate productivity efficiency across the study area, while rainfall was incorporated as a climatic variable to examine its potential influence on both NDVI values and yield outcomes. Through the integration of geospatial data and statistical analysis, this study aimed to evaluate the applicability of geoinformatics and satellite-derived vegetation indices as tools for yield estimation and strategic orchard management in durian cultivation. By integrating remote sensing technologies with agricultural and climatic datasets including rainfall, the research sought to delineate spatial productivity patterns and identify key biophysical determinants influencing yield variability. In light of durian's economic significance and the increasing vulnerability of agricultural systems to climate variability, this study emphasizes the value of implementing scalable, data-driven frameworks that enhance production efficiency, support adaptive management, and promote sustainability in high-value perennial crop systems. Moreover, such approaches serve as strategic instruments for advancing climate adaptation, sustainable land use, and food security in alignment with global development goals. [11, 12].

2. Materials and Methods

All animal experiments were conducted and managed in strict compliance with the established guidelines for the ethical use of animals in scientific research.

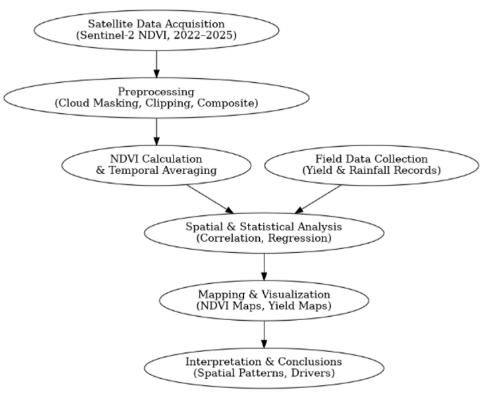

Fig. 1. Flow diagram of research methodology.

2.1 Geographic scope

This study was conducted in Chanthaburi, located in the eastern region of Thailand, which serves as the principal durian producing area of the country. Geographically, the province lies between 12°31′-13°09′ N and 101°46′-102°22′ E and encompasses a diverse landscape characterized by coastal plains, rolling hills, and upland plateaus. These physiographic conditions contribute to a heterogeneous agroecological environment, highly conducive to the cultivation of perennial fruit crops. Chanthaburi has a tropical monsoon climate, with an annual precipitation range of 2,500 to 3,500 mm, predominantly occurring between May and October. The average temperature ranges between 25°C and 30°C and the relative humidity often exceeds 80%, making the region ideal for high value horticultural production, particularly *D. zibethinus*. Administratively, the province is divided into ten districts (amphoes): Mueang Chanthaburi, Makham, Tha Mai, Khao Khitchakut, Pong Nam Ron, Laem Sing, Na Yai Am, Khlung, Soi Dao, and Kaeng Hang Maeo, all of which were included in this study. These districts represent a mix of intensively cultivated lowland orchards and upland agroforestry systems, allowing for comprehensive spatial assessment of durian productivity efficiency using geoinformatics-based approaches.

2.2 Data sources

This study employed a combination of geospatial datasets and official agricultural statistics derived from both open access and governmental sources to ensure a robust spatial and temporal analysis of durian productivity in Chanthaburi. The primary dataset utilized was Sentinel-2 imagery, obtained through the Copernicus Open Access Hub. Sentinel-2's Multispectral Instrument (MSI) provides a spatial resolution of 10 meters in the visible and near-infrared bands, meaning that each pixel corresponds to an area of 10 m2 on the ground, making it particularly suitable for monitoring vegetative health in perennial orchard systems. In addition, point-based

NDVI sampling was conducted by generating stratified random points within durian-growing areas using QGIS. A minimum distance threshold of 200 meters was applied between points to reduce spatial autocorrelation. Each sampling point was used to extract the NDVI pixel value using the "Point Sampling Tool", allowing for fine-scale analysis of NDVI distribution. The final sample included 250 points. A series of cloud free Sentinel-2 images from the years 2022 to 2025 was selected to ensure consistency in temporal comparisons and to capture interannual vegetation dynamics. Special emphasis was placed on acquiring imagery within the phenological window between January and June each year, which corresponds to the critical growth stages of durian, including vegetative development, floral initiation, flowering, and early fruiting. This temporal window was chosen because NDVI values observed during this period are indicative of overall tree vigor and are strongly correlated with the crop's reproductive success and eventual yield potential. During these months, adequate canopy development and sustained photosynthetic activity are essential for successful fruit set and quality, making NDVI a reliable proxy for productivity forecasting in durian systems.

