FORUM GEOGRAFI
ISSN: 0852-0682 | E-ISSN: 2460-3945

HTTPS://JOURNALS.UMS.AC.ID/INDEX.PHP/FG/

Research article

A Phenomenon of Disparity Between Regional Spatial Planning and Actual Land Use in the Citarum River Corridor, Indonesia

Iwan Setiawan*, Dede Rohmat, Suhendro

Department of Geography Education, Universitas Pendidikan Indonesia, Bandung 40111, Indonesia.

*) Correspondence: iwansetiawan@upi.edu

Citation:

Setiawan, I., Rohmat, D., & Suhendro, S. (2025). A Phenomenon of Disparity: Between Regional Spatial Planning and Actual Land Use in Citarum River Corridor, Indonesia. Forum Geografi. 39(3), 318-346.

Article history:
Received: 14 May 2025
Revised: 15 August 2025
Accepted: 8 September 2025
Published: 22 September 2025

Abstract

The Citarum River in Indonesia is a sensitive and strategic area and is known as the dirtiest river in the world. The root of the problem lies in the existence of gaps along the corridor that are not subject to regional spatial plan (RSP). This study aims to (1) present empirical data illustrating these spatial discrepancies, and (2) analyse the underlying factors contributing to them. A spatial analytical approach was employed, integrating geospatial technologies and an Autel EVO 2 Pro V3 drone, alongside questionnaire surveys based on multi-criteria decision analysis (MCDA) (37 respondents) and in-depth interviews with local communities (35 respondents). The analysis of Sector 3 exhibited the highest disparity (49.85%) in gap area coverage, while Sector 1 showed the lowest (9.41%). A comprehensive investigation was conducted using MCDA to examine the underlying causes of these discrepancies. The findings indicate that economic, environmental and socio-demographic factors; public knowledge of RSP; the role of RSP; and community engagement with RSP are the root causes of the observed disparities along the Citarum River corridor (Sectors 1–4). We recommend aligning RSP with actual geospatial conditions; adopting adaptive zoning; enforcing laws; and enhancing public outreach for sustainable Citarum River management.

Keywords: spatial disparity; current land utilization; regional development planning; Citarum river; river corridor land use.

1. Introduction

Water pollution in river systems has emerged as a global issue, with far-reaching implications for environmental sustainability, human health and economic stability. Several notable cases have been documented, including the Ganga River in India (Sigdel *et al.,* 2023; Singh *et al.,* 2025; Tiwari *et al.,* 2022); the Yangtze River in China (Shu *et al.,* 2024; Xiang *et al.,* 2022; J. Xu *et al.,* 2021; Y. Xu *et al.,* 2024); the Kuning River in China (Z. H. Li *et al.,* 2021; Quan *et al.,* 2022; Wang *et al.,* 2023; F. Xie *et al.,* 2022; Xie *et al.,* 2023; Xu *et al.,* 2024; Zhang *et al.,* 2021) and the Buriganga River in Bangladesh (Majed *et al.,* 2022; Pandit *et al.,* 2024; Rakib *et al.,* 2024). In Indonesia, the Citarum River is frequently cited as one of the most polluted rivers in the world. It has become the focus of various national strategic programmes, as stipulated in Presidential Regulation No. 15 of 2018. By 2013, it had already attracted significant attention due to its severe pollution levels.

The Citarum River is one of the most important rivers in Indonesia, holding strategic value as both an ecological and economic corridor. It not only supports the lives of surrounding communities and ecosystems (Marselina *et al.,* 2022), but also serves as an economic lifeline for the people of West Java, through to Jakarta (Pratiwi *et al.,* 2023). Unfortunately, severe environmental degradation and increasingly complex pollution have led to the river being labeled one of the most polluted in the world (Permatasari *et al.,* 2022). As highly vulnerable ecosystems, rivers are particularly affected by anthropogenic pressures, including land conversion, pollution and development activities (Best & Darby, 2020; Setiawan *et al.,* 2024; Tampo *et al.,* 2021). Consequently, the river corridor has become a focal point for addressing these challenges.

River corridors are defined as surface areas comprising land and water units that interact directly with rivers (Du *et al.,* 2025). However, their natural flow and functions are increasingly disrupted by ecological fluctuations and human activities. Rapid economic growth and urban expansion have worsened these conditions, which are manifested in land degradation, resource depletion, pollution, and the acceleration of global warming (Bosah *et al.,* 2023; Wu *et al.,* 2021; Yang *et al.,* 2024; Zhao *et al.,* 2023). Population growth has increased social interactions, in turn correlating with increased crime rates (Amirusholihin *et al.,* 2024; Norita *et al.,* 2024); reduced environmental carrying capacity; and potential long-term ecosystem damage (Rakuasa & Pakniany, 2022), along with significant changes in land control and property rights (Pradoto *et al.,* 2024). According to the Regulation of the Ministry of Agrarian Affairs and Spatial Planning/Head of the National Land Agency Number 11 of 2021, the Regional Spatial Plan (RSP), is defined as the outcome of spatial planning for a given territory, which constitutes a geographical unit together with all related elements, the boundaries and systems of which are determined based on administrative considerations. To overcome these challenges caused by anthropogenic activities challenges, spatial planning plays a crucial role.

Spatial use must be managed with a high-quality development orientation, and mediation in spatial planning is needed as a scientific tool to mitigate land conflicts and reduce developmental inequality (Yanbo *et al.,* 2023). However, in practice, a significant gap remains between spatial plans and actual land use. Rapid urbanisation has triggered uncontrolled land use and land cover transformations, further exacerbating the mismatch between ecological space availability and demand. Ecological degradation in response to ecological demand in the Yellow River Delta region (YRDR) is gradually becoming worse (Zhang *et al.,* 2024). This situation results in adverse outcomes such as habitat loss, declining biodiversity, soil erosion, and disrupted ecosystem processes (Peng *et al.,* 2023). These gaps are especially prominent in developing countries such as Indonesia, where land use conflicts often emerge due to mounting human activity (Yu *et al.,* 2025). Furthermore, overlaps between residential and agricultural zones contribute to social segregation and the degradation of habitat quality (Adam & Dadi, 2024; Li *et al.,* 2023; Tadesse & Baye, 2024) Amid consensus on the seriousness of this issue, key questions remain: Why does this phenomenon occur? And how does society perceive it? These questions form the basis of the novelty of our research.

Previous studies on the Citarum River have focused on various angles, such as the impact of land cover changes on ecosystem services using machine learning (Hakim *et al.,* 2025); spatial planning based on local wisdom and community aspirations (Rohmat *et al.,* 2024); land use analysis using remote sensing (Mukhoriyah *et al.,* 2023); and landscape dynamics (Dede *et al.,* 2024). However, most of these studies have not examined the underlying causes of spatial disparity in depth. Furthermore, previous research has primarily focused on landscape changes and have not empirically investigated the driving factors within the Citarum watershed (Ismail *et al.,* 2024). Several studies have examined place-based and multi-level governance in the context of urban river restoration (Novalia *et al.,* 2024); the construction of the Citarum Living Lab as a collaborative platform for shaping a shared vision of sustainable river revitalization (Hadfield *et al.,* 2024); and flood management policies in Bandung City, including potential strategies and challenges within the Upper Citarum area (Setiadi *et al.,* 2023). In addition, research has explored how different land use types affect the composition, distribution and functional guilds of macroinvertebrates in the upper reaches of the Citarum River (Pratiwi *et al.,* 2024).

Despite these contributions, many of the studies have provided no empirical analysis of the spatial planning disparity phenomenon, constituting a research gap which is addressed in this study. Therefore, our study aims to conduct an in-depth analysis of the disparity between regional spatial plans and actual conditions along the Citarum River corridor. Specifically, the objectives of the research are to (1) present a data-driven portrait of the spatial disparity along the Citarum River corridor in West Java Province, Indonesia, and (2) analyse the underlying factors contributing to this disparity. Through a comprehensive approach that integrates geospatial analysis with an in-depth investigation of causal factors, the study offers a methodological innovation. Given that our focus area is both strategic and environmentally sensitive, the application of a cross-sectoral perspective combined with an integrated analytical model constitutes significant added value. This approach positions the study as a reference sampling campaign that can inform policy-making for river restoration in other sectors of the same river system or in other rivers.

2. Research Methods

2.1. Overview of Method

This study employed a mixed-methods approach was employed, incorporating surveys and focus group discussions (FGDs). The methodological framework included both geospatial and regional planning approaches, combined with a critical review of local community perspectives on the observed disparities. The research was implemented systematically over several stages, as visualised in Figure 1.

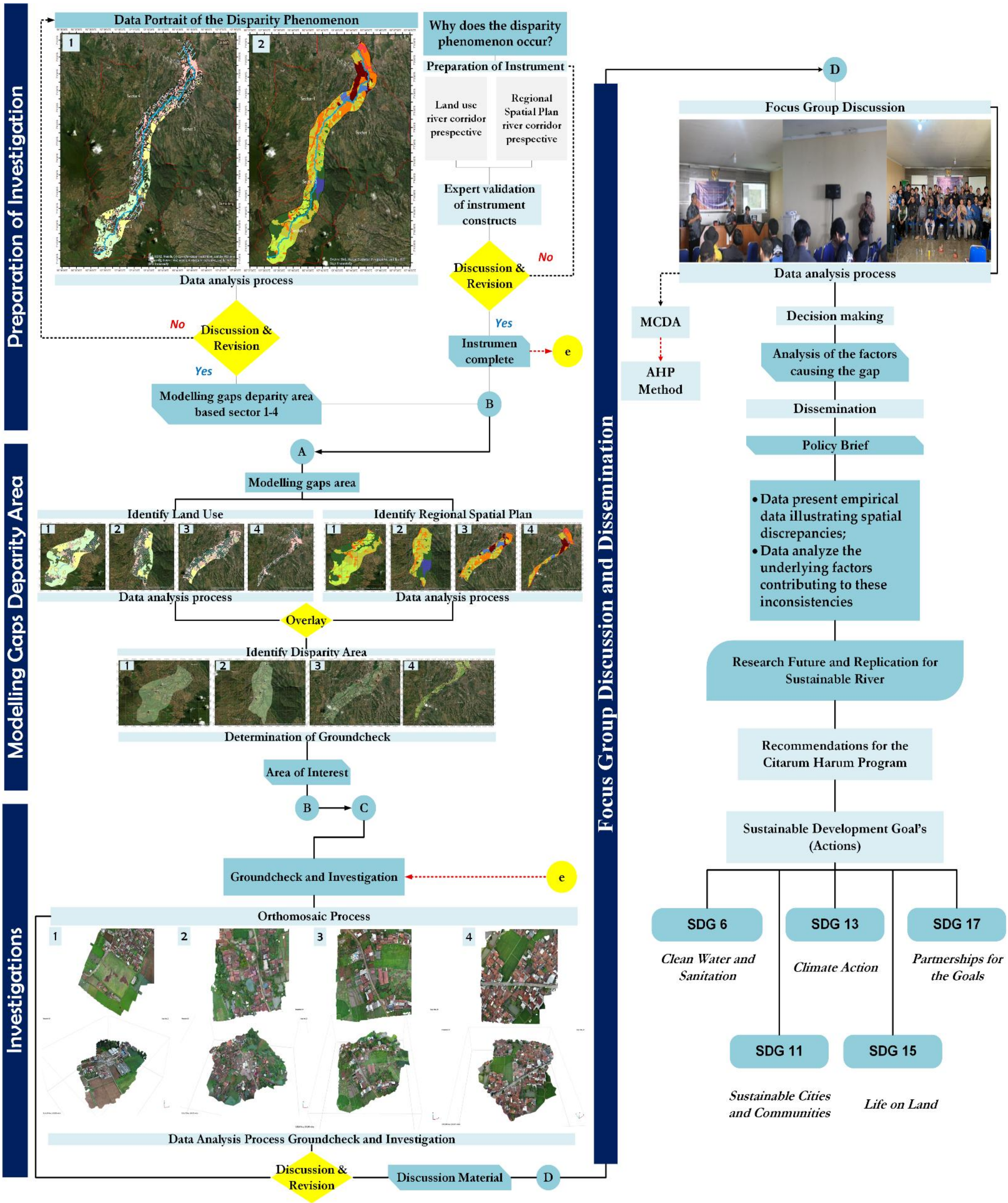

Figure 1. Research Procedure (Preparation, Modelling Gaps, Investigations, FGD and Dissemination).

2.1. Study Area

The research was conducted in the Citarum River area, specifically in the Cirasea sub-watershed located within the administrative region of Bandung Regency, Indonesia (Figure 2). Sampling was made in Sectors 1, 2, 3 and 4 to investigate the disparities between the regional spatial plan and actual land use conditions.

The justification for selecting the Cirasea sub-watershed as the research location was based on several strategic and ecological considerations. It is one of the areas experiencing considerable environmental pressure within the Citarum River Basin, primarily due to land-use conversion, intensive agricultural practices, and rapid urbanisation in Bandung Regency. Furthermore, this sub-watershed exhibits complex hydrological and topographical characteristics, making it representative of micro-scale environmental degradation dynamics within the broader context of the basin. Compared to other sub-watersheds, Cirasea also benefits from the availability of historical data and strong institutional support from local government and community stakeholders, enabling more in-depth and sustained research implementation. Consequently, the study of the Cirasea sub-watershed is not only scientifically relevant, but also practically significant in supporting rehabilitation efforts and the integrated management of the river basin.

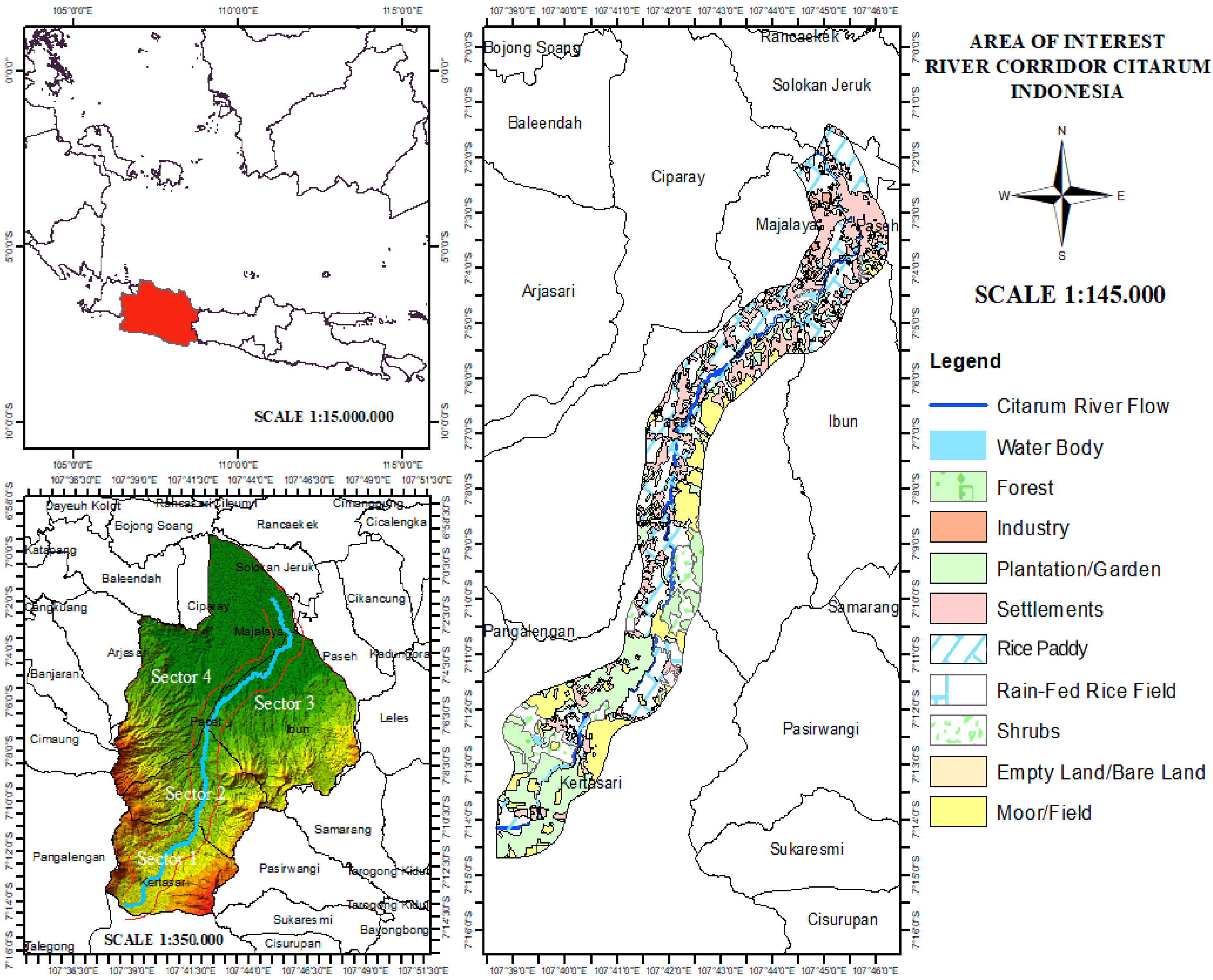

Figure 2. Study Area: Citarum River Corridor, Cirasea Sub-Watershed, Indonesia.

The sectors were determined based on a spatial approach relevant to the needs of field analysis, while also aligning with priority zoning within the framework of the Citarum Harum Program, which is a strategic government programme to revitalise the Citarum River Basin, as stipulated in Presidential Regulation No. 15 of 2018. The selection of the four sectors as part of the sampling campaign was intended to serve as a reference framework for replication in integrated watershed management in other locations. The investigation area was defined as the river corridor, which refers to the surface area consisting of land and water units that interact and are directly influenced by river dynamics (Du *et al.*, 2025). We argue that if the spatial planning within this corridor is poorly managed, it could significantly impact water quality (Rohmat *et al.*, 2024). A visualisation of the river corridor is provided in Figure 3.

