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Implementation of Spatial Analysis Using KNN-5 in GIS for Mapping Mushroom Houses in Karawang Regency

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ABSTRACT
This research aims to develop a Geographic Information System (GIS) to map the locations of straw mushroom farms in Karawang Regency by applying spatial analysis based on the K-Nearest Neighbors algorithm with k = 5. This approach examines the spatial proximity relationship between mushroom production sites and the nearest markets to inform location-based distribution decisions. The research method employs a quantitative approach through mapping, geographic coding, and analysis of geographic distances, which are integrated into the GIS. Spatial data are obtained from field observations and collected from mushroom farmers, then analyzed using distance calculations based on geographic coordinates. The results show that the K-Nearest Neighbors analysis with k = 5 can dynamically identify the nearest markets and more objectively represent the spatial relationship between production and markets than a static radius approach. Additionally, proximity analysis between farms reveals local-scale spatial clustering patterns, while radius analysis provides an initial overview of limited spatial accessibility. Integrating the analysis results into the Geographic Information System enables comprehensive spatial visualization and supports more efficient, data-driven decision-making for straw mushroom distribution.

Keywords : Geographic Information System; K-Nearest Neighbors; Mushroom Farming; Market Proximity; Spatial Analysis.

INTRODUCTION

Karawang Regency has a long history of developing straw mushroom cultivation in Indonesia. This practice was initially introduced by Chinese farmers in Jakarta and later adopted and developed by local farmers in Karawang, particularly from the Purwasari area, making this region one of the national centers for straw mushroom cultivation. However, in recent years, Karawang's competitiveness has declined due to more efficient raw material use and distribution systems in other regions, such as Lampung. This situation underscores the need for technology-based innovation in management, data collection, and mapping of mushroom farm locations to sustainably optimize Karawang's local potential once again.

The development of Geographic Information Systems (GIS) has made this technology an important tool for spatial analysis and decision-making in agricultural production systems[1]. GIS enables the integration of spatial data and attributes to comprehensively understand the distribution of production and environmental conditions, and it also supports precision agriculture and the formulation of policies based on empirical data [2], [3].

In addition to supporting internal production analysis, GIS plays a vital role in evaluating the spatial relationships between agricultural production locations and market accessibility[4]. Spatial proximity analysis assesses the accessibility of production sites to distribution centers and markets to reduce transportation costs, minimize distribution time, and enhance the competitiveness of agricultural products[5]. Previous studies have shown that using GIS in spatial proximity analysis can identify more strategic production locations relative to the market, thereby contributing to increased supply chain efficiency and farmers' profitability [6].

In practice, GIS-based agricultural studies generally use nearest-neighbor analysis methods, such as Nearest Neighbor Analysis and K-Nearest Neighbors (KNN), to quantitatively assess proximity between geographic objects [7]. Integrating GIS with digital technology and real-time data makes spatial analysis more adaptable to the dynamics of the market and agricultural environment [8].

Overall, the literature indicates that GIS plays a strategic role in supporting spatial analysis, decision-making, and the evaluation of relationships between agricultural production locations and market access. However, the application of this approach remains dominated by major agricultural commodities, while specific commodities such as straw mushrooms, particularly in mapping mushroom beds and analyzing proximity between production and markets, the available data remain relatively limited[9]. This situation presents opportunities for more targeted and contextual GIS-based spatial analysis in the mushroom production system in Karawang Regency.

However, although the K-Nearest Neighbors (KNN) algorithm has been widely used in GIS integration for spatial analysis and agricultural distribution planning, its systematic application to analyze proximity between production and markets in small-scale agricultural systems has not yet been well formalized. Previous studies generally applied KNN to general agricultural classification and recommendations, but it remains rare to specifically examine non-primary commodities such as mushroom cultivation in relation to the spatial dynamics of production and markets [10], [11]. Furthermore, there are few studies that explicitly compare the effectiveness of KNN-based spatial analysis with conventional buffering techniques in supporting GIS-based agricultural distribution planning, so the understanding of KNN's analytical advantages in representing real spatial dynamics remains incomplete [12], [13].

