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# Public Perceptions on Land Use Change and Flood Incidence in the Kendal Watershed Area

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**ABSTRACT**

Uncontrolled land-use changes driven by rapid population growth and expanding residential development have significantly heightened flood risk in the Kendal Watershed, Kendal District. The conversion of agricultural and open land into built-up areas has altered hydrological processes, reducing water infiltration capacity and increasing surface runoff. This study aims to (1) identify spatial and temporal land-use changes from 2017 to 2025, (2) analyze public perceptions regarding land conversion and flooding, and (3) assess the resulting social and environmental impacts within the watershed area. A quantitative descriptive approach was employed by integrating Geographic Information System (GIS)-based analysis of Sentinel-2A satellite imagery with primary data collected through Likert-scale questionnaires administered to 96 respondents residing in flood-prone areas. The results indicate a substantial decline in rice field areas by 44.19 hectares, accompanied by a notable increase in residential land of 36.12 hectares over the study period. Community perceptions reveal that these land-use changes have contributed to increased flood frequency, greater flood intensity, and longer inundation duration. The observed social impacts include disruptions to daily activities, reduced access to clean water, economic losses, and a higher incidence of waterborne and skin-related diseases. Environmental impacts are reflected in declining sanitation conditions, increased waste accumulation, river sedimentation, and persistent water pollution. These findings underscore the urgent need for stricter land-use regulation, restoration of green and infiltration areas, and adaptive, sustainable spatial planning to reduce flood risk and enhance community resilience in the Kendal Watershed.

## INTRODUCTION

Global climate change, land degradation, biodiversity loss, and food security are international challenges that are driving discussions of current land-use policies and future policy directions (Zscheischler & Rogga, 2021). In Indonesia, rapid population growth increases the need for land for housing, public facilities, and (Fitri & Putra, 2024). This has resulted in the conversion of previously productive land into built-up areas, reducing environmental capacity and increasing disaster risk (Wahyuni & Suranto, 2021).

Land use is a complex interaction between humans and nature, where urban and infrastructure development puts pressure on ecosystems through land sealing

and landscape fragmentation (Zscheischler & Rogga, 2021). Land use change is influenced by direct factors, such as agricultural and residential activities, as well as indirect factors, including social, economic, cultural, and political conditions (Arowolo & Deng, 2018). Population growth accompanied by improvements in the quality of human resources can be a potential development driver, but it also increases the need for social services and living space (Andriyani et al., 2019; Masyuri, 2018; Fitri & Putra, 2024).

The Kedungsepur area, including Kendal District, has experienced significant land conversion. Between 2010 and 2020, agricultural land was converted to built-up areas at an average rate of 3.25% per year (Adiyaksa & Djojomartono, 2020). Kendal District itself experienced a population surge to 61,429 in 2023, with a density of 2,235 people/km². Urbanization and industrial expansion have driven increased land demand, resulting in the conversion of agricultural land to residential and infrastructure uses (Handayani et al., 2020; Harahap et al., 2016; Latief et al., 2021).

Rapid development has resulted in limited green open space and increased surface runoff, leading to flooding (Masyuri, 2018; Zhang et al., 2024) (Wahyuni & Suranto, 2021). Flooding is a consequence of decreased water-absorption capacity due to changes in land use, particularly in watersheds that experience changes in hydrological characteristics and water-catchment quality (Nilasari, 2018; Mubarok et al., 2022).

Recent international studies increasingly emphasize integrating spatial land-use analysis with environmental perception surveys as part of state-of-the-art approaches to better understand socio-environmental impacts and community responses to flooding and climate-related hazards. Studies conducted in Europe, South Asia, and Latin America demonstrate that combining remote sensing data with perception-based surveys provides a more comprehensive understanding of flood vulnerability and adaptive behavior (Zscheischler & Rogga, 2021; Arowolo & Deng, 2018; Vargas et al., 2024; Freihardt, 2024).

However, methodological discussions on the design, validation, and analysis of perception surveys related to environmental impacts remain limited, particularly in Southeast Asian contexts. Recent studies, such as Vargas et al. (2024) in Colombia, Altanlar & Özdemir (2025) on sustainable urban environment perception, and Freihardt (2024) in Bangladesh, highlight the increasing need for survey instruments that integrate quantitative perception data with spatial and ecological indicators, reflecting state-of-the-art practices in socio-environmental assessment.

In Southeast Asia, including Indonesia, research explicitly linking land-use change dynamics to public flood perception using spatially explicit approaches remains limited. While several studies have examined land conversion and flooding separately, few have integrated satellite-based land use change detection with structured perception surveys at the sub-watershed scale. This study addresses this gap by combining Sentinel-2A imagery, GIS-based spatial analysis, and community perception surveys to examine flood impacts in the Kendal Watershed. By adopting an approach comparable to studies conducted in Colombia, Bangladesh, and European urban watersheds, this research contributes to the global discourse on integrated socio-environmental assessment and provides empirical evidence from a rapidly urbanizing coastal watershed in Southeast Asia.

Kendal District is topographically located in a lowland at 0–4 meters above sea level, with a dominant slope of 0–8%. It is traversed by the Kendal River, which is 9.5 km long and has a watershed area of 40.5 km² (Balai PSDA Bodri Kuto, 2022). The Kendal watershed has high levels of sedimentation and waste accumulation, as well as limited water catchment areas, making it highly vulnerable to runoff flooding (Nurdiana et al., 2020).

According to Regional Regulation No. 20 of 2020, Kendal District is designated as a flood-prone area. Data from the Regional

Disaster Management Agency (BPBD) shows that in January 2024, 18 of the 20 villages in the district were affected by flooding. High rainfall, reaching 300–400 mm per month during the rainy season, is exacerbated by a suboptimal drainage system (Badan Meteorologi dan Klimatologi Geofisika, 2024; Pemerintah Kabupaten Kendal, 2024).

Previous studies on land use change and flooding in Central Java have generally focused on large watersheds or regional-scale hydrological modeling (Adiyaksa & Djojomartono, 2020; Mubarok et al., 2022). However, specific spatial-temporal analyses linking land conversion patterns with flood frequency at the sub-watershed scale, such as in the Kendal River Basin, remain limited. This study introduces a spatially explicit, quantitative approach that integrates land use change detection with flood distribution analysis and community perception surveys. The findings contribute not only to local watershed governance and disaster mitigation in Indonesia but also to the broader discourse on sustainable urban watershed management and climate adaptation policies in developing countries.

Therefore, this study, entitled "The Impact of Changes in Land Use Patterns on Flood Disasters in the Kendal River Basin (DAS), Kendal District", aims to analyze the spatial relationship between land use change and flood disaster occurrence while incorporating community flood perception to provide new insights for integrated watershed and urban planning.

## RESEARCH METHODS

### Location and Time of Research

This study was conducted in the Kendal River Basin (DAS), administratively located in Kendal District, Kendal Regency, Central Java Province. This watershed, part of the Bodri Kuto River Basin, is characterized by relatively flat topography and a high susceptibility to flooding. The Kendal watershed covers an area of 40.50 km², with a river length of 9.50 km, spanning 12 villages that constitute the field observation locations.