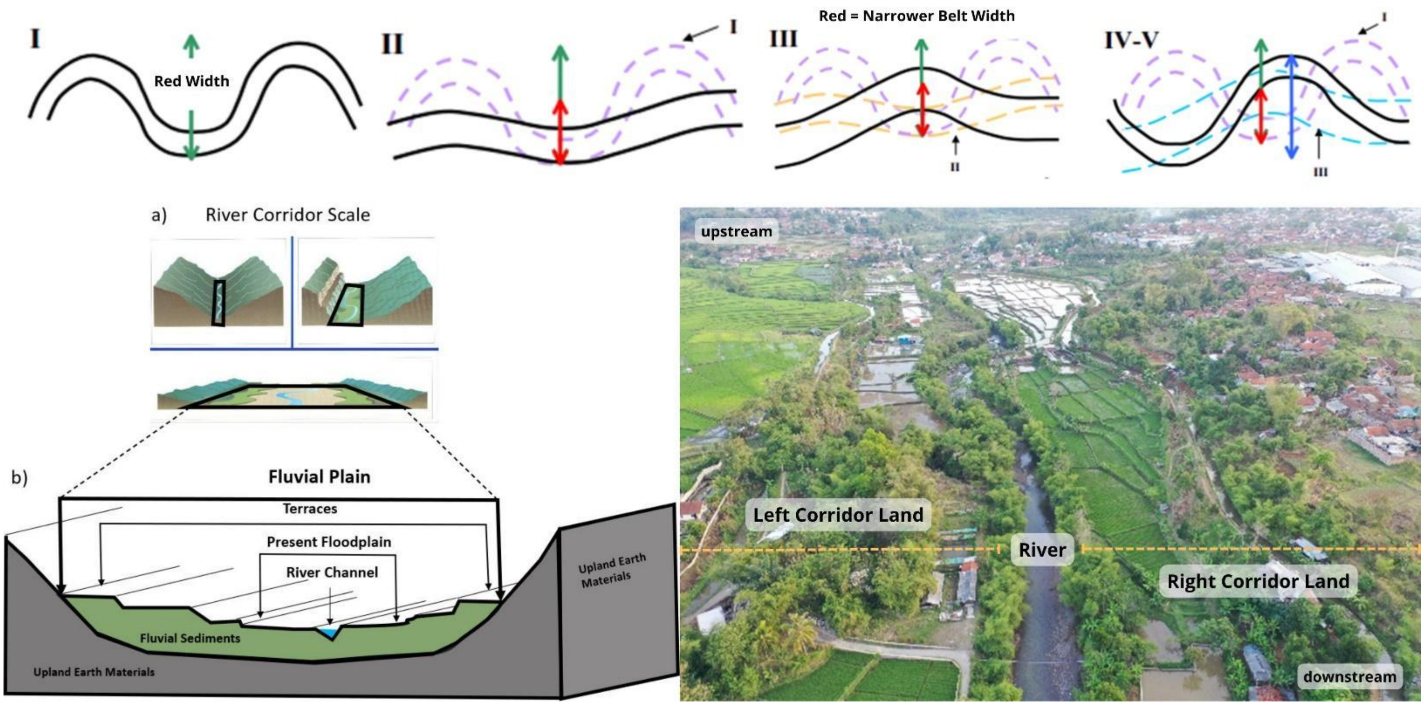

Figure 3. Visualisation of the River Corridor (Source: Modified from Bosché (2012); Rohmat et al. (2024) and Woessner (2020).

2.2. Participants

The investigation involved a range of participants to obtain comprehensive and in-depth data. In addition to aerial photography as the primary data source, we examined the gap areas through two complementary methods: focus group discussions (FGDs) and questionnaire distribution to local residents.

1) The FGDs involved 35 participants, comprising traditional leaders, local residents, community members, and local government officials. This approach was employed to identify the underlying factors, including socio-economic and spatial planning issues, contributing to the observed gaps along the river corridor from Sector 1 to Sector 4.

2) The questionnaires were administered in each sector where the gaps occurred. Participants were selected through accidental sampling, and voluntarily agreed to complete the questionnaire and participate in in-depth interviews. This process involved a total of 37 respondents, all selected from within the ground check areas.

2.3. Data Collection

To identify and assess the disparity between the regional spatial plan and actual land use, a variety of data sources were processed to gain a detailed understanding of the empirical conditions. The data sources used are listed in Table 1.

Table 1. Research Data Collection

Data Type	Data requirements	Data source
Primary Data	Aerial photographs	Photographs of the gap area using an Autel EVO 2 Pro V3 drone, processed using ArcGIS and Agisoft Metashape software.
	Focus group discussions	Discussions with local communities from each of the four sectors along the Citarum River corridor (Sectors 1, 2, 3 and 4).
	Distribution of questionnaires	The questionnaire was constructed based on previous literature reviews (Table 2), and focused on land use and regional spatial plans along the river corridors.
Secondary Data	Land use in 2024	USGS Satellite Imagery available at https://www.usgs.gov/landsatmissions/landsat-data-access
	Regional spatial plan for 2011-2031	Bandung Regency of Public Works and Public Housing (PUPR) Ministry (permission is required to access the data)
	Regional administration	Ina-Geoportal, which can be accessed at https://tanahair.indonesia.go.id/portal-web/
	Main river flow	River Basin Agency (BWWS) Citarum (permission is required to access the data)
	River sectorisation (sector 1, sector 2, sector 3 and sector 4)	Citarum River Basin Center (permission is required to access the data)

Data were collected using geospatial technology, including the Autel EVO 2 Pro V3 drone, with further data processing through ArcGIS and Agisoft Metashape software to identify discrepancies between actual land use and the Regional Spatial Plan. The rapid advances in photogrammetry and UAV technology has made aerial data collection more practical and cost-effective, enabling quick acquisition of high-resolution surface data (Hematang et al., 2024; Polat & Kaya, 2021). In addition, qualitative data were collected through FGDs and questionnaire distribution among residents, traditional leaders, community members, and local government officials to identify perceived causes of spatial disparity. The development of the instrument indicators used in the analysis is presented in Table 2.

Table 2. Indicators for Measuring the Discrepancy Between Spatial Planning and Actual Land Use

Variable	Symbol	Indicator's parameter	Option description	References
Land use in river corridors	X_1	Knowledge of river corridors	Knows or does not know	(Mazzorana *et al.,* 2018; Ward & Packman, 2019)
	X_2	Knowledge of land	Knows or does not know	(Richelle *et al.,* 2018; White, 2020)
	X_3	Knowledge of land use	Knows or does not know	(Brunet *et al.,* 2018; Mattsson *et al.,* 2018)
	X_4	Knowledge of land change	Knows or does not know	(Brown *et al.,* 2018; Tran *et al.,* 2018)
	X_5	Knowledge of land ownership	Owns land or does not own land	(Bush & Doyon, 2023)
	X_6	Actual condition of land use	Rice fields, housing, gardens, industry, fisheries, livestock	(Zhao *et al.,* 2023)
	X_7	Land ownership permits	Has a land ownership letter, but does not have land ownership papers	(Purnomo *et al.,* 2019; Wily, 2018)
	X_8	Land density	Very dense, dense, or not dense	(Dong *et al.,* 2020; Keeratikasikorn, 2018)
	X_9	Land suitability with regional spatial planning	Suitable or not suitable	(Hack *et al.,* 2020; Salviano *et al.,* 2021; Wei *et al.,* 2022)
	X_{10}	Intensity of land use socialisation activities	Socialisation has or has not been conducted	(Pazder, 2020)
	X_{11}	Availability of residents for relocation	Willing or not willing	(Wang *et al.,* 2021)
	X_{12}	Track record of land change	Knows about land change; not aware of land change; does not care about land change	(S. Feng *et al.,* 2022; Gollnow *et al.,* 2018; Tomsett & Leyland, 2019)
	X_{13}	Impact of land change	Environmental impact, economic impact, disaster impact, social impact	(Deberiostraat & Mwaijengo, 2020; Fernandes *et al.,* 2020; J. Li et al., 2022)
	X_{14}	Factors causing land change	Environment, social demographics, and economy	(Cui *et al.,* 2021; Qu *et al.,* 2021)
Regional spatial plan along the river corridor	X_{15}	Knowledge of regional spatial planning	Knows or does not know	(L. Huang *et al.,* 2022)
	X_{16}	Intensity of socialisation of regional spatial planning	Has or has not been conducted	(Balta & Yenil, 2019; S. Lin *et al.,* 2024)
	X_{17}	Role of spatial planning policies in society	Very important or not important	(Mazzorana *et al.,* 2018; Meng *et al.,* 2019)
	X_{18}	Conflict between society and government	Very often, rarely occurs, or never happens	(Baigún & Minotti, 2021; Y. Lin *et al.,* 2022; Mazzorana *et al.,* 2018)
	X_{19}	Incompatibility with building layout	Has or has not occurred	(Jahani & Barghjelveh, 2021)
	X_{20}	Building layout permits	Agree or disagree	(Cialdea & Pompei, 2022; Jasim *et al.,* 2024; Ren *et al.,* 2018)
	X_{21}	Perspective of regional spatial planning as an obstacle to regional development	Agree or disagree	(Bonakdar & Audirac, 2021)
	X_{22}	Residents are enthusiastic about regional spatial planning policies	Agree or disagree	(H. Xu *et al.,* 2020)

2.4. Data Analysis

The field data were analysed using geospatial methods to identify areas with the most significant disparities. This was achieved by overlaying spatial planning data onto current land use data to delineate gap areas. A binary scoring system was employed: suitable areas were scored as [Equation 1] and non-suitable areas as (0), facilitating the generation of a gap map through GIS processing. As noted by Somantri (2024), GIS tools enhance spatial analysis by providing visual elements that aid in interpreting area-related data (in hectares). In this equation, ARSP,i represents regional spatial plan areas and AFactual,I Factual land use conditions.

$$A_{Gap,I} = [\ A_{RSP,i} - A_{Factual,i}\ ] \quad (1)$$

Using Calculate Geometry on the attributes of the overlay polygon to obtain A_{Gap}, the result related to the most significant gap area obtained became our consideration for conducting a ground check (GC) on each sector. In this case, we defined the two terms in the gap area as follows:

1) Conforming Pattern, an area or actual condition that conforms to local spatial planning.
2) Non-conforming Pattern, an area or actual condition that does not conform to local spatial planning.

The formulation for standardising the gap area is shown in Equations 2 - 4, where S_i is the area of suitable land in sector i (hectares); S_{total} is the total suitable area across all sectors (hectares); N_i is the area of non-suitable land in sector i (hectares); N_{total} is the total non-suitable area across all sectors units (hectares); A_i is the area of suitable or non-suitable land in sector i (hectares); and $A_{total,i}$ is the total area of sector i (hectares).

$$Suitable\ Area\ Percentage_i = \frac{S_i}{S_{total}} \times 100\% \quad (2)$$

$$Non-Suitable\ Area\ Percentage_i = \frac{N_i}{N_{total}} \times 100\% \quad (3)$$

$$Area\ Percentage\ Relative\ to\ Sector_i = \frac{A_i}{A_{total,i}} \times 100\% \quad (4)$$

Once the gap areas were identified, the largest priority areas (measured in hectares) were selected for ground verification. Orthomosaic data were then processed using 3D modeling techniques to visualise these locations in high detail (Figure 4).

Figure 4. Modelling of Gap Areas: (a) 2D Orthomosaic Model; (b) 3D Orthomosaic Model.

Orthomosaic modeling, based on UAV imagery, offers a practical alternative for producing very high-resolution images, an essential advantage for land monitoring (Hematang *et al.,* 2024). It also supports the effectiveness of field ground checks. As spatial assessments and mapping become increasingly vital in guiding and mobilising regional resources, this methodological approach aligns with best practices in regional development studies (Tang *et al.,* 2025).

Data analysis was also conducted by considering the R-squared value to identify the contribution of the influence of the gap on the position of the sector from upstream to downstream (Equations 5 - 6). Equation 5 is the general equation of linear regression (Montgomery *et al.,* 2021), where a is the slope or inclination of a line; b is the intercept or intersection point; x_i is the value of the independent variables or specific sectors; y_i is the dependent variable value or percentage of the suitable area; $\bar{x}$ is the mean of x_i; and $\bar{y}$ is the mean of y_i. The contribution value or proportion of variation y that can be explained by x (R^2) (Equation 6).

$$y = ax + b \quad (5)$$

Each variable is equal to :

$$a = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^{n}(x_i - \bar{x})^2} \quad (5a)$$

$$b = \bar{y} - a\bar{x} \quad (5b)$$

$$R^2 = \frac{[\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})]^2}{[\sum_{i=1}^{n}(x_i - \bar{x})^2][\sum_{i=1}^{n}(y_i - \bar{y})^2]} \quad (6)$$

through the criterion of $0 \leq R^2 \leq 1$

Furthermore, the processing of FGD data was conducted qualitatively by revealing the issues of spatial discrepancies along the river corridor, while the analysis of the questionnaire results was made using percentage calculations, compiled incidentally in each study sector. The formulation developed to determine the percentage of each indicator in processing community perspectives on the river corridor and the regional spatial plan was based on the Multi-Criteria Decision Analysis (MCDA) approach of Sipahi and Timor (2010) and Saaty (2013) (Equations 7 - 9).

$$a'_{jk} = \frac{a_{jk}}{\sum_{p=1}^{n} a_{pk}} \quad (7a)$$

$$w_j = \frac{1}{n}\sum_{k=1}^{n} a'_{jk} \quad (7b)$$

$$\lambda_{max} \approx \frac{1}{n}\sum_{j=1}^{n} \frac{(Aw)_j}{w_j} C \quad (7c)$$

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (7d)$$

$$CR = \frac{CI}{RI} \quad (7e)$$

where a_{jk} represents a comparison value between criteria j to k; a'_{jk} represents the normalized result value of a_{jk}; symbol n is the total criteria; and p represents row indices on the comparison matrices. CI is the Consistency Index; CR the Consistency Ratio; and RI represents the Random Index, or reference value from Saaty, depending on the number of criteria (Equation 7).

$$r_{ij} = \frac{x_{ij} - x_{ij}}{x_{ij} - x_{ij}} \quad (8)$$

$$S_i = \sum_{j=1}^{n} w_j \cdot r_{ij} \quad (9)$$

where x_{ij} represents the original value of alternative i for criterion j; r_{ij} is a normalized value; S_i represents the final score of alternative i; w_j represents the weight of criterion j from AHP; and r_{ij} is the normalized value of alternative i on criterion j. A higher value for Si indicates a higher priority (Equations 8 - 9).

Furthermore, qualitative analysis was conducted employing the triangulation method, integrating multiple sources of information gathered throughout the investigation. This procedure served to cross-verify the responses between the participants, thereby enhancing the validity, consistency and credibility of the findings while minimising potential bias.

3. Results and Discussion

3.1. Data Portrait of the Disparity Phenomenon

Based on the investigations, several key findings were identified, which are presented as data portraits for each sector. The purpose of these portraits is to visualise current land use, highlight areas where discrepancies exist between actual land use and the regional spatial plan, and support these findings with field data observations. Each sector is explained in detail below.

1. Investigation of Sector 1

We conducted ground checks at several locations to visualize the actual situation (Figure 5). Sector 1, situated within the Kertasari District of Bandung Regency, is classified as a rural area. The inherent value of rural environments as residential settings extends beyond their agricultural and economic foundations to encompass the ecological and aesthetic benefits derived from agricultural landscapes, including scenic vistas and open spaces (Dai *et al.,* 2023; Inglis *et al.,* 2023). However, the intricate nexus between agricultural land utilisation and demographic dynamics underscores the paramount importance of judicious land management in maintaining the long-term economic and social viability of rural communities (Lillemets *et al.,* 2025). A salient challenge in this context is land fragmentation, which can significantly impede agricultural productivity and profitability (Janus *et al.,* 2023). Furthermore, modifications in land cover patterns exert a direct influence on the volume and quality of surface water runoff, with the different imperviousness characteristics of industrial, commercial and residential land uses resulting in distinct hydrological responses (Simpson *et al.,* 2022; Taşkın & Manioğlu, 2024).

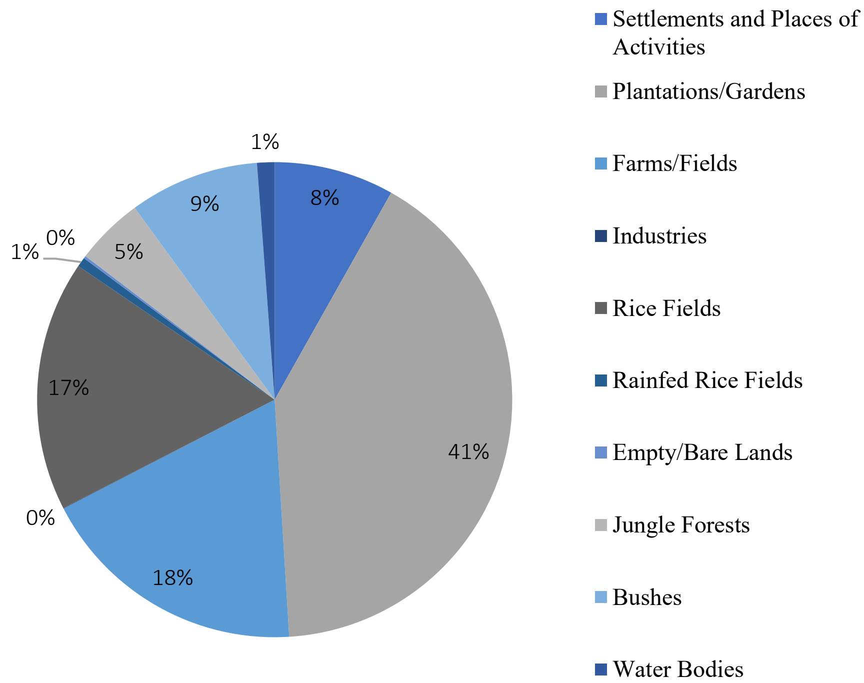

Figure 5. Data Portrait of Sector 1 Land Use.