Although Landsat-8 imagery, with a coarser spatial resolution of 30 meters, was initially considered for analysis, it was ultimately excluded in favor of Sentinel-2, which better aligns with the scale of orchard level assessments and offers superior spatial detail for NDVI based productivity mapping. The NDVI was derived from Sentinel-2 images using spectral reflectance values in the red band (Band 4, ~665 nm) and the near-infrared band (Band 8, ~842 nm). These values were used as indicators of spatial variation in biomass and productivity across different districts. This seasonally adjusted NDVI extraction approach ensured that the derived indices accurately reflect the biological productivity of durian during its most crucial developmental phases, thereby enhancing the reliability of subsequent spatial analyses and correlations with yield and rainfall data.

In addition to remote sensing data, ground based statistical data were incorporated to enhance the analytical depth of this study. Durian yield data for each of the ten districts in the province of Chanthaburi were obtained from the Chanthaburi Provincial Agricultural Office for the years 2023 and 2024. These datasets included information on total production (in tons), standing crop area, and fruiting area (in rai). Yield per rai (1,600 m^2) was calculated and later correlated with spatial NDVI values to evaluate the consistency between satellite-derived vegetation indices and actual agricultural output. To further contextualize spatial productivity differences, land use and soil suitability data were integrated into the analysis. These datasets were sourced from the Land Development Department of Thailand (LDD) and consisted of vector land use classifications and soil series maps. This information provided insight into the biophysical constraints that may influence durian productivity across heterogeneous landscapes.

Lastly, meteorological data, specifically annual rainfall records from 2022 to 2024, were collected from the Thai Meteorological Department (TMD). These data were incorporated into the correlation analysis to examine the extent to which rainfall variability may influence NDVI trends and yield performance at the district level. The integration of remote sensing, field-based statistics and climate data allowed for a comprehensive assessment of durian productivity efficiency using a geoinformatics-based approach.

2.3 NDVI calculation

NDVI was calculated using multi-spectral imagery from the Sentinel-2 satellite. The resulting mean NDVI values were then used as spectral proxies to evaluate vegetative vigor and canopy density. It is defined as shown in Eq. (2.1)

$$NDVI = \frac{NIR - RED}{NIR + RED}, \qquad (2.1)$$

where NIR refers to reflectance in the near-infrared band (Sentinel-2 Band 8), and RED refers to reflectance in the red band (Sentinel-2 Band 4).

NDVI values range from -1 to +1, where higher values (typically >0.6) correspond to dense, healthy vegetation, while lower or negative values indicate sparse vegetation, soil, or water [13]. All NDVI layers were atmospherically corrected and masked for cloud and shadow artifacts using Sentinel-2 Level-2A surface reflectance products and scene classification layers (SCL).

2.4 GIS and statistical analysis

To analyze spatial variability in durian productivity and its relationship with environmental and agronomic factors, this study employed an integrated geospatial statistical methodology. The analysis was conducted using a combination of ArcGIS Pro, QGIS, and Python, with the support of key libraries including rasterio, geopandas, and scikit learn. These tools enabled both raster- and vector-based processing, facilitating the fusion of satellite-derived NDVI data with yield and climatic statistics. The first stage of the analysis involved the preprocessing of Sentinel-2 imagery, which included atmospheric correction using the Sen2Cor processor, cloud and shadow masking based on the Scene Classification Layer (SCL), geometric correction, and clipping of imagery to the study area boundaries using vector shapefiles. These steps ensured the consistency and accuracy of the NDVI calculations across different acquisition dates. To ensure data quality, all scenes were filtered for cloud contamination using Sentinel-2's SCL. NDVI was calculated for each acquisition date between 2022 and 2025 by applying the standard index formula using reflectance values from the red (Band 4) and near-infrared (Band 8) bands. The individual NDVI images were then composited to generate seasonal and annual average NDVI layers for each year, ensuring temporal consistency in vegetation monitoring. Subsequently, zonal statistical analysis was conducted to extract average NDVI values at the district level. This was achieved by overlaying the NDVI raster datasets with administrative boundary shapefiles, allowing the calculation of mean NDVI values within each district polygon. This process ensured that vegetation indices were spatially aligned with the available durian yield data, which was also aggregated at the district level. To further enhance the spatial understanding of productivity distribution, spatial interpolation techniques were applied. In particular, Inverse Distance Weighting (IDW) was used to interpolate NDVI values across the study area, generating continuous surface maps that highlighted zones of high and low vegetation vigor. This approach was instrumental in detecting potential productivity hotspots and areas requiring agronomic intervention.