The site was selected based on the high intensity of land-use changes and the frequency of significant flooding in recent years. Furthermore, this area is a strategic region undergoing rapid development, both industrially and residentially. The research was conducted over one month, encompassing a literature review, field data collection through observation and questionnaires, satellite imagery processing, GIS mapping, and the preparation of the research report.

### Method of Data Collection

This study employed a descriptive, quantitative approach, in which collected data were processed numerically and analyzed statistically. Following established quantitative research procedures in geography and environmental studies (Creswell, 2014; Sugiyono, 2019). Multiple data collection techniques were employed to ensure completeness, accuracy, and validity:

1. Questionnaires

Questionnaires were distributed to communities around the Kendal Watershed to gather information on perceptions of land-use changes and flooding impacts. Respondents were selected using purposive sampling, a non-probability sampling technique commonly applied in socio-environmental perception studies (Etikan et al., 2016). with criteria including being at least 17 years old, residing within the study area, and willing to provide responses based on actual observations. A total of 96 respondents were surveyed, representing the 12 villages within the watershed. Although this sample size is adequate according to the Yamane formula for small populations, it may not fully represent the entire watershed population (Yamane, 1967). Consequently, the findings are interpreted as indicative trends rather than generalizations to the broader population.

2. Direct observation

Field observations were conducted to document existing land conditions, land-use changes, and areas affected by flooding. following standard field survey approaches in geographic research (Creswell, 2014; Longley et al., 2015).

3. Remote Sensing and GIS Analysis

Sentinel satellite imagery from 2017, 2021, and 2025 was processed using GIS software to map and analyze land cover changes. following established remote sensing and GIS-based land-use change analysis methods (European Space Agency, 2023; Lillesand et al., 2015).

4. Literature Review

Secondary data were collected from technical agencies, such as the DPU-PR and BPBD of Kendal Regency, to complement primary data, as recommended in applied geographic and disaster risk research (Neuman, 2014).

5. Photo And Video Documentation

Photographs and videos were captured to support the visualization of field conditions and to enhance the validity of observational data.

6. Instrument Validity and Reliability

The questionnaire was pretested to ensure construct validity and internal consistency. Construct validity was assessed through expert judgment, involving two academic experts in environmental perception and one practitioner from the Kendal BPBD. Reliability was assessed using Cronbach's Alpha, yielding a coefficient of 0.81, indicating high consistency among items (Nunnally & Bernstein, 1994).

7. Bias Consideration

To minimize potential social desirability bias, anonymity and confidentiality were guaranteed for all respondents. Enumerators were trained to emphasize that all opinions were equally valuable. Question phrasing was carefully designed to avoid leading or emotionally charged language, thereby reducing information bias.

**Data Analysis Methods**

Three main analytical techniques were employed: descriptive statistical analysis, GIS analysis, and public perception analysis.

1. Descriptive Statistical Analysis

Used to describe land use conditions in 2017, 2021, and 2025, as well as the influence of land use changes on flood intensity, frequency, and socio-environmental impacts. Data were presented in tables and diagrams to clearly depict trends.

2. GIS Analysis

Employed to classify land use and detect land cover conversions (e.g., agricultural to residential/industrial) across the study periods. The results were visualized through thematic maps to provide a spatial and temporal overview.

3. Scoring Analysis

Designed to analyze the influence of land use changes on flooding and assess socio-environmental impacts. A four-level Likert scale (strongly agree, agree, disagree, strongly disagree) was used to minimize neutral response bias. Scores were categorized into class intervals representing flood frequency, water levels, flood duration, housing conditions, and affected areas. Likert scale–based perception surveys are widely recognized as robust instruments for assessing public awareness and responses to flood risks, and their validity is supported by high-impact empirical studies (Palazzoli et al., 2025; Chen et al., 2025).

4. Inferential Statistical Analysis.

Pearson's correlation and simple linear regression were used to examine relationships between land-use changes (independent variable) and perceptions of flood impacts (dependent variable). This analysis strengthens the findings by testing whether observed trends are statistically significant.

**Conceptual Framework**

To provide a clear analytical structure, a conceptual framework was developed to illustrate the hypothesized relationships between land-use changes, flood perception, and social-environmental impacts. This framework guides the selection of variables, the design of questionnaires, and the integration of spatial and statistical analyses, ensuring a coherent interpretation of results.

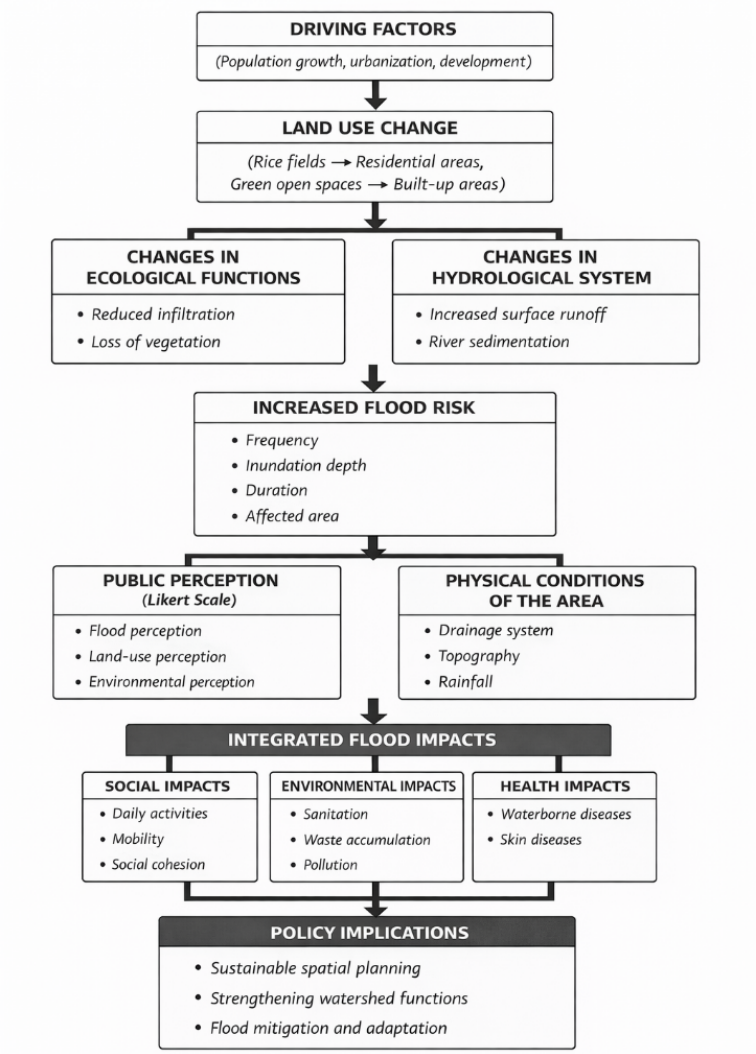



Figure 1. Conceptual Framework (Source: Research Results, 2025).