The findings show that sector 1 is dominated by plantation land use, as climate factors support the elevation in this area. If we examine the land mismatch in this region, we arrive at an area of 16.16 hectares (Table 3), so it can be considered to be the smallest of the four sectors experiencing the phenomenon of inequality.

Table 3. Portrait of Sector 1 Disparity Data.

Pattern Deviation	Land Area (Ha)	Location
Conforming Pattern	2181.39	Kertasari, Bandung Regency, Indonesia
Non-conforming Pattern	16.16	

We identified several areas with disparities that are dominated by conversion to industrial activities. For example, the field findings indicate that tea factories have been built since the Dutch Colonial era (Figure 6a). Moreover, anthropogenic activities, particularly the presence of residential areas, constitute the largest gap area, covering 11.01 ha out of the total 16.16 ha. Between 2019 and 2023, the Kertasari Subdistrict Statistics Agency reported continuous population growth, increasing from 71,779 inhabitants in 2019, to 71,992 in 2020, 72,787 in 2021, 73,836 in 2022, and 74,511 in 2023 (BPS, 2024a). This population growth is a key driver of the spatial gap in Sector 1.

We identified several contributing factors were identified, including: (a) residential expansion, driven by the development of housing complexes in South Bandung (Hakim *et al.,* 2019); (b) urbanisation and increased population mobility (Atharinafi & Wijaya, 2019), coupled with improved infrastructure and public services such as schools, healthcare facilities and enhanced accessibility; and (c) economic expansion, including the development of plantation estates (Hakim *et al.,* 2019). The appeal of exotic tourism destinations, such as “0 Km Citarum,” and picturesque plantation landscapes draws visitors to the area, some of whom settle there and invest in the development of lodging facilities.

Figure 6. Documentary portrait of the Kertasari area in Sector 1: (a) Portrait of the Kertasari settlement; (b) Example of easy accessibility, categorised as good; (c) Portrait of Cisanti 0 Km Citarum; (d) Portrait of the Kertasarie, a tea factory from the Dutch colonial era.

Below, the dominant land use in the gap area in Sector 1 is described quantitatively. Specifically, the land area disparity is presented in Table 4. The phenomenon of disparity areas is largely dominated by the existence of residential areas, followed by industrial areas.

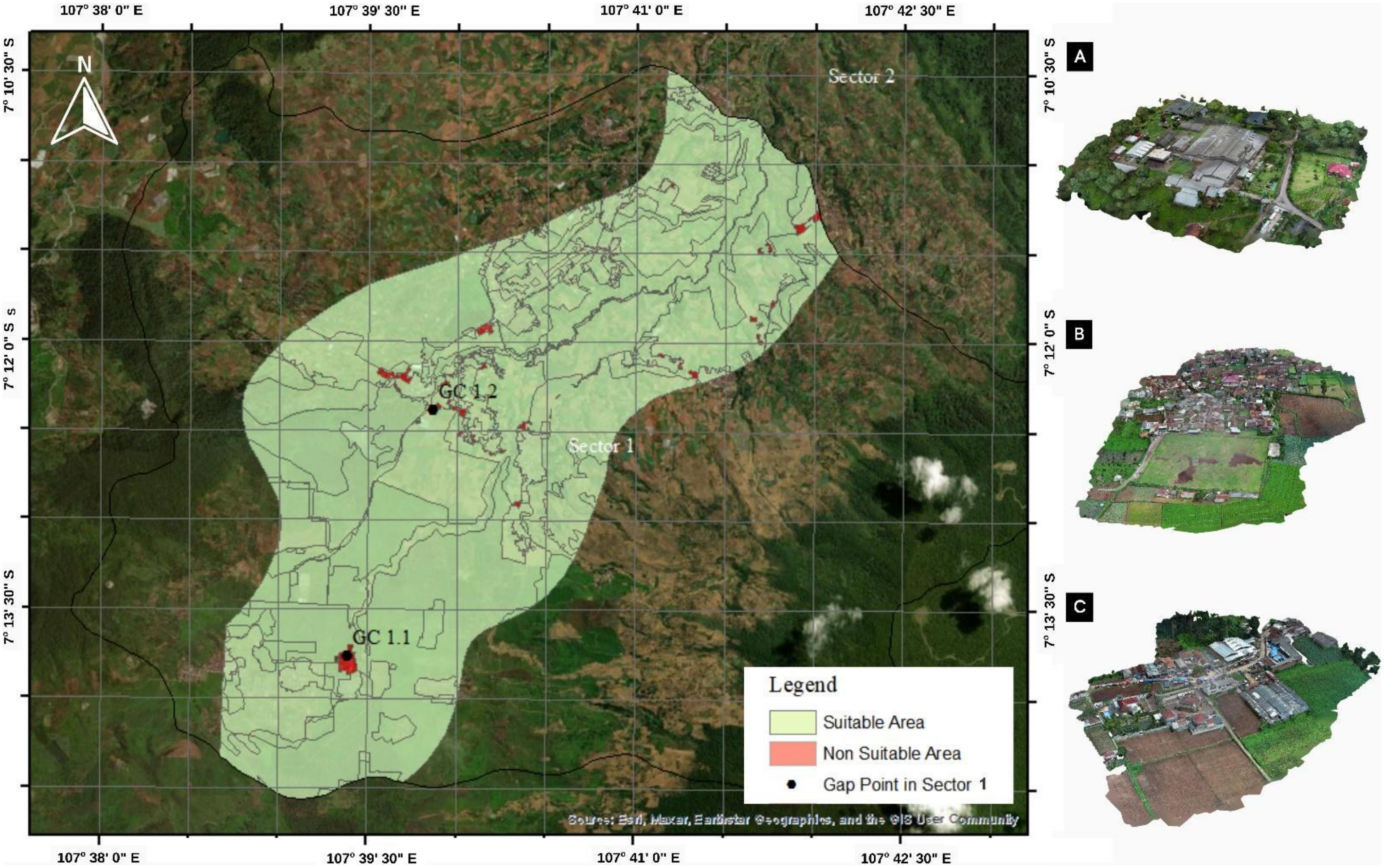

Figure 7. Sector 1 Investigation Point Distribution: (a) Land Disparities from Wet Agriculture to Industrial Areas (GC 1.1); b) Land Disparities from Wet Agriculture to Settlements (GC 1.2); and (c) Land Disparities from Residential Areas to Industrial Areas (GC 1.3).

Table 4. Sector 1 Disparity Data Specifications.

Spatial Planning	Actual Conditions	Pattern deviation	Σ (Ha)	AOI
Wetland Agricultural Area	Industrial Area	Non-conforming	2.16	QC 1.1
Wetland Agricultural Area	Settlements	Non-conforming	11.01	QC 1.2
Residential Area	Industrial Area	Non-conforming	2.35	QC 1.3
Protected Forest	Industrial Area	Non-conforming	0.004	None
Annual Crop Area	Industrial Area	Non-conforming	0.62	None

This situation depicted in Figure 7 is further compounded by the progressive conversion of agricultural land to industrial zones, engendering substantial concerns regarding food security, diminished agricultural output, and a contraction of the agricultural labour force (Zhang *et al.,* 2023). Numerous developing nations, including India and China, have witnessed extensive transformations of agricultural land for industrial purposes concomitant with periods of economic expansion (Zhang *et al.,* 2023). However, imprudent land conversion practices can render previously productive land economically unviable and may even exacerbate global warming and climate change (Huang *et al.,* 2023; Zhang *et al.,* 2023). Moreover, industrial expansion poses a considerable threat to ecological systems; intensifies the impacts of climate change; and leads to a reduction in biodiversity (Kennedy *et al.,* 2023; Salviano *et al.,* 2021). Since the 20th century, while urbanisation and industrialisation have served as primary drivers of economic development, environmentally unsustainable governmental policies have facilitated the widespread proliferation of construction land and a corresponding depletion of natural resource endowments (Xie *et al.,* 2023).

1. Investigation of Sector 2

In contrast to Sector 1, Sector 2 is predominantly characterised by its agrarian landscape (Figure 8), exhibiting a notable prevalence of paddy cultivation, encompassing both irrigated and rain-fed systems, alongside open fields and moorland. However, preliminary indications suggest a nascent trend towards the development of residential settlements, and an associated reduction in forested areas within this sector. While dedicated industrial zones are not currently discernible, the increasing presence of settlements may serve as a leading indicator of future land conversion pressures, particularly in the absence of stringent regulatory frameworks governing land use.

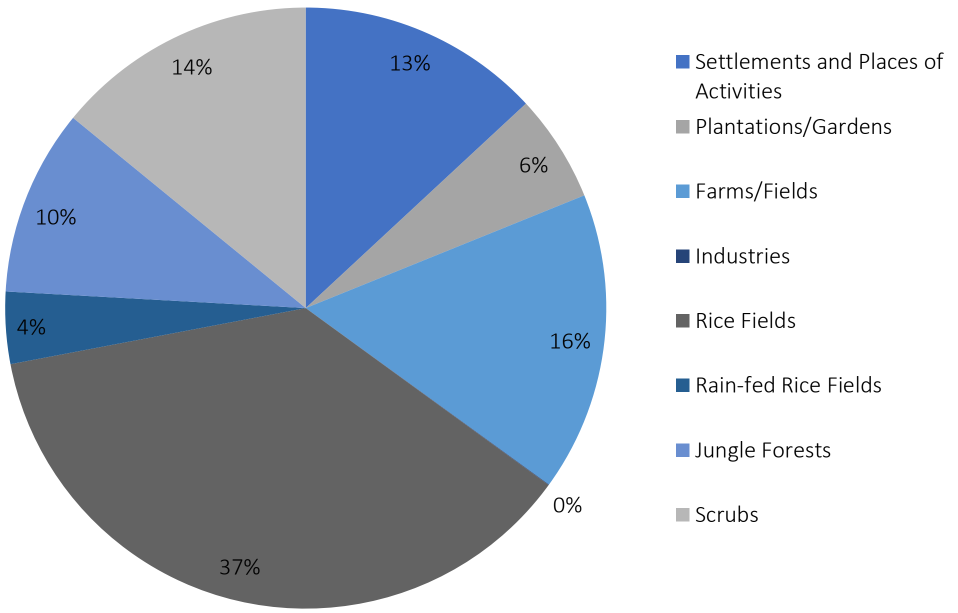

Figure 8. Data Portrait of Sector 2 Land Use.

The data overview highlights the dominance of land in Sector 2, primarily consisting of rice fields (37%), which serve as the primary source of livelihood due to the area's highly fertile morphology and climate which is well-suited for rice cultivation. Furthermore, we also identified a gap area totalling 20.14 hectares (Table 5), a higher figure than in Sector 1.

Table 5. Sector 2 Disparity Investigation.

Pattern Deviation	Land Area (Ha)	Location
Conforming Pattern	1399.65	Kertasari-Pacet,
Non-conforming Pattern	20.14	Bandung Regency, Indonesia

Administratively, Sector 2 covers parts of Kertasari and Pacet. Population growth in both areas was identified based on data from the Central Statistics Agency in Pacet Subdistrict, which showed a total population of 114,075 in 2019; 115,066 in 2020; 120,997 in 2021; 124,594 in 2022; and 126,819 in 2023 (BPS, 2024b). These data indicate that the population growth rate continues to increase year by year. Similar to Kertasari, Pacet is an area with a cool climate and tourist destinations that support its appeal, making it no surprise that the region is one of the targets for urbanisation by the city of Bandung. Urbanisation is considered as an increase in the number and density of urban populations, causing changes in rural life (Suhendro, 2021). This is closely related to the current conditions at both locations. Additionally, improvements in the quality of life, such as education, healthcare and the economy, including the presence of cafes, Pertamina stations, markets and others, play a role in the process (Figure 9). These three Human Development Index factors can trigger inbound migration, while also driving natural growth.

Figure 9. Documentary portrait of the Kertasari and Pacet areas in Sector 2: (a) Local residents' economic activities utilising the Citarum River, such as fishing for small fish; (b) Portrait of the cool climate in Pacet; (c) Portrait of the existence cafe in one of the local residents' economic expansion areas.

The land use dominance occurring in the gap area for sector 2 was identified, and is presented in Table 6. Despite the general conformity of Sector 2 land use with the Regional Spatial Plan (RSP), preliminary analysis revealed evidence of unauthorised land conversion affecting approximately 20.14 hectares. These deviations from the designated land use predominantly involve the transformation of irrigated agricultural land and production forests into residential zones. Such non-compliance warrants diligent monitoring and follow-up due to its potential ramifications for local food security, ecosystem equilibrium, and the integrity of regional spatial governance. Furthermore, our investigation identified several instances of spatial discrepancies within the Citarum River corridor, which are visually documented in Figure 10.

Table 6. Land Area Specifications (Sector 2).

Spatial Planning	Actual Conditions	Pattern Deviation	Σ (Ha)	AOI
Wetland Agricultural Area	Settlements	Non-conforming	8.40	QC 2.1
Wetland Agricultural Area	Settlements	Non-conforming	10.37	QC 2.2
Production Forest	Settlements	Non-conforming	1.37	QC 2.3

Within Sector 2, specifically along the Kertasari to Pacet corridor in Bandung Regency, discernible instances of land-use change from wet agricultural land to residential areas were observed. This transformation has precipitated a range of environmental and social consequences. Parallels can be drawn with research conducted in the Johor River Basin, Malaysia, which indicated that such conversions can significantly alter river morphology, modify hydrological flow regimes, and raise the potential for fluvial inundation (Kang & Kanniah, 2022). Furthermore, alterations in land cover have been shown to exert a substantial influence on land surface temperature (LST), a critical determinant in the dynamics of climate change (Tabassum *et al.,* 2023). Consequently, for governments in the Southern Hemisphere to formulate efficacious mitigation and adaptation strategies, a comprehensive approach is imperative, one that explicitly addresses the intricate interdependencies between land use and land cover change (LULC) and increased surface temperatures (Tabassum *et al.,* 2023).

It is crucial to acknowledge that rural transformation driven by land conversion engenders significant shifts in the socio-economic fabric of the region. This process encompasses not only the displacement of traditional agricultural practices, but also a fundamental redefinition of rural area functions, patterns of inter- and intra-sectoral population migration, and the development of new interrelationships between the primary (agricultural) sector and secondary/tertiary sectors, such as residential and service industries (Wang *et al.,* 2023). These multifaceted changes necessitate the adoption of more integrated spatial planning frameworks to effectively minimise adverse impacts on both the environment and rural communities.

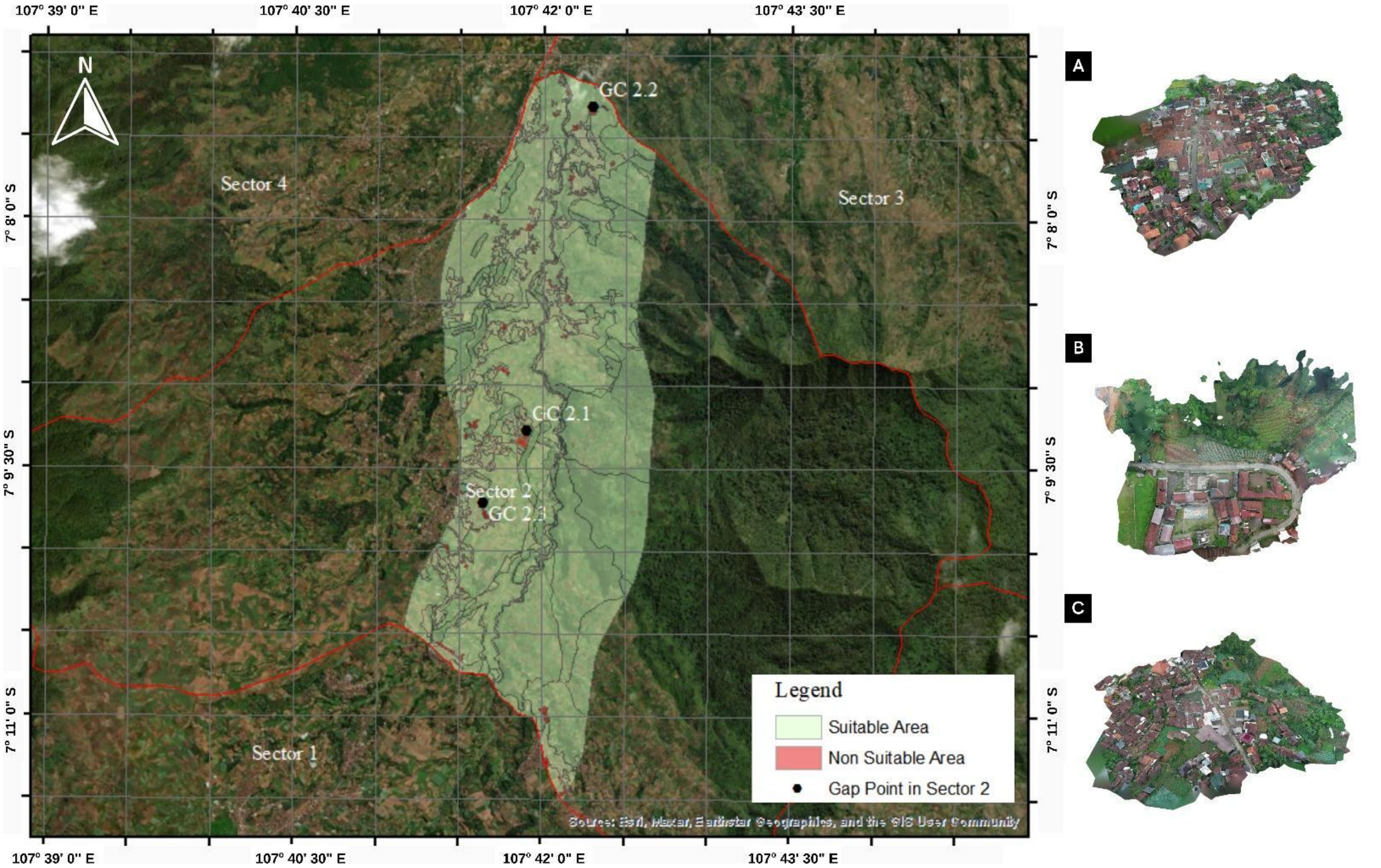

Figure 10. Sector 2 Investigation Point Distribution: (a) Land Disparities from Wet Agriculture to Settlements (GC 2.1); (b) Land Disparities from Wet Agriculture to Settlements (GC 2.2); (c) Land Gaps from Wet Agriculture to Settlements (GC 2.3).