METHOD

This research developed a Geographic Information System (GIS) to map the locations of mushroom cultivation sites in Karawang Regency, using spatial analysis based on the K-Nearest Neighbors (KNN-5) algorithm. A quantitative approach was used through mapping, geocoding, and KNN-5 distance analysis to

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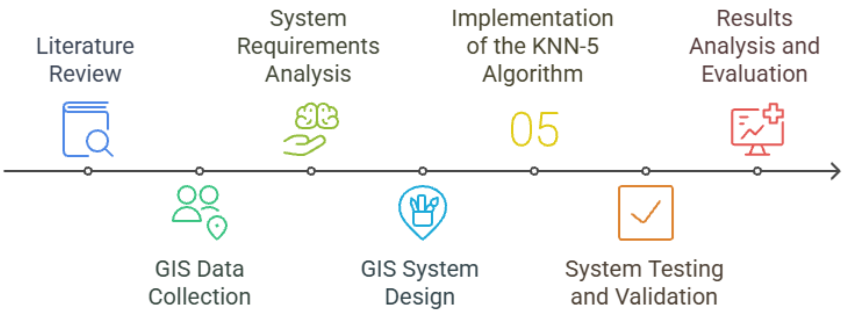
examine the spatial proximity between mushroom production sites and the nearest markets, in order to support location-based decision making[14], [15].

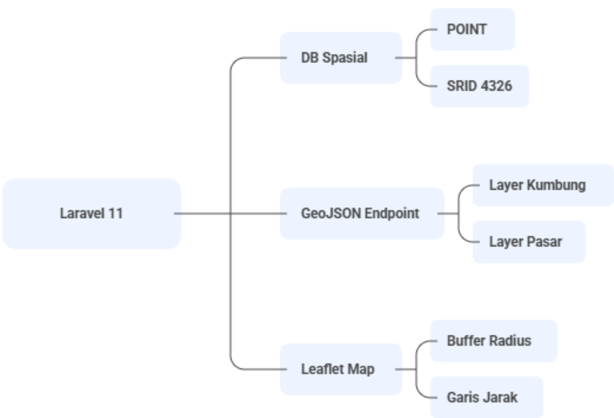
The selection of k = 5 in the K-Nearest Neighbours (KNN) analysis is based on methodological considerations commonly used in spatial proximity studies. A moderate value of k allows the analysis to capture local spatial relationships whilst avoiding excessive smoothing that may occur with larger k values. In market accessibility analysis, k = 5 provides a balanced representation of the nearest distribution options that are realistically reachable from each mushroom farm location. Previous studies have also shown that small to moderate k values are effective in proximity-based spatial analysis for supporting location-based decision-making, particularly in agricultural and distribution systems.



Picture 1. Research Stages

The research was conducted in Karawang Regency, West Java Province, from July to October 2025, with stages including a literature review, data collection, system design and implementation of a GIS, application of the KNN-5 algorithm, and testing and evaluation. The scope of the research focused on visualizing the distribution of mushroom beds, presenting location attributes, and analyzing the five nearest markets using KNN-5, without including advanced spatial analysis.

The research data consisted of primary and secondary spatial data. Primary data were obtained through field observations to record the coordinates of mushroom houses, while secondary data were collected via farmer questionnaires that included information on addresses, production capacity, and market linkages. The address data were then processed through geocoding to obtain geographic coordinates and managed within an integrated spatial database in the GIS system.



