



Integrating spatial scoring into critical land rehabilitation for sustainable ecosystem restoration

Chandra Egy Setiawan^{1,*}

¹ Graduate School of Sustainable Development, Universitas Indonesia, Central Jakarta, DKI Jakarta 10430, Indonesia.

*Correspondence: chandra.egy@ui.ac.id

Received Date: July 16, 2025

Revised Date: December 3, 2025

Accepted Date: August 18, 2026

ABSTRACT

Background: Land rehabilitation is an effort to restore land functions according to their intended use to achieve ecosystem balance, enhance soil infiltration, and improve water retention capacity. Land degradation can trigger a range of environmental issues such as soil erosion, and it is also one of the primary causes of landslides and floods. **Methods:** This study employed a spatial scoring method to assess land conditions in Tasikmalaya City. The goal was to develop appropriate rehabilitation approaches for critical land areas based on spatial characteristics and severity levels. **Findings:** The results indicated that critical land areas remain in several sub-districts within Tasikmalaya City, necessitating targeted rehabilitation efforts. Three main rehabilitation approaches were identified as suitable: (1) community forest and agroforestry systems, (2) community forest combined with non-structural slope reinforcement, and (3) environmental greening initiatives. **Conclusion:** Rehabilitation efforts in Tasikmalaya must be tailored to the specific conditions of degraded areas. Integrating ecological-based practices such as agroforestry and community involvement is essential in restoring the land's function and preventing future disasters. **Novelty/Originality of this article:** This study contributes a spatially-based decision-making model for land rehabilitation planning, offering a practical, location-specific approach for addressing land degradation in urban areas such as Tasikmalaya City.

KEYWORDS: critical land; land rehabilitation; spatial scoring; Tasikmalaya city.

1. Introduction

Environmental issues related to land degradation caused by anthropogenic activities remain persistent as long as humans continue to pursue development. Nevertheless, efforts to address, or at least mitigate, these problems such as land degradation must continue to be pursued, one of which is through land rehabilitation. Forest and land rehabilitation is an effort to restore the function and productivity of forests or land that have been damaged or degraded due to human activities, such as illegal logging, forest fires, or inappropriate land use (Hakim, et al., 2023). These efforts must be properly implemented in areas that have experienced land function degradation. Critical land areas are therefore the primary rehabilitation target. Critical land is defined as a condition in which the land's capability does not match its use, leading to physical, chemical, and biological damage (Munir & Rinduwati, 2023).

Critical land is the result of land-use conversion without accompanying restoration efforts. Mastur et al. (2021) argues that continuous land-use changes without conservation measures can lead to declining land productivity or land degradation, which subsequently

Cite This Article:

Setiawan, C. E. (2026). Integrating spatial scoring into critical land rehabilitation for sustainable ecosystem restoration. *Critical Issues of Sustainable Future*, 3(2), 198-219. <https://doi.org/10.61511/crsusf.v3i2.2100>

Copyright: © 2026 by the author. This article is distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).



causes various issues, one of which is the emergence of critical land areas (Zachrani et al., 2024). In addition to anthropogenic factors, natural elements may also contribute to the formation of critical land. According to Kubangun et al. (2014), Unfavorable physical characteristics, such as high rainfall, steep slopes, and easily erodible soils, can naturally trigger the development of critical land areas (Nurdin, 2022). The scale of the problem is not merely local. More than 2.6 billion people across over 100 countries are affected by deteriorating land conditions (Singh et al., 2023), and land degradation is now considered both a global environmental challenge (Yang et al., 2023) and one of the structural barriers to achieving the Sustainable Development Goals (Jiang et al., 2024).

Currently, critical land areas in Indonesia refer to stretches of land that have experienced significant unproductivity due to poor land management and inadequate implementation of soil and water conservation practices. This phenomenon has led to various problems, including soil erosion, environmental degradation, and the decline of both the physical and chemical quality of the land (Purwadi & Siswanto, 2021, as cited in Mangela et al., 2024). Critical land conditions can serve as a trigger for environmental disasters, such as floods. According to the Indonesian Disaster Data and Information (DIBI), between the beginning of the year and May 27, 2024, a total of 449 flood events have been recorded across the country (Rahmadani et al., 2024).

In the city of Tasikmalaya, more than 30 locations are identified as flood-prone during the rainy season (Irawan et al., 2024). Meanwhile, data from the Tasikmalaya City Regional Disaster Management Agency/*Badan Penanggulangan Bencana Daerah* (BPBD) reported 28 flood events and 34 landslides throughout 2024. These Figures indicate not only inadequate infrastructure management but also point strongly to a lack of water infiltration capacity and green coverage functioning as ecological buffers. Left unaddressed, that kind of land degradation reaches further than flooding alone: it erodes food availability, livelihoods, and biodiversity locally (AbdelRahman, 2023), and correlates nationally with worsening food security, public health, and socioeconomic outcomes (Jinger et al., 2023).

Land rehabilitation addresses critical land directly: it restores ecosystem balance, raises groundwater capacity, and improves soil quality, which together help buffer drought impacts (Rizki, 2023). It takes several forms, among them agroforestry, community-based forestry, and environmental greening, and agroforestry in particular has a track record against land degradation, deforestation, shrinking water reserves, and long-term greenhouse gas accumulation. According to Patel & Moore (2017), that track record extends to the socioeconomic side too, where it has helped stabilize community livelihoods in the agribusiness sector (Hilalia et al., 2024). Evidence for what makes rehabilitation work is converging on a few recurring factors rather than a single formula. Community-based forest management improves land cover and contributes to climate mitigation (Putri et al., 2024), and within these schemes, outcomes track closely with two design choices: prioritizing multipurpose trees for erosion control and food security, also investing in community capacity rather than treating planting as a one-off intervention (Sukamdani & Sukwika, 2023).

At the landscape scale, rehabilitation also functions as a lever for carbon sequestration (Supandi et al., 2025), though its ability to cut landslide risk depends heavily on whether the chosen land use actually suits the site, a constraint that gets harder to satisfy as land-use change and mismanagement accelerate (Zildan & Marhaento, 2025). None of this happens in isolation from broader development pressure: rehabilitation planning needs to be integrated with, not bolted onto, the accelerated growth of dynamic areas (Hidayat et al., 2025), which is precisely why it has become a recurring concern in urban development as cities expand (Abirami et al., 2024). Institutionally, that means pairing rehabilitation with sustained oversight, since forest managers and local government still need to monitor agricultural activity on the ground for interventions to hold (Ningrum et al., 2024). Tracking whether any of this is actually working is its own challenge, and remote sensing has become the practical tool for monitoring vegetation change and evaluating rehabilitation outcomes over time (Rijal et al., 2025).