2. Investigation of Sector 3

Sector 3 is characterised by a predominance of agricultural land (Figure 11), with rice fields constituting the most significant proportion (42.55%), followed by moorlands and open fields. However, the significant presence of settlements, accounting for approximately 32% of the land cover, warrants further investigation due to its potential to drive increasingly widespread conversion of agricultural land. In contrast to Sector 2, the limited extent of industrial land conversion suggests that this sector has thus far remained relatively unaffected by industrial development pressures.

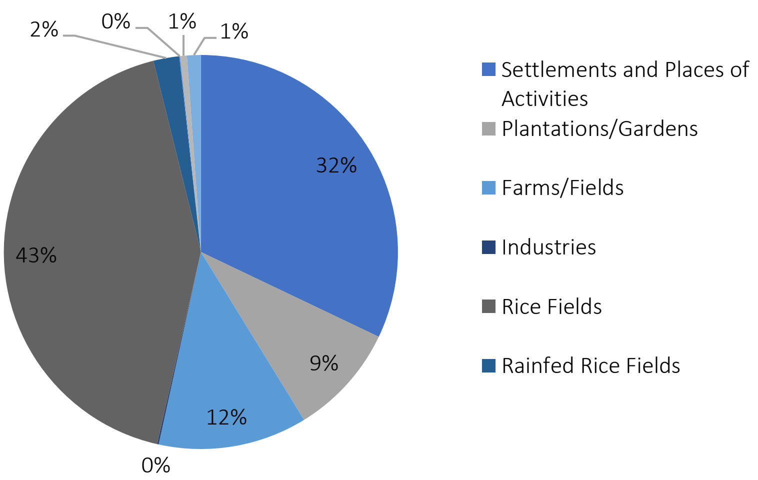

Figure 11. Data Portrait of Sector 3 Land Use.

While the majority of land use in Sector 3 aligns with the prevailing spatial plan, a notable deviation of approximately 85.6 hectares was identified. This discrepancy is significant enough to necessitate an in-depth analysis to ascertain its causes and potential consequences. Similar to the preceding sectors, several locations of spatial incongruities within the Citarum River corridor have been identified and are visually represented in Figure 13. Detailed specifications regarding the land area distribution within this sector are presented in Table 7.

Table 7. Sector 3 Disparity Investigation.

Pattern Deviation	Land Area (Ha)	Location
Conforming Pattern	1530.18	Ibun-Majalaya,
Non-conforming Pattern	85.60	Bandung Regency, Indonesia

The investigation of Sector 3 covers two administrative districts, Ibun and Majalaya. The disparities in this sector are more dominant in residential areas, industrial areas and rice fields, which means that the area can be described as undergoing intensive urbanisation. Therefore, it is no surprise that the population growth rate has continued to rise over the past four years, starting from a total of 87,020 people in 2020, to 90,026 in 2021, 92,552 in 2022, and 93,831 in 2023 (BPS, 2024c). These figures reflect the growing disparity in zones such as residential areas as places of residence; industrial zones as sources of employment; and agricultural lands as means of livelihood (Figure 12).

Figure 12. Documentary portrait of the Ibun river corridor area in Sector 3: (a) Portrait of settlements in the river corridor; (b) Portrait of rice fields in the river corridor; (c) Portrait of industry in the river corridor.

We specifically identified which areas were quantitatively disadvantaged, as presented in Table 8. Rapid development has put pressure on land resources (Miswar et al., 2023). Agricultural land within Sector 3 is currently subject to significant conversion pressures, primarily driven by the expansion of residential and industrial zones.

Table 8. Land Area Specifications (Sector 3).

Spatial Planning	Actual Conditions	Pattern Deviation	Σ (Ha)	AOI
Fishing Area	Settlements	Non-conforming	9.54	QC 3.1
Residential Area	Rice Fields	Non-conforming	39.49	QC 3.2
Fishing Area	Settlements	Non-conforming	11.90	QC 3.3
Wetland Agricultural Area	Industrial Area	Non-conforming	1.60	None
Wetland Agricultural Area	Settlements	Non-conforming	9.38	None
Residential Area	Industrial Area	Non-conforming	0.83	None
Wetland Agricultural Area	Industrial Area	Non-conforming	1.21	None
Wetland Agricultural Area	Settlements	Non-conforming	1.03	None
Residential Area	Industrial Area	Non-conforming	0.31	None
Wetland Agricultural Area	Settlements	Non-conforming	10.6	None
Border	Settlements	Non-conforming	0.75	None
Wetland Agricultural Area	Industrial Area	Non-conforming	1.60	None
Wetland Agricultural Area	Settlements	Non-conforming	9.38	None
Residential Area	Industrial Area	Non-conforming	0.83	None
Wetland Agricultural Area	Settlements	Non-conforming	1.21	None
Wetland Agricultural Area	Industrial Area	Non-conforming	1.03	None
Residential Area	Settlements	Non-conforming	0.31	None
Wetland Agricultural Area	Industrial Area	Non-conforming	10.6	None
Border	Settlements	Non-conforming	0.75	None

From the total land area of 1,615.78 hectares in this sector, approximately 5.3% (85.60 hectares) is currently utilised in a manner inconsistent with the designated land use outlined in the Regional Spatial Plan. This pattern of land conversion reflects broader trends associated with urbanisation and industrial growth, which pose a potential threat to local food security and the critical ecological functions of wetland ecosystems within the area. This is because agriculture plays an important role in the Indonesian economy and is the main source of livelihood for most of the rural population (Anja, 2024). As previously noted, several locations exhibiting spatial incongruities within the Citarum River corridor have been identified and are visually documented in Figure 13.

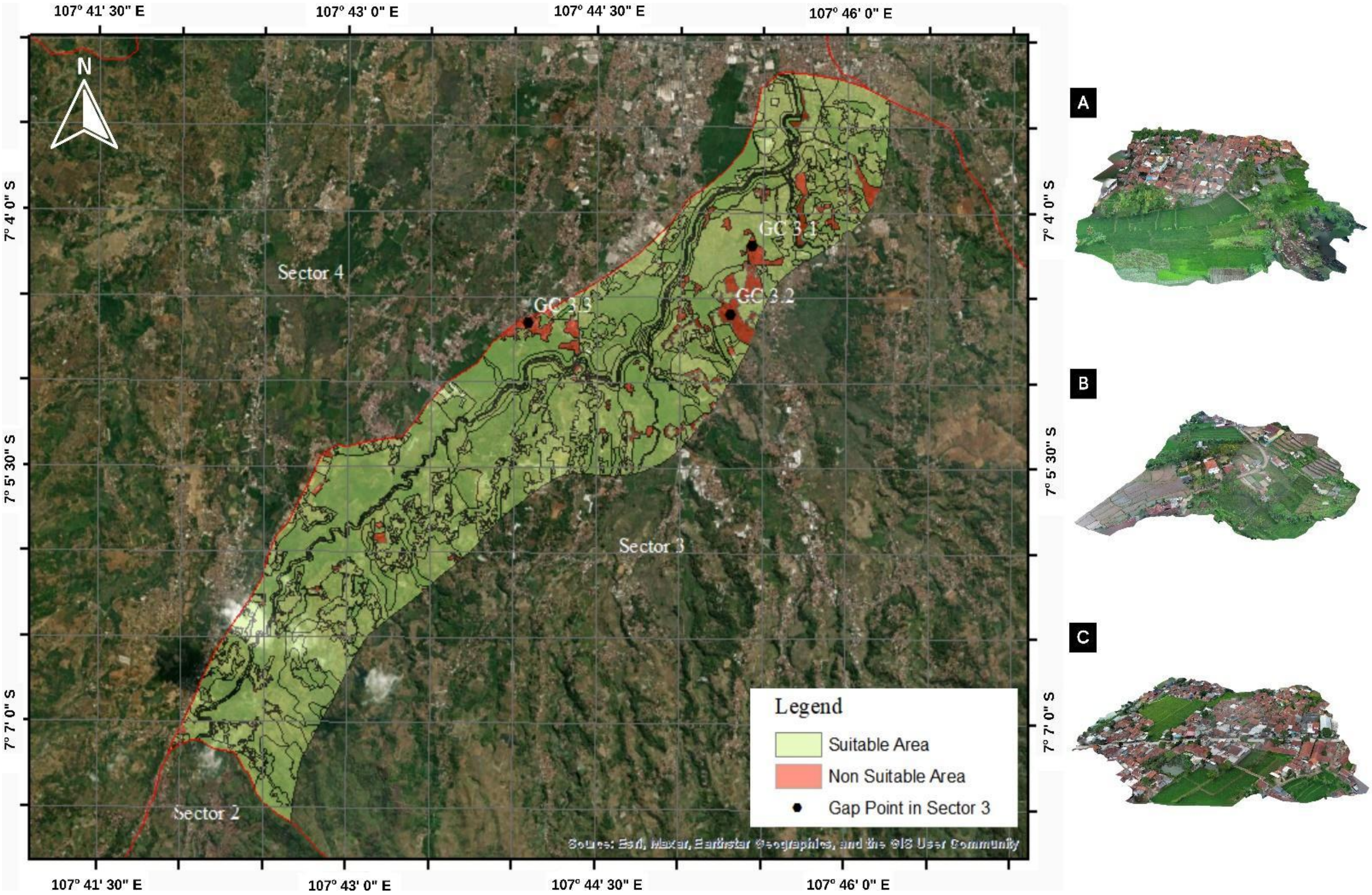

Figure 13. Sector 3 Investigation Point Distribution: (a) Land Disparities from Wet Agriculture to Settlements (GC 3.1); (b) Land Disparities from Wet Agriculture to Settlements (GC 3.2); (c) Land Disparities from Wet Agriculture to Settlements (GC 3.3).

Furthermore, within this sector, the conversion of traditional fishing areas into residential and industrial zones has demonstrably influenced both land use patterns and the livelihoods of local communities. These observations align with findings from previous research conducted at Poyang Lake, China, which indicated that policy-driven transformations can significantly alter the livelihoods of fishing communities, subsequently impacting agricultural landscape configurations and contributing to land fragmentation (Ou *et al.,* 2022).

Similarly, research in Cambodia has revealed that infrastructure development and the effects of climate change have disrupted natural seasonal flooding regimes and critical fish migration pathways, leading to adverse consequences for fish biodiversity and the food security of local populations (Tilley *et al.,* 2024). It is also pertinent to note that industrial development within riverine corridors can result in substantial riparian ecosystem degradation. Scholarly investigations have shown that activities such as land reclamation and infrastructure construction can disrupt the intrinsic ecological functions of rivers and elevate the risk of flood events (Han *et al.,* 2022).

Conversely, instances of land-use change from resettlement areas back to wetland agriculture, specifically rice cultivation, represent potential ecosystem restoration initiatives. However, this form of conversion necessitates systemic adjustments, including the revitalisation of existing irrigation infrastructure and the adaptation of community practices to an agrarian mode of life. A primary challenge in this context is the restoration of land productivity in areas previously fragmented by settlement development, while concurrently ensuring both ecological integrity and social sustainability.

3. Investigation of Sector 4

Sector 4 is primarily characterised by its agricultural land use, with rice fields constituting the dominant land cover (Figure 14). However, a notable increase in residential areas indicates significant pressure for land conversion within the sector. Furthermore, initial indications of industrial area development are also discernible, albeit on a limited scale at present. It is anticipated that if these prevailing trends persist, the extensive rice fields in this sector could face a significant threat of conversion, particularly to residential developments. This observation aligns with broader patterns, whereby rapid urbanisation in recent years has driven significant changes in land use and land cover, with a particularly salient impact being the fragmentation of existing green spaces (Nazombe & Nambazo, 2023).

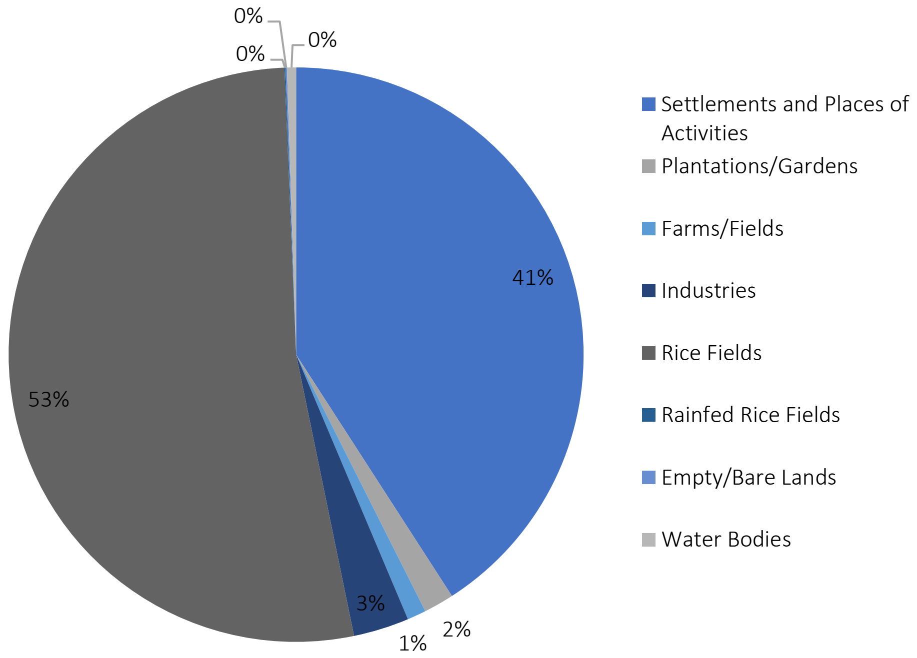

Figure 14. Data Portrait of Sector 4 Land Use.

The investigation of this sector, encompassing the Majalaya area, reveals that rice fields and residential settlements predominantly characterise land use. However, similar to the preceding sector, the area is not exempt from the phenomenon of spatial disparity. We identified a gap area covering approximately 49.80 hectares (Table 9), indicating that anthropogenic activities may gradually erode established spatial planning regulations and/or previously formulated policies.

Table 9. Sector 4 Disparity Investigation

Pattern Deviation	Land Area (Ha)	Location
Conforming Pattern	1261.56	Majalaya, Bandung Regency, Indonesia
Non-conforming Pattern	49.80	

The phenomenon occurring in Sector 4 is very similar to that of Sector 3, with the extent of the gap dominated by residential and industrial areas. Over the past four years, the population has also experienced significant growth, from 102,082 in 2019, to 160,617 in 2020, 165,687 in 2022, and 166,861 in 2023 (BPS, 2024d). Data for 2021 are unavailable. This demographic trend reflects an accelerated peri-urbanisation process, which in turn has driven local industrialisation. Such rapid growth and industrial expansion signify a broader transformation from an agrarian-based economy to an industrial one in this region. Significant changes in land cover have been documented (Anggraheni *et al.,* 2025), alongside recurring flood events in Majalaya (Burnama *et al.,* 2023; Rohmat *et al.,* 2022); deteriorating water quality in the Citarum River (Pratiwi *et al.,* 2023); and various other environmental concerns. Field observations revealed visible signs of environmental degradation along the Citarum river (Figure15a). Further investigation indicated that the deterioration in water quality was primarily caused by industrial wastewater discharges, in blatant violation of the agreed Environmental Impact Assessment (AMDAL) provisions.

Figure 15. Documentary portrait of the Majalaya area in Sector 4: (a) Portrait of industrial waste in Majasetra Village, Majalaya; (b) Portrait of residential land along the river corridor in Neglasari Village; (c) Portrait of industrial presence in Majasetra.

Several locations of disparity phenomena that have occurred in the Citarum river corridor have been identified, and are illustrated in Figure 16. The specifications of the sector land area are shown in Table 10. While the dominant land use in Sector 4 currently aligns with the prevailing spatial plan, the sector is exhibiting increasing pressure from land conversion, notably from agricultural land to both settlements and industrial areas. Alarmingly, protected buffer zones are reportedly being utilised for industrial activities, signifying a potential violation of their designated protective function. The functional shift from wet agricultural land to residential areas represents a primary land management challenge in this sector, corroborating the quantitative data presented in earlier analysis (40.89% residential versus 52.59% rice fields). Spatial discrepancies within the Citarum River corridor have also been identified and are visually documented in Figure 16.