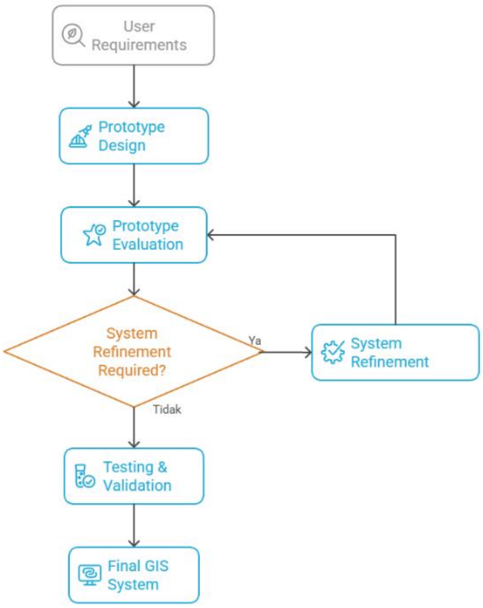
Picture 2. GIS System Design

The spatial analysis framework in this study integrates spatial databases, GeoJSON, and Leaflet maps. GIS serves as the primary platform for managing, processing, and visualizing spatial data, while the KNN-5 algorithm identifies the five nearest markets to each mushroom cultivation site based on geographic proximity[16]. Integrating KNN-5 into the GIS environment uses efficient spatial data structures to optimize nearest-neighbor searches and improve computational efficiency in spatial analysis [17], [18].

$$d = 2r \arcsin \quad sqrt\left(\sin^2\left(\frac{\Delta\varphi}{2}\right) + \cos(\varphi 1) * \cos(\varphi 2) * \left(\sin^2\left(\frac{\Delta\lambda}{2}\right)\right)\right) \qquad (1)$$

In spatial distance measurement, this study uses Haversine distance, where:

- d= distance between two points (kilometres)
- r= Earth's radius (6,371 km)
- ϕ_1, ϕ_2= latitude from point 1 and point 2
- λ_1, λ_2= longitude from point 1 and point 2
- $\Delta\phi = \phi_2 - \phi_1$and $\Delta\lambda = \lambda_2 - \lambda_1$



Picture 3. Prototype-based System Development Life Cycle for GIS Development

A GIS system was developed using a prototype approach within an iterative Software Development Life Cycle framework to enable system refinement based on user feedback. The system integrates a spatial database, GeoJSON endpoints, and map visualization to support efficient spatial analysis. The KNN-5-based spatial analysis was validated through a comparison of distance calculations and an evaluation of spatial pattern consistency to ensure the reliability and accuracy of the results. This approach aligns with practices in spatial research evaluation based on machine learning, emphasizing the stability and reliability of models in representing spatial proximity [19], [20].

RESULTS AND DISCUSSION

This analysis provides an empirical overview of the spatial proximity between mushroom cultivation sites and the nearest markets, as well as revealing variations in distribution accessibility resulting from differences in geographical conditions and the spatial distribution of mushroom farms within the research area.