## RESULTS AND DISCUSSION

The study area in this research is the Kendal River Basin (DAS), which is administratively located in Kendal District, Kendal Regency, Central Java Province. This watershed is within the Bodri Kuto River basin and is fed by the Kendal River. This river flows for 9.50 km and covers approximately 40.50 km². The Kendal Watershed crosses 15 villages: Balok, Bandengan, Kalibuntu Wetan, Karangsari, Kebondalem, Langenharjo, Ngilir, Patukangan, Pegulon, Pekauman, Sijeruk, and Trompo, which collectively form a densely populated area in Kendal District.

Astronomically, Kendal District is located between 109°59' – 110°18' East Longitude and 6°32' – 7°41' South Latitude, with an administrative area of 27.50 km². Its boundaries are: to the north, it borders directly on the Java Sea; to the south, with Ngampel District; to the west, with Patebon District; and to the east, with Brangsong District. According to BPS data from 2023, the population of Kendal District reached 61,642, with a high population density of 2,241 people per km², reflecting social pressure on land and residential space.

Topographically, the Kendal District is relatively flat, especially in the northern and coastal areas, with elevations ranging from 0 to 4 meters above sea level. Most of the area has a slope of 0–15%, with specific regions of the southern part of the watershed experiencing steeper slopes of 15–25%. This topography results in much of the area being classified as a floodplain, highly susceptible to waterlogging during the rainy season.

The dominant soil types in the Kendal watershed are hydromorphic alluvial and gray alluvial associations, which originate from river sedimentation. These soils have a muddy texture and are not yet fully compacted, resulting in low permeability and a high susceptibility to erosion and flooding. Furthermore, these soils are prone to land subsidence under water-saturated conditions.

From a climatic perspective, Kendal District falls within a humid tropical climate zone with an average annual rainfall of 166.08 mm. The peak rainy season occurs in February, with rainfall reaching 585 mm and up to 20 rainy days. This high rainfall, if not balanced by a proper drainage system and vegetative cover, has the potential to cause surface runoff and flooding in the Kendal watershed.

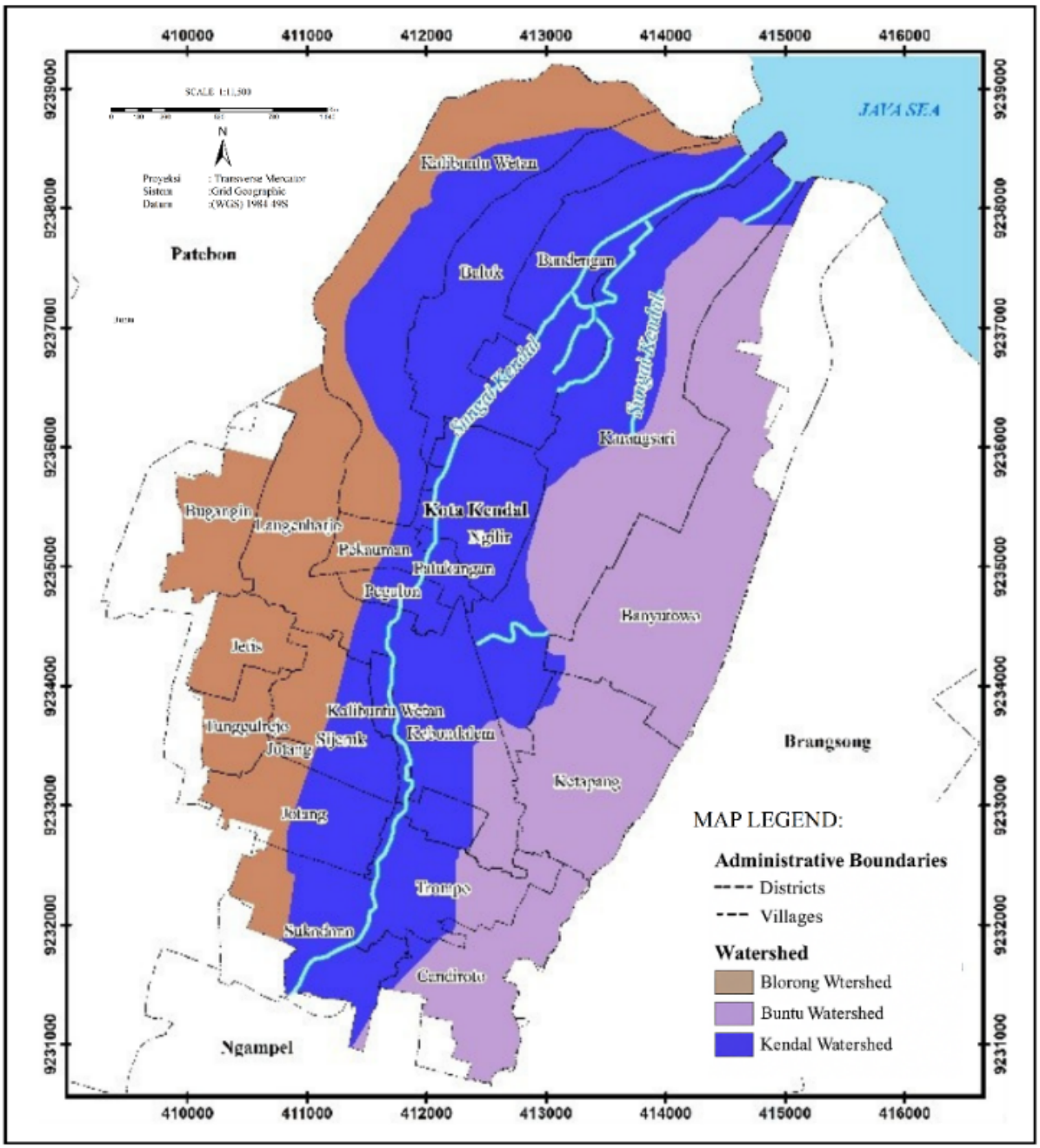



Figure 2. Watershed Map Of Kendal District (Source: Research Results, 2025)

**Land Use Changes in the Kendal Watershed 2017 - 2025**

a. Land Use Classification for 2017, 2021, and 2025

Land use in the Kendal watershed exhibited dynamics over the three time periods analyzed (Figure 3). Based on satellite imagery, land use was classified into several main categories using a Geographic Information System (GIS), including rice paddies, settlements, scrubland, and open land.

1) Land Use of the Kendal Watershed in 2017

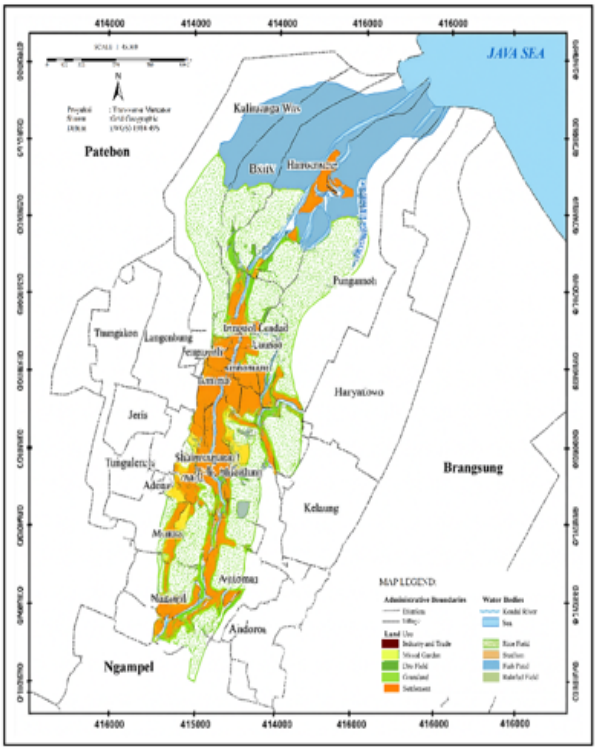
This year, land use remained dominated by agricultural land, particularly rice paddies, totaling 1,115.02 hectares. Vegetative areas, such as shrubs and green open spaces, remained relatively extensive, thereby maintaining the region's hydrological function as a catchment area. Residential areas were underdeveloped, and land pressure was relatively low. This indicates that the Kendal Watershed remained relatively ecologically stable during this period.

2) Land Use Of Kendal Watershed in 2021

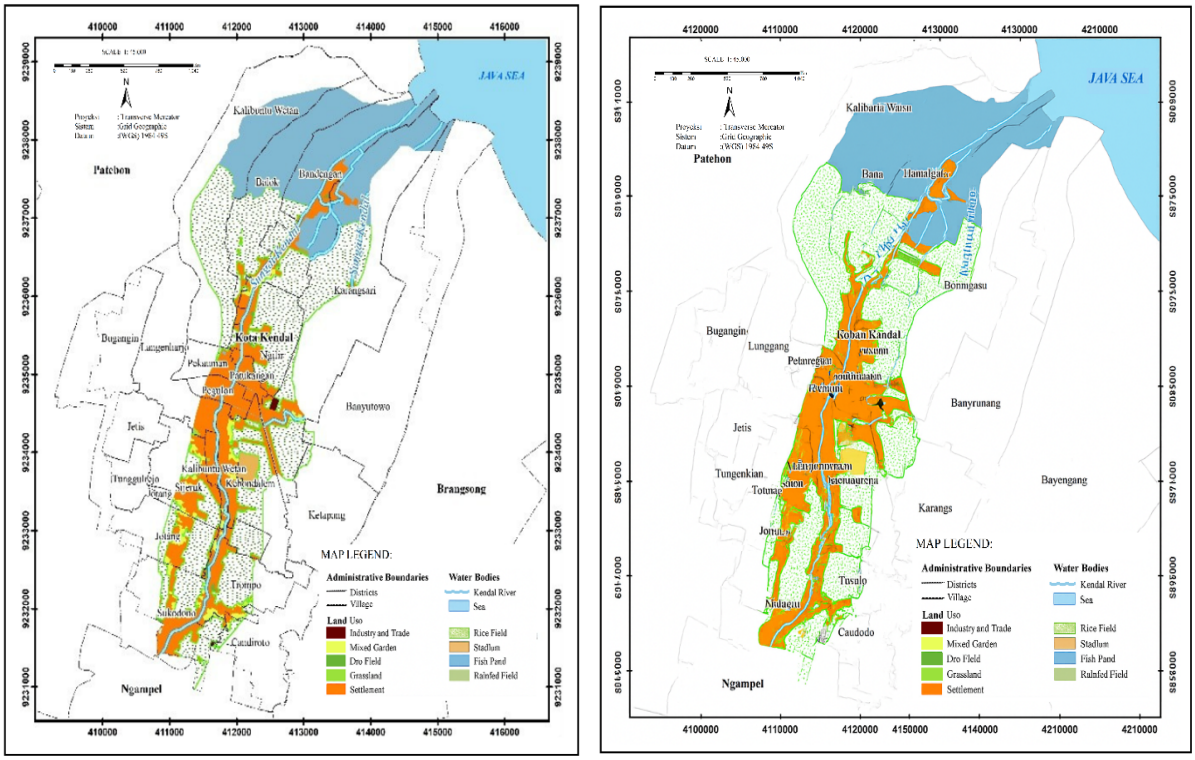
There was a decrease in rice paddy area to 1,101.95 hectares, while residential land area increased to 435.8 hectares. This increase in settlements is an early indication of significant changes resulting from urbanization. Areas that previously served as scrubland or open land are being converted into buildings, public facilities, and residential places. This indicates a transition in land use from ecological to socio-economic functions.

3) Land Use Of Kendal Watershed in 2025

This year's projections show that land conversion is becoming increasingly massive. Rice paddy fields have shrunk by 1,070.47 hectares, while residential areas have increased by 469.22 hectares. Scrub and the open regions have shrunk drastically, indicating intense development pressure on watershed areas. Land conversion on this scale reflects a development trend that no longer considers the region's ecological capacity and significantly alters surface conditions and hydrological stability (Kumalawati et al., 2024). Areas that previously served as rainwater buffer zones have now been transformed into built-up areas, increasing the potential for surface runoff.




(a) 2017




(b) 2021 (c) 2025

Figure 3. Land Use Map of Kendal Watershed, Kendal District, (a) 2017, (b) 2021, (c) 2025 (Source: Research Results, 2025).

b. Results of Land Use Change Classification for 2017–2021 and 2021–2025

Based on spatial analysis and tabulation of land use changes, the pattern and rate of land use changes in the two analysis periods can be seen:

1) Changes in Land Use of the Kendal Watershed for the 2017–2021 Period

During this period, the area of rice paddies decreased by 13.07 hectares, while the area of the residential regions gradually increased. The land use conversion process at this stage is still ongoing on a moderate scale. The development of new residential areas on the outskirts of the city or around main transportation routes drives this change. Shrubland has also decreased due to land encroachment for the construction of economic and social facilities. While not yet drastic, this pattern indicates a clear shift toward urbanization.

2) Changes in Land Use of the Kendal Watershed for the 2021–2025 Period

Land use changes during this period occurred more rapidly and on a larger scale. Rice paddies shrank by 31.48 hectares, and residential areas expanded by approximately 33.42 hectares. This indicates that the land conversion process is not only continuing but also accelerating. This situation suggests intense pressure from the residential and industrial sectors on green open spaces. If left unchecked, this trend has the potential to lead to a decline in the ecological function of the Kendal Watershed and increase the risk of hydrological disasters such as flooding.

Table 1. Land Use Change in the Kendal Watershed in 2017, 2021, and 2025

| Land Use | Land Area (Ha) | | |
|---|---|---|---|
| | 2017 | 2021 | 2025 |
| Stadium | 10,78 | 10,78 | 10,78 |
| Industry and Trade | 2,37 | 1,19 | 2,55 |
| Rainfed Field | 74,24 | 78,03 | 71,32 |

| Land Use | Land Area (Ha) | | |
|---|---|---|---|
| | 2017 | 2021 | 2025 |
| Mixed Field | 4,7 | 14 | 4,49 |
| Settlement | 435,47 | 435,8 | 469,22 |
| Dry Field | 3,65 | 4,67 | 6,19 |
| Rice Field | 1115,02 | 1101,95 | 1070,47 |
| River | 11,72 | 11,72 | 11,82 |
| Fish Pond | 362,85 | 362,65 | 373,97 |
| Total | 2020,8 | 2020,80 | 2020,80 |

(Source: Research Results, 2025)

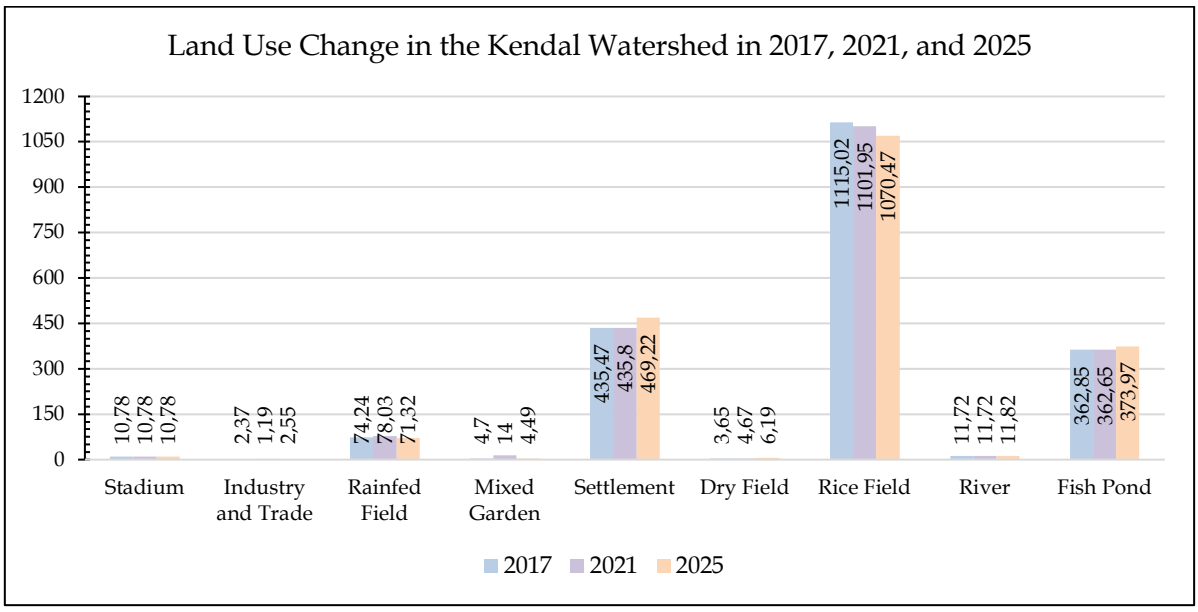



Figure 4. Graphic Land Use Change in the Kendal Watershed in 2017, 2021, and 2025
(Source: Research Results, 2025)

**Public Perception of Land Use Changes and Flooding in the Kendal Watershed**

Land use changes in the Kendal watershed show a strong correlation with increased flood risk. Analysis of community perceptions reveals that flooding has become a significant, regular occurrence in recent years. The majority of respondents stated that flooding occurs once or twice a year (54%), with a frequency of 2.48 (mean 2.48). Most flooding occurs between January and March (78%), coinciding with the region's rainy season. The average duration of inundation ranges from 1 to 3 days (mean 3.22), indicating that the drainage system is functioning reasonably well in some areas, although not evenly.

Before data collection, the questionnaire instrument was evaluated for construct validity through expert judgment, involving two academics in environmental perception studies and one practitioner from the Kendal BPBD. Reliability testing using Cronbach's Alpha yielded a coefficient of 0.81, indicating high internal consistency and reliability of the survey items.

A total of 96 respondents were involved, representing 12 villages within the watershed. Although this sample size is considered adequate based on the Yamane formula for small populations, it may not fully represent the entire population of the Kendal Watershed. Therefore, the findings are interpreted primarily as indicative trends rather than generalizable conclusions for the broader watershed population.

Regarding water levels, 55% of the community experienced inundation of less

than 0.5 meters, with a mean of 3.70 (very low category). Most of the inundation affected only the house terrace (41%), and the impact on homes was relatively minor (mean 3.23). However, the coverage of the affected area was considered quite extensive, with 48% of respondents stating that inundation occurred in most areas (mean 2.66). In addition, 70% of respondents reported being affected by flooding 3-5 times in the past few years, indicating that the community is frequently affected by flooding.

This data highlights the community's growing awareness of the link between land-use changes and recurring flood events, which is closely related to disaster literacy and adaptive capacity(Afrian et al., 2025). Studies in other urban contexts have found that socio-demographic characteristics, such as education and past flood experience, significantly influence flood risk perception, with more vulnerable groups often exhibiting higher perceived risk (Liu et al., 2022)The perceived increase in flood frequency and extent suggests that natural absorption area, such as forests, wetlands, and agricultural lands may have been reduced or converted to impervious surfaces, such as buildings and roads. Empirical research has shown that flood experience and social norms significantly influence public perceptions of flood risk, suggesting that both cognitive and social factors shape how communities interpret flood hazard information (Wolf et al., 2024).

To further validate these findings, a correlation analysis was conducted between the perceived frequency of flooding and the extent of land-use change derived from GIS data. The Pearson correlation coefficient ($r = 0.71$, $p < 0.01$) indicates a strong positive relationship, suggesting that areas experiencing greater land conversion also report higher flood frequencies. This statistical evidence reinforces the community's perception that urban expansion directly increases flood risk. This evidence reinforces that urban expansion increases flood risk, though preparedness often varies despite moderate risk perception (Li & Wang, 2025).

These findings align with global studies demonstrating that socio-environmental perceptions and prior flood experiences shape public awareness and preparedness, underscoring the need to integrate survey data with spatial analyses for robust flood risk assessment (Santoro et al., 2023; Iqbal & Nazir, 2023; Abdullah & Maryani, 2024).

To further quantify the relationship between land-use changes and flood perception, a simple linear regression analysis was conducted. The results indicate that increases in residential and built-up areas significantly predict the perceived frequency and intensity of flooding ($\beta = 0.68$, $p < 0.01$), reinforcing the conclusion that land conversion is a key determinant of community-reported flood impacts.

Santoro et al. (2023) emphasize that evaluating citizens' risk perceptions is essential for supporting flood risk management decision-making, particularly for identifying the community groups most exposed to risk and informing targeted mitigation strategies. Additionally, Joumar et al. (2025) demonstrate that while respondents in Greece are generally aware of flood risks and governmental plans, there is a clear gap between risk awareness and actual preparedness behaviors, underscoring the need for localized risk communication and community-driven initiatives to strengthen resilience. The inclusion of such perception-based approaches can enhance local disaster management and improve adaptation outcomes.

Although floodwater levels remain relatively low and the physical damage to homes is generally minor, the widespread distribution and consistent occurrence of floods indicate a persistent environmental and infrastructural challenge. Strengthening watershed management, improving land use planning, and enhancing community-based adaptation strategies are essential to Institutional and community-based resilience, which play a critical role in reducing disaster vulnerability and supporting long-term adaptation (Maruddani et al., 2025). Mitigating future flood risks in the Kendal watershed area, particularly through integrating disaster mitigation concepts into spatial planning and education (Aliman et al., 2025).

Compared with international cases, similar patterns are observed in rapidly urbanizing watersheds across Southeast Asia

and beyond. For example, Freihardt (2024) in Bangladesh and Altanlar & Özdemir (2025) in Turkey, it was observed that unplanned land conversion significantly increases urban flood frequency. Likewise, Liu et al. (2022) China emphasized that reduced green spaces and poor drainage are primary drivers of recurrent flooding in peri-urban areas. These parallels suggest that the Kendal watershed reflects broader global challenges in balancing economic growth with environmental sustainability.

Critically comparing these findings with international cases reveals that, while Kendal experiences lower flood heights than highly urbanized watersheds in China or Turkey, the patterns of increased surface runoff and reduced infiltration due to rapid land conversion are consistent across these watersheds. Differences in topography, drainage infrastructure, and local governance partly explain variations in flood intensity, highlighting the importance of context-specific adaptation strategies and reinforcing the idea that Kendal's experience reflects broader global trends in socio-environmental vulnerability.

Table 2. Community Perception of Flood Characteristics in the Kendal Watershed, Kendal District

| Flood Characteristics Indicator | Mean |
|---|---|
| Public perception of flood frequency | 2,48 |
| Public perception of inundation duration | 3,22 |
| Public perception of increased intensity | 3,7 |
| Public perception of flood height | 3,7 |
| Public perception of flooding in houses | 2,81 |
| Public perception of impact on houses | 3,23 |
| Public perception of flood area | 2,66 |
| Public perception of families affected by flooding | 2,6 |

(Source: Research Results, 2025)

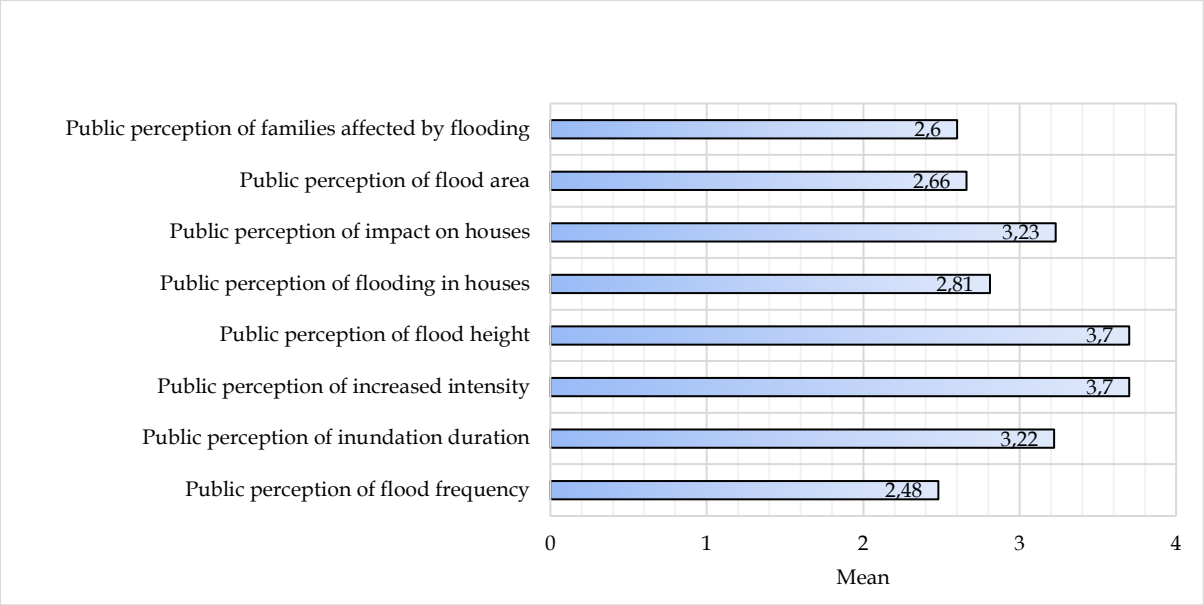



Figure 5. Graphic Perception of Flood Characteristics in the Kendal Watershed, Kendal District (Source: Research Results, 2025)

Regarding public awareness of environmental issues, data shows that the public has a high level of concern about changes in land use and their impact on the environment. The average awareness of land-use changes was 3.19, and awareness of the

environmental effects was 3.30, indicating that the public understands the ecological degradation occurring in the Kendal watershed. Sixty-eight percent of respondents strongly agreed that land use changes have occurred over the past five years (mean 2.92 – agree category). This is reinforced by the 77% of respondents who agreed that changes in land-use patterns have caused increased flooding (mean 3.11), and the 88% who stated that flood intensity has increased in recent years (mean 2.98).

On the other hand, the public assessed the drainage system's performance as less than optimal, with an average rating of 2.48. Most respondents stated that the drainage system was either not fully functioning or only partially functioning, thus failing to channel rainwater runoff optimally. This exacerbated the flooding's impact in densely populated areas.

Table 3. Public Perception of Land Use Change in Kendal Watershed, Kendal District

| Land Uses Indicator | Mean |
|---|---|
| Public perception of land use change in the last 5 years | 2,92 |
| Public perception of land use change increasing due to population growth | 2,76 |
| Public perception of land use change awareness | 2,92 |
| Public perception of development reducing water catchment areas | 3,3 |
| Public perception of land use change awareness on the environment | 3,19 |
| Public perception of land use change increasing intensity | 2,98 |
| Public perception of land use change awareness increasing flooding | 3,11 |
| Public perception of drainage system | 2,48 |

(Source: Research Results, 2025)

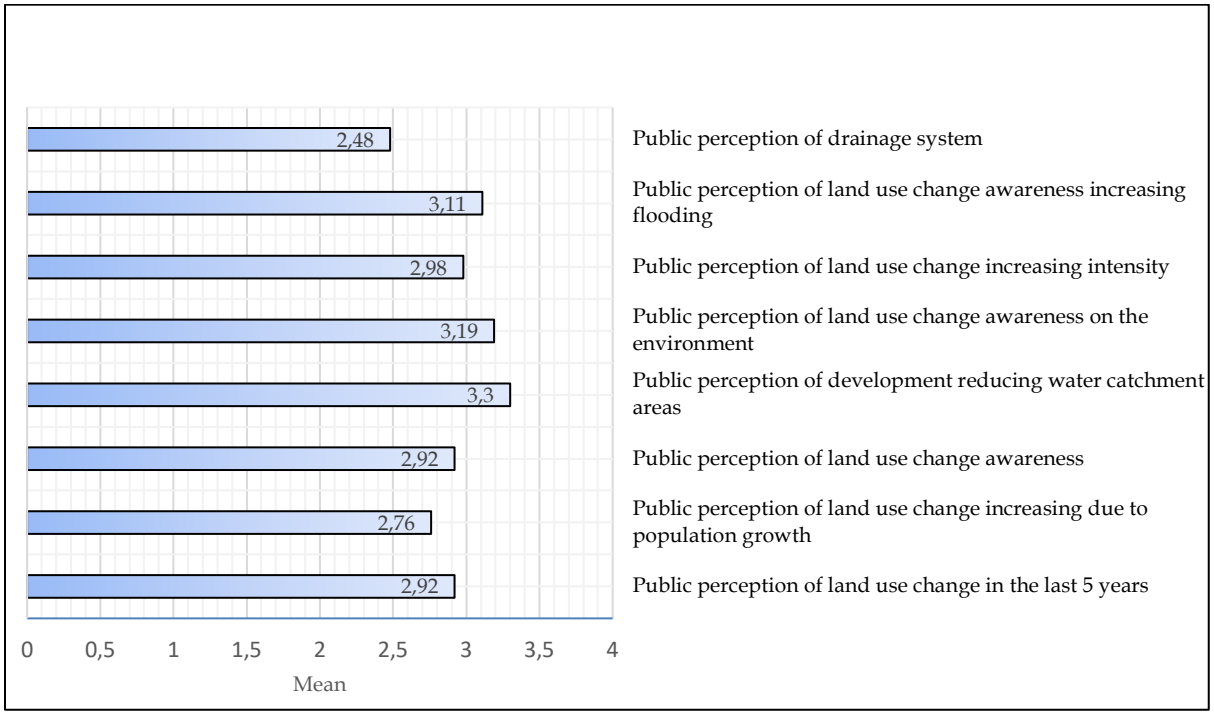



Figure 5. Graphic Public Perception of Land Use Change in Kendal Watershed, Kendal District
(Source: Research Results, 2025)

**Public Perception of the Social and Environmental Impacts of Flooding in the Kendal Watershed**

The flooding in the Kendal watershed had a significant social impact on community activities and well-being. According to respondents' perceptions, daily activities such as work, school, and mobility were disrupted,

with the majority (93%) stating that their activities were affected.

The average activity disruption score was 3.16, placing it in the moderate impact category. Furthermore, post-flood illnesses, such as diarrhea and dengue fever, were also experienced by some residents, with a mean score of 2.84, indicating the need for health service preparedness during floods.

Access to clean water was relatively unaffected (mean 2.41), and the incidence of displacement was relatively low (mean 2.28). However, the majority of residents had experienced flooding in the past 1–5 years, indicating that the social impacts were recurring and quite disruptive to community life. Respondents also noted the growth of social solidarity during and after the floods, demonstrated by high levels of community cooperation (mean 3.35).

Environmental Impact

From an environmental perspective, flooding in the Kendal Watershed significantly impacts the quality of people's living spaces. Perception results indicate that converting green areas to built-up areas reduces water catchment areas, which is the primary driver of increased flood risk. The average public perception score for this impact was 3.27, indicating a severe impact. Furthermore, residential and industrial development was also assessed as increasing the intensity and extent of flooding (mean 3.21).

Other environmental impacts experienced by the community included a dirty environment and the emergence of unpleasant odors during and after the flood, each with a mean of 3.26. This indicates poor sanitation and waste management during the disaster. Post-flood cleanup also takes time, with the majority of residents requiring 1–2 days to clean the affected area (mean 2.55 **).**

Table 5. Public Perception of Flood Impacts on Society and the Environment in the Kendal Watershed, Kendal District

| Flood Impacts Indicator | Mean |
|---|---|
| Public perception of disrupted activities | 3,16 |
| Public perception of increased illness | 2,84 |
| Public perception of access to clean water | 2,41 |
| Public perception of Public solidarity | 3,35 |
| Public perception of displaced residents | 2,28 |
| Public perception of reduced infiltration areas | 3,27 |
| Public perception of flood risk | 3,21 |
| Public perception of dirty environment | 3,26 |
| Public perception of smelly environment | 3,26 |
| Public perception of cleaning time | 3,16 |

(Source: Research Results, 2025)

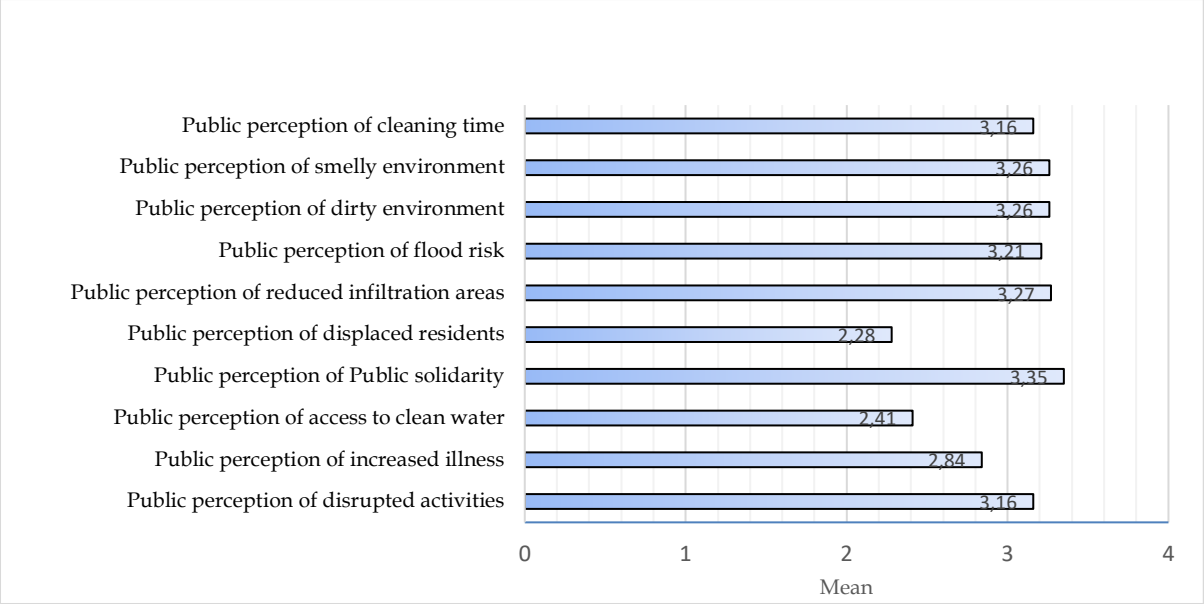



Figure 7. Graphic Public Perception of Flood Impacts on Society and the Environment in the Kendal Watershed, Kendal District (Source: Research Results, 2025)

**Land Use Changes in the Kendal Watershed in 2017, 2021, and 2025**

Land-use changes in the Kendal watershed show a significant trend from 2017 to 2025. Based on Sentinel-2A satellite imagery, the area previously dominated by agricultural land is gradually being converted to residential and other built-up areas. Rice fields, which were recorded at 1,115.02 hectares in 2017, decreased to 1,101.95 hectares in 2021 and further reduced to 1,070.47 hectares in 2025. These changes indicate a significant conversion during these two periods.

The conversion of agricultural land to residential areas occurred evenly across various zones of the Kendal watershed, particularly in the downstream regions adjacent to the city center and significant infrastructure. This change aligns with findings from ,Marhendi & Munir (2021), Mubarok et al. (2022) and Mulyani (2024), which show that population growth and housing development are direct drivers of land conversion. The increase in residential area, which reached 33.42 hectares between 2021 and 2025, demonstrates the high pressure of urbanization in this area (Handayani et al., 2020).

Furthermore, the decline in vegetation, such as mixed gardens, dry fields, and shrubs, indicates a decline in the area's ecological function. These results reinforce the argument that land-use change not only affects spatial aspects but also reduces the watershed's ecological capacity as a rainwater buffer and natural flood control system.

**Public Perception of Land Use Changes and Flooding in the Kendal Watershed**

The massive land-use changes occurring in the Kendal watershed are directly linked to increased flood frequency and duration. Most residents stated that flooding is no longer an incidental event, but rather a routine occurrence. This aligns with studies Hoirisky et al. (2018) in the Buah Palembang Watershed, which shows that the increase in flood points is in line with the conversion of open land into built-up land.

In addition to frequency, the duration of flooding in the Kendal watershed has also increased, with some locations reporting inundation lasting more than a day. Exacerbating factors are the low absorption capacity of the alluvial soil and the suboptimal drainage system. This is reinforced by the findings Suryani et al. (2020) which states that the conversion of non-built-up land such as rice fields into settlements will reduce the soil infiltration capacity.

Changes in water flow also occur due to significant infrastructure developments such as the Semarang-Batang Toll Road, which alters the direction of water flow and causes

flooding in residential areas. Settlements closer to riverbanks also increase the risk of flooding. These findings align with Cakrapravastha & Akliyah (2023), Saraswati et al. (2017), and Yin et al. (2022), which state that converting agricultural land to residential areas increases the extent and depth of flooding.

In line with Khoirunisa & Yuwono (2022) and Yendri et al. (2019), this shows that the growth of built-up areas is significantly correlated with the increase in flood frequency and intensity in urban areas. In Semarang City, the expansion of built-up land reached 59.8% in 2021, leading to an increase in flash floods.

This is comparable to conditions in the Kendal watershed, where the conversion of rice fields and shrubs into settlements gradually increases the volume of surface runoff and shortens the concentration time of the flow (Adi & Muladi, 2022; Rahardian & Buchori, 2016). Public perception supports this finding, with the majority of respondents strongly agreeing that changes in land use over the past five years have led to increased flood intensity (mean 2.98) and reduced catchment areas (mean 3.30).

**Public Perception of the Social and Environmental Impacts of Flooding in the Kendal Watershed**

Flooding impacts communities in various ways. In this study, the impact aspects used are social and environmental. From a social perspective, flooding in the Kendal watershed has disrupted community activities on a wide scale. Disruptions to work, education, and mobility indicate that flooding has reduced the overall quality of life. These findings align with research Mahulauw et al. (2023) which states that flooding triggers economic losses for households and reduces people's work productivity.

In addition, research findings indicate concerns about the potential for increased cases of diseases such as diarrhea, itching, flu, and other skin diseases, which generally arise from exposure to dirty water during a flood (Findayani, 2015).

Despite low access to clean water and low levels of displacement, the frequency of impacts remains high, indicating that flooding remains a real threat every year. This aligns (Qadriina et al., 2025). The high value on the cooperation indicator (mean 3.35) shows that disasters actually strengthen social solidarity.

Besides that, Antoine & Hsieh (2023) they stated that this solidarity is essential to building community resilience to disasters.

From an environmental perspective, the flooding was a direct consequence of ecological function degradation resulting from land-use changes (Lumban-Gaol et al., 2024). In line with the findings Nurhamidah et al. (2018), which state that converting vegetated land to residential and industrial areas results in the loss of natural water-catchment regions, increasing the potential for surface runoff during heavy rain.

This is in line with the findings Rizani et al. (2023) , Christian & Hendrasarie (2023) which state that urbanization without ecological mitigation increases the risk of runoff and reduces the quality of residential environments.

Poor post-flood sanitation, the emergence of foul odors, and the long cleanup time highlight that the waste management system and environmental infrastructure in the Kendal watershed are not prepared for recurring disasters. Therefore, an environmentally driven development strategy is needed that balances regional growth with protection of the watershed's ecological functions.

These findings have important policy implications. The observed land-use conversion and increased flood risk highlight the urgency of aligning regional development with national spatial planning regulations, such as Indonesia's Rencana Tata Ruang Wilayah Nasional (RTRWN) and Government Regulation No. 21 of 2021 on spatial planning implementation. Integrating watershed management into urban planning can strengthen local resilience to hydrometeorological disasters. From a broader perspective, these results are consistent with global climate adaptation frameworks such as the Sendai Framework for Disaster Risk Reduction and the Paris Agreement. Encouraging nature-based solutions, such as restoring green open spaces and strengthening urban infiltration systems, would contribute to both flood mitigation and the achievement of

Indonesia's Nationally Determined Contribution (NDC) targets.

**Research Limitations**

This study has several limitations that should be acknowledged. First, the spatial coverage is limited to the Kendal River Basin, which may not represent the hydrological and socio-environmental dynamics of other watersheds in Central Java or Indonesia. Second, the data collection period was relatively short, one month, so the findings may not fully capture seasonal variations in flooding or land-use dynamics. Third, although the questionnaire instrument was validated and statistically reliable, potential public perception biases, such as social desirability or recall bias, might still influence responses. Future research should involve a larger, more diverse sample, multi-seasonal data collection, and the use of more advanced inferential statistical models to generalize findings and strengthen causal inferences.

**Concluding Analytical Note**

Overall, this study provides empirical evidence that local-scale land-use dynamics are strongly linked to flood vulnerability in developing urban regions. While the results are contextually grounded in Indonesia, the observed trends resonate globally, underscoring the need for integrated watershed governance and adaptive spatial policies that balance urbanization and ecological integrity.

## CONCLUSION

Over the past eight years, the Kendal Watershed has experienced significant changes in land-use patterns, marked by shrinking rice paddies and expanding residential areas, particularly in downstream areas. Urbanization, unaccompanied by conservation strategies, has led to land conversion, reducing soil absorption capacity and increasing surface water runoff, increasing the risk of flooding. Community surveys indicate that flooding occurs quite frequently, even entering homes and lasting for several days. Flooding also impacts social and environmental aspects. Community activities are disrupted, and mobility is limited, while environmental sanitation quality declines and puddles mixed with waste appear. This situation is exacerbated by infrastructure that is not yet ready to handle flooding effectively. Therefore, an environmentally conscious development approach is needed to maintain a balance between regional growth and the protection of watershed ecological functions.

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