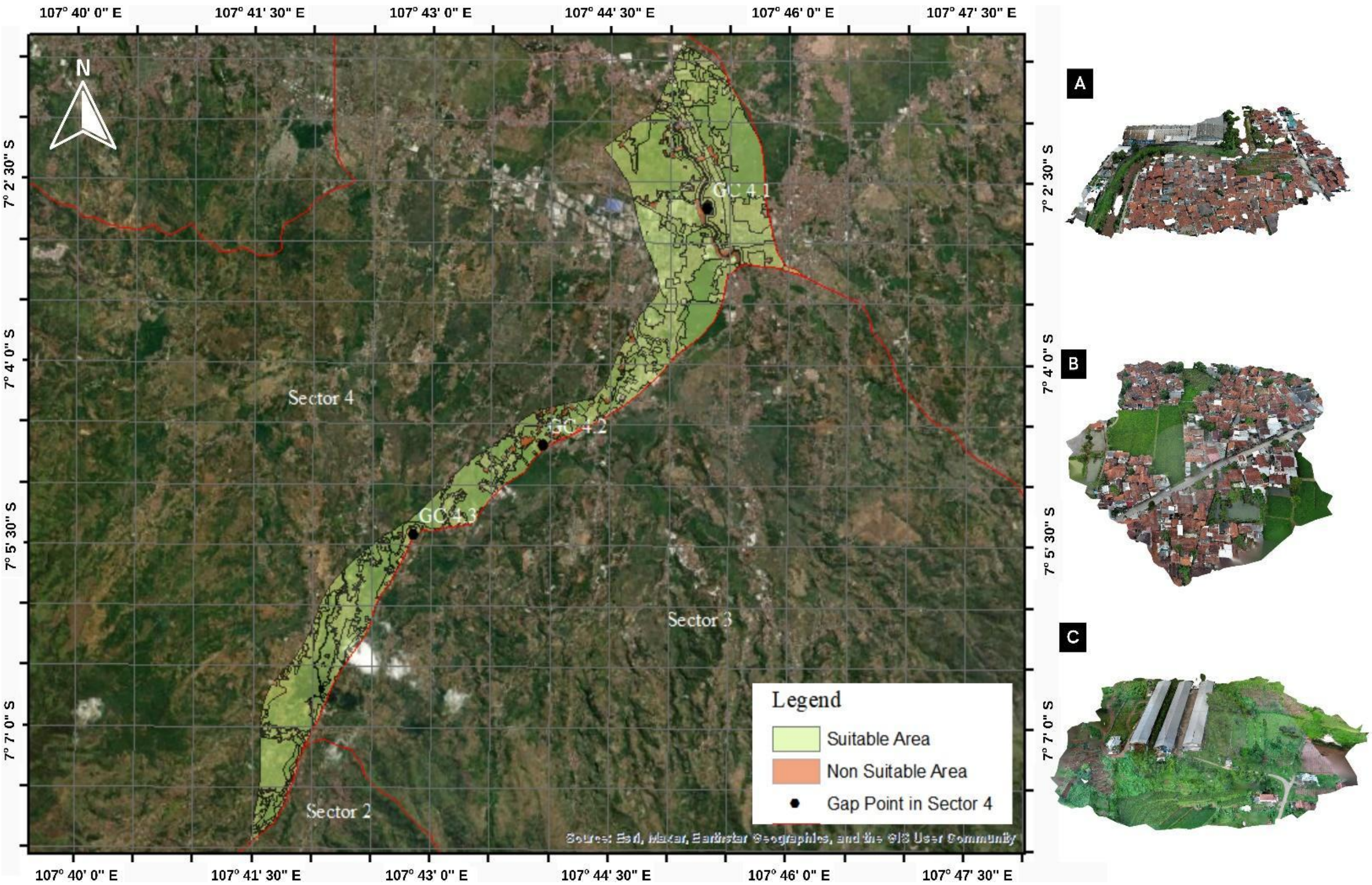

Figure 16. Sector 4 Investigation Point Distribution: (a) Land Disparities from Wet Agriculture to Settlements (GC 4.1); (b) Land Disparities from Wet Agriculture to Settlements (GC 4.2); (c) Land Disparities from Wet Agriculture to Settlements (GC 4.3).

Table 10. Land Area Specifications (Sector 4)

Spatial Planning	Factual Conditions	Pattern deviation	Σ (Ha)	AOI
Border	Industrial Area	Non-conforming	9.11	QC 4.1
Fishing Area	Settlements	Non-conforming	11.94	QC 4.2
Wetland Agricultural Area	Settlements	Non-conforming	7.20	QC 4.3
Wetland Agricultural Area	Settlements	Non-conforming	0.64	None
Border	Settlements	Non-conforming	0.02	None
Residential Area	Industrial Area	Non-conforming	5.44	None
Wetland Agricultural Area	Industrial Area	Non-conforming	1.07	None
Wetland Agricultural Area	Settlements	Non-conforming	13.56	None
Border	Industrial Area	Non-conforming	9.11	None
Wetland Agricultural Area	Industrial Area	Non-conforming	0.43	None
Residential Area	Industrial Area	Non-conforming	0.05	None
Border	Industrial Area	Non-conforming	0.31	None

The area in Sector 4 includes Majalaya, which represents more of a city than settlements in the other sectors. Not surprisingly, the conversion of non-urban land into urban land is designed to accommodate the expansion of residential areas and meet the increasing spatial demands of urbanisation (Norita *et al.,* 2024). For example, the conversion of river borders into industrial and residential areas has caused complex and interrelated environmental impacts. The case of the Citarum River in Indonesia is a clear example of massive land conversion on the riverbanks causing water quality degradation that is difficult to restore (Rohmat *et al.,* 2024).

A similar phenomenon can be observed globally, where riparian land conversion triggers three critical impacts: first, damage to aquatic ecosystems, characterised by a decrease in water quality due to industrial and domestic pollution, as well as loss of biodiversity of up to 40-60% in some cases (Rodríguez-Echeverry, 2023; Wang *et al.,* 2023); second, systemic hydrological disturbances in the form of an increase in flooding frequency of 30-50% due to reduced catchment areas and increased impervious surfaces (Wang *et al.,* 2023); and third, the loss of essential ecosystem services such as natural pollutant filtering and flood control (Atesoglu *et al.,* 2025; Zhuge *et al.,* 2023). We conclude that each sector we investigated is experiencing discrepancies between regional spatial planning and actual conditions.

We now summarise and conduct analysis of the relationship between the gap phenomenon and sectorization in the area from upstream (sector 1) to downstream (sector 4). The findings are presented in Table 11.

Table 11. Total Area Suitable and Non-Suitable Area.

Sector	Suitable Area (Ha)			Non-Suitable Area (Ha)			Area Total (Ha)	
	Land area per sector	Total area	%	Land area per sector	Total area	%	Total	%
Sector 1	2181.40			16.16		9.41		43.64
Sector 2	1399.65			20.14		11.73		33.69
Sector 3	1530.19			85.60		49.85		73.86
Sector 4	1261.56			49.81		29.01		48.80
Total Area						100.00	6544.52	200.00

Source: Data Processing Results (2025)

Linear regression modelling and coefficient of determination (R^2) formulations were conducted to identify the influence of spatial changes in area gaps using the following formulation (Figure 17). We indicate that certain factors influence the size of the gap in sectors 1-4 (Figure 17), with the significance of our results being 69.4%. We conclude that there is an influential contribution from upstream to downstream areas; the further downstream, the greater the mismatch. This is because many anthropogenic factors are increasing, characterised by land conversion such as industry, settlements and rice fields.

However, in Sector 3, the mismatch is smaller than in Sector 2. It cannot be denied that the closer the rural area is to the city, the higher the level of agricultural land use (Pradoto *et al.,* 2024). We conclude that local policies or the implementation of spatial plans contribute significantly. This is supported by the results of previous research, which show that changes in land use depend on the plans and policies of each government in pursuing the country's development path (Tuan, 2022).

The findings from this in-depth analysis warrant further investigation into why Sector 3 exhibits a greater disparity than Sector 2, which is geographically oriented toward the upstream area. It is essential to determine whether there are specific interventions or management practices implemented in Sector 2 that are absent in Sector 3. Our preliminary indications suggest that such disparities may be attributable to a combination of factors, including community awareness, land-use politics, the egocentrism of industrial stakeholders, and/or the influence of local political dynamics.

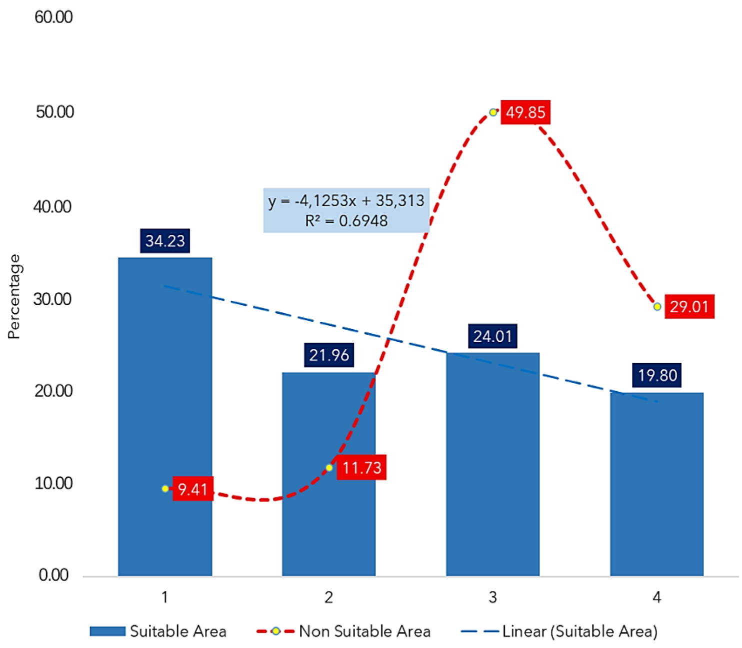

Figure 17. Significance of land suitability based on inter-spatial (Sector 1-4).

3.2. Why does the disparity phenomenon occur?

The disparity phenomenon usually occurs because the demand for spatial resources by industrial and residential activities has increased dramatically, leading to substantial encroachment of ecological space (Xu *et al.,* 2024). As supported by various experts, this occurs because watershed-scale anthropogenic activities, such as agricultural expansion, urbanisation, reforestation and deforestation, are the dominant single or integrated drivers of LUCC (Chu *et al.,* 2022; Feng *et al.,* 2023; Lyu *et al.,* 2024; Tafazzoli, 2023). We explored in depth the perspectives of local communities along the Citarum river corridor, from their way of thinking about land use, to regional spatial planning.

1. Land Use Implementation Perspective

The results of the investigation through the distribution of questionnaires along the Citarum river corridor regarding people's perspectives on the implementation of land use change, using MCDA with the AHP technique, are visualised in Figure 18.

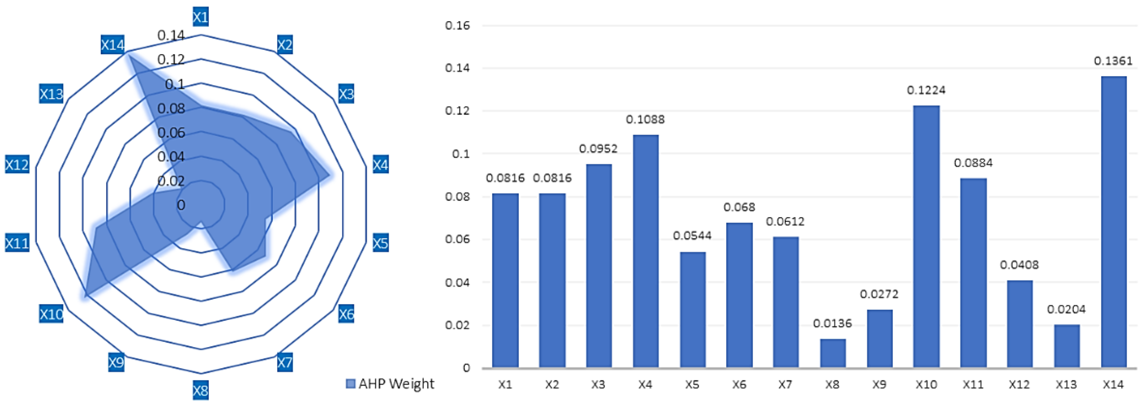

Figure 18. Perspective of Land Use-Based MCDA. Description: Community knowledge of river corridors (X_1); Community knowledge of land and soil (X_2); Community knowledge of land use (X_3); Community knowledge of land change (X_4); Land ownership (X_5); Land ownership use (X_6); Land ownership permits (X_7); Land density (X_8); Land conformity with regional spatial planning (X_9); Intensity of land use socialisation activities (X_{10}); Availability of residents for relocation (X_{11}); Land change track record (X_{12}); Land change impact (X_{13}); Factors causing land change (X_{14}).

The MCDA results shown in Figure 18 indicate a predominant tendency toward the variable representing community perspectives on the drivers of land-use change (X14, with an AHP weight score of 0.1361). Upon further investigation, a significant proportion of respondents identified economic factors (70.27%), environmental factors (43.24%), and socio-demographic factors (37.83%) as the primary contributors. To substantiate why these factors were perceived as central to the phenomenon of spatial planning discrepancies, further clarification is provided below.

Economic and socio-demographic factors. The investigation revealed that the economic needs of residents for daily living serve as a primary reason for selling land, with such transactions often involving immigrants who purchase these parcels. The process indirectly contributes to the phenomenon of urbanisation. Furthermore, the land acquired by newcomers is frequently developed into residential housing, villas serving as lodging facilities, or industrial sites for business ventures.

Environmental and economic factors. The findings indicate that, particularly in Sectors 3 and 4, local communities expressed concern over the turbidity of the Citarum River, which they attributed to solid waste, industrial effluents and mining activities. These environmental degradations have become a driving factor behind the decision of many residents to sell their land.

Socio-demographic and economic factors. It was also found that much of the land in question is inherited across generations. Initially underutilised or barren, it has been progressively converted into residential properties, plantations and rice fields, fulfilling the communities' needs for shelter, food and livelihoods. This transformation has persisted from the first generation through to the third generation of the same families.

Fundamentally, the three economic, socio-demographic and environmental factors are interrelated, together influencing the phenomenon of spatial disparities along the Citarum River corridor. The phenomenon contributes to land conversion that deviates from its intended use, precipitates social conflicts, and impacts the sustainability of ecological functions within river corridor area.. It is crucial to acknowledge that unsuitable land change is an environmental transformation driven by complex interactions between climate change and anthropogenic activities aimed at fulfilling human needs (Lyu *et al.,* 2024; Reinhart *et al.,* 2023; Wang *et al.,* 2021), representing a tangible manifestation of human influence on the environment (Feng *et al.,* 2023; Lyu *et al.,* 2024). While the dynamics of land use are paramount for effective area management (Alausa *et al.,* 2023; Ray *et al.,* 2023), gaps along river corridors driven by personal and industrial interests can lead to numerous detrimental impacts (Saputra *et al.,* 2023), including soil erosion, sedimentation and even instream landslides (Mwasenga & Mjemah, 2023), affecting river water quality (Novita *et al.,* 2022) and increasing vulnerability to flooding (Devitt *et al.,* 2023). Consequently, strategic planning and management of land use are essential to address both current needs and future challenges (Yu *et al.,* 2025). Various studies advocate ecosystem-based solutions as a sustainable approach, with Corgo *et al.* (2024) recommending the implementation of buffer zones at least 100 metres wide, integrated within the regional spatial plan.

2. Regional Spatial Planning Implementation Perspective

The measurement was conducted in the same manner as in the findings in the previous subsection , in which the MCDA using the AHP method identified several factors contributing to the disparity phenomenon from the perspective of the local community's spatial planning (Figure 19).

The MCDA analysis identified tendencies in the community's knowledge of RSP, the role of RSP within society, and public enthusiasm toward RSP, which are elaborated as follows.

Community knowledge of RSP (X15). The findings reveal that all residents encountered during the investigation were aware of RSP. However, it is important to emphasise that such awareness was mostly limited to having heard about it through social media or through occasional visits by relevant agencies, and even then, only in Kertasari Village (Sector 1). Upon further inquiry, it became evident that residents lacked explicit and implicit understanding of RSP functions, meaning and societal role.

The role of RSP within society (X_{17}). The data indicated that 36 out of the 37 respondents acknowledged that RSP is highly important; however, they lacked comprehension of its practical implementation in daily life. This finding strongly correlates with the earlier clarification regarding their limited knowledge of RSP.

Community enthusiasm towards RSP (X_{22}). A marked difference was observed between communities experiencing low and high levels of river pollution. In Sectors 1–2, where river pollution was minimal, residents generally expressed indifference toward possible relocations for RSP implementation, as long as compensation was provided. In contrast, residents in Sectors 3–

4 demonstrated strong enthusiasm for RSP implementation, primarily due to the severe pollution of the Citarum River caused by industrial activities. As previously discussed in the sub-study on Ibun and Majalaya Districts, the discharge of industrial waste has heightened local concern and motivated communities to support RSP enforcement along the Citarum River corridor to restore the river's ecological condition.

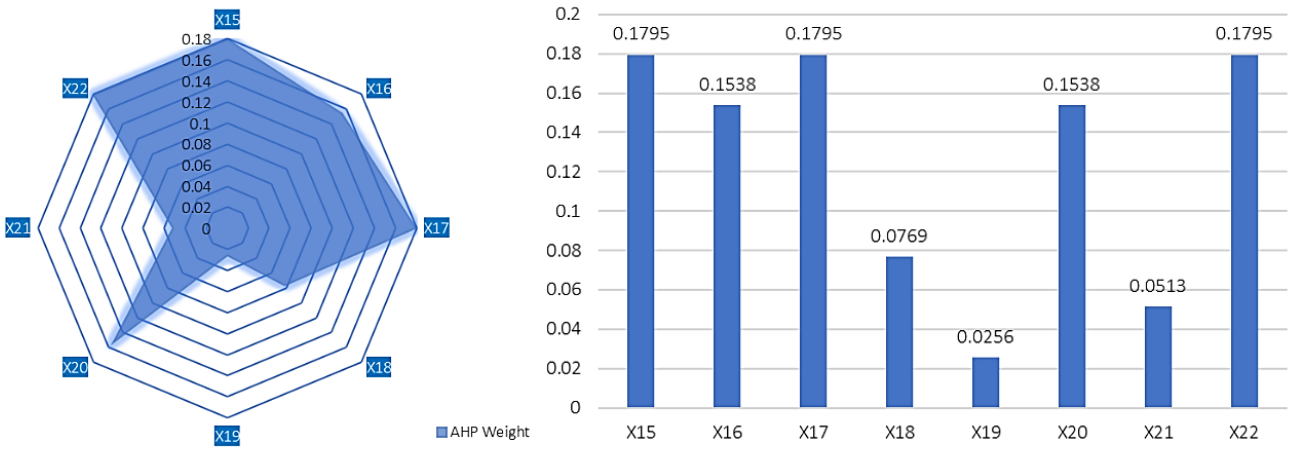

Figure 19. Perspective of Regional Spatial Plan-Based MCDA. Description: Knowledge of regional spatial planning (X_{15}); Intensity of socialisation of regional spatial planning (X_{16}); Role of regional spatial planning in the community (X_{17}); Community conflict with the government (X_{18}); Case examples of building inconsistencies (X_{19}); Permits for building layout (X_{20}); Spatial planning as an obstacle to the development of a region (X_{21}); Public enthusiasm for spatial planning (X_{22}).