One of the approaches used in analyzing critical land and planning land rehabilitation is the spatial approach. Geographic Information Systems (GIS) facilitate the provision of accurate biophysical land information efficiently, without requiring excessive time or financial resources (Tupanno et al., 2023). The level of land degradation can be mapped using GIS, allowing for effective planning of which areas require restoration and improved land management (Ramli et al., 2023).

Indonesia's national Forest and Land Rehabilitation of Watershed Areas/*Rehabilitasi Hutan dan Lahan Daerah Aliran Sungai* (RHL-DAS) framework (Permen LHK No. 10/2022 and its predecessor P.32/2009) already prescribes this integration: it defines priority categories combining critical land status, infiltration (recharge area) condition, and disaster susceptibility, generated through a mandated spatial overlay procedure. That procedure, however, is designed around watershed units (DAS or sub-DAS), which is how it has typically been applied in practice, from DAS Cimanuk to DAS Juwana. Administrative city governments, who are responsible for local disaster mitigation and land-use permitting, operate on jurisdictional boundaries that rarely align with a watershed. This study applies the standard method within the administrative boundary of Tasikmalaya City rather than a DAS unit, producing a rehabilitation recommendation output the city government can act on directly, which is relevant given the flood and landslide record reported above.

The objective of this study is to map areas in Tasikmalaya City that require land rehabilitation, based on several parameters: critical land status, water infiltration conditions, and susceptibility to landslides and flooding. The study also aims to recommend appropriate rehabilitation approaches for each specific case or condition of land degradation, in relation to the other spatially mapped variables.

1.1 Urban ecology

One perspective in urban ecology is that current ecological theory does not fully capture the complexity of urban ecosystems, where natural and human systems interact, a dynamic often labeled socio-ecological or coupled human-ecological systems. According to Alberti (2008) that gap is pushing researchers toward urban ecological theory that pulls in concepts across disciplines to explain how urban ecosystems actually behave (Parris, 2016).

Jones et al. (1994) argue that humans can be viewed as ecosystem engineers in urban environments. Ecosystem engineers are organisms that directly or indirectly regulate the availability of resources to other species by causing physical changes in biotic or abiotic materials; in doing so, they modify, maintain, and create habitats. Humans, therefore, can be classified as allogenic ecosystem engineers, meaning they reshape their surroundings by converting materials from one physical state into another (Parris, 2016).

Urban ecology is the study of ecosystems that include humans living in cities and the resulting changes in the landscape. It is a relatively new field that embraces an interdisciplinary approach aimed at understanding the dynamic relationship between humans and their environment (Ridhoi, 2023).

1.2 Growth phenomena and land use change cases

Urban phenomena describe how cities function, grow, and change structurally, with morphological and spatial patterns shaping much of that transformation. As socio-human settlements, cities vary in density and intensity and run on social institutions built around integration and diversity. Urban studies typically examine how city sizes are distributed and ranked, since that hierarchy shapes development rules, spatial planning, and, downstream, infrastructure provision (Sihombing & Utami, 2023).

In the context of urban spatial structure, land rent patterns and land use can be understood through Von Thünen's theory (O'Kelly & Bryan, 1996). Activities that require quick access to markets, such as horticulture, are typically located close to the city center and are associated with higher land rents, while activities like forestry and grazing are located further from the center and are associated with lower land values.

Modifications to this theory include geographic factors, such as rivers, which reshape land use patterns by enabling development and land use activities to cluster near waterways or other geographic features. Thus, physical environmental factors also influence urban transformation. Astuti & Lukito (2020), argue that another driver of land use change is the decreasing productivity of rice fields, which has led many landowners to convert their agricultural land for other uses in pursuit of greater economic returns (Monsaputra, 2023).

1.3 Ecosystem/land insecurity and degradation

Ecosystem vulnerability refers to conditions that may lead to ecosystem damage, including the degradation of both ecological structure and function. This vulnerability arises from various forms of disturbance, whether natural or anthropogenic, each exerting different effects and resulting in diverse impacts depending on the nature and intensity of the disturbance. Nature is the medium through which ecosystems function, and it needs to be preserved for that reason alone: living beings, humans included, depend on it directly for their well-being (Salsabil et al., 2024).

Ecosystem degradation is defined as a decline in ecosystem quality, marked by alterations in structure and function due to environmental pressures, whether natural or human caused. Such changes disrupt the balance between biotic (living organisms) and abiotic (physical elements) components within an ecosystem (Ravera, 1987). Mining activities, both legal and illegal, often involve extensive deforestation, which is a major driver of forest ecosystem degradation (Febi et al., 2024).

Land degradation refers to the process of declining land functionality and utility, encompassing economic, ecological, social, and cultural aspects. This condition reduces the land's capacity to provide essential ecosystem services, including water regulation and the production of food, housing materials, and clothing (Wahyunto & Dariah, 2014). Land-use conversion accelerates this decline directly: it shifts carbon stocks between terrestrial systems, the hydrosphere, and the atmosphere, and that redistribution feeds back into the same ecosystem services the land is meant to provide (Ersoy Mirici & Berberoglu, 2024).

2. Methods

The primary reference used in this study for determining the mapping units targeted for Forest and Land Rehabilitation (LHR) in Tasikmalaya City (the research locus) is Appendix I of the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia regulation of the Minister of Environment and Forestry Number 10 of 2022 concerning the Preparation of General Plans for Watershed Forest and Land Rehabilitation and Annual Plans for Forest and Land Rehabilitation. The analytical method employed is spatial analysis, which includes the identification and assessment of: (1) critical land classification, (2) infiltration area vulnerability, and (3) disaster-prone area assessment. The classification of critical land (Table 1) serves as a key consideration, as it represents the highest priority in rehabilitation programs. The spatial data used include a 1:50,000-scale critical land map obtained from the Watershed and Protected Forest Management Agency (Watershed Management Agency/*Balai Pengelolaan Daerah Aliran Sungai* (BPDAS) Cimanuk-Citanduy), accessed through the One Map portal in October 2024.

Table 1. Land criticality class

Land Criticality Class	Code	Category/Code
Non-Critical	TK	Non-Critical/TK
Potentially Critical	PK	
Slightly Critical	AK	
Critical	K	Critical/K
Very Critical	SK	

The vulnerability of infiltration areas was identified by analyzing both natural infiltration potential and actual infiltration conditions. To determine natural infiltration classes (Table 2), a scoring method was applied to the following variables: (1) slope gradient, derived from National Digital Elevation Model/*Digital Elevation Model Nasional* (DEMNAS) data (Table 3); (2) soil type, sourced from FAO and adjusted according to the national classification system (Table 4); (3) average annual rainfall values obtained from the Meteorological, Climatological, and Geophysical Agency/*Badan Meteorologi, Klimatologi, dan Geofisika* (BMKG) (Table 5); and (4) groundwater potential in shallow aquifers from the Ministry of Energy and Mineral Resource/*Energi dan Sumber Daya Mineral* (ESDM) (Table 6).

Actual infiltration was identified using a scoring approach based on land cover data from the Ministry of Environment and Forestry/*Kementerian Lingkungan Hidup dan Kehutanan* (KLHK, 2020) (Table 7). By overlaying both natural and actual infiltration maps using a spatial overlay method, the classification of infiltration area conditions was determined (Table 8).

Table 2. Total natural infiltration score from several variables

Total Score	Natural infiltration potential class	Notation
>17	Very High	a
14 – 17	High	b
10–13	Moderate	c
6 – 9	Low	d
< 6	Very Low	e

Table 2 illustrates the classification of natural infiltration potential obtained from score calculations based on a number of environmental variables that affect the soil's ability to absorb water. This classification aims to group infiltration potential levels into several categories, thereby facilitating the assessment of the hydrological conditions of an area. This scoring system can determine the potential of an area to support water infiltration into the soil.

Table 3. Relationship between slope and infiltration

Class	Slope (%)	Description	Transformation Result	
			Infiltration	Score
I	< 8	Flat	> 0.8	5
II	8 – 15	Gentle	0.7 – 0.8	4
III	15 – 25	Wavy	0.5 – 0.7	3
IV	25 – 40	Steep	0.2 – 0.5	2
V	> 40	Very Steep	< 0.2	1

Table 3 explains the relationship between slope inclination and the level of infiltration that occurs in an area. Slope inclination affects the rate and volume of water that can seep into the ground, so each slope class is given a transformation value in the form of a score for quantitative analysis purposes. This approach allows for the integration of topographical factors into a more comprehensive and objective evaluation of infiltration potential.

Table 4. Infiltration in each soil type

Soil Type	Soil Texture	Infiltration Rate	Score
Regosol	Rough	High	5
Alluvial, andosol	Slightly Rough	Slightly High	4
Latosol, Yellow Red Podzolic	Moderate	Moderate	3
Lithosol, mediteran	Slightly Smooth	Slightly Low	2
Grumusol	Smooth	Low	1

Table 4 explains the variation in infiltration rates based on soil type and texture. Each soil type has a different ability to absorb water, which is then represented by a score to

facilitate quantitative analysis. This assessment is important in understanding the contribution of soil physical properties to the infiltration process and groundwater availability in a region.

Table 5. Rainfall to Infiltration Value

Description	Annual Rainfall (mm)	Score
Very High	> 5,500	5
High	4,500-5,500	4
Moderate	3,000-4,500	3
Low	1,500-3,000	2
Very Low	<1,500	1

Table 5 and Table 6 describe other factors supporting infiltration, namely rainfall and groundwater potential. Table 5 relates annual rainfall to infiltration values, showing the effect of rainfall intensity on the soil's ability to absorb water. Meanwhile, Table 6 assesses infiltration potential based on shallow aquifer conditions, reflecting the capacity of the subsoil to store and drain water vertically.

Table 6. Groundwater potential for infiltration

Groundwater Potential	Infiltration	Score
High in Shallow Aquifer	High	4
Moderate in Shallow Aquifer	Slightly High	3
Low in Shallow Aquifer	Moderate	2
Nil in Shallow Aquifer	Low	1

Table 7. Actual infiltration based on land cover

Land Cover Class Group	Actual Infiltration Class	
	Description	Notation
Primary Dryland Forest, Secondary Dryland Forest	High	A
Production Forest, Plantation, Forest Plantation	Slightly High	B
Scrub, Grassland	Moderate	C
Horticulture, Dryland Agriculture, Mixed Dryland Agriculture	Slightly Low	D
Settlement, Paddy Field, Airport, Swamp Scrub, Primary Mangrove Forest, Secondary Mangrove Forest, Primary Swamp Forest, Secondary Swamp Forest, Mining, Swamp, Pond, Open Land, Transmigration, Water Body	Low	E

Table 8. Infiltration area condition

Class	Description	Information	Code	Category
I	Good	eA, eB, eC, eD, dA, dB, dC, cA, cB, bA	Rb	Rt
II	Natural Normal	aA, bB, cC, dD, eE	Rn	
III	Starting to get critical	aB, bC, cD, dE	Ra	Rk
IV	Slightly Critical	aC, bD, cE	Rmk	
V	Critical	aD, bE	Rkr	
VI	Very Critical	aE	Rsk	

For simplification purposes in this study and based on the spatial plan of Tasikmalaya City for 2011–2031 as outlined in Regional Regulation No. 4 of 2012 (Figure 1), all areas were considered as cultivation zones. Protected areas within the spatial plan include railway buffer zones, lake buffers, river buffers, and high-voltage transmission line corridors.

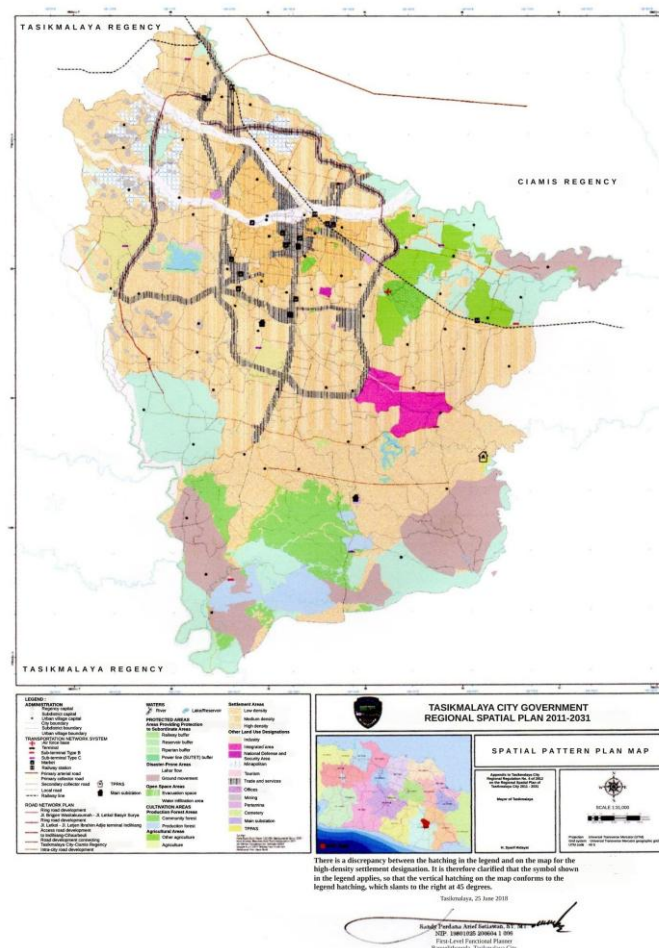


Fig. 1. Spatial pattern of Tasikmalaya City 2011-2031
(Tasikmalaya City Regional Regulation Number 4 of 2012 on the Spatial Plan 2011–2031)

The next step involves classifying vulnerability levels for runoff based on flood hazard index data from the National Disaster Management Agency/*Badan Nasional Penanggulangan Bencana* (BNPB) (Table 9) and landslide susceptibility, which was analyzed using DEMNAS data (Table 10).

Table 9. Runoff prone class

Runoff Prone Class	Class	Category/Code
Low	< 25	T
Normal	26 - 50	
High	51 - 75	Ro
Extreme	76 - 100	

(Chow, 1964; Directorate General of Watershed Management and Social Forestry/*Direktorat Jenderal Bina Pengelolaan Daerah Aliran Sungai dan Perhutanan Sosial* (Ditjen BPDASPS), 2011)

Table 10. Landslide Prone Class

Classification	Class	Category/Code
Not Vulnerable	< 9	
Slightly Vulnerable	10 - 13	T
Moderate	14 - 17	
Vulnerable	18 - 21	L
Very Vulnerable	> 21	

(Paimin et al., 2006; Ditjen BPDASPS, 2011)

Land cover types targeted in the Forest and Land Rehabilitation (FLR) program include dryland agriculture, mixed dryland agriculture, plantations, shrubs, open land, as well as

residential and transmigration areas. The land rehabilitation recommendation matrix (Table 11) was developed through a spatial overlay process combining data on critical land, infiltration conditions, and flood and landslide vulnerability.

Table 11. Matrix of RHL-DAS activity recommendations

Critical Land	Infiltration Condition	Landslide			Runoff			Non-Vulnerable		
		Plk	ST	Pm	Plk	ST	Pm	Plk	ST	Pm
K	Rk	KB-HR-Pt-Agr	KB-HR-Pt-Agr	KB-PL	KB-HR-Agr	KB-HR-Agr	KB-PL	KB-HR-Agr	KB-HR-Agr	KB-PL
		KB-HR-Pt-Agr	KB-HR-Pt-Agr	KB-PL	KB-HR-Agr	KB-HR-Agr	KB-PL	KB-HR-Agr	KB-HR-Agr	KB-PL
		KB-HR-Pt-Agr	KB-HR-Pt-Agr	KB-PL	KB-HR-Agr	KB-HR-Agr	KB-PL	KB-HR-Agr	KB-HR-Agr	KB-PL
	Rt	KB-HR-Pt-Agr	KB-HR-Pt-Agr	KB-PL	KB-HR-Agr	KB-HR-Agr	KB-PL	KB-HR-Agr	KB-HR-Agr	KB-PL
		KB-HR-Pt-Agr	KB-HR-Pt-Agr	KB-PL	KB-HR-Agr	KB-HR-Agr	KB-PL	KB-HR-Agr	KB-HR-Agr	KB-PL
		KB-HR-Pt-Agr	KB-HR-Pt-Agr	KB-PL	KB-HR-Agr	KB-HR-Agr	KB-PL	KB-HR-Agr	KB-HR-Agr	KB-PL
TK	Rk	KB-HR-Pt-Agr	KB-HR-Pt-Agr	KB-PL	KB-HR-Agr	KB-HR-Agr	KB-PL	KB-HR-Agr	KB-HR-Agr	KB-PL
	Rt	KB-HR-Pt-Agr	KB-HR-Pt-Agr	KB-PL	KB-HR-Agr	KB-HR-Agr	KB-PL	-	-	-

Plk refers to Plantation, Dryland Agriculture, and Mixed Dryland Agriculture. ST denotes Shrubs and Open Land. Pm stands for Settlement and Transmigration. Agr refers to Agroforestry Reforestation, while Agr is simply Agroforestry. Ri indicates Intensive Reforestation. Pt stands for Slope Reinforcement (non-structural civil engineering). HA refers to Community Forest. PL stands for Environmental Greening. K denotes Critical (including both critical and highly critical classes). TK refers to Non-Critical (including slightly critical, potentially critical, and non-critical classes). Rk indicates Critical Recharge (including critical and highly critical recharge classes), while Rt refers to Non-Critical Recharge.

3. Results and Discussion

3.1 Identification of critical land

The delineation of critical land based on data from the Cimanuk-Citanduy BPDAS in Tasikmalaya City (Table 12) shows that Kawalu District has the largest extent of strictly critical (K) land, at 420.7 hectares, followed by Tamansari District at 387.9 hectares. When the slightly critical (AK) class is added, however, Tamansari records the larger combined extent – $387.9 + 1,804.2 = 2,192.1$ hectares – compared with Kawalu's $420.7 + 1,620.4 = 2,041.1$ hectares. Both districts therefore carry the heaviest critical-land burden in the city; which one ranks first depends on whether the comparison uses the strictly "critical" class alone or the combined "critical" and "slightly critical" classes. On the other hand, districts such as Cihideung, Cipedes, and Indihiang are almost entirely classified as "non-critical." The distribution map of critical land can be seen in Figure 2.

The concentration of critical land in Kawalu and Tamansari follows the city's terrain. Both districts sit in the hillier, southern part of the city, where steeper slopes and more erodible soils create the natural predisposition toward land criticality described by Kubangun et al. (2014, as cited in Nurdin, 2022): critical land can emerge from biophysical conditions alone, and human land-use pressure then compounds that baseline vulnerability, which is plausible in Kawalu and Tamansari given their mix of dryland agriculture on sloped terrain. Conversely, the almost entirely non-critical status of Cihideung, Cipedes, and Indihiang reflects their position as the built-up urban core of Tasikmalaya City, where lower

density and less agricultural conversion pressure limit exposure to the processes that typically precede critical land formation elsewhere in the city.

Table 12. Critical land area in Tasikmalaya City based on subdistricts

District	Status of Critical Land (Ha)				Grand Total
	Critical	Slightly Critical	Potentially Critical	Non-Critical	
Bungursari	1.0	121.9	530.2	1,113.4	1,766.5
Cibeureum	-	21.2	1,086.8	773.8	1,881.8
Cihideung	-	-	8.9	537.3	546.2
Cipedes	-	-	125.3	781.1	906.4
Indihiang	-	-	0.4	1,089.0	1,089.4
Kawalu	420.7	1,620.4	460.1	1,800.9	4,302.1
Mangkubumi	-	53.5	195.5	2,156.9	2,405.9
Purbaratu	12.8	112.5	795.8	397.2	1,318.3
Tamansari	387.9	1,804.2	823.3	721.3	3,736.7
Tawang	-	-	91.1	609.0	700.1
Grand Total	822.4	3,733.7	4,117.4	9,979.9	18,653.4

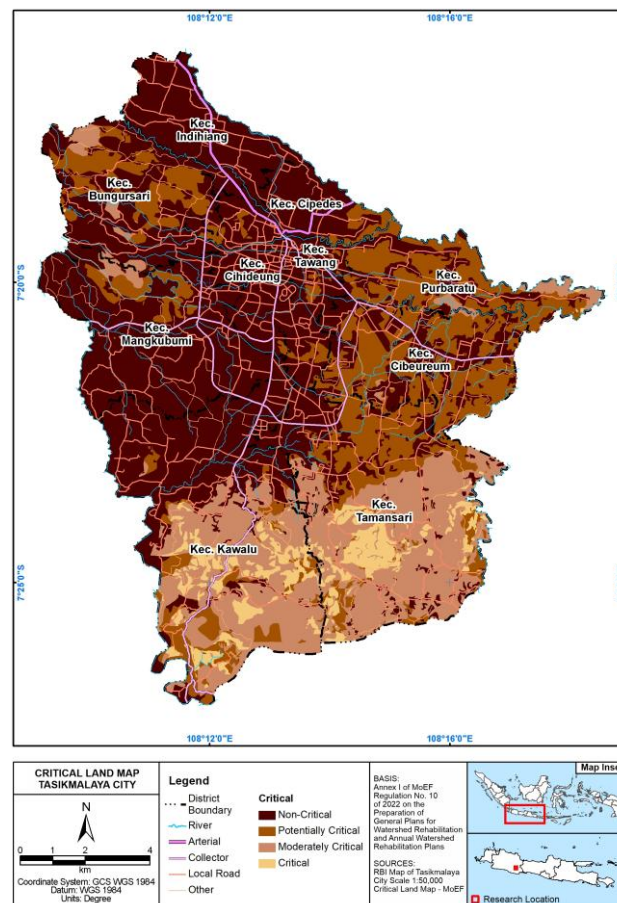


Fig. 2. Critical land map of Tasikmalaya City

3.2 Infiltration area condition

3.2.1 Natural infiltration

The processing of natural infiltration data (Figure 3) was carried out using a scoring analysis, as described in the previous research methodology. This included scoring data on slope gradient (Figure 4a), soil type (Figure 4b), average annual rainfall (Figure 4c), and

groundwater potential (Figure 4d). The results from the analysis of these four variables were then classified into low, medium, and high infiltration levels (Table 13).

The analysis results show that Kawalu District has the largest natural infiltration area in Tasikmalaya City, totaling 4,230.0 hectares. The majority of this area falls under the medium infiltration category (2,769.7 hectares), followed by high infiltration (1,125.4 hectares) and low infiltration (334.9 hectares). Mangkubumi District ranks second with a total of 2,399.7 hectares, most of which is also classified as high infiltration (2,138.8 hectares), while the medium and low categories account for smaller portions. Cibeureum District has a total natural infiltration area of 1,839.7 hectares, predominantly in the "medium" infiltration category (1,831.5 hectares), with only a small portion classified as "low" (8.2 hectares) and no areas identified as having "high" infiltration.

Table 13. Natural Infiltration Class of Tasikmalaya City

District	Natural Infiltration			Grand Total
	High	Moderate	Low	
Bungursari	1,584.5	176.2	-	1,760.7
Cibeureum	-	1,831.5	8.2	1,839.7
Cihideung	535.5	10.6	-	546.1
Cipedes	757.0	145.6	0.7	903.3
Indihiang	997.2	84.1	-	1,081.3
Kawalu	1,125.4	2,769.7	334.9	4,230.0
Mangkubumi	2,138.8	260.4	0.5	2,399.7
Purbaratu	-	1,171.3	83.6	1,254.9
Tamansari	131.5	3,246.1	319.9	3,697.5
Tawang	424.8	267.9	-	692.7
Grand Total	7,694.7	9,963.4	747.8	18,405.9

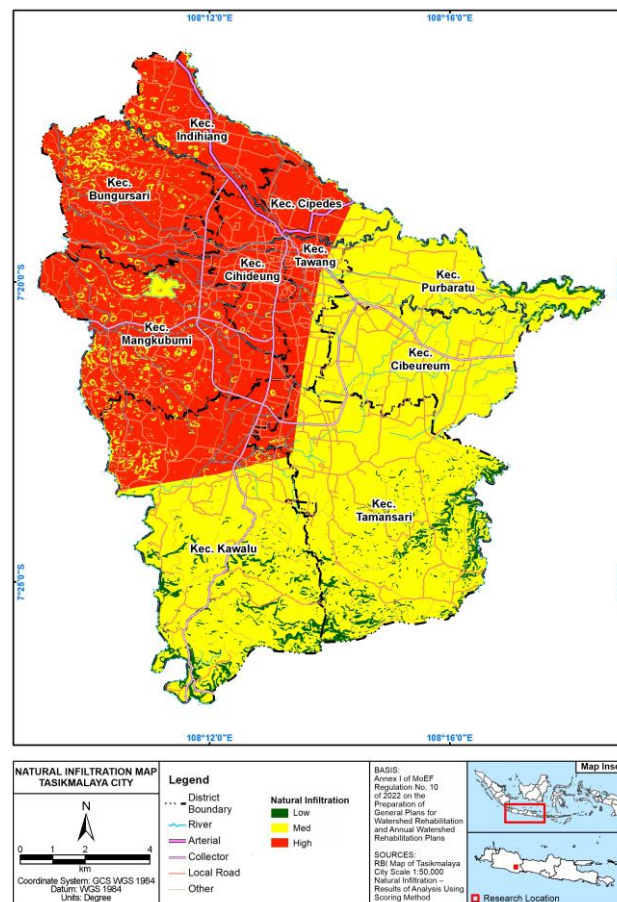


Fig. 3. Natural infiltration map of Tasikmalaya City

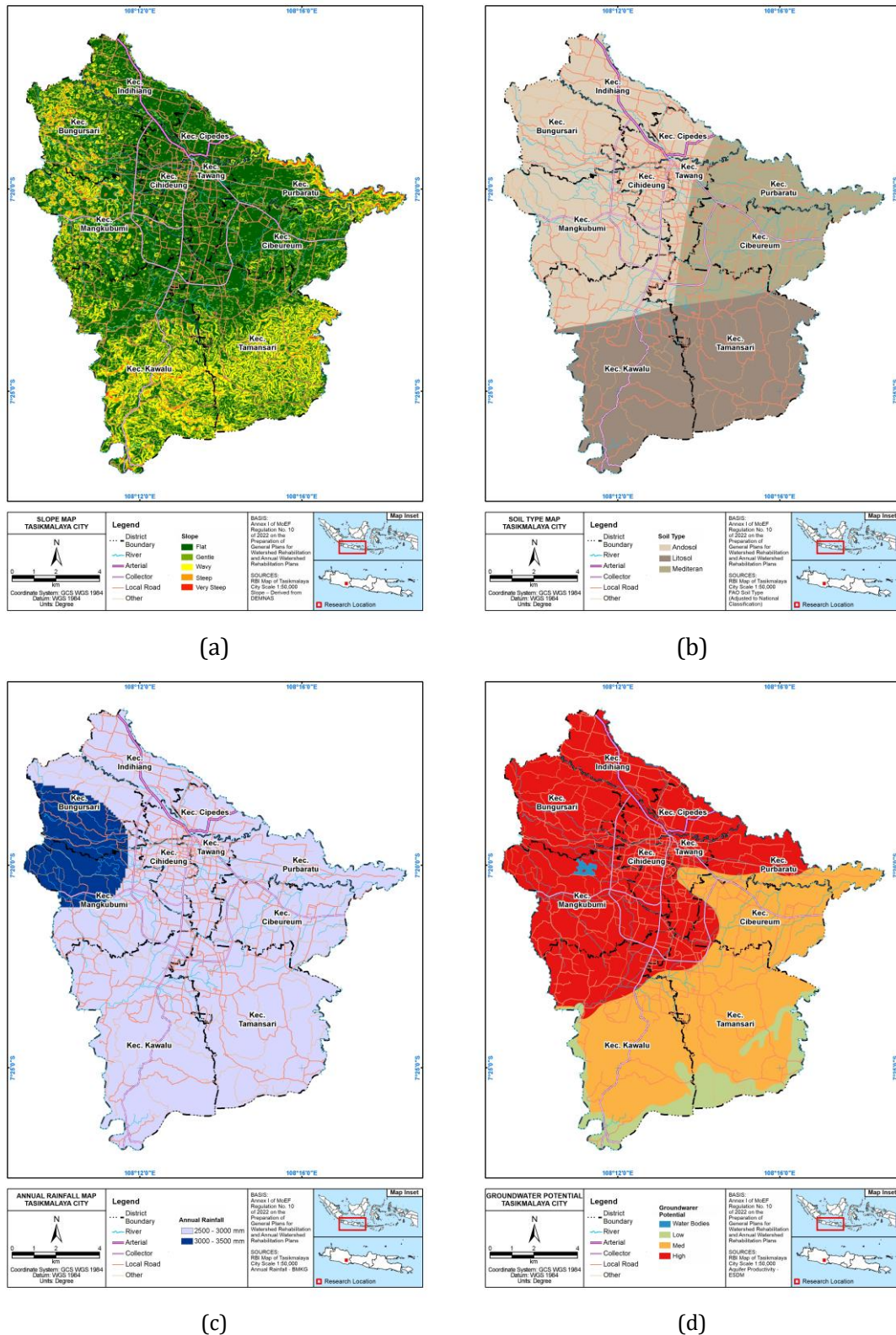


Fig. 4. Input parameter maps for natural infiltration in Tasikmalaya City: (a) slope, (b) soil type, (c) annual rainfall, and (d) groundwater potential

Meanwhile, Tamansari District has a total infiltration of 3,697.5 hectares, with a strong dominance of the medium category (3,246.1 hectares), while the high and low categories account for 131.5 hectares and 319.9 hectares, respectively. Cihideung District, with a relatively small total infiltration area (546.1 hectares), is dominated by the high infiltration

category (535.5 hectares), with only a minimal portion classified as medium (10.6 hectares). These natural infiltration values are, of course, also influenced by the total area of each district.

3.2.2 Actual infiltration

The analysis of actual infiltration in Tasikmalaya City, derived from land cover (Figure 5) and mapped in Figure 6, shows that Kawalu District recorded the highest infiltration value, totaling 4,245.1 hectares, primarily from the Slightly Low category (2,078.3 hectares) and the Low category (1,929.4 hectares). Cihideung District recorded the lowest total actual infiltration area, at 546.1 hectares, almost entirely under the Low category (Table 14). Indihiang District similarly records a modest total of 1,089.4 hectares, nearly all of which falls under the Low category.

Table 14. Actual infiltration class of Tasikmalaya City

District	Actual Infiltration (ha)								Grand Total
	Slightly High				Slightly Low				
	HT	PK	PLK	PLKC	BA	BD	PM	SW	
Bungursari	-	-	700.1	31.9	-	-	262.5	771.9	1,766.4
Cibeureum	-	-	39.9	1,359.1	-	43.3	401.6	-	1,843.9
Cihideung	-	-	-	10.3	-	-	418.0	117.8	546.1
Cipedes	-	-	66.9	88.1	-	-	586.1	165.4	906.5
Indihiang	-	-	0.4	-	-	-	353.9	735.1	1,089.4
Kawalu	152.6	84.8	316.3	1,762.0	49.1	-	404.0	1,476.3	4,245.1
Mangkubumi	-	-	-	288.4	21.0	-	518.8	1,577.7	2,405.9
Purbaratu	-	-	13.9	1,001.2	-	-	243.8	7.6	1,266.5
Tamansari	-	0.2	278.6	3,036.8	-	-	187.0	206.9	3,709.5
Tawang	-	-	11.3	124.6	-	-	556.7	-	692.6
Grand Total	152.6	85.0	1,427.4	7,702.4	70.1	43.3	3,932.4	5,058.7	18,471.9

Comparing the natural and actual infiltration results (Tables 13 and 14) exposes a clear gap between potential and realized performance. Kawalu's natural infiltration is mostly moderate (2,769.7 ha), with a smaller high share (1,125.4 ha), yet its actual infiltration is dominated by the slightly low (2,078.3 ha) and low (1,929.4 ha) categories once land cover is taken into account. The same pattern holds in Tamansari, where a natural infiltration profile dominated by the moderate class (3,246.1 ha) collapses into an actual infiltration profile that is almost entirely slightly low (3,315.4 ha). This divergence is best explained by land-cover conversion: both districts carry substantial areas of dryland and mixed dryland agriculture, land covers that score as only slightly low infiltration regardless of the favorable slope, soil, or rainfall conditions beneath them. In effect, humans are acting as allogenic ecosystem engineers in these districts (Jones et al., 1994, as cited in Parris, 2016), converting land cover in ways that suppress the infiltration capacity the underlying biophysical conditions would otherwise support.

Overlaying the natural and actual infiltration results according to the classification in Table 8 produces the recharge condition that feeds directly into the rehabilitation matrix (Table 11). Because Kawalu and Tamansari combine a predominantly moderate natural infiltration base with a heavily agriculture- and settlement-dominated land cover, both districts are expected to fall predominantly into the starting to get critical through critical range, rather than the good or natural normal condition that districts with less land-cover pressure, such as Cihideung, would occupy. This inference is corroborated by the final recommendation output discussed in Section 3.2.4, where Kawalu and Tamansari again record the largest areas requiring the most intensive rehabilitation category: community forest combined with non-structural slope reinforcement and agroforestry, which is only triggered under critical-recharge conditions.

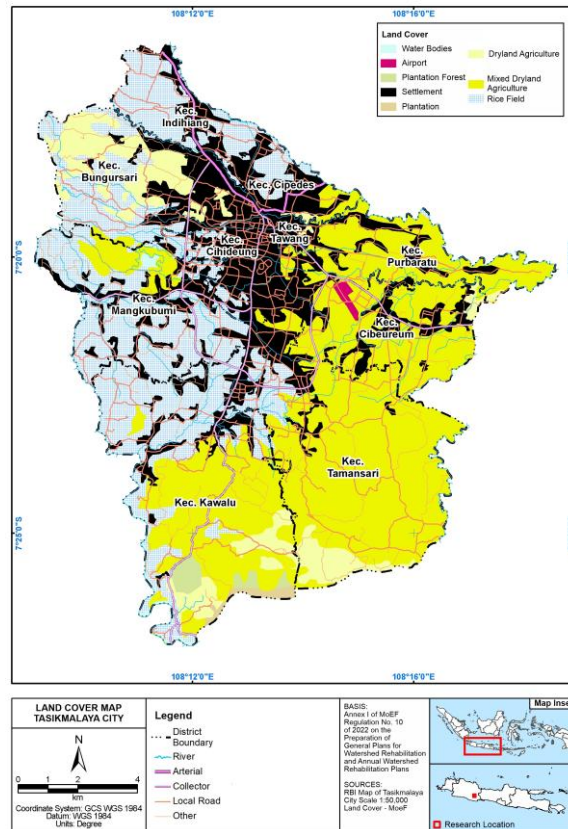


Fig. 5. Land cover map of Tasikmalaya City

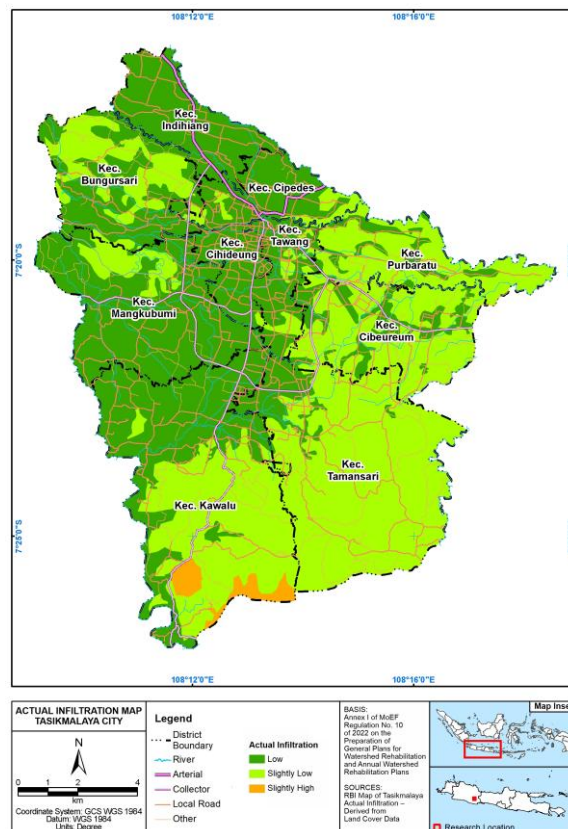


Fig. 6. Actual infiltration map of Tasikmalaya City

Tamansari District presents an interesting case, with a "Slightly High" infiltration value of 0.2 hectares, and the highest infiltration in the "Slightly Low" category across the city, amounting to 3,315.4 hectares. This makes Tamansari one of the districts with the highest total infiltration, at 3,709.5 hectares. These actual infiltration values are also influenced by the land area of each respective district.

HT refers to Plantation Forest, while PK stands for Plantation. PLK denotes Dryland Agriculture, and PLKC refers to Mixed Dryland Agriculture. BA represents Water Bodies, BD stands for Airport, PM refers to Settlement or Residential Area, and SW indicates Rice Field.

3.2.3 Disaster prone assessment

The identified disaster vulnerability classes include landslide vulnerability, which was analyzed using DEMNAS data according to the methodology described in the research, and runoff vulnerability, which was assessed based on the flood hazard index from the National Disaster Management Agency (BNPB).

The analysis of landslide vulnerability (Table 15 and Figure 7) shows that Kawalu, Tamansari, and Mangkubumi Districts recorded the largest areas in the very vulnerable and vulnerable categories. Kawalu District has 426.4 hectares classified as very vulnerable to landslides, the highest among all districts, along with 390.5 hectares in the vulnerable category. Tamansari District ranks second, with 335.5 hectares identified as very vulnerable and 375.0 hectares as vulnerable. Mangkubumi District ranks third, with 185.4 hectares in the very vulnerable class and 124.7 hectares in the vulnerable class. On the other hand, Cihideung and Tawang Districts have very low areas in both categories, with only 2.4 hectares and 1.4 hectares classified as very vulnerable, and 3.8 hectares and 2.7 hectares as vulnerable, respectively.

Table 15. Landslide vulnerability class of Tasikmalaya City

District	Landslide Vulnerability Class					Grand Total
	Slightly Vulnerable	Vulnerable	Very Vulnerable	Moderate	Not Vulnerable	
Bungursari	306.0	104.0	143.9	178.6	1,028.1	1,760.6
Cibeureum	219.3	29.8	20.2	78.3	1,492.2	1,839.8
Cihideung	45.7	3.8	2.4	12.4	481.8	546.1
Cipedes	77.1	10.4	12.5	23.7	779.7	903.4
Indihiang	135.5	24.6	39.2	52.2	829.8	1,081.3
Kawalu	806.0	390.5	426.4	606.6	2,000.4	4,229.9
Mangkubumi	348.6	124.7	185.4	197.0	1,544.1	2,399.8
Purbaratu	143.2	59.9	171.5	84.3	795.9	1,254.8
Tamansari	718.0	375.0	335.5	562.9	1,706.3	3,697.7
Tawang	45.0	2.7	1.4	10.3	633.2	692.6
Grand Total	2,844.4	1,125.4	1,338.4	1,806.3	11,291.5	18,406.0

The runoff vulnerability analysis (Table 16 and Figure 8) indicates that Kawalu District has the highest extreme runoff, covering 26.5 hectares, followed by Purbaratu with 16.4 hectares and Cipedes with 13.4 hectares. Conversely, Bungursari and Cihideung Districts recorded the lowest extreme runoff, each with only 0.9 hectares. In the high runoff category, Kawalu again leads with 276.3 hectares, followed by Cipedes (216.7 hectares) and Indihiang (172.5 hectares). Tamansari District records the lowest figure in this category, at only 0.3 hectares of high runoff area, with Mangkubumi also comparatively low at 12.0 hectares.

Table 16. Tasikmalaya City runoff vulnerability class

District	Runoff Vulnerability Class				Grand Total
	Extreme	High	Normal	Low	

Bungursari	0.9	60.3	18.3	1,687.3	1,766.8
Cibeureum	5.0	168.8	111.1	1,559.4	1,844.3
Cihideung	0.9	67.4	59.4	418.8	546.5
Cipedes	13.4	216.7	34.8	642.0	906.9
Indihiang	4.7	172.5	19.7	892.8	1,089.7
Kawalu	26.5	276.3	51.7	3,891.5	4,246.0
Mangkubumi	6.5	12.0	1.2	2,386.1	2,405.8
Purbaratu	16.4	129.5	30.9	1,090.1	1,266.9
Tamansari	-	0.3	-	3,709.3	3,709.6
Tawang	7.6	125.8	43.2	516.3	692.9
Grand Total	81.9	1,229.6	370.3	16,793.6	18,475.4

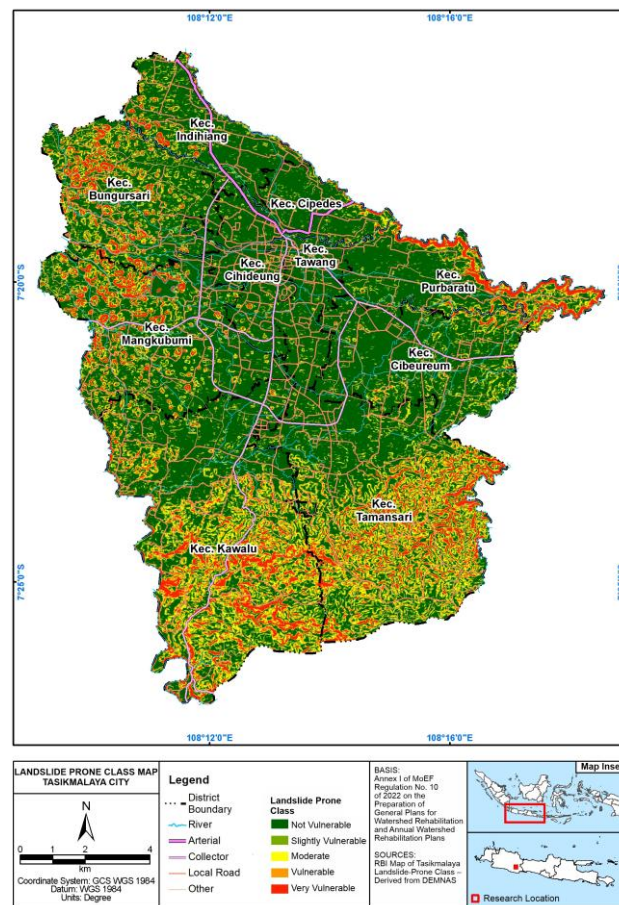


Fig. 7. Map of landslide vulnerability in Tasikmalaya City

The disaster-vulnerability results reinforce the spatial pattern already established by the critical land and infiltration analyses: Kawalu, Tamansari, and Mangkubumi repeatedly emerge as the districts of concern across all three assessment layers. This convergence is consistent with the terrain-driven logic of the RHL-DAS scoring system itself, in which slope contributes directly to both the infiltration score and the landslide susceptibility score, so districts with steeper topography are structurally more likely to register as vulnerable on multiple axes simultaneously rather than by coincidence. Practically, this convergence is what justifies the non-structural slope reinforcement component recommended for these districts in Section 3.2.4: rehabilitation planning that addresses only critical land status or only infiltration, without accounting for landslide susceptibility, would understate the intervention these areas require. This is broadly consistent with Zildan and Marhaento (2025), who emphasize that species and structural choices for landslide-prone

rehabilitation must be matched to site-specific slope and susceptibility conditions rather than applied uniformly.