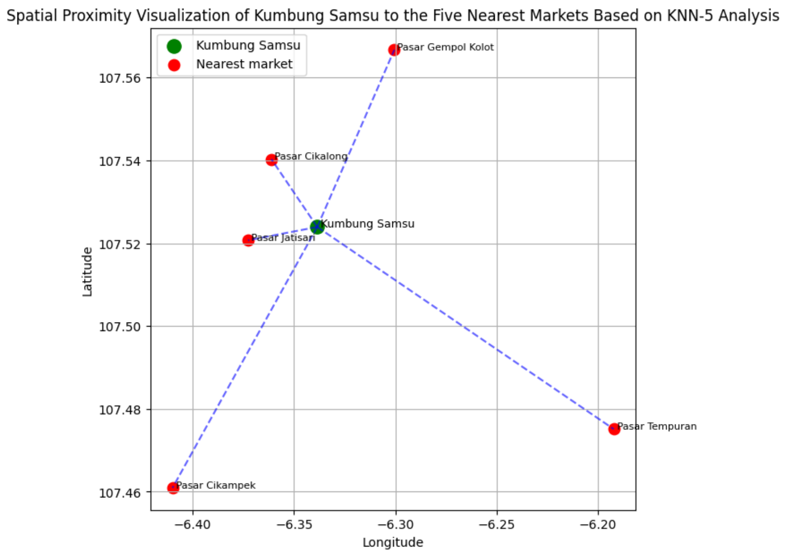
KNN-Based Spatial Proximity Analysis

This analysis was conducted to identify the five nearest markets from each mushroom farm location in Karawang Regency, based on spatial proximity. The KNN-5 approach was used to generate distance relations that represent the spatial relationship between mushroom production sites and market distribution points.In this stage of the analysis, a mushroom farm location was selected as a reference point to evaluate the results of applying the KNN-5 algorithm. The analysis focused on identifying the five nearest markets from that farm location based on geographical distance, thereby obtaining a sequence of markets that objectively represent spatial proximity.

Table 1. KNN-5 Analysis Results for the Five Closest Markets to Kumbung Samsu

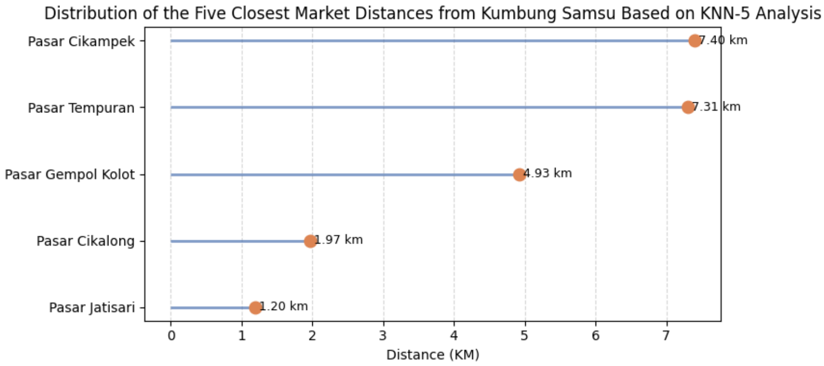
No	Market Name	Distance (KM)
1	Cikalong Market	1,20
2	Jatisari Market	1,97
3	Gempol Kolot Market	4.93
4	Tempuran Market	7,31
5	Cikampek Market	7,40

The results of the KNN-5 analysis for Samsu mushroom farm are presented in Table 1, which lists the five nearest markets and their respective distances in kilometers. This table provides a quantitative overview of the variation in distribution distances between the mushroom production site and surrounding markets.



Picture 4 Spatial Proximity Visualization of Kumbung Samsu to the Five Nearest Markets Based on KNN-5 Analysis

The visualization in Picture 4 shows the spatial relationship between Kumbung Samsu and five nearby markets identified through KNN-5 analysis. The connecting lines indicate proximity based on geographic distance, with markets closer in distance shown by shorter lines. This visual pattern aligns with the numerical results in Table 1, which confirm the order of the nearest markets by distance.



Picture 5. Distribution of The Five Closest Market Distances from Kumbung Samsu Based on KNN-5 Analysis

The graph in Picture 5 shows the distribution of the five nearest markets to Kumbung Samsu, based on the results of the KNN-5 analysis. It can be seen that the distance to the nearest markets is relatively low, while the furthest markets are farther away, forming a range of distances that is quite varied. This pattern indicates that the level of market accessibility from the mushroom farm location is not uniform and is influenced by the spatial distribution of surrounding markets.

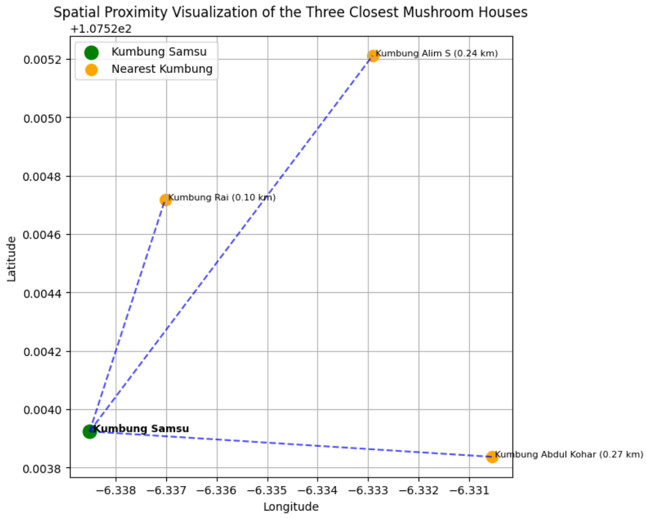
In addition to analyzing the spatial proximity between the mushroom farm location and the market, the KNN analysis is also applied to identify the proximity between mushroom farm locations. This approach is used to observe internal spatial patterns in mushroom production sites, using Kumbung Samsu as the reference point.

Table 2. Results of the KNN Analysis on the Three Nearest Mushroom Houses

No	Kumbung Name	Owner's Name	Distance (KM)
1	Kumbung Rai	Rai	0,10
2	Kumbung Alim S	Alim S	0,24
5	Kumbung Abdul Kohar	Abdul Kohar	0,27

The analysis results indicate that there are three mushroom farm locations closest to Kumbung Samsu, with relatively short distances. Kumbung Rai is identified as the nearest location at approximately 0.10 km, followed by Kumbung Alim S at 0.24 km and Kumbung Abdul Kohar at 0.27 km. These short distances suggest a concentration of mushroom production sites within a narrow geographical area.

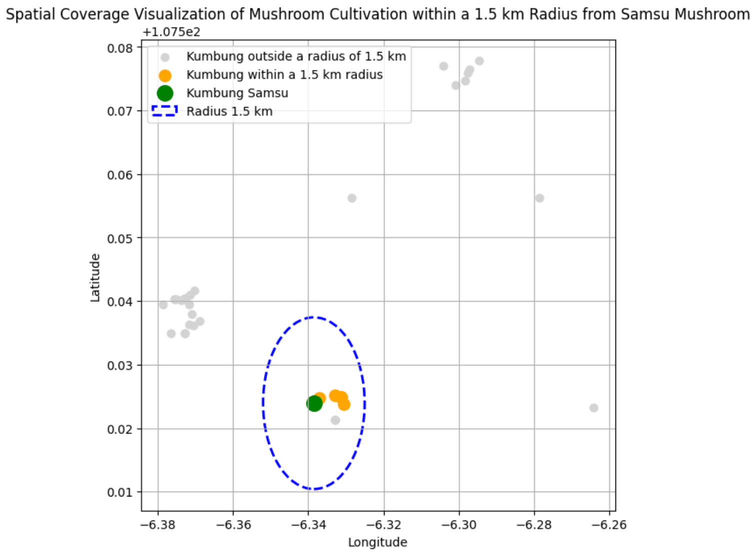
The visualization in Picture 6 shows the spatial relationship between Kumbung Samsu and the three nearest mushroom farm locations identified through KNN-3 analysis. The connecting lines indicate proximity based on geographic distance, with Kumbung Rai the closest location, followed by Kumbung Alim S and Kumbung Abdul Kohar. This pattern indicates a concentration of mushroom farm locations within a relatively close geographic area.



Picture 6. Spatial Proximity Visualization of the Three Closest Mushroom Houses

Radius-Based Spatial Buffering Analysis

The radius-based spatial buffering analysis was conducted to identify the spatial coverage of the mushroom farm location within a fixed distance of 1500 meters from the reference point. This approach was used as a comparative analysis to assess spatial accessibility based on a static distance limit without considering variations in spatial distribution between points.



Picture 7. Spatial Coverage Visualization of Mushroom Cultivation within a 1.5 km Radius from Samsu Mushroom Farm

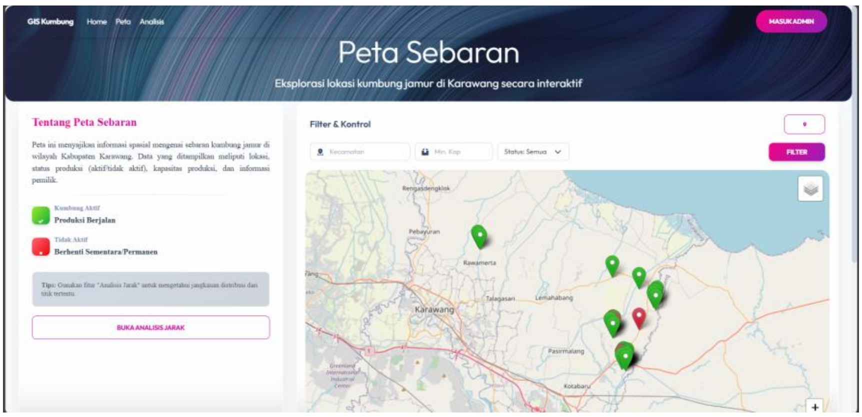
The analysis results indicate that not all mushroom barn locations fall within the specified radius. Some barns are identified within the buffer area, while others are outside the range despite being relatively close to the reference point. This pattern shows that the spatial coverage produced by the fixed radius is limited and does not always accurately represent the actual proximity relationships between locations. Overall, the radius buffering analysis provides an initial overview of spatial accessibility based on a fixed distance, which can then be compared with the results of the KNN analysis to understand the differences in spatial proximity patterns produced by the two approaches.

GIS Visualization of Spatial Analysis Results

Visualization of the spatial analysis results was conducted using a Geographic Information System (GIS) to present the relationship between mushroom house locations and the results of the spatial proximity analysis. The GIS map served as an integration platform to display the results of the KNN-5 analysis, the proximity analysis between mushroom houses, and the buffering radius coverage within a unified spatial framework.

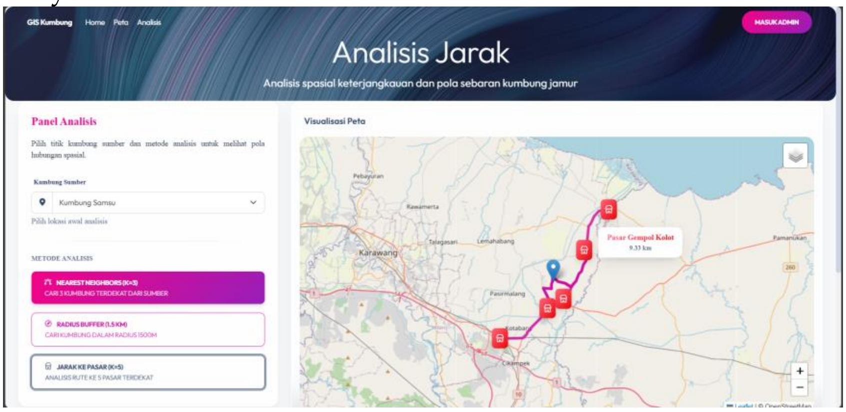
Picture 8. GIS Dashboard for Mushroom House Spatial Analysis in Karawang Regency

In the system display, spatial information is presented through a GIS interface that shows a summary of the number of mushroom huts, the number of markets, the analysis coverage area, and the data update time. The system also provides interactive features to display the results of KNN-5 analysis, 1.5 km radius analysis, and distance to markets, allowing users to explore spatial relationships intuitively and in an integrated manner.



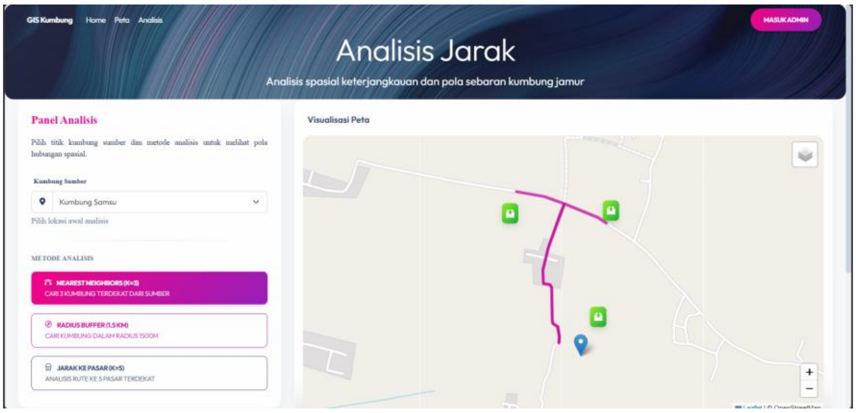
Picture 9. Spatial Distribution Map of Straw Mushroom Houses in Karawang Regency

The map display presents the spatial distribution of oyster mushroom farms in Karawang Regency interactively. Each point represents a farm, with attributes such as production status, capacity, and ownership. The system includes filtering by district, minimum capacity, and production status to support targeted exploration of spatial data. This visualization allows users to identify distribution patterns, concentrations of active sites, and spatial relationships between farms within the analysis area.



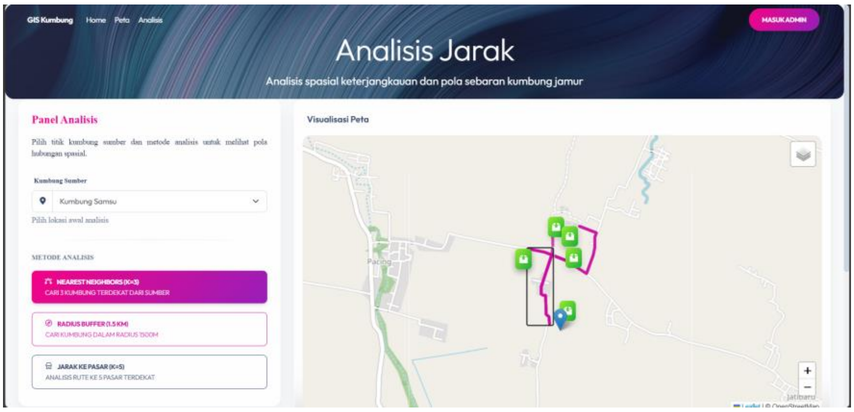
Picture 10. KNN-5–Based Market Distance Analysis Visualization in the WebGIS System

The 5-Nearest Neighbors (KNN-5) analysis of the nearest markets was conducted by designating Kumbung Samsu as the source point to identify the five closest markets based on geographic distance calculations. The analysis results were visualized on a GIS map as connecting lines representing the spatial proximity routes between Kumbung Samsu and each market. This visualization shows the order of the nearest markets spatially as well as the variation in travel distances, thereby providing a more measured and location-based understanding of the accessibility of mushroom distribution outcomes.



Picture 11. GIS Visualization of KNN-3–Based Nearest Mushroom House Analysis

The three mushroom sheds nearest Kumbung Samsu were identified using the K-Nearest Neighbors (KNN) approach as the source points. The results of the analysis were visualized on a GIS map as connecting lines that show the spatial proximity relationships between the sheds. This visualization illustrates the sequence of closeness and the variation in distances between the shed locations, thereby providing an overview of the spatial clustering pattern of mushroom production at a local scale.



Picture 12. GIS Visualization of KNN-3–Based Nearest Mushroom House Analysis from Kumbung Samsu

A 1.5 km radius analysis was conducted by setting Kumbung Samsu as the central point to identify mushroom farms within a fixed-distance boundary. The GIS map visualization shows that some farms are within the radius, while others are outside the area. This pattern illustrates the limitations of a static radius-based spatial reach and provides an initial overview of local accessibility between mushroom farms locations.

Validation and Testing of GIS Analysis Results

To support the validation of the spatial analysis results, a comparison is made between the distances produced by the KNN-5-based GIS system and the reference distances calculated using the Haversine formula and digital maps. This comparison aims to ensure the consistency and accuracy of the spatial proximity analysis results generated by the system.

Table 3. Validation of KNN-5 Spatial Distance Results

No	Location (Kumbung)	Nearest Market	Distance by KNN-5 (km)	Reference Distance (km)	Difference (km)	Validation Result
1	Kumbung Samsu	Cikalong Market	1.20	1.22	0.02	Consistent
2	Kumbung Samsu	Jatisari Market	1.97	1.95	0.02	Consistent
3	Kumbung Samsu	Gempol Kolot Market	4.93	4.91	0.02	Consistent
4	Kumbung Samsu	Tempuran Market	7.31	7.29	0.02	Consistent
5	Kumbung Samsu	Cikampek Market	7.40	7.42	0.02	Consistent

The reference distance is calculated using the Haversine formula based on the geographical coordinates of the mushroom farm and the market. The comparison shows minimal differences between the KNN-5 results and the reference distance, indicating that the spatial proximity analysis produces consistent and geographically valid results.

After validating the spatial analysis results, system testing continued using the black-box testing method to ensure that all main functions of the GIS system operate in accordance with user needs without reviewing the internal code structure. The testing focused on validating the input, process, and output of each main feature, including map visualization, KNN-5 analysis, nearest hive analysis, and the 1.5 km buffering radius. The test results showed that all system functions could be executed properly and produced outputs that met the designed functional specifications.

Table 4. Black-Box Testing Results of the GIS System

No	Tested Function	Input	Expected Output	Actual Result	Status
1	Display distribution map	Load GIS page	Map and location markers displayed	Map and markers displayed correctly	Pass
2	Select source mushroom farm	Choose "Kumbung Samsu"	Source location highlighted on map	Source location displayed correctly	Pass
3	KNN-5 market analysis	Run KNN-5 analysis	Five nearest markets displayed with routes	Five nearest markets and routes displayed	Pass
4	Nearest mushroom farms (KNN-3)	Run nearest neighbors analysis	Three nearest farms displayed	Three nearest farms displayed correctly	Pass
5	Radius buffering (1.5 km)	Set radius to 1.5 km	Buffer area and included farms displayed	Buffer area and farms displayed correctly	Pass
6	Attribute information display	Click location marker	Attribute information shown	Attribute information displayed correctly	Pass

Based on the results of black-box testing, the developed GIS system is functionally reliable and capable of supporting spatial analysis as well as visualizing the distribution and proximity of mushroom farms.

Spatial analysis results indicate that the KNN-5 approach can dynamically identify the nearest markets based on the geographic proximity of mushroom farm locations. KNN analysis of the nearest farm reveals spatial clustering patterns at a local scale that are not fully captured by the static radius approach. Meanwhile, the 1.5 km radius analysis provides an initial overview of spatial accessibility but has limitations in representing the actual proximity variations between locations. Integrating all analysis results into a GIS system allows for comprehensive visualization of spatial relationships and supports location-based decision-making.

CONCLUSION

Based on the objectives and issues outlined in the introductory section, this research is expected to provide a comprehensive spatial overview of the distribution of straw mushroom cultivation sites and the proximity relationship between production and markets in Karawang Regency through the application of KNN-5 analysis based on GIS. The analysis results and visualizations presented in the Results and Discussion section will serve as a basis for evaluating the effectiveness of the KNN approach compared to conventional spatial methods and for assessing its contribution to supporting location-based agricultural distribution decision-making.

Furthermore, the findings of this study are expected to be developed in future research with a broader regional scope, the integration of additional spatial variables, or the application of more advanced spatial analysis methods. The GIS system developed also has the potential to be used as a tool to support policy and planning for the distribution of other agricultural commodities in small- and medium-scale agriculture.

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