In contrast, residents in Sectors 3–4 demonstrated strong enthusiasm for the implementation of RSP, largely due to the worsening pollution of the Citarum River caused by industrial activities. This phenomenon has been detailed in the earlier sub-study on the disparity areas within Ibun and Majalaya Districts. The persistent presence of industrial waste has heightened community concern, fostering a strong commitment among residents to support RSP enforcement along the Citarum River corridor as a means to restore the river's ecological condition.

Based on clarifications derived from the in-depth MCDA analysis, integrating both actual land-use perspectives and the RSP framework, it can be concluded that economic factors, environmental conditions, socio-demographic characteristics, community knowledge of RSP, the perceived role of RSP in society, and public enthusiasm toward its implementation collectively form the underlying drivers of disparity along the Citarum River corridor in Sectors 1–4. To reinforce these findings, we conducted a follow-up investigation through a focus group discussion in Cikitu Village, Bandung Regency (Figure 20), aimed at deliberating on the disparity phenomenon observed across Sectors 1–4 along the Citarum River corridor.

Figure 20. Focus group discussion for further investigation: (a) Presentation of investigation objectives; (b) Perception of Citarum community leaders; (c) End of FGD session.

Strengthening the MCDA analysis (Figures 18 and 19), the disparity phenomenon has profoundly eroded the long-standing cultural practices traditionally upheld by communities along the Citarum River corridor, as reflected in the narratives shared during our community discussions.

Respondent A:

*"…Nowadays, many cultural traditions have almost disappeared. In the past, there was a tradition called **Ngabedahkeun** (a communal practice of draining fishponds during the harvest season, when villagers would enthusiastically gather to harvest fish together). This was commonly held, especially in Kertasari and Pacet Districts, which once had tens of thousands of ponds. My parents, like most residents of Tarumajaya Cibeureum in Kertasari District, owned ponds. But now, most of these have been converted into gardens, leading to the loss of the **Ngabedahkeun** tradition. Moreover, the fish found today in Kertasari and Pacet mostly come from Saguling and Cirata reservoirs, which are unfit for consumption. The disappearance of this tradition is mainly due to urbanization, shrinking land availability and the diminishing water supply.""*

(FGD Findings, 2024)

As a consequence of this disparity, the cultural tradition of Ngabedahkeun has begun to fade due to various contributing factors: urbanisation (a socio-demographic factor); increasing land scarcity (an economic and socio-demographic factor); and diminishing water resources (an environmental factor) along the Citarum River corridor, particularly in Sectors 1 and 2. This observation is further reinforced by subsequent discussion findings; one participant stated:

Respondent B:

*"………There is customary law introduced by the Dutch, reflecting their efforts to classify communities, similar to the arrangement of the river corridor, which primarily emphasized the functional use of the river. Furthermore, in the customary law established by the Dutch, the term **Leuweung Walungan Jero** refers to social order within the community".*

(FGD Findings, 2024)

In the customary law concept of ***Leuweung Walungan Jero***, rivers and their surrounding areas are regarded as a single, integrated ecosystem that holds both ecological and social value. Consequently, their utilisation is strictly regulated to ensure environmental sustainability and social order. When examined in relation to spatial disparity, these customary legal principles should serve as a reference in spatial planning. However, empirical realities reveal that the designated riparian buffer zones often shift due to pressures from development, urbanisation and community economic activities. As a result, many areas originally designated as conservation zones in RSP have been converted into residential areas, rice fields, and even industrial sites.

Respondent C:

"………The cultural belief in the existence of Raden Kalung Bimanagara has also now disappeared. I still recall my grandfather saying, "Mun pasosoré tong leuwih teuing ngagarap lahan ke sisi Citarum, Raden Kalung bisi ngadat", which translates to, "When afternoon falls, do not excessively cultivate land near the banks of the Citarum, or Raden Kalung will be angered." Raden Kalung Bimanagara, once revered as the guardian deity of the Citarum River, is no longer acknowledged in contemporary local practice, but was a belief once deeply rooted in Sundanese culture.

In the past, village-scale development initiatives were frequently implemented within our community, often intertwined with these cultural values. However, current regulatory frameworks, such as those outlined in the Regulation of the Minister of Public Works and Public Housing Number 28/PRT/M/2015 of 2015, address riparian zones primarily from a technical standpoint. When it comes to the determination of riparian buffer boundaries, the regulation largely delegates authority back to each respective regional government".

(FGD Findings, 2024)

In responding to and reflecting upon the erosion of cultural values and local beliefs surrounding the mythology of ***Raden Kalung Bimanagara,*** once revered as the guardian or "deity" of the Citarum River, it is evident that this tradition functioned as an unwritten social norm regulating human activities along the riverbanks, particularly at certain times of the day. For example, the customary prohibition "mun pasosoré tong leuwih teuing ngagarap lahan ke sisi Citarum" ("when afternoon falls, do not excessively cultivate land near the Citarum") effectively created a natural buffer zone that preserved riparian areas, without the need for formal governmental regulation.

The disappearance of these beliefs has in turn exacerbated environmental degradation along the Citarum River corridor, contributing to the emergence of spatial disparity phenomena. In addressing this issue, the government's current regulatory framework, such as the Ministry of Public Works Regulation Number 28 of 2015 on the designation of riparian boundaries, has often been criticised in terms of field implementation, as the enforcement of such regulations is largely delegated to regional authorities.

In light of this, we recommend that local governments integrate nature-based solutions (NbS) for river corridors into policy implementation in a sustainable manner (Rohmat *et al.,* 2025). Such approaches are critical, as rivers constitute an essential component of water resources and play a pivotal role in sustaining life; they therefore require long-term preservation (Afriyani *et al.,* 2024). Without effective regional support, there will be an imbalance between land use, potential and needs (Miswar *et al.,* 2023). Wise measures are needed in managing land in order to create sustainable land use (Arsa *et al.,* 2025). Research in China and Turkey indicates that riparian vegetation restoration can significantly reduce sedimentation (by up to 25%) and enhance pollutant filtration capacity (Atesoglu *et al.,* 2025; Wang *et al.,* 2024).

Emerging policy implications include: (1) the strengthening of regulations protecting riverine buffer zones, (2) the mandatory implementation of environmental impact assessments based on hydro-ecological studies, and (3) the development of real-time monitoring systems utilising remote sensing technology. The case of the South-to-North Water Diversion project in China (Zhuge *et al.,* 2023) provides a valuable precedent for considering the value of ecosystem services in large-scale development planning. The dynamic interplay between natural and anthropogenic factors in shaping land cover underscores the importance of continuous monitoring and adaptive management in conservation efforts (Alikhanov *et al.,* 2024). This transformation necessitates a strategic shift towards sustainable river management through an integrated approach encompassing ecological, hydrological (water resource management), and socio-economic considerations within a sustainable development framework (Agli *et al.,* 2024).

5. Conclusion

Regional spatial planning (RSP) serves as a critical framework for guiding land use practices. However, spatial disparities persist, as evidenced along the Citarum River corridor, based on our field investigation covering Sectors 1, 2, 3 and 4. The most pronounced disparity was identified in Sector 3, encompassing approximately 85.60 ha out of a total 1,615.79 ha (49.85%), whereas the smallest disparity occurred in Sector 1, at about 16.16 ha out of 2,197.56 ha (9.41%). Furthermore, our analysis revealed that the influence of inter-sector dynamics from upstream to downstream accounts for approximately 69.4% of the variation in disparity extent.

The expansion of residential areas, paddy fields and industrial zones has emerged as the root cause of these spatial disparities. Beyond quantitative measurements, we conducted an in-depth exploration of local community perspectives along the river corridor regarding land use and the Regional Spatial Plan (RSP). Using MCDA, we concluded that these disparities are driven by interrelated qualitative factors, namely economic conditions, environmental pressures, socio-demographic characteristics, public knowledge of the RSP the perceived role of RSP within the community, and community enthusiasm toward its implementation.

We acknowledge several limitations in the study, including the shortage of human resources to conduct a more in-depth investigation, as many underlying issues along the river corridor remain unexplored. In addition, the use of the Autel EVO 2 Pro V3 drone provided only a moderate level of ground-check accuracy compared to the higher precision of LiDAR-based drones. Consequently, we recommend that future research address these limitations by incorporating cutting-edge technological innovations to support the long-term restoration of the Citarum River as a theoretical implication We anticipate that the findings of this research will serve as a relevant evaluation and valuable reference for the planning of sustainable spatial management along the Citarum River corridor in the future. In particular, we propose (1) synchronising RSP with existing conditions through periodic spatial assessments in other sectors using advanced geospatial technologies; (2) establishing derivative regulations specific to river corridor zones that provide more detailed land-use restrictions, including adaptive zoning provisions for sectors with high relaxation levels, such as Sector 3; (3) enhancing law enforcement capacity through well-defined incentive and sanction mechanisms for spatial planning violations; and (4) conducting periodic community outreach to raise awareness regarding the functions and roles of RSP among communities along the Citarum River corridor. We further expect that the innovative research framework developed herein can serve as a sampling campaign model for replicating sustainable river restoration initiatives in other contexts.

Acknowledgements

The researchers would like to thank the communities of Citarum sector 1, sector 2, sector 3 and sector 4 and the Geography Education students of Universitas Pendidikan Indonesia who have assisted in the field survey for data collection

.

Author Contributions

Conceptualization: Setiawan, I., Rohmat, D., & Suhendro, S.; **methodology**: Setiawan, I.; **investigation**: Setiawan, I., Rohmat, D., & Suhendro, S.; **writing—original draft preparation**: Setiawan, I., & Suhendro, S.; **writing—review and editing**: Setiawan, I., & Suhendro, S.; **visualization**: Setiawan, I., & Suhendro, S.. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

All authors declare that they have no conflicts of interest.

Data availability

The data supporting this study are available from the corresponding author upon reasonable request

Funding

This research was funded by BIMA Progamme with Scheme Fundamental of 2024, grant number 082/ E5/ PG.02.00.PL/ 2024 with Agreement Decree Number: 1128/UN40.LP/PT.01.03/2024

References

Adam, A. G., & Dadi, T. T. (2024). Perspectives for smooth bridging of dichotomized urban–rural land development in the peri-urban areas of Ethiopia: Toward a continuum approach. *Regional Science Policy and Practice*, 16(3). doi: 10.1111/rsp3.12733

Afriyani, M. P., Muttakin, M., Desfandi, M., Azis, D., Afriza, R., & Ruliani, R. (2024). Phreatic Groundwater Quality Analysis Based on Physical and Chemical Parameters in Kuta Raja Sub-District. *Forum Geografi*, 38(2), 178–188. doi: 10.23917/forgeo.v38i2.4450

Agli, S., Ahmed, A., Abdellah, A., Abdelouahed, F., Said, M., Abdelfattah, A., & Ghouat Akram, E. (2024). Modelling of Soil Erosion Susceptibility Using the Multi-Influencing Factor Method in the Amizmiz Basin, Morocco. *Forum Geografi*, 38(V), 343–357. doi: 10.23917/forgeo.v381i3.6263

Alausa, O. A., Adaradoun, O. S., Adekunle, G. T., & Priyono, K. D. (2023). Leveraging Geospatial Technology for Enhanced Utility Management: A Case Study in Electrical Distribution Power Systems. *Forum Geografi*, 37(2), 164–177. doi: 10.23917/forgeo.v37i2.21982

Alikhanov, B., Pulatov, B., & Samiev, L. (2024). The Detection of Past and Future Land Use and Land Cover Change in Ugam Chatkal National Park, Uzbekistan, Using CA-Markov and Random Forest Machine Learning Algorithms. *Forum Geografi*, 38(2), 121–137. doi: 10.23917/forgeo.v38i2.4221

Amirusholihin, Rahadiantino, L., Nilasari, A., Rakhmawati, D. Y., & Fatoni, F. (2024). How population density and welfare affect crime rates: A study in East Java Province, Indonesia. *Revista de Gestao Social e Ambiental*, *18*(8). https://doi.org/10.24857/rgsa.v18n8-028

Anggraheni, E., Hamdany, A. H., Maricar, F., Andika, N., Sisinggih, D., Tanlie, F. S., & Respati, F. A. R. (2025). Hydrological Response of Land Use and Climate Change Impact on Sediment Rate in Upper Citarum Watershed. *Fluids*, 10(2), 36. doi: 10.3390/fluids10020036

Anja, A. . A.-F. M. . & A. D. (2024). Tingkat Kesejahteraan Petani Pala Di Kecamatan Meukek Kabupaten Aceh Selatan. *Jurnal Pendidikan Geosfer*, 9(2), 301–310.

Arsa, M. F. . & A. D. (2025). evelopment of Agroforestry on Degraded Land in the Saree Grand Forest Park, Indonesia. *Jurnal Penelitian Geografi (JPG)*, 13(1), 127–136.

Atesoglu, A., Bulut, F. S., Ozel, H. B., & Zeren Cetin, I. (2025). Large-scale earth observation and monitoring of riparian zone land-cover changes in Türkiye. *International Journal of Environmental Science and Technology*. doi: 10.1007/s13762-025-06399-0

Atharinafi, Z., & Wijaya, N. (2021). Land Use Change and Its Impacts on Surface Runoff in Rural Areas of the Upper Citarum Watershed (Case Study: Cirasea Sub-watershed). *Journal of Regional and City Planning*, 32(1), 36–55. doi: 10.5614/jpwk.2021.32.1.3

Baigún, C. R. M., & Minotti, P. G. (2021). Conserving the Paraguay-Paraná Fluvial Corridor in the XXI Century: Conflicts, Threats, and Challenges. *Sustainability (Switzerland)*, 13(9). doi: 10.3390/su13095198

Balta, M. Ö., & Yenil, H. Ü. (2019). Multi criteria decision making methods for urban greenway: The case of Aksaray, Turkey. *Land Use Policy*, 89. doi: 10.1016/j.landusepol.2019.104224

Best, J., & Darby, S. E. (2020). The Pace of Human-Induced Change in Large Rivers: Stresses, Resilience, and Vulnerability to Extreme Events. In *One Earth*, 2,(6), 510–514). Cell Press. doi: 10.1016/j.oneear.2020.05.021

Bonakdar, A., & Audirac, I. (2021). City planning, urban imaginary, and the branded space: Untangling the role of city plans in shaping Dallas's urban imaginaries. *Cities*, 117. doi: 10.1016/j.cities.2021.103315

Bosah, C. P., Li, S., Ampofo, G. K. M., & Sangare, I. (2023). A continental and global assessment of the role of energy consumption, total natural resource rent, and economic growth as determinants of carbon emissions. *Science of The Total Environment*, 892, 164592. doi: 10.1016/J.SCITOTENV.2023.164592

Bosché, B. (2012). Defining River Corridors. *Vermont DEC River Management Program*. https://dec.vermont.gov/sites/dec/files/wsm/rivers/docs/rv_definingrcfactsheet.pdf-]

BPS. (2024a). Kecamatan Ibun dalam Angka 2024. Retrieved from https://bandungkab.bps.go.id/id/publication/2024/09/26/7c94caf97d40d489febfaeb9/kecamatan-ibun-dalam-angka-2024.html

BPS. (2024b). *Kecamatan Kertasari dalam Angka 2024*. Retriefre fromL https://bandungkab.bps.go.id/id/publication/2024/09/26/ab768c62e8cd7bc9aafdb47e/kecamatan-kertasari-dalam-angka-2024.html

BPS. (2024c). *Kecamatan Majalaya dalam Angka 2024*. Retriefed from : https://bandungkab.bps.go.id/id/publication/2024/09/26/48af32de525b9b1c0178d961/kecamatan-majalaya-dalam-angka-2024.html

BPS. (2024d). *Kecamatan Pacet dalam Angka 2024*. Retriefed from : https://bandungkab.bps.go.id/id/publication/2024/09/26/33e5479178ccc7848b13f038/kecamatan-pacet-dalam-angka-2024.html

Brown, C., Alexander, P., & Rounsevell, M. (2018). Empirical evidence for the diffusion of knowledge in land use change. *Journal of Land Use Science*, 13(3), 269–283. doi: 10.1080/1747423X.2018.1515995

Brunet, L., Tuomisaari, J., Lavorel, S., Crouzat, E., Bierry, A., Peltola, T., & Arpin, I. (2018). Actionable knowledge for land use planning: Making ecosystem services operational. *Land Use Policy*, 72, 27–34. doi: 10.1016/j.landusepol.2017.12.036

Burnama, N. S., Rohmat, F. I. W., Farid, M., Kuntoro, A. A., Kardhana, H., Rohmat, F. I. W., & Wijayasari, W. (2023). The Utilization of Satellite Data and Machine Learning for Predicting the Inundation Height in the Majalaya Watershed. *Water*, 15(17), 3026. doi: 10.3390/w15173026

Bush, J., & Doyon, A. (2023). Planning a just nature-based city: Listening for the voice of an urban river. *Environmental Science and Policy*, 143, 55–63. doi: 10.1016/j.envsci.2023.02.023

Chu, X. Lei, Lu, Z., Wei, D., & Lei, G. ping. (2022). Effects of land use/cover change (LUCC) on the spatiotemporal variability of precipitation and temperature in the Songnen Plain, China. *Journal of Integrative Agriculture*, 21(1), 235–248. doi: 10.1016/S2095-3119(20)63495-5

Cialdea, D., & and Pompei, C. (2022). An overview of the River Contract tool: new aims in planning and protected areas issues. *European Planning Studies*, 30(4), 684–704. doi: 10.1080/09654313.2021.2007523

Corgo, J., Santos Cruz, S., & Conceição, P. (2024). Nature-based solutions in spatial planning and policies for climate change adaptation: A literature review. *Ambio*. doi: 10.1007/s13280

Cui, J., Kong, X., Chen, J., Sun, J., & Zhu, Y. (2021). Spatially explicit evaluation and driving factor identification of land use conflict in yangtze river economic belt. *Land*, 10(1), 1–24. doi: 10.3390/land10010043

Dai, X., Felsenstein, D., & Grinberger, A. Y. (2023). Viewshed effects and house prices: Identifying the visibility value of the natural landscape. *Landscape and Urban Planning*, 238, 104818. doi: 10.1016/J.LANDURBPLAN.2023.104818

Deberiostraat, C., & Mwaijengo, G. N. (2020). Towards sustainable management of inland waters in Tanzania: Assessing the ecological integrity of river ecosystems in the Upper Pangani River Basin (Tanzania). *Urban Science*. www.kuleuven.be

Dede, M., Sunardi, S., Lam, K. C., Withaningsih, S., Hendarmawan, H., & Husodo, T. (2024). Landscape dynamics and its related factors in the Citarum River Basin: a comparison of three algorithms with multivariate analysis. *Geocarto International*, 39(1). doi: 10.1080/10106049.2024.2329665

Devitt, L., Neal, J., Coxon, G., Savage, J., & Wagener, T. (2023). Flood hazard potential reveals global floodplain settlement patterns. *Nature Communications*, *14*(1). https://doi.org/10.1038/s41467-023-38297-9

Dong, J., Peng, J., Liu, Y., Qiu, S., & Han, Y. (2020). Integrating spatial continuous wavelet transform and kernel density estimation to identify ecological corridors in megacities. *Landscape and Urban Planning*, 199. doi: 10.1016/j.landurbplan.2020.103815

Du, X., Fang, Y., Zhao, H., & Xu, X. (2025). Spatiotemporal evolution and driving forces of landscape structure and habitat quality in river corridors with ceased flow: A case study of the Yongding River corridor in Beijing, China. *Journal of Environmental Management*, 374, 123861. doi: 10.1016/J.JENVMAN.2024.123861

Feng, H., Wang, S., Zou, B., Nie, Y., Ye, S., Ding, Y., & Zhu, S. (2023). Land use and cover change (LUCC) impacts on Earth's eco-environments: Research progress and prospects. *Advances in Space Research*, 71(3), 1418–1435. doi: 10.1016/J.ASR.2022.09.054

Feng, S., Li, W., Xu, J., Liang, T., Ma, X., Wang, W., & Yu, H. (2022). Land Use/Land Cover Mapping Based on GEE for the Monitoring of Changes in Ecosystem Types in the Upper Yellow River Basin over the Tibetan Plateau. *Remote Sensing*, 14(21). doi: 10.3390/rs14215361

Fernandes, M. R., Aguiar, F. C., Martins, M. J., Rivaes, R., & Ferreira, M. T. (2020). Long-term human-generated alterations of Tagus River: Effects of hydrological regulation and land-use changes in distinct river zones. In *Catena*, 188. doi : 10.1016/j.catena.2020.104466

Gollnow, F., Göpel, J., deBarros Viana Hissa, L., Schaldach, R., & Lakes, T. (2018). Scenarios of land-use change in a deforestation corridor in the Brazilian Amazon: combining two scales of analysis. *Regional Environmental Change*, 18(1), 143–159. doi: 10.1007/s10113-017-1129-1

Hack, J., Molewijk, D., & Beißler, M. R. (2020). A conceptual approach to modeling the geospatial impact of typical Urban threats on the habitat quality of river corridors. *Remote Sensing*, 12(8). doi : 10.3390/RS12081345

Hadfield, P., Prescott, M., Holden, J., Novalia, W., Suwarso, R., Marthanty, D. R., Priadi, C., Kirana, K. H., Endyana, C., Hardesty, B. D., Taufik, F. D., Zurbrügg, C., Josey, B., Astuti, N., Wong, T., Ramirez-Lovering, D., & Raven, R. (2024). Citarum Living Lab: Co-creating visions for sustainable river revitalisation. *PLOS Water*, *3*(8), e0000200. doi: 10.1371/journal.pwat.0000200

Hakim, A. M. Y., Santosa, B. H., Martono, D. N., Sencaki, D. B., Prayogi, H., Arifandri, R., Apip, A., Ningrum, W., Schröter, K., & Steinhausen, M. J. (2025). Exploring land cover change impacts on ecosystem services using machine learning technique and scenario simulation: case study of the Upper Citarum River Basin, Indonesia. *Modeling Earth Systems and Environment*, 11(3), 211. doi: 10.1007/s40808-025-02352-9

Han, Q., Wang, X., Li, Y., & Zhang, Z. (2022). River Ecological Corridor: A Conceptual Framework and Review of the Spatial Management Scope. In *International Journal of Environmental Research and Public Health,* 19,(13). doi: 10.3390/ijerph19137752

Hematang, F., Murdjoko, A., Kesaulija, F., Marwa, J., & Ungirwalu, A. (2024). Grouping Land Cover Using Orthophoto in Small Islands: An Application of Low-Cost UAV on Mansinam Island. *Forum Geografi*, 38(2), 189–202. doi: 10.23917/forgeo.v38i2.4870

Huang, L., Wang, J., & Chen, X. (2022). Ecological infrastructure planning of large river basin to promote nature conservation and ecosystem functions. *Journal of Environmental Management*, *306*, 114482. doi: 10.1016/J.JENVMAN.2022.114482

Huang, S., Ghazali, S., Azadi, H., Movahhed Moghaddam, S., Viira, A. H., Janečková, K., Sklenička, P., Lopez-Carr, D., Köhl, M., & Kurban, A. (2023). Contribution of agricultural land conversion to global GHG emissions: A meta-analysis. *Science of The Total Environment*, 876, 162269. doi: 10.1016/J.SCITOTENV.2023.162269

Inglis, N. C., Vukomanovic, J., Petrasova, A., & Meentemeyer, R. K. (2023). Viewscape change highlights shifting drivers of exurban development over time. *Landscape and Urban Planning*, *238*, 104833. doi: 10.1016/J.LANDURBPLAN.2023.104833

Ismail, A., Greve, K., Widiawaty, M. A., Dede, M., & Nandi, N. (2024). Effect of Vegetation Cover Changes on the Runoff Coefficient Characteristics in the Cisangkuy Watershed, Indonesia. *Anuario Do Instituto de Geociencias*, *47*. doi: 10.11137/1982-3908_2024_47_61104

Jahani, N., & Barghjelveh, S. (2021). Urban landscape services planning in an urban river-valley corridor system case study: Tehran's Farahzad River-valley landscape system. *Environment, Development and Sustainability*. doi: 10.1007/s10668-021-01474-1

Janus, J., Ertunç, E., Muchová, Z., & Tomić, H. (2023). Impact of selected land fragmentation parameters and spatial rural settlement patterns on the competitiveness of agriculture: Examples of selected European and Asian countries. *Habitat International*, 140, 102911. doi: 10.1016/J.HABITATINT.2023.102911

Jasim, I. A., Laheab A., A.-M., & and Al-Mamoori, S. K. (2024). Water corridors management: a case study from Iraq. *International Journal of River Basin Management*, *22*(1), 1–11. doi: 10.1080/15715124.2022.2079662

Kang, C. S., & Kanniah, K. D. (2022). Land use and land cover change and its impact on river morphology in Johor River Basin, Malaysia. *Journal of Hydrology: Regional Studies*, 41. doi: 10.1016/j.ejrh.2022.101072

Keeratikasikorn, C. (2018). A comparative study on four major cities in Northeastern Thailand using urban land density function. *Geo-Spatial Information Science*, 21(2), 93–101. doi: 10.1080/10095020.2018.1455320

Kennedy, C. M., Fariss, B., Oakleaf, J. R., Garnett, S. T., Fernández-Llamazares, Á., Fa, J. E., Baruch-Mordo, S., & Kiesecker, J. (2023). Indigenous Peoples' lands are threatened by industrial development; conversion risk assessment reveals need to support Indigenous stewardship. *One Earth*, 6(8), 1032–1049. doi : 10.1016/j.oneear.2023.07.006

Li, J., Dong, S., Li, Y., Wang, Y., Li, Z., & Li, F. (2022). Effects of land use change on ecosystem services in the China–Mongolia–Russia economic corridor. *Journal of Cleaner Production*, *360*, 132175. doi : 10.1016/J.JCLEPRO.2022.132175

Li, S., Congmou, Z., Li, Y., Dong, B., Tan, K., & Deng, X. (2023). Agricultural space function transitions in rapidly urbanizing areas and their impacts on habitat quality: An urban–Rural gradient study. *Environmental Impact Assessment Review*, *99*, 107019. doi: 10.1016/J.EIAR.2022.107019

Li, Z. H., Li, Z. P., Tang, X., Hou, W. H., & Li, P. (2021). Distribution and risk assessment of toxic pollutants in surface water of the lower yellow river, China. *Water (Switzerland)*, *13*(11), 1582. doi: 10.3390/w13111582

Lillemets, J., Viira, A. H., & Fertő, I. (2025). The intertwined geographies of agricultural land and human settlement in Europe. *Land Use Policy*, 153, 107527. doi: 10.1016/J.LANDUSEPOL.2025.107527

Lin, S., Maruthaveeran, S., & Yusof, M. J. M. (2024). Visitors' recreational & leisure experiences in urban river corridors? A case study of Hutuo River in Shijiazhuang, China. *Urban Forestry & Urban Greening*, 98, 128416. doi: 10.1016/J.UFUG.2024.128416

Lin, Y., Peng, C., Chen, P., & Zhang, M. (2022). Conflict or synergy? Analysis of economic-social- infrastructure-ecological resilience and their coupling coordination in the Yangtze River economic Belt, China. *Ecological Indicators*, 142. doi: 10.1016/j.ecolind.2022.109194

Lukmanul Hakim, Oekan S. Abdoellah, Parikesit, & Withaningsih, S. (2019). Impact of agricultural crop type and hunting on bird communities of two villages in Bandung, West Java, Indonesia. *Biodiversitas Journal of Biological Diversity*, 21(1). doi: 10.13057/biodiv/d210109

Lyu, X., Jia, Y., Qiu, Y., Du, J., Hao, C., Dong, H., & Chang, J. (2024). Influence of human-induced land use change on hydrological processes in semi-humid and semi-arid region: A case in the Fenhe River Basin. *Journal of Hydrology: Regional Studies*, 51. doi: 10.1016/j.ejrh.2023.101605

Majed, N., Real, M. I. H., Redwan, A., & Azam, H. M. (2022). How dynamic is the heavy metals pollution in the Buriganga River of Bangladesh? A spatiotemporal assessment based on environmental indices. *International Journal of Environmental Science and Technology*, 19(5), 4181–4200. doi: 10.1007/s13762-021-03434-8

Marselina, M., Wibowo, F., & Mushfiroh, A. (2022). Water quality index assessment methods for surface water: A case study of the Citarum River in Indonesia. *Heliyon*, 8(7). doi: 10.1016/j.heliyon.2022.e09848

Mattsson, E., Ostwald, M., & Nissanka, S. P. (2018). What is good about Sri Lankan homegardens with regards to food security? A synthesis of the current scientific knowledge of a multifunctional land-use system. *Agroforestry Systems*, 92(6), 1469–1484. doi: 10.1007/s10457-017-0093-6

Mazzorana, B., Nardini, A., Comiti, F., Vignoli, G., Cook, E., Ulloa, H., & Iroumé, A. (2018). Toward participatory decision-making in river corridor management: two case studies from the European Alps. *Journal of Environmental Planning and Management*, 61(7), 1250–1270. doi: 10.1080/09640568.2017.1339593

Meng, M., Dąbrowski, M., Tai, Y., Stead, D., & Chan, F. (2019). Collaborative spatial planning in the face of flood risk in delta cities: A policy framing perspective. *Environmental Science and Policy*, 96, 95–104. doi: 10.1016/j.envsci.2019.03.006

Miswar, D., Suyatna, A., Zakaria, W. A., Wahono, E. P., Saleh, Y., & Suhendro, S. (2023). Geospatial Modeling of Environmental Carrying Capacity for Sustainable Agriculture Using GIS. *International Journal of Sustainable Development and Planning*, 18(1), 99–111. doi: 10.18280/ijsdp.180110

Miswar, D., Suyatna, A., Zakaria, W. A., Wahono, E. P., Salsabilla, A., Mubarak, R. A., & Saleh, Y. (2023). Land cover changes in Bandar Lampung City, Indonesia 2016-2021. *Geografia,* 19(4), 30-43. doi: 10.17576/geo-2023-1904-03

Montgomery, D. C., Peck, E. A., & Vining, G. G. (2021). Introduction to linear regression analysis. John Wiley & Sons. ISBN 978-0-470-54281-1

Mukhoriyah, Arifin, S., Kushardono, D., Ardha, M., & Yulianto, F. (2023). Analysis of land use and spatial planning in the Upstream Citarum watershed of West Java based on remote sensing data. *Journal of Degraded and Mining Lands Management*, 10(3), 4315–4324. doi: 10.15243/jdmlm.2023.103.4315

Mwasenga, J. M., & Mjemah, I. C. (2023). Socio-Economic Feasibility for Implementation of Environmental Legislation along the Riparian Buffer Zones in Urban Rivers of Northern Tanzania. *Urban Science*, 7(3). doi: 10.3390/urbansci7030073

Nazombe, K., & Nambazo, O. (2023). Monitoring and assessment of urban green space loss and fragmentation using remote sensing data in the four cities of Malawi from 1986 to 2021. *Scientific African*, 20. doi: 10.1016/j.sciaf.2023.e01639

Norita, N., Masron, T., Ahmad, A., & Soda, R. (2024). Investigating the Spatial Relation between Landuse and Property Crime in Kuching, Sarawak through Location Quotient Analysis. *Forum Geografi*, 38(2), 153–166. doi: 10.23917/forgeo.v38i2.4575

Novalia, W., Suwarso, R., & Nurdin, I. (2024). Connecting place and multilevel governance for urban river restoration. *Territory, Politics, Governance*. doi: 10.1080/21622671.2024.2336608

Novita, E., Karomi, A. Z., & Pradana, H. A. (2022). Spatial Distribution of Potential Pollution Load Point Source of Bedadung River in the Urban Area Segment. *Forum Geografi*, 36(2). doi: 10.23917/forgeo.v36i2.12019

Ou, M., Zhong, Y., Ma, H., Wang, W., & Bi, M. (2022). Impacts of Policy-Driven Transformation in the Livelihoods of Fishermen on Agricultural Landscape Patterns: A Case Study of a Fishing Village, Island of Poyang Lake. *Land*, 11(8). doi: 10.3390/land11081236

Pandit, D., Haque, M. M., Bhuyan, M. S., Harun-Al-Rashid, A., Barman, P. P., Roy, R., Sarker, B., Saifullah, M. K., & Kunda, M. (2024). A comprehensive scenario of heavy metals pollution in the rivers of Bangladesh during the last two decades. *Environmental Science and Pollution Research*, 32(16), 10240–10257. doi: 10.1007/s11356-024-34225-6

Pazder, D. (2020). Aestheticization of Public Greenery as an Element of Socialisation of Urban Planning Process. Case Study of Old River Bank in the City of Poznan in Poland. Aestheticization of Public Greenery as an Element of Socialisation of Urban Planning Process. Case Study of Old River Bank in the City of Poznan in Poland. *International Journal of Advanced Science and Technology*, 29(7s), 851–863.

Peng, J., Tang, H., Su, C., Jiang, H., Dong, J., & Xu, D. (2023). Regarding reference state to identify priority areas for ecological restoration in a karst region. *Journal of Environmental Management*, 348. doi: 10.1016/j.jenvman.2023.119214

Permatasari, P. A., Amalo, L. F., Pangestu, R., & Putra, M. D. (2022). Pollution load capacity in the Downstream Citarum Watershed: 4 years after Citarum Harum Program. *Jurnal Pengelolaan Sumberdaya Alam Dan Lingkungan*, 12(4), 706–719. doi: 10.29244/jpsl.12.4.706-719

Polat, N., & Kaya, Y. (2021). Investigation of the Performance of Different Pixel-Based Classification Methods in Land Use/Land Cover (LULC) Determination. *Türkiye İnsansız Hava Araçları Dergisi*, 3(1), 1–6. doi: 10.51534/tiha.829656

Pradoto, W., Setiyono, B., Wahyono, H., & Joong Choi, M. (2024). Peri-urbanisation in Surakarta City and Economic Transformation in the Fast-Growing Region of Sukoharjo Regency. *Forum Geografi*, 38(2), 203–221. doi: 10.23917/forgeo.v38i2.5497

Pratiwi, D., Sumiarsa, D., Oktavia, D., Fatharani, R. H., & Sunardi. (2024). Effect of land use type on macrobenthos assemblages, distribution, and functional guild in Upstream Citarum River. *Ecological Indicators*, 160. doi: 10.1016/j.ecolind.2024.111849

Pratiwi, D., Sumiarsa, D., Oktavia, D., & Sunardi, S. (2023). Water Quality Influences Self-Purification in the Cihawuk and Majalaya Segments Upstream of the Citarum River, West Java, Indonesia. *Water (Switzerland)*, 15(16). doi: 10.3390/w15162998

Presidential Regulation No. 15 of 2018. (2018). on the Acceleration of Control of Pollution and Damage to the Citarum River Basin. Retriefed from https://peraturan.bpk.go.id/Details/73584/perpres-no-15-tahun-2018

Purnomo, E. P., Ramdani, R., Agustiyara, Tomaro, Q. P. V., & Samidjo, G. S. (2019). Land ownership transformation before and after forest fires in Indonesian palm oil plantation areas. *Journal of Land Use Science*, 14(1), 37–51. doi: 10.1080/1747423X.2019.1614686

Qu, Y., Zong, H., Su, D., Ping, Z., & Guan, M. (2021). Land use change and its impact on landscape ecological risk in typical areas of the yellow river basin in China. *International Journal of Environmental Research and Public Health*, 18(21). doi: 10.3390/ijerph182111301

Quan, J., Xu, Y., Ma, T., Wilson, J. P., Zhao, N., & Ni, Y. (2022). Improving surface water quality of the Yellow River Basin due to anthropogenic changes. *Science of The Total Environment*, *836*, 155607. doi: 10.1016/j.scitotenv.2022.155607

Rakib, M. R. J., Sarker, A., Mejjad, N., Islam, A. R. M. T., Kumar, R., Sharma, P., & Idris, A. M. (2024). Spatiotemporal distribution, trophic transfer, and research uncertainty of heavy metals in a subtropical highly polluted Buriganga River: A critical review. *Regional Studies in Marine Science*, *69*, 103327. doi: 10.1016/j.rsma.2023.103327

Rakuasa, H., & Pakniany, Y. (2022). Spatial Dynamics of Land Cover Change in Ternate Tengah District, Ternate City, Indonesia. *Forum Geografi*, 36(2). doi: 10.23917/forgeo.v36i2.19978

Ray, R., Das, A., Hasan, M. S. U., Aldrees, A., Islam, S., Khan, M. A., & Lama, G. F. C. (2023). Quantitative Analysis of Land Use and Land Cover Dynamics using Geoinformatics Techniques: A Case Study on Kolkata Metropolitan Development Authority (KMDA) in West Bengal, India. *Remote Sensing*, *15*(4). doi : 10.3390/rs15040959

Regulation of the Ministry of Agrarian Affairs and Spatial Planning. (2021). Procedures for the Preparation, Review, Revision, and Issuance of Substantive Approval of Provincial, Regency, and City Spatial Plans and Detailed Spatial Plans. Retriefed from https://peraturan.bpk.go.id/Details/209795/permen-agrariakepala-bpn-no-11-tahun-2021

Reinhart, H., Putra, R. D., Rafida, M. R., Majiid, M. A., & Maulita, N. S. (2023). Karst of Gunung Sewu Land Use and Land Covers Dynamics: Spatio-Temporal Analysis. *Forum Geografi*, *36*(2). doi: 10.23917/forgeo.v36i2.19868

Ren, C., Yang, R., Cheng, C., Xing, P., Fang, X., Zhang, S., Wang, H., Shi, Y., Zhang, X., Kwok, Y. T., & Ng, E. (2018). Creating breathing cities by adopting urban ventilation assessment and wind corridor plan – The implementation in Chinese cities. *Journal of Wind Engineering and Industrial Aerodynamics*, 182, 170–188. doi: 10.1016/J.JWEIA.2018.09.023

Richelle, L., Visser, M., Bock, L., Walpole, P., Mialhe, F., Colinet, G., & Dendoncker, N. (2018). Looking for a dialogue between farmers and scientific soil knowledge: Learnings from an ethno-geomorphopedological study in a Philippine's upland village. *Agroecology and Sustainable Food Systems*, 42(1), 2–27. doi: 10.1080/21683565.2017.1322661

Rodríguez-Echeverry, J. (2023). Extensification of Agricultural Land-Use Generates Severe Effects on the Critically Endangered Inter-Andean Dry Forest in the Ecuadorian Andean Landscape. *Journal of Landscape Ecology(Czech Republic)*, 16(3), 132–148. doi: /10.2478/jlecol-2023-0020

Rohmat, D. . R. M. . S. I. . S. S. . & R. F. I. W. (2025). Concept and Implementation of River Corridor to Ensure Environmental Sustainability of Citarum River, Indonesia. *Jurnal Penelitian Geografi*, *13*(1), 159–175. doi: 10.23960/jpg

Rohmat, D., Setiawan, I., Ismail, A., & Suhendro, S. (2024). *Koridor sungai: antara budaya pemanfaatan lahan dan parameter kualitas air di DAS Citarum*. Referensi Cendekia.

Rohmat, D., Trianawati, N., Malik, Y., Ridwana, R., Ihsan, M., Megantara Putri, I., Wijaya, M. A., Hakiki, F. N., Rizal, D., & Sudrajat, F. (2024). Structuring and Developing The Citarum River Corridor Space Based on The Wisdom And Aspirations of Local Communities. *Jurnal GEA*. doi: 10.17509/gea.v24i1.42520

Rohmat, F. I. W., Sa'adi, Z., Stamataki, I., Kuntoro, A. A., Farid, M., & Suwarman, R. (2022). Flood modeling and baseline study in urban and high population environment: A case study of Majalaya, Indonesia. *Urban Climate*, 46, 101332. doi: 10.1016/j.uclim.2022.101332

Saaty, T.L. (2013). Analytic Hierarchy Process. In: Gass, S.I., Fu, M.C. (eds) Encyclopedia of Operations Research and Management Science. Springer, Boston, MA. doi: 10.1007/978-1-4419-1153-7_31

Salviano, I. R., Gardon, F. R., & dos Santos, R. F. (2021). Ecological corridors and landscape planning: a model to select priority areas for connectivity maintenance. *Landscape Ecology*, 36(11), 3311–3328. doi: 10.1007/s10980-021-01305-8

Saputra, A. E., Nugraha, S., & Noviani, R. (2023). Analysis of Urbanisation's Relationship with Clean Water Supply Ecosystem Services in Sukoharjo Regency, Indonesia. *Forum Geografi*, 37(2), 178–190. doi: 10.23917/forgeo.v37i2.21218

Setiadi, S., Sumaryana, A., Bekti, H., & Sukarno, D. (2023). The flood management policy in Bandung city: Challenges and potential strategies. *Cogent Social Sciences*, 9(2). doi: 10.1080/23311886.2023.2282434

Setiawan, I., Rohmat, D., Ismail, A., & Suhendro, S. (2024). Landuse culture and water quality (BOD, COD, DO) in the upper citarum river corridor. *E3S Web of Conferences*, 600. doi: 10.1051/e3sconf/202460002009

Shu, L., Wang, T., Liu, J., Chen, Z., Wu, H., Qu, Y., Li, M., & Xie, M. (2024). Elucidating drivers of severe wintertime fine particulate matter pollution episodes in the Yangtze River Delta region of eastern China. *Science of The Total Environment*, 912, 169546. doi: 10.1016/j.scitotenv.2023.169546

Sigdel, R., Carlton, G., & Gautam, B. (2023). Resolving the Ganges pollution paradox: A policy-centric systematic review. *River*, 2(1), 126–141. doi: 10.1002/rvr2.35

Simpson, I. M., Winston, R. J., & Brooker, M. R. (2022). Effects of land use, climate, and imperviousness on urban stormwater quality: A meta-analysis. *Science of The Total Environment*, *809*, 152206. doi: 10.1016/J.SCITOTENV.2021.152206

Singh, P. K., Singh, A., Srivastava, A. K., Chauhan, R., Basniwal, R. K., & Chauhan, A. (2025). Microplastic pollution in the Ganga River: A state-of-the-art review of pathways, mechanisms, and mitigation. *Water Supply*, *25*(2), 249–267. doi: 10.2166/ws.2025.009

Sipahi, S., & Timor, M. (2010). The analytic hierarchy process and analytic network process: an overview of applications. Management decision, 48(5), 775-808. doi: 10.1108/00251741011043920

Somantri, L. (2024). Spatial Modelling Analysis for Potential Expansion of Cipanas City Candidate Area as Autonomous City. *Forum Geografi*, 38(1), 57–73. doi: 10.23917/forgeo.v38i1.3579

Suhendro, S. . S. Y. . M. H. . H. M. H. . N. N. . N. S. B. . & bin G. M. K. A. (2021). Change of Small Urban Centers in the Northern Corridor of Selangor From the Expansion of Klang-Langat Metropolitan Region Valley, Malaysia. *Sumatra Journal of Disaster, Geography and Geography Education*, 5(2), 77–86.

Tabassum, A., Basak, R., Shao, W., Haque, M. M., Chowdhury, T. A., & Dey, H. (2023). Exploring the Relationship Between Land Use Land Cover and Land Surface Temperature: a Case Study in Bangladesh and the Policy

Implications for the Global South. *Journal of Geovisualization and Spatial Analysis*, 7(2), 25. doi: 10.1007/s41651-023-00155-z

Tadesse, B., & Baye, F. (2024). The impact of land expropriation on changing livelihoods: The case of displaced peri-urban farmers in Kon and Gashena towns, Ethiopia. *Heliyon*, 10(11). doi: 10.1016/j.heliyon.2024.e31942

Tafazzoli, M. (2023). Hydrologic responses to urbanization: Towards a holistic approach for maximizing green roofs' performance in controlling urban precipitations. *Urban Climate*, 48, 101352. doi: 10.1016/J.UCLIM.2022.101352

Tampo, L., Kaboré, I., Alhassan, E. H., Ouéda, A., Bawa, L. M., & Djaneye-Boundjou, G. (2021). Benthic Macroinvertebrates as Ecological Indicators: Their Sensitivity to the Water Quality and Human Disturbances in a Tropical River. *Frontiers in Water*, 3. doi: 10.3389/frwa.2021.662765

Tang, R., Hou, G., Chen, Y., Liu, X., Chu, S., & Li, L. (2025). Spatial and temporal characteristics and driving mechanisms of recreational ecosystem services supply-demand mismatch in rapidly urbanizing areas: Evidence from the Yangtze River Delta. *Ecological Indicators*, 171. doi: 10.1016/j.ecolind.2025.113153

Taşkın, H. F., & Manioğlu, G. (2024). Evaluation of the impact of land use ratios and cover materials in settlement design on stormwater runoff. *Land Use Policy*, 146, 107314. doi: 10.1016/J.LANDUSEPOL.2024.107314

Tilley, A., Freed, S., Cagua, E. F., Longobardi, L., Sean, V., Mith, S., Miratori, K., & Kura, Y. (2024). Retention of fish biodiversity in a mixed-use agroecosystem in Cambodia. *Hydrobiologia*, 851(6), 1475–1488. doi: 10.1007/s10750-023-05400-6

Tiwari, N. K., Mohanty, T. R., Swain, H. S., Manna, R. K., Samanta, S., & Das, B. K. (2022). Multidecadal assessment of environmental variables in the river Ganga for pollution monitoring and sustainable management. *Environmental Monitoring and Assessment*, 194(8), 554. doi: 10.1007/s10661-022-10233-2

Tomsett, C., & Leyland, J. (2019). Remote sensing of river corridors: A review of current trends and future directions. In *River Research and Applications*, 35(7), 779–803. doi: 10.1002/rra.3479

Tran, H., Nguyen, Q., & Kervyn, M. (2018). Factors influencing people's knowledge, attitude, and practice in land use dynamics: A case study in Ca Mau province in the Mekong delta, Vietnam. *Land Use Policy*, 72, 227–238. doi: 10.1016/j.landusepol.2017.12.009

Tuan, N. T. (2022). Urbanization and land use change: A study in Vietnam. *Environmental and Socio-Economic Studies*, 10(2), 19–29. doi: 10.2478/environ-2022-0008

Wang, D., Chen, C., & Findlay, C. (2023). A review of rural transformation studies: Definition, measurement, and indicators. *Journal of Integrative Agriculture*, 22(12), 3568–3581. doi: 10.1016/J.JIA.2023.10.038

Wang, H.-X., Wu, W., Wang, Q.-K., Yang, X.-Q., & Yin, X.-W. (2023). [Impact of land use pattern on water quality under different riparian buffer zone scales in Gaya River Basin, Northeast China]. *The Journal of Applied Ecology*, 34(12), 3203–3213. doi: 10.13287/j.1001-9332.202312.026

Wang, H., Feng, R., Li, X., Yang, Y., & Pan, Y. (2023). Land Use Change and Its Impact on Ecological Risk in the Huaihe River Eco-Economic Belt. *Land*, 12(6). doi: 10.3390/land12061247

Wang, P., Lyu, L., & Xu, J. (2021). Factors influencing rural households' decision-making behavior on residential relocation: Willingness and destination. *Land*, 10(12). doi: 10.3390/land10121285

Wang, Y., Zhang, Z., & Chen, X. (2024). Impact of Land Use Change on Water-Related Ecosystem Services under Multiple Ecological Restoration Scenarios in the Ganjiang River Basin, China. *Forests*, 15(7). doi: 10.3390/f15071225

Ward, A. S., & Packman, A. I. (2019). Advancing our predictive understanding of river corridor exchange. In *Wiley Interdisciplinary Reviews: Water*, 6(1). John Wiley and Sons Inc. doi: 10.1002/WAT2.1327

Wei, W., Liu, C., Ma, L., Zhang, X., & Xie, B. (2022). Ecological Land Suitability for Arid Region at River Basin Scale: Framework and Application Based on Minmum Cumulative Resistance (MCR) Model. *Chinese Geographical Science*, 32(2), 312–323. doi: 10.1007/s11769-022-1261-9

White, R. E. (2020). The Value of Soil Knowledge in Understanding Wine Terroir. *Frontiers in Environmental Science*, *8*. doi: 10.3389/fenvs.2020.00012

Wily, L. A. (2018). Collective land ownership in the 21st century: Overview of global trends. *Land*, 7(2). doi: 10.3390/land7020068

Woessner, W. W. (2020). *Groundwater-Surface Water Exchange: Rivers, Lakes, and Wetlands*. Groundwater Project. doi: 10.21083/978-1-7770541-5-1

Wu, J., Zhu, Q., Qiao, N., Wang, Z., Sha, W., Luo, K., Wang, H., & Feng, Z. (2021). Ecological risk assessment of coal mine area based on "source-sink" landscape theory – A case study of Pingshuo mining area. *Journal of Cleaner Production*, 295. doi: 10.1016/j.jclepro.2021.126371

Xiang, M., Ma, J., Cheng, J., Lei, K., Li, F., Shi, Z., & Li, Y. (2022). Collaborative evaluation of heavy metal pollution of soil-crop system in the southeast of Yangtze River Delta, China. *Ecological Indicators*, *143*, 109412. doi: 10.1016/j.ecolind.2022.109412

Xie, F., Yu, M., Yuan, Q., Meng, Y., Qie, Y., Shang, Z., Luan, F., & Zhang, D. (2022). Spatial distribution, pollution assessment, and source identification of heavy metals in the Yellow River. *Journal of Hazardous Materials*, *436*, 129309. doi: 10.1016/j.jhazmat.2022.129309

Xie, Q., Han, Y., Zhang, L., & Han, Z. (2023). Dynamic Evolution of Land Use/Land Cover and Its Socioeconomic Driving Forces in Wuhan, China. *International Journal of Environmental Research and Public Health*, *20*(4). doi: 10.3390/ijerph20043316

Xu, D., Wang, Z., Tan, X., Xu, H., Zhu, D., Shen, R., ... & Yang, Z. (2024). Integrated assessment of the pollution and risk of heavy metals in soils near chemical industry parks along the middle Yangtze River. Science of the Total Environment, 917, 170431. doi: 10.1016/j.scitotenv.2024.170431

Xu, H., Zhao, G., Fagerholm, N., Primdahl, J., & Plieninger, T. (2020). Participatory mapping of cultural ecosystem services for landscape corridor planning: A case study of the Silk Roads corridor in Zhangye, China. *Journal of Environmental Management*, 264. doi: 10.1016/j.jenvman.2020.110458

Xu, J., Huang, X., Wang, N., Li, Y., & Ding, A. (2021). Understanding ozone pollution in the Yangtze River Delta of eastern China from the perspective of diurnal cycles. *Science of The Total Environment*, *752*, 141928. doi: 10.1016/j.scitotenv.2020.141928

Xu, Y., Zhao, X., Huang, P., Pu, J., Ran, Y., Zhou, S., Zhao, Q., Feng, Y., Tang, Y., Tao, J., & Zhang, Y. (2024). A new framework for multi-level territorial spatial zoning management: Integrating ecosystem services supply-demand balance and land use structure. *Journal of Cleaner Production*, *441*, 141053. doi: 10.1016/J.JCLEPRO.2024.141053

Yanbo, Q., Shilei, W., Yaya, T., Guanghui, J., Tao, Z., & Liang, M. (2023). Territorial spatial planning for regional high-quality development – An analytical framework for the identification, mediation and transmission of potential

land utilization conflicts in the Yellow River Delta. *Land Use Policy*, 125, 106462. doi: 10.1016/J.LANDUSEPOL.2022.106462
Yang, N., Zhang, T., Li, J., Feng, P., & Yang, N. (2024). Landscape ecological risk assessment and driving factors analysis based on optimal spatial scales in Luan River Basin, China. *Ecological Indicators*, *169*. doi: 10.1016/j.ecolind.2024.112821
Yu, T., Jia, S., Zhang, Y., & Cui, X. (2025). How can urban expansion and ecological preservation be balanced? A simulation of the spatial dynamics of production-living-ecological spaces in the Huaihe River Eco-Economic Belt. *Ecological Indicators*, 171. doi: 10.1016/j.ecolind.2025.113192
Zhang, X., Zhang, Y., Shi, P., Bi, Z., Shan, Z., & Ren, L. (2021). The deep challenge of nitrate pollution in river water of China. *Science of The Total Environment*, 770, 144674. doi: 10.1016/j.scitotenv.2020.144674
Zhang, Z., Ghazali, S., Miceikienė, A., Zejak, D., Choobchian, S., Pietrzykowski, M., & Azadi, H. (2023). Socio-economic impacts of agricultural land conversion: A meta-analysis. *Land Use Policy*, 132. doi: 10.1016/j.landusepol.2023.106831
Zhang, Z., Wang, Q., Feng, Y., Sun, Y., Liu, N., & Yan, S. (2024). The spatio-temporal evolution of spatial structure and supply-demand relationships of the ecological network in the Yellow River Delta region of China. *Journal of Cleaner Production*, 471, 143388. doi: 10.1016/J.JCLEPRO.2024.143388
Zhao, F., Yang, L., Tang, J., Fang, L., Yu, X., Li, M., & Chen, L. (2023). Urbanization–land-use interactions predict antibiotic contamination in soil across urban–rural gradients. *Science of The Total Environment*, *867*, 161493. doi: 10.1016/J.SCITOTENV.2023.161493
Zhuge, J., Zeng, J., Chen, W., & Zhang, C. (2023). Impacts of Land-Use Change on Ecosystem Services Value in the South-to-North Water Diversion Project, China. *International Journal of Environmental Research and Public Health*, 20(6). doi: 10.3390/ijerph20065069