In addition to spatial mapping, statistical correlation analysis was employed to quantify the relationships between variables. Pearson's correlation coefficient (r) was calculated to examine the strength and direction of the association between district level NDVI values and yield (in tons) per rai. Moreover, NDVI values were compared with average annual rainfall from 2022 to 2024 to assess the impact of climatic variability on vegetative health and biomass accumulation. The outcomes of these analyses were visualized through a set of thematic maps, including choropleth representations of NDVI values, yield efficiency, and rainfall distribution. These visualizations facilitated intuitive interpretation of spatial trends and supported evidence-based conclusions regarding cultivation efficiency. All geospatial data were standardized and reprojected to a common coordinate reference system, WGS 84 / UTM Zone 47N (EPSG:32647), to ensure consistency in map scale and geographic accuracy. The integrated GIS and statistical framework facilitated spatial assessment of durian cultivation in Chanthaburi, enabling identification of key biophysical drivers of yield variability and supporting data-driven orchard management strategies.

3. Results and Discussion

3.1 Spatiotemporal NDVI trends

Using Sentinel-2 imagery, NDVI values across Chanthaburi were analyzed annually from 2022 to 2025. Spatial patterns indicated consistently high NDVI in southern districts including Mueang Chanthaburi, Tha Mai, and Laem Sing, whereas districts like Soi Dao and Kaeng Hang Maeo in the northern uplands displayed lower NDVI values (Fig. 2). This suggests geographical differentiation in vegetative vigor, which can be attributed to variations in elevation, soil properties, and microclimate zones [14, 15]. Importantly, a general downward trend in NDVI was observed during 2023, particularly in areas with high land-use change.

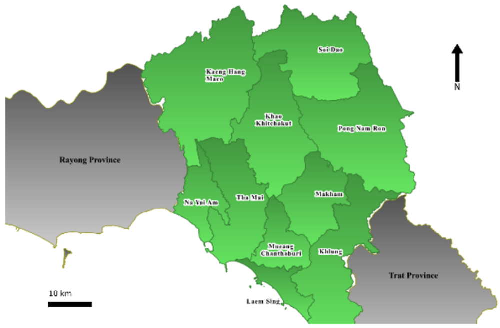

Fig. 2. Administrative map of Chanthaburi with district boundaries.

The spatial distribution of NDVI values across Chanthaburi encompasses a broad range of land covers, including agricultural fields, forested areas, and expanding orchard zones. Although the map does not isolate durian orchards specifically, the observed NDVI patterns reflect the broader vegetative dynamics influenced by land-use change. The decline was most evident in districts where existing crops and forests were cleared to establish new durian orchards. This expansion, driven by the high market demand for durian, led to reduced vegetative cover and immature canopy development in recently planted areas. Young durian trees exhibit lower leaf density and reduced photosynthetic activity compared to mature plantations, contributing to the decrease in NDVI values [7, 16]. These spatial changes are further supported by the temporal trends illustrated in Fig. 3. The graph reveals a moderate fluctuation in vegetative vigor, with a noticeable decline in 2023, likely linked to both climatic conditions and land-use transitions. However, in the two years following, NDVI values showed a recovery in several districts, indicating enhanced plot stability and the progression of orchards into more mature, productive stages. This upward trend corresponds with higher average yields per rai, reinforcing the positive association between NDVI and durian yield potential (Fig. 3). These patterns were particularly noticeable in upland districts such as Kaeng Hang Maeo and Soi Dao. Interannual NDVI values showed moderate fluctuations, with a marked decline observed in 2023, coinciding with below average rainfall (Fig. 5). Meanwhile, 2024 and 2025 saw a recovery in NDVI, likely supported by favorable climatic conditions and improved agronomic practices [2, 17, 18]. This demonstrates that NDVI can effectively capture dynamic vegetation responses to both environmental and land-use changes (Table 1) [19].

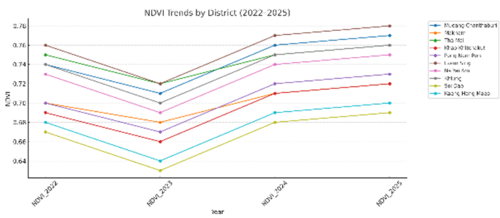

Fig. 3. Annual NDVI trends by district.

3.2 Relationship Between NDVI and yield per rai

The results revealed diverse patterns of alignment between vegetative vigor and harvest area, reflecting varying levels of orchard maturity, agronomic management, and environmental suitability. Central districts such as Mueang Chanthaburi and Tha Mai demonstrated strong alignment between NDVI and productive area. In Mueang Chanthaburi, productive area increased, with corresponding increases in NDVI values. This trend suggests the presence of mature orchards with dense canopies and efficient management practices. Similarly, Tha Mai maintained high and stable NDVI levels, while productive area expanded from 66,954 to 77,130 rai.

This consistency in vegetation vigor and land use reflects the district's long-standing reputation for high quality durian cultivation, where NDVI significantly predicts yield per rai ($R^2 = 0.70$), as shown in Fig. 4.

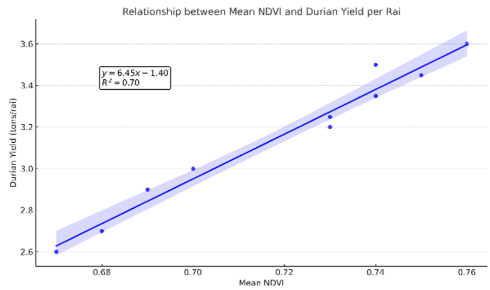

Fig. 4. Linear regression between mean NDVI (2022-2025) and durian yield per rai.

Other districts such as Khlung also showed synchronized increases in NDVI and harvest area, reaching 59,135 rai in 2023. The temporal consistency of NDVI in this district indicates stable canopy development and sustained biomass, aligning with prior research that links stable NDVI to perennial crop performance [1]. In contrast, districts like Pong Nam Ron exhibited steady expansion in productive area from 14,235 to 16,457 rai without a proportional rise in NDVI. This discrepancy likely reflects the dominance of young orchards that have not yet developed full canopy cover, resulting in lower NDVI values despite increased cultivation [2]. Similar lagging NDVI trends were observed in Kaeng Hang Maeo, where the harvest area increased significantly from 11,475 to 17,676 rai, but NDVI values rose only modestly. This could be due to immature plantings or less favorable soil and drainage conditions, as suggested by Appelt et al. [3]. The most notable divergence between NDVI and productive area was found in Soi Dao; although harvest area grew rapidly from 406 to 1,061 rai, NDVI remained low throughout the

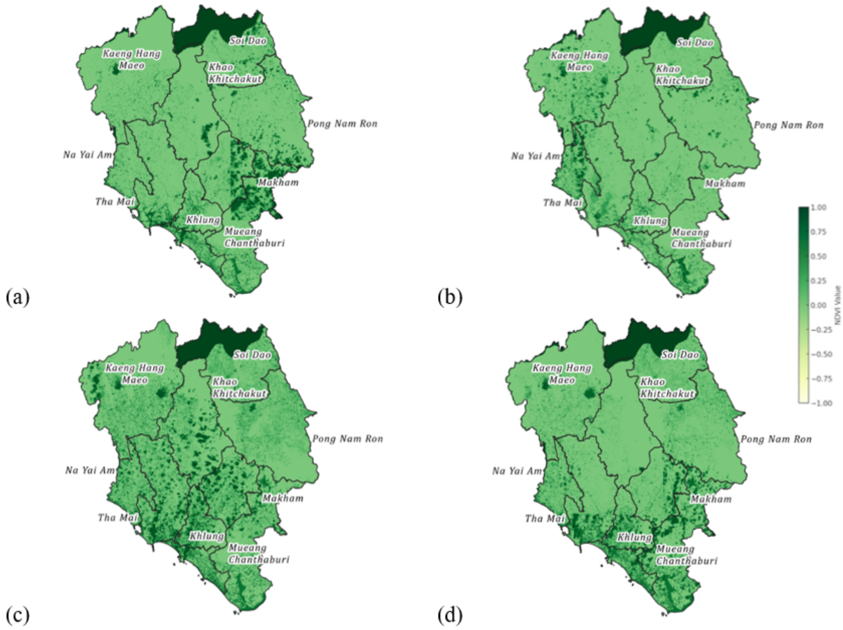

Fig. 5. Annual NDVI distribution maps of Chanthaburi derived from Sentinel-2 imagery during January-June for the years (a) 2022, (b) 2023, (c) 2024, and (d) 2025.

period. This decoupling suggests expansion into ecologically marginal zones or the adoption of suboptimal planting materials, consistent with the patterns identified by Zhang et al. [4]. In contrast, districts like Makham and Na Yai Am showed steady growth in both NDVI and productive area. Makham's productive area increased from 24,885 to 27,508 rai, indicating a balanced progression of canopy development and land utilization. Na Yai Am exhibited a gain of over 6,000 rai across the study period, accompanied by moderately high NDVI, suggesting consistent orchard maturation. Laem Sing, constrained by its coastal geography, maintained a stable productive area with minimal NDVI fluctuation, indicative of established orchards with limited expansion. Finally, Khao Khitchakut showed synchronized increases in NDVI and productive area, reaching nearly 40,000 rai. This indicates a successful transition of orchards into productive maturity in this upland zone. Overall, the district-level analysis confirms that NDVI can serve as a reliable indicator of orchard productivity, especially in well-established districts with mature durian orchards [5,6]. The calculated yield per rai, derived by dividing total production by standing crop area, exhibited strong correlation with NDVI values; however, newly expanded cultivation zones often exhibit a temporal lag between increases in area and corresponding NDVI development, reflecting the time required for canopy maturation and productive establishment. A Pearson correlation coefficient of $r = 0.74$ ($p < 0.01$) indicates a statistically significant relationship. Districts with higher NDVI values such as Mueang Chanthaburi, Tha Mai, and Laem Sing consistently yielded more durian per unit area, confirming that NDVI is a reliable proxy for orchard productivity [20, 21]. This relationship supports the use of geoinformatics in evaluating crop efficiency and guiding precision agriculture practices. A linear regression model constructed using NDVI as the independent variable and yield per rai as the dependent variable produced the following Eq. (3.1).

$$\frac{\text{Yield}}{\text{rai}} = 6.45 \times NDVI - 1.40, \text{ with } R^2 = 0.70. \quad (3.1)$$

This indicates that approximately 70% of the variation in durian yield can be explained by NDVI alone. While the differences between districts are statistically significant, they fall within an acceptable agronomic range and are considered acceptable in real-world orchard conditions [22, 23]. These findings underscore the importance of using NDVI in conjunction with productivity and environmental data to support targeted decision-making in orchard development and sustainable land use planning.

3.3 Impact of rainfall on NDVI and yield dynamics

To assess the influence of climatic variability on durian orchards, average annual rainfall data from 2022 to 2024 were analyzed in relation to both NDVI and yield per rai across the ten districts. A moderate correlation ($r = 0.61, p < 0.05$) was observed between rainfall and NDVI, suggesting that areas receiving higher precipitation generally exhibit greater vegetative vigor. In contrast, a weaker but still positive correlation was found between rainfall and yield per rai ($r = 0.48, p < 0.10$), indicating that while rainfall contributes to fruit production, its effect is not as pronounced as it is on vegetative health (Table 2).

Notably, the year 2023, which recorded the lowest rainfall, also corresponded with the lowest NDVI values observed across the province. These results underscore the sensitivity of vegetative indices like NDVI to climatic inputs and highlight their utility as early indicators of productivity risk. While rainfall remains an important environmental driver, NDVI demonstrates higher consistency and spatial robustness in predicting durian yield variation across heterogeneous agroecological zones [17, 19].

3.4 Spatial and temporal drivers of durian productivity

To develop a holistic understanding of durian productivity, spatial NDVI data, yield per rai, and rainfall records from 2022 to 2025 across the ten districts of Chanthaburi were integrated. By applying a multidimensional spatial analysis framework, this multivariable analysis enables the identification of patterns and interactions that are not apparent when variables are examined independently. The comparative analysis revealed distinct spatial patterns. For example, Mueang Chanthaburi consistently demonstrated high NDVI and yield values despite only moderate rainfall, highlighting the impact of intensive orchard management and efficient input use. In contrast, areas like Pong Nam Ron and Kaeng Hang Maeo exhibited lower productivity despite comparable or higher rainfall levels. These discrepancies point toward additional limiting factors such as young orchard age, soil limitations, or poor drainage, consistent with findings by Appelt et al. [2] and Lobell et al. [24]. By synthesizing NDVI trends with productivity and climatic data, this study demonstrates that NDVI is a more consistent and spatially sensitive predictor of yield variation than rainfall alone. NDVI acts as a proxy for canopy vigor and crop performance, allowing stakeholders to detect zones of underperformance and to formulate strategies for targeted interventions. Furthermore, rainfall data help

Table 1. Average NDVI by District.

District	NDVI_2022	NDVI_2023	NDVI_2024	NDVI_2025	Interpretation
Mueang Chanthaburi	0.74	0.71	0.76	0.77	High NDVI stability strong orchard maturity
Makham	0.73	0.69	0.74	0.75	Moderate productivity, mild recovery
Tha Mai	0.75	0.70	0.75	0.76	Consistent vegetative health
Khao Khitchakut	0.69	0.66	0.71	0.72	Variable NDVI, land use transition zone
Pong Nam Ron	0.70	0.67	0.72	0.73	NDVI recovering with better management
Laem Sing	0.76	0.72	0.77	0.78	Highest NDVI mature plantations
Na Yai Am	0.73	0.69	0.74	0.75	Stable productivity potential
Khlung	0.74	0.70	0.75	0.76	Productivity stability southern district
Soi Dao	0.67	0.63	0.68	0.69	Low NDVI replanting or forest clearing
Kaeng Hang Maeo	0.68	0.64	0.69	0.70	Transition to durian, lower canopy density

Table 2. Yield per rai, NDVI, and average rainfall by district.

District	Yield/rai (tons)	NDVI_2024	Rainfall Avg (mm)	Interpretation
Mueang Chanthaburi	3.50	0.76	3,228	High yield and NDVI optimal rainfall
Makham	3.20	0.74	3,201	Moderate yield and climate support
Tha Mai	3.45	0.75	3,215	Strong productivity, stable conditions
Khao Khitchakut	2.90	0.71	3,043	Lower yield, moderate NDVI
Pong Nam Ron	3.00	0.72	3,102	Moderate productivity zone
Laem Sing	3.60	0.77	3,285	Highest values in all categories
Na Yai Am	3.25	0.74	3,240	Stable across indicators
Khlung	3.35	0.75	3,187	High performance across variables
Soi Dao	2.60	0.68	3,026	Lowest productivity, low NDVI
Kaeng Hang Maeo	2.70	0.69	3,015	Suboptimal conditions, young orchards

contextualize the biophysical limitations of each site, especially in districts like Soi Dao where both NDVI and yield remained persistently low despite average precipitation. The practical value of this integration lies in its applicability to decision-support systems. The results facilitate precise zoning for input management, yield forecasting, and resilience planning under climate variability. This is especially important in the context of SDG 2 (Zero Hunger) and SDG 13 (Climate Action), where geospatial tools play a key role in achieving sustainable agriculture. The insights derived from this integrated analysis emphasize the relevance of using remote sensing and geostatistical tools for improving orchard productivity and for advancing adaptive agricultural management in the durian-growing regions of Southeast Asia.

4. Conclusion

The findings of this research underscore the essential contribution of geoinformatics in evaluating the spatial and temporal dynamics of durian productivity in Chanthaburi, Thailand. By integrating Sentinel-2 derived NDVI datasets, yield per rai statistics, and rainfall data from 2022 to 2025, the analysis revealed significant correlations between vegetative vigor and agricultural output. High NDVI values were closely associated with higher yields, with a strong positive correlation ($r = 0.74$, $p < 0.01$), affirming NDVI's value as a proxy for orchard performance. Moreover, the analysis demonstrated that NDVI trends respond sensitively to climatic fluctuations, particularly rainfall variability, reinforcing its utility in early detection of productivity risks. Spatial disparities in NDVI and yield were observed across districts, with southern lowland areas such as Mueang Chanthaburi and Laem Sing outperforming northern upland districts like Soi Dao and Kaeng Hang Maeo. These variations were attributed to differences in microclimate, soil characteristics, orchard age, and management intensity. While rainfall played a supportive role (NDVI vs. Rainfall$r$ = 0.61; Yield vs. Rainfall r = 0.48), NDVI proved more robust in capturing site-level differences in productivity. The integrated approach provided in this research emphasizes the potential for using NDVI in conjunction with climatic and agronomic datasets to inform spatially targeted agricultural strategies. Practical applications include zoning for input allocation, prioritizing investment in underperforming areas, and enhancing climate resilience through improved monitoring. Furthermore, this study contributes to global sustainability goals, particularly SDG 2 (Zero Hunger), SDG 13 (Climate Action), and SDG 15 (Life on Land), by showcasing how geospatial technologies can support sustainable land-use and decision-making in perennial crop systems.

Future research should consider incorporating additional environmental parameters such as soil nutrient profiles, land slope, and economic inputs to further refine productivity models. The integration of machine learning techniques with remote sensing may also enhance the predictive capacity of NDVI-based frameworks. Ultimately, these findings affirm the strategic importance of geoinformatics in advancing precision agriculture, especially in high-value perennial crop sectors such as durian cultivation.

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