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Analysis of Land Use Changes and Their Impact on Environmental Quality in Kembaran Subdistrict (2016–2022)

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ABSTRACT

The conversion of agricultural land to non-agricultural use in Kembaran District, prompted by the development of Purwokerto, has resulted in multiple environmental impacts. This study seeks to analyze land changes and their effects on environmental quality from 2016 to 2022, employing a mixed-methods approach that integrates both quantitative and qualitative data within a spatial framework. The analysis identifies six categories of land use changes. Mixed Gardens are transformed into Rare Villages (1,954 ha) and Rare Housing (0.156 ha); Irrigated Rice Fields are converted into Small Industries (5,838 ha), Road Networks (0.270 ha), Rare Villages (3,374 ha), and Sparse Housing (2,642 ha). The alterations impact the quality of the residential environment, categorized into good (131,758 ha), medium (311,003 ha), and poor (310,903 ha) classifications. High-quality settlements exhibit low to medium density, abundant shade trees, and significant distance from pollution sources. In contrast, the medium category is characterized by medium density and a moderate presence of shade trees. Poor-quality settlements exhibit high density, a scarcity of shade trees, and closeness to pollution sources. The findings indicate that agricultural land conversion diminishes productive land and exacerbates environmental quality, particularly in densely populated areas with limited vegetation and proximity to pollution sources.

A. Introduction

Indonesia, as an agrarian nation, has a long history of substantial agricultural resource production and supply. The abundance of agricultural land serves as a primary asset for Indonesia's economy. However, economic development, population growth, and policy changes have significantly impacted agricultural land use in the country. Data from Statistics Indonesia (BPS, 2023b) indicates that the national rice field area decreased from 8,068,327 hectares in 2009 (BPS, 2012) to 7,463,948 hectares in 2019, a reduction of 604,379 hectares within a decade. The increase in population and human activities has rendered land a scarce resource, making land use changes inevitable to meet the growing demands of the population (Wahyuni et al., 2014). These changes often involve converting agricultural land into non-agricultural or built-up areas (Wahyudi et al., 2023). The decline in agricultural land can be attributed to factors such as population growth, suburban and rural development, and central or regional development policies (Hauser, 1985).

Suburban areas are particularly susceptible to land use changes, primarily due to the conversion of agricultural land into non-agricultural land driven by urban expansion (Rahayu, 2009). Additionally, urban development extending into rural areas occurs due to limited urban land, which drives up urban land prices. Consequently, people tend to seek more affordable land in suburban areas. This phenomenon makes suburban regions magnets for development, characterized by their urban and rural duality, leading to changes in physical and socio-economic aspects, consistent with Pryor's theory (1968) as cited in Yunus (2008). As a suburban area, Kembaran Subdistrict has undergone significant development influenced by the growth of Purwokerto, the capital city of Banyumas Regency, affecting physical, social, and economic dimensions. The physical development of Kembaran is evident from the establishment of facilities such as the Jogjakarta International Hospital (JIH) and Muhammadiyah University of Purwokerto (UMP). Socio-economic development is reflected in increased public awareness of education and health and the advancement of the trade sector, evidenced by the presence of 11 shopping complexes, 4 permanent markets, 1 semi-permanent market, 28 supermarkets, 28 restaurants, 956 food stalls, and 1,022 convenience stores (BPS, 2023a).

According to Regional Regulation No. 10 of 2011 on the Spatial Plan of Banyumas Regency, most of Kembaran Subdistrict is designated for wetland agriculture. However, Kembaran has the highest population density after Purwokerto (BPS, 2023a). From 2016 to 2023, population density in Kembaran increased by 3.54%, according to BPS data. This population growth, coupled with ongoing development, has transformed agricultural land into residential areas, leading to discrepancies with the Banyumas Regency Spatial Plan. Supporting this, Sultoni et al. (2014) reported significant transformations in Kembaran over the past decade, marked by infrastructure development and the establishment of universities. Furthermore, Awanis (2022) documented that the conversion of agricultural land to residential use in Kembaran reached 119.036 hectares between 2010 and 2020.

The increasing rate of agricultural land conversion in Kembaran requires special attention due to its potential negative impacts, including declining groundwater quality (Suwarsito & Sarjanti, 2021), environmental pollution, and the reduction of food crop farming areas. These impacts necessitate government intervention through land use control measures.

Previous studies have explored land use change themes, but there remains a need for further research into the typology of land use changes and environmental impact analyses. For instance, Riyanto (2019) utilized GIS technology to analyze the conversion of agricultural land into residential areas across 11 villages in Sukoharjo City during 2005–2015, finding that Bulakan Village experienced the largest change due to its status as a craft center accompanied by population growth and improved accessibility. Fajar (2022) employed K-Nearest Neighbor and overlay techniques to analyze land use changes in Sukoharjo Regency, revealing that 3,811 hectares of agricultural land were converted to non-agricultural uses from 2005 to 2015, with 30% occurring in Grogol and Kartasura Subdistricts and 40% becoming residential areas. Sari and Yuliani (2021), using a literature review approach, examined the impacts of land conversion in Semarang, Bali, Lamongan, and Klaten, finding positive impacts such as new employment opportunities and business prospects near residential areas, as well as negative impacts like the loss of agricultural land, reduced farmer income, and increased land values along major roads due to adequate public facilities. This study differs from previous research by focusing specifically on the typology of land use changes from agricultural to non-agricultural use and their environmental impacts in Kembaran Subdistrict.

B. Methods

This study employs a mixed-methods approach, which, according to Iskandar et al. (2021), integrates qualitative and quantitative approaches to achieve broader and deeper validation of findings (Creswell, 2010). The researcher utilized a classification comparison approach and a spatial approach, grounded in spatial characteristics. Technically, the spatial approach is applicable in this analysis as all data is spatially bound and can be analyzed using Geographic Information System (GIS) software (Arminah, 2012). The study's population consists of land use data covering 16 villages in Kembaran Subdistrict, Banyumas Regency, Central Java Province. This population was analyzed spatially to identify changes in land use from agricultural to non-agricultural purposes. The residential environmental quality population included all delineated residential blocks based on the 2022 land use map.

Primary and secondary data were collected through field observations and analyses of SPOT 6 and SPOT 7 satellite imagery from 2016, 2019, and 2022, as well as related documents such as the Banyumas Regency Administrative Map and Kembaran Subdistrict Administrative Map. After data collection, the researcher conducted satellite image interpretation as a form of spatial processing to identify land use maps for Kembaran Subdistrict in 2016, 2019, and 2022, along with their changes. Observations were also conducted to validate land use maps and assess the environmental impact of agricultural land conversion to non-agricultural use in Kembaran Subdistrict.

Land use change analysis in this study employed spatial analysis techniques with a classification comparison approach. Spatial analysis was performed using the 2016, 2019, and 2022 Land Use Maps at a 1:25,000 scale. The interpreted land use data was validated for accuracy using Fitzpatrick Lins' formula (as cited in Kurniadi, 2014) to ensure consistency with on-the-ground conditions. A total of 36 sample points were selected through purposive sampling, focusing on smaller polygons to minimize errors due to image interpretation. Each sample was used to test the accuracy of agricultural-to-non-agricultural land use change (confusion matrix) and the accuracy of residential environmental quality assessment. The study adhered to the minimum interpretation accuracy level set by the United States Geological Survey (USGS), which is approximately 85% (Derajat et al., 2020).

To evaluate the impact of land use changes on environmental quality, an analysis of residential environmental quality was conducted. Residential environmental quality was categorized into three classes: good, moderate, and poor, using a scoring or weighting system. The parameters used for environmental quality analysis were based on the Directorate General of Human Settlements (2006), including residential density, roadside protective trees, and residential locations derived from the 2022 land use map. These parameters were multiplied by weighting factors based on Kurniadi (2014).

The weighting factors were applied to measure the degree of impact of each parameter on residential quality. Detailed parameters for assessing residential environmental quality are presented in Table 1.

Table 1. Scores and Weighting Factors for Parameters

Parameter	Score			Weighting Factor
	3	2	1	
Residential Density	< 40%	40% - 60%	>60%	3
Roadside Shade Trees	-	Presence of roadside trees	Absence of roadside trees	2
Residential Location	Distant from pollution sources (bus stations, factories, stations, waste) by ± 5 km and still within proximity to the city	Unaffected by pollution activities directly, with a distance of ± 3 km from the location	Located in proximity to pollution sources, approximately 1 km from the residential area.	2

Source: Directorate General of Human Settlements, Department of Public Works (2006), Kurniadi (2014), M. Farizki, et al. (2017) modified.

Environmental quality class is determined using the formula: $Ci = \frac{R}{K}$ where: Ci = Class interval; R = *Range* (highest score minus lowest score); and K = Class. The results of the residential environmental quality classification are presented in Table 2.

Table 2. Residential Environmental Quality Classes

Total Score	Criteria	Class
38-48	Good Quality	I
27-37	Moderate Quality	II
16-26	Poor Quality	III

Source: Aris Kurniadi, 2014

C. Typology and Area of Agricultural-to-Non-Agricultural Land Use Change in Kembaran

The land use changes analyzed in this study for Kembaran Subdistrict were derived from intersecting the 2016-2019 Land Use Map, the 2019-2022 Land Use Map, and the 2016-2022 Land Use Map. These changes specifically refer to the conversion of agricultural land to non-agricultural land use. Agricultural land use includes irrigated rice fields cultivated twice annually and mixed gardens, while non-agricultural land use encompasses sparse settlements, dense settlements, grasslands, small industries, road networks, and rivers, as classified in the Thematic Survey and Mapping Guidelines (NSPK) 2012 for a 1:25,000 scale.

The most significant land use changes between 2016-2019 and 2019-2022 involved agricultural land, particularly irrigated rice fields cultivated twice annually. Over the period 2016-2022, a total of 12.121 hectares underwent conversion. A significant portion of these irrigated rice fields was converted into small industrial areas and sparse settlements. The maps illustrating the conversion of agricultural to non-agricultural land use in Kembaran Subdistrict for the periods 2016-2019, 2019-2022, and 2016-2022 are presented in Figure 2.

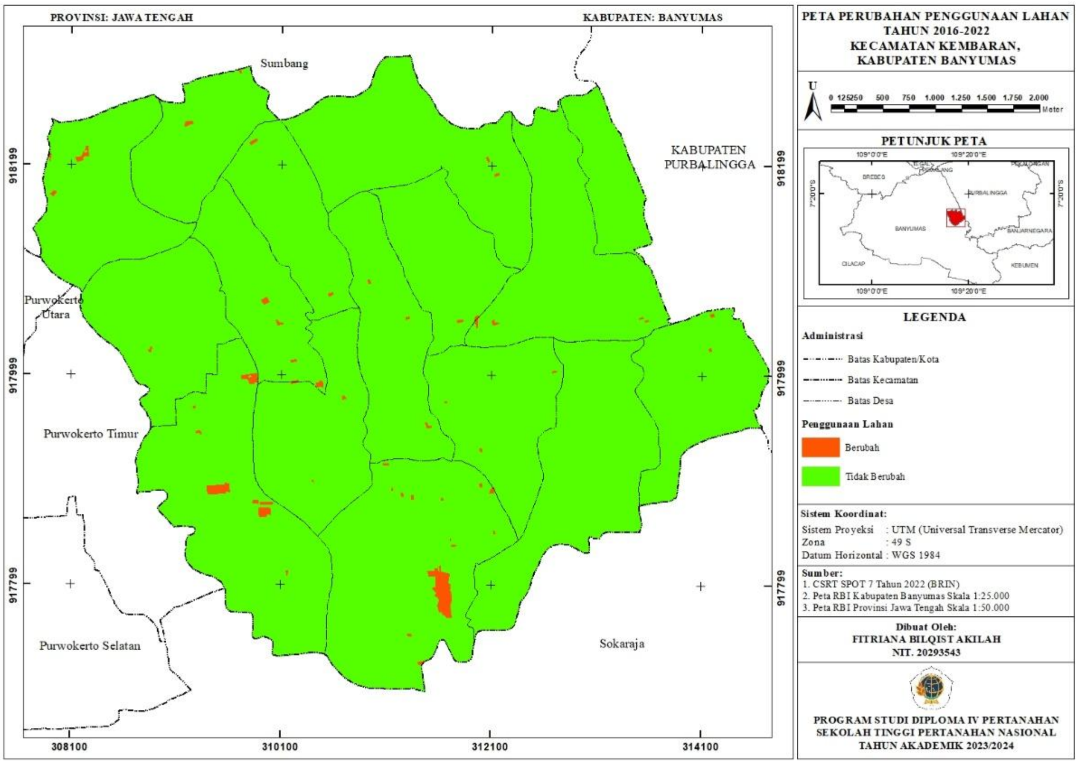

Figure 2. Conversion of Agricultural Land to Non-Agricultural Land in Kembaran (2016-2022)

The analysis of the maps illustrating the conversion of agricultural to non-agricultural land use in Kembaran Subdistrict for the periods 2016-2019, 2019-2022, and 2016-2022 is summarized in Table 3.

Table 3. Land Use Changes in Kembaran Subdistrict (2016-2019 and 2019-2022)

No	Land Use	Area (2016)		Area (2019)		Area (2022)		Change (2016-2019)		Change (2019-2022)		Change (2016-2022)	
		Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
Agricultural													
1	Irrigated Rice Paddies (Double-Cropped)	1468,831	55,3%	1465,726	55,2%	1456,706	54,9%	-3,104	-0,117%	-9,020	-0,34%	-12,124	-0,46%
2	Mixed Gardens	423,958	16,0%	423,318	15,9%	421,849	15,9%	-0,641	-0,024%	-1,469	-0,06%	-2,110	-0,08%
Non Agricultural													
3	Small-Scale Industry	17,064	0,6%	17,290	0,7%	22,902	0,9%	0,226	0,009%	5,612	0,21%	5,838	0,22%
4	Road Networks	40,936	1,5%	41,030	1,5%	41,206	1,6%	0,094	0,004%	0,176	0,01%	0,270	0,01%
5	Low-Density Settlements	423,845	16,0%	426,416	16,1%	429,558	16,2%	2,570	0,097%	3,142	0,12%	5,713	0,22%
6	Density Settlements	191,019	7,2%	191,019	7,2%	191,019	7,2%	0,000	0,000%	0,000	0,00%	0,000	0,00%
7	Grassland	24,865	0,9%	24,540	0,9%	24,481	0,9%	-0,325	-0,012%	-0,059	0,00%	-0,384	-0,01%
8	Low-Density Housing	33,504	1,3%	34,685	1,3%	36,302	1,4%	1,181	0,044%	1,617	0,06%	2,798	0,11%
9	River	30,298	1,1%	30,298	1,1%	30,298	1,1%	0,000	0,000%	0,000	0,00%	0,000	0,00%
	Total	2654,320	100%	2654,320	100,0%	2654,320	100,0%						

Source: Processed by the Researchers, 2024

The typology of land use change from agricultural to non-agricultural purposes between 2016 and 2022 is categorized into six distinct typologies, encompassing a total area of 14.234 hectares. These typologies comprise the conversion of mixed garden areas to both sparsely populated settlements and low-density housing developments; the transformation of irrigated rice paddies with two annual harvests to areas designated for small-scale industrial activities, road infrastructure expansion, and low-density settlements; and finally, the conversion of such rice paddies into low-density housing developments. The map illustrating the typology of agricultural-to-non-agricultural land use changes in Kembaran Subdistrict for the period 2016-2022 is shown in Figure 3.

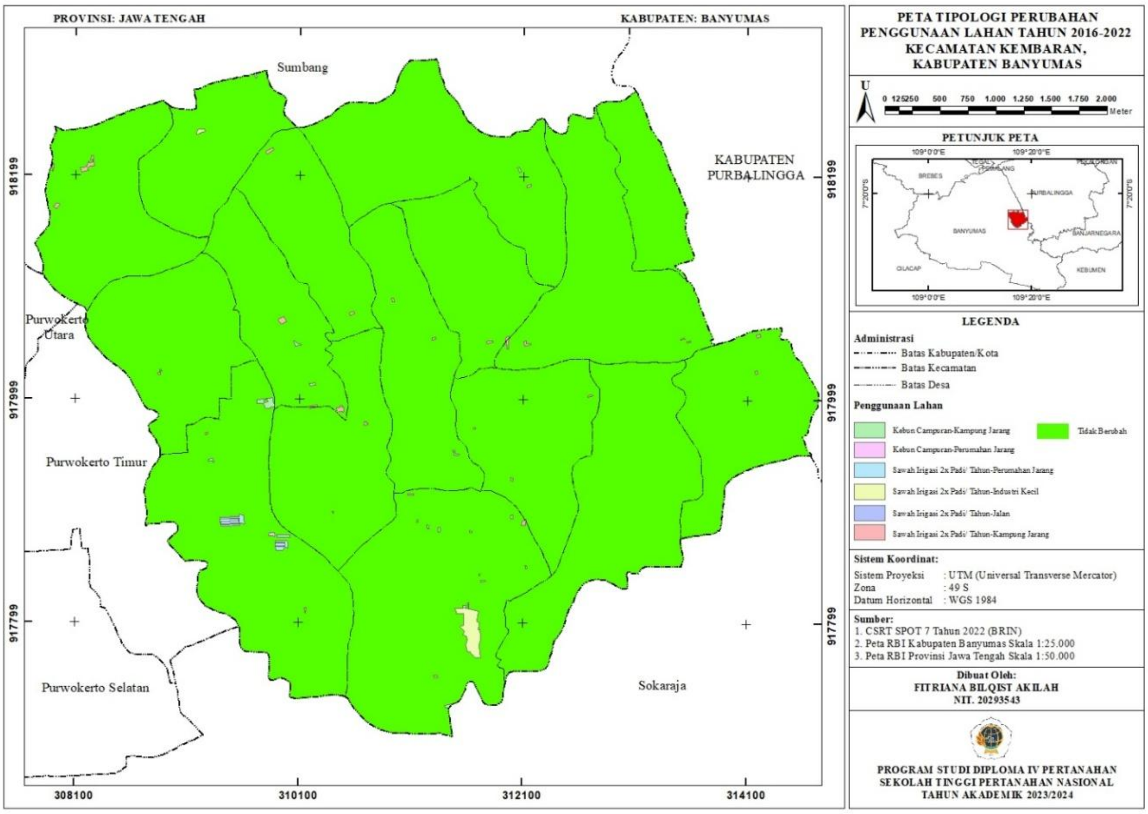

Figure 3. Typology of Land Use Changes in Kembaran (2016-2022)

The results of the land use change analysis, derived from the Typology Map of Agricultural-to-Non-Agricultural Land Use Changes in Kembaran Subdistrict for the period 2016-2022, are presented in Table 4.

Table 4. Typology of Land Use Change in Kembaran District, 2016-2022

No.	Land Use Change Typology (2016-2022)	Area	
		Ha	%
Agricultural - Non-agricultural			
1	Mixed Gardens to Low-Density Settlements	1.954	13%
2	Mixed Gardens to Low-Density Housing	0.156	1%
3	Irrigated Rice Paddies (Double-Cropped) to Small-Scale Industry	5.838	40%
4	Irrigated Rice Paddies (Double-Cropped) to Road Networks	0.270	2%

5	Irrigated Rice Paddies (Double-Cropped) to Low-Density Settlements	3.374	23%
6	Irrigated Rice Paddies (Double-Cropped) to Low-Density Housing	2.642	18%
Non-agricultural - Non-agricultural			
7	Grassland to Low-Density Settlements	0.384	3%
	Total	14.619	100%

Source: Processed by the Researchers, 2024

D. Impact of Land Use Changes on Environmental Quality in Kembaran Subdistrict

The quality of the residential environment was assessed based on several key parameters influencing settlement quality, utilizing SPOT 7 satellite imagery from 2022. The interpreted imagery was subsequently scored using ArcMap 10.8. The parameters employed in determining residential environmental quality are as follows:

1. Residential Density

Residential density was classified into three criteria: low, medium, and high density. The analysis utilized digitized data of residential blocks based on land use in Kembaran Subdistrict for the year 2022. These digitized residential blocks were analyzed using the kernel density tool in ArcMap 10.8. The resulting analysis was then classified into three categories: good, moderate, and poor. The classification thresholds were as follows: good with a density score of 0-40%, moderate with a density score of 41-60%, and poor with a density score of >60%. The results of the kernel density analysis are depicted in Figure 4.

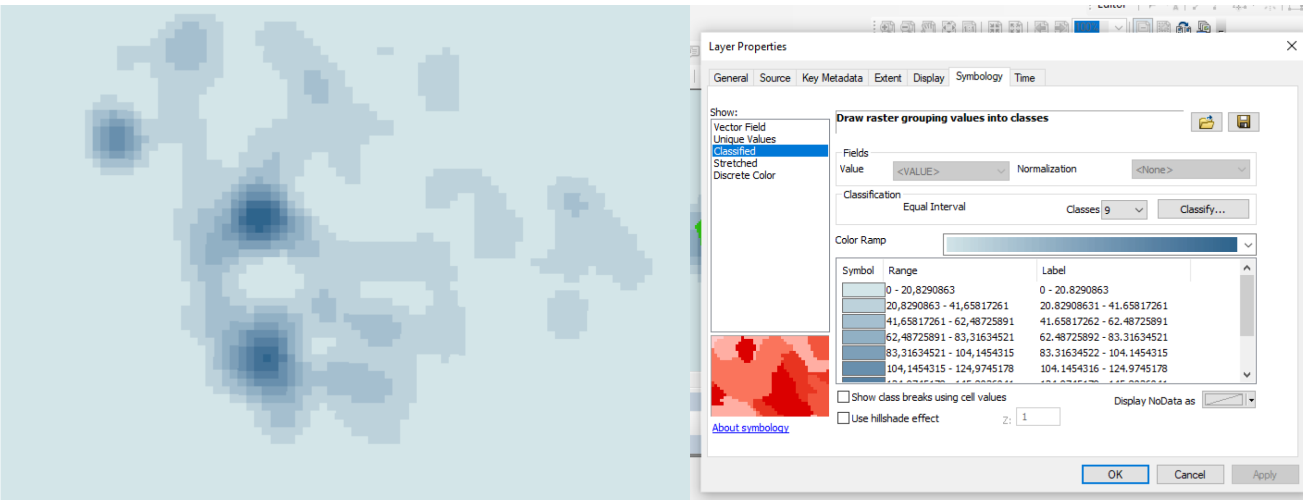

Figure 4. Kernel Density Analysis Results. Source: Processed by the Researchers, 2024

In Figure 4, the left panel illustrates a color gradient ranging from light to dark, where darker shades indicate higher residential density. The right panel presents the interval classes for residential density.

Residential areas in Kembaran Subdistrict are predominantly of medium density. This is demonstrated in the Residential Density Map of Kembaran Subdistrict, Banyumas Regency, for the year 2022, shown in Figure 5. The map provides an analysis of the area of residential blocks in each density category, as detailed in Table 5.

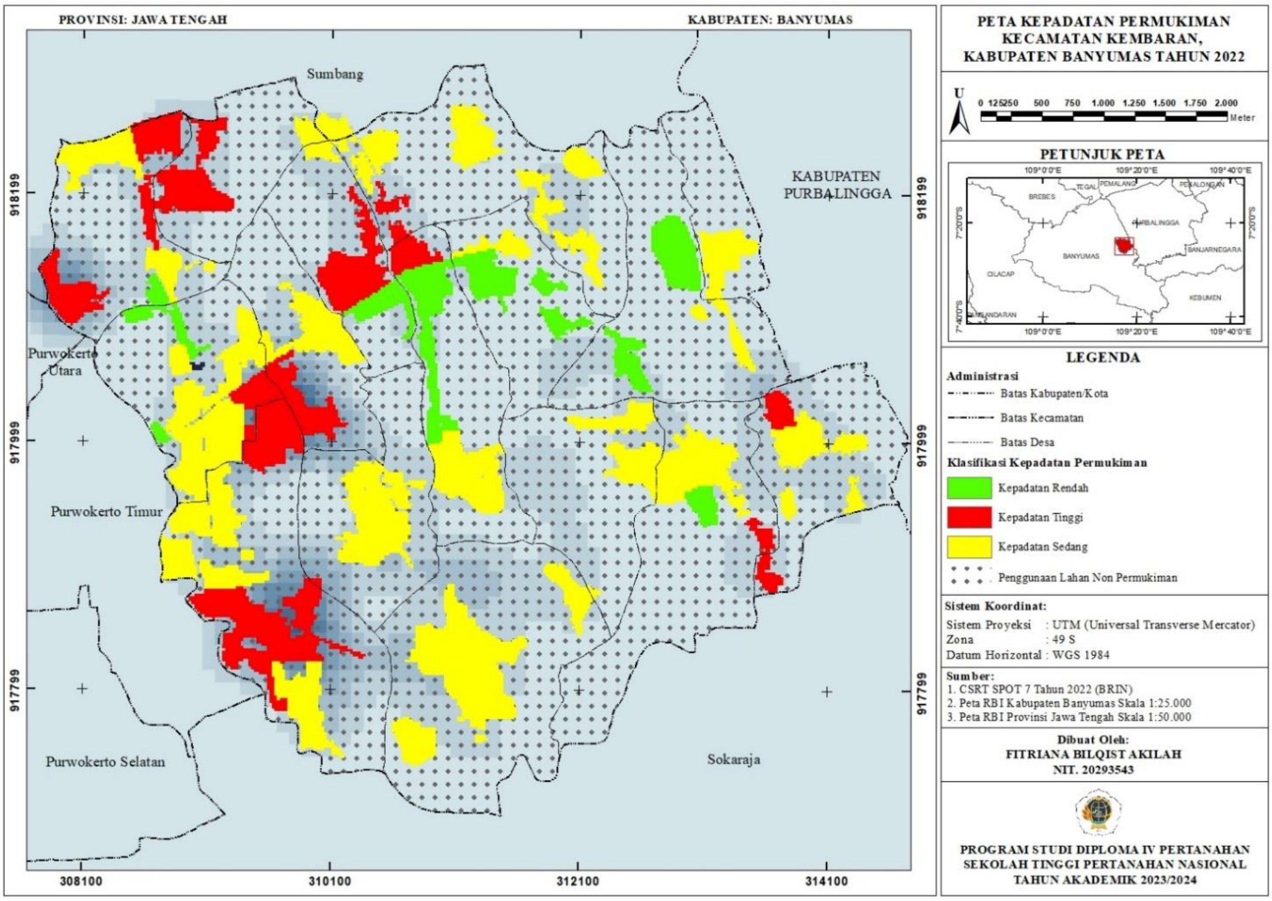

Figure 5. Residential Density in Kembaran, 2022. Source: Processed by the Researchers, 2024

Table 5. Residential Block Area by Density Class.

Criteria	Classification	Area (Ha)	Percentage (%)
Low Density	Good	102.7	14%
Moderate Density	Moderate	455.7	60%
Hgh Density	Poor	195.2	26%
Total		753.6	100%

Source: Processed by the Researchers, 2024

Based on Table 4, residential blocks in Kembaran Subdistrict are predominantly categorized as medium-density settlements, covering an area of 455.7 hectares, or 60% of the total residential block area in the subdistrict. The high density of buildings significantly impacts the environmental quality in the area. Densely built environments often face challenges such as limited road access, reduced water absorption capacity, and restricted sunlight penetration. These limitations can lead to various environmental issues, including water pooling due to inadequate drainage systems and increased noise pollution caused by the close proximity of buildings.

2. Roadside Shade Trees

Roadside shade trees play a crucial role in improving air quality in residential environments. The presence of such trees is directly proportional to environmental quality; the greater the number of trees, the more effectively pollution can be absorbed, resulting in cooler air temperatures and less heat in the residential area. Figure 6 provides an example of a residential block with roadside shade trees.

Figure 6. Roadside Shade Trees in Saphire Residence, Tambaksari Kidul, Kembaran.
Source: Field Observation by the Researcher, 2024.

In this study, roadside shade trees were categorized into two classes: *good* and *poor*. A residential block was classified as *good* if it contained roadside shade trees, and *poor* if no such trees were present. The research findings indicate that all residential blocks in Kembaran Subdistrict fall under the *good* category, as every block was found to contain roadside shade trees.

3. Residential Location

Residential locations are classified into three categories: *good*, *moderate*, and *poor*. This classification is based on the proximity of residential blocks to pollution sources. In Kembaran Subdistrict, there are nine identified pollution sources: Soun Factory, Sari Limbah (Scrap Yard), Bakul Rongsok (Scrap Collector), Rongsok Lapak Pliken Lor (Scrap Yard), Pelus River, Dukuhwaluh Terminal, Plastic Factory, Bogasari Vermicelli Factory, and Soun Factory Soka Indah.

The distance from pollution sources was calculated using the buffer tool in ArcGIS 10.8, resulting in the Map of Pollution Center Proximity to Residential Locations in Kembaran Subdistrict in 2022, shown in Figure 7. The darker shades on the map indicate greater distances from pollution sources, while residential blocks are marked in green.

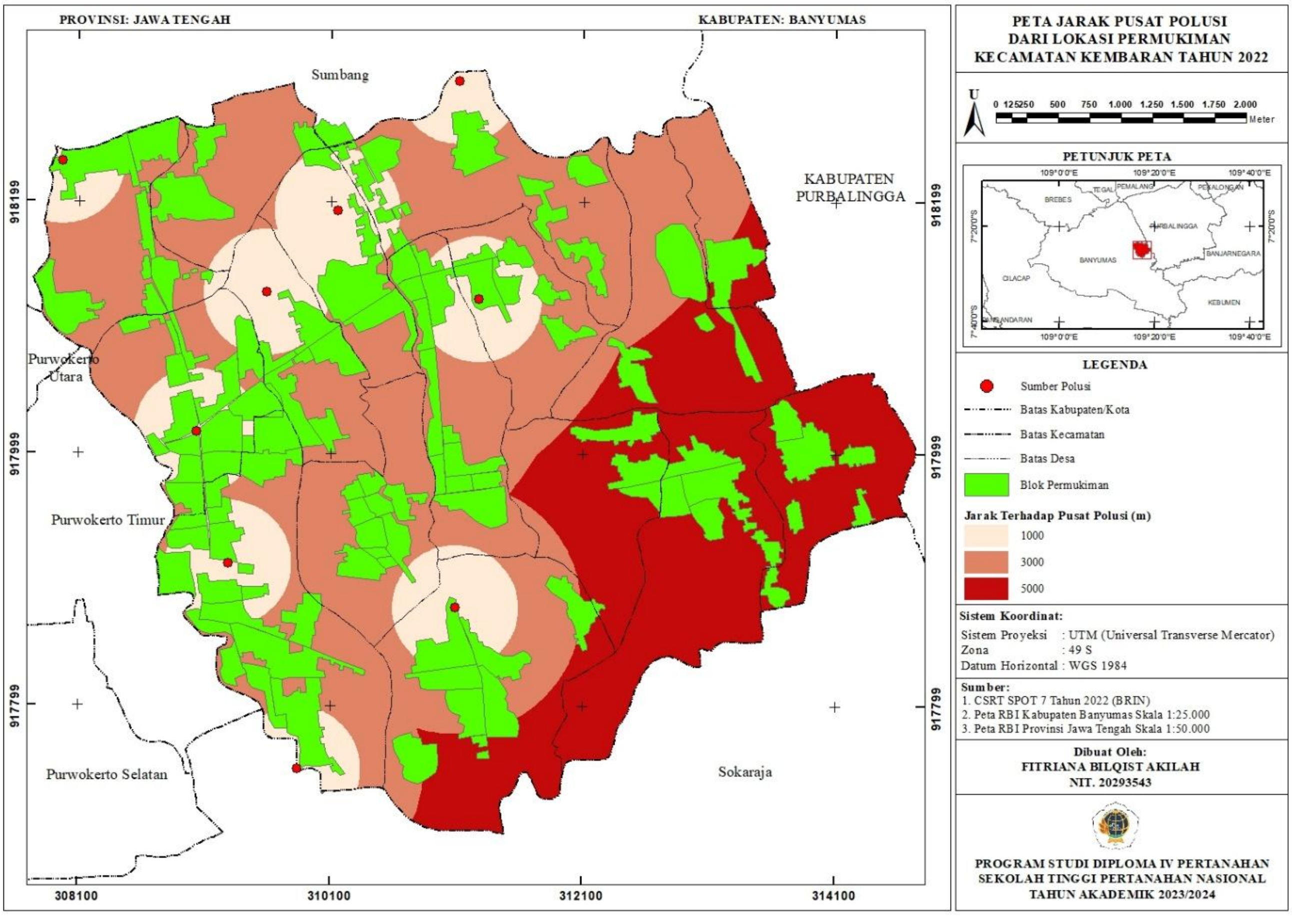

Figure 7. Proximity of Pollution Centers to Residential Locations. Source: Author's Analysis, 2024.

According to the analysis, residential blocks located near arterial roads, such as those in Dukuhwaluh and Ledug villages, are more exposed to vehicle pollution. Additionally, these blocks' proximity to terminals further exacerbates pollution levels in their surroundings. The following table presents the area of residential blocks categorized by their proximity to pollution sources.

Table 6. Area of Residential Blocks Based on Proximity to Pollution Sources

Criteria	Classification	Area (Ha)	Percentage (%)
If the residential location is far from pollution sources (terminals, factories, stations, waste) at a distance of ±5 km and still close to urban areas	Good	195.1	26%
If the residential location is not directly affected by pollution activities, at a distance of ±3 km from the residential area	Moderate	323.5	43%
If the residential location is close to pollution sources, at a distance of ±1 km from the residential area	Poor	235.0	31%
Total		753.6	100%

Source: Processed by the Researchers, 2024

As presented in Table 6, the largest percentage of residential blocks, 43%, covers a total area of 323.5 hectares and falls under the *moderate* classification, located approximately ±3 km from pollution sources. The assumption is that the closer a residential block is to a pollution source, the poorer its environmental quality. Figure 8 depicts the primary collector road network connecting Banyumas Regency with Purbalingga Regency, which serves as one of the pollution sources in Kembaran Subdistrict, Banyumas Regency.

Figure 8. Regional Road Network. Source: Google Street View, 2024

The results from the three parameters were aggregated by calculating the total scores using weighted values and scaling factors. These scores were then overlaid to classify the environmental quality of settlements into three categories: good (I), moderate (II), and poor (III). Details of the classification are presented in the table below.

Table 7. Environmental Quality of Residential and Non-Residential Blocks

Criteria	Class	Area (Ha)	Percentage
Good Residential Quality	I	131.758	17%
Moderate Residential Quality	II	311.0034	41%
Poor Residential Quality	III	310.9026	41%
Total Residential Area		753.66	100%
Non-Residential		1900.66	-

Source: Processed by the Researchers, 2024

Based on Table 7, the total area of residential blocks with good environmental quality (Class I) in Kembaran District covers 131.758 hectares, constituting 17% of the total residential area. In contrast, Classes II and III have almost equal areas of 311.0034 hectares and 310.9026 hectares, respectively, each comprising 41%. The highest concentration of poor environmental quality (Class III) is found in Ledug Village. The Environmental Quality Map of Residential Areas in Kembaran District, Banyumas Regency, for the year 2022 is shown in Figure 9.

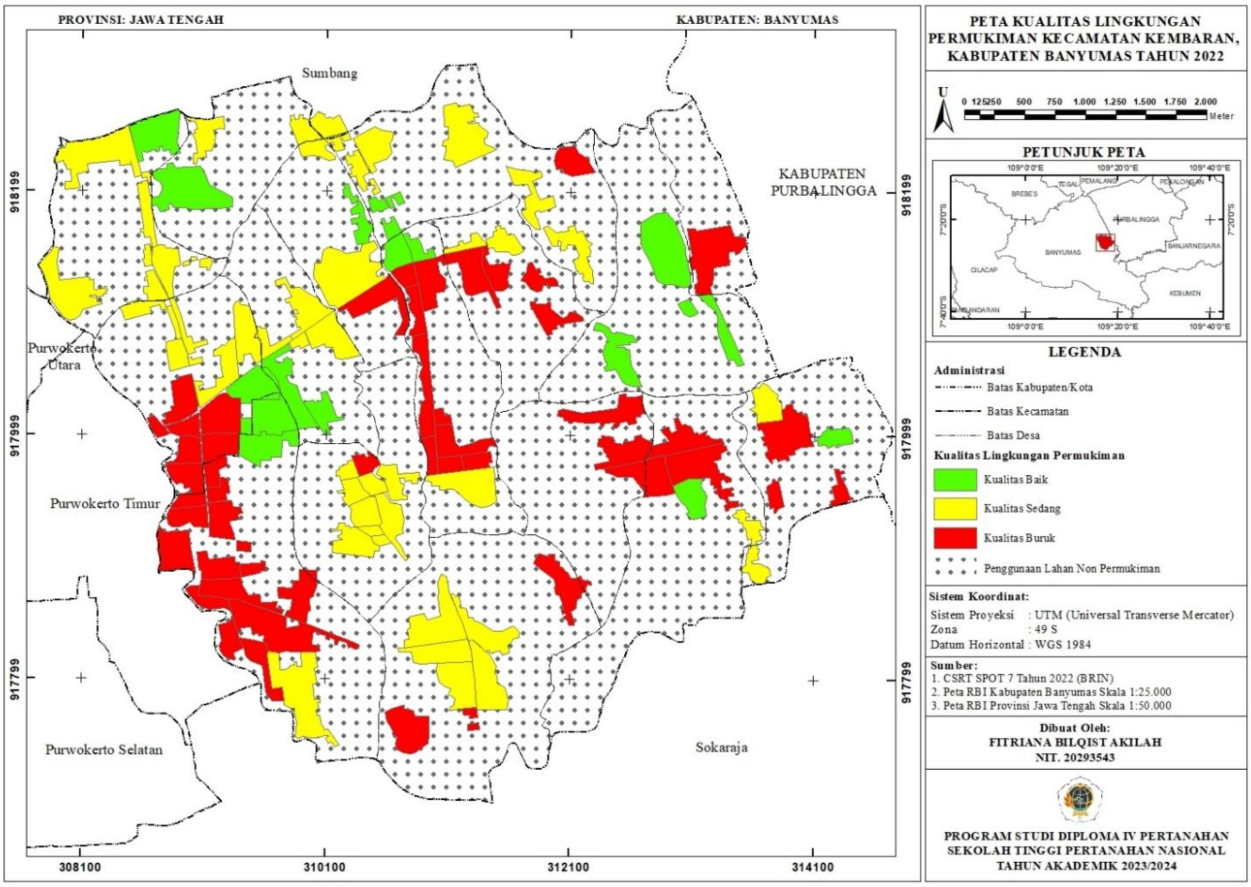

Figure 9. Environmental Quality of Kembaran District. Source: CSRT SPOT 7 BRIN, 2022.

The image interpretation analysis yielded a classification of residential environmental quality in Kembaran District. To ensure accuracy, the interpretation results were validated through an accuracy test using 36 purposively selected samples, where larger classifications were assigned more samples. The accuracy test results indicated an overall accuracy of 93%.

The minimum interpretation accuracy standard set by the United States Geological Survey (USGS) is approximately 85% (Derajat dkk., 2020). Therefore, the data interpretation and analysis conducted by the researchers are deemed suitable for further investigation. Representative images of residential environmental quality are provided in Figure 10, where (a) depicts good quality, (b) moderate quality, and (c) poor quality.

(a) (b) (c)

Figure 10. Residential Environmental Quality. Source: Google Street View, 2024

E. Conclusion

This study identifies significant land-use conversion from agricultural to non-agricultural purposes in Kembaran District between 2016 and 2022. The transition encompasses six primary changes, including the transformation of mixed gardens and irrigated rice fields into residential areas, industrial zones, and road networks. These shifts have directly impacted the environmental quality of residential areas, influenced by factors such as population density, the presence of roadside vegetation, and proximity to pollution sources. The study reveals that 131.758 hectares, or 17% of the total residential area, exhibit good environmental quality, while 311.0034 hectares (41%) fall into the moderate category, and 310.9026 hectares (41%) are classified as poor. Residential areas with poor environmental quality are characterized by high density, limited roadside vegetation, and proximity to pollution sources such as factories and arterial roads, leading to deteriorated air quality and increased environmental challenges. These findings underscore the urgent need for sustainable spatial planning to manage agricultural land conversion and mitigate environmental impacts. Proactive measures, including roadside vegetation planting, residential density control, and ensuring safe distances from pollution sources, should be implemented. The study further emphasizes the importance of integrating spatial analysis into developmental decision-making to balance regional growth with environmental quality.

Recommendations

1. Local governments in Kembaran District should tighten permitting processes to prevent the conversion of irrigated rice fields (producing two harvests per year) into residential areas to safeguard agricultural land sustainability.
2. Investors should be required to implement comprehensive waste treatment measures before disposal to preserve environmental quality and public health.
3. Communities should actively participate in preventing agricultural land-use changes by reporting violations to relevant authorities.
4. Extensive outreach programs should be conducted to raise awareness among Kembaran District residents about the mechanisms and impacts of agricultural land-use changes to foster greater community participation.

5. Future research should focus on areas with high rates of agricultural land-use conversion to facilitate a more comprehensive analysis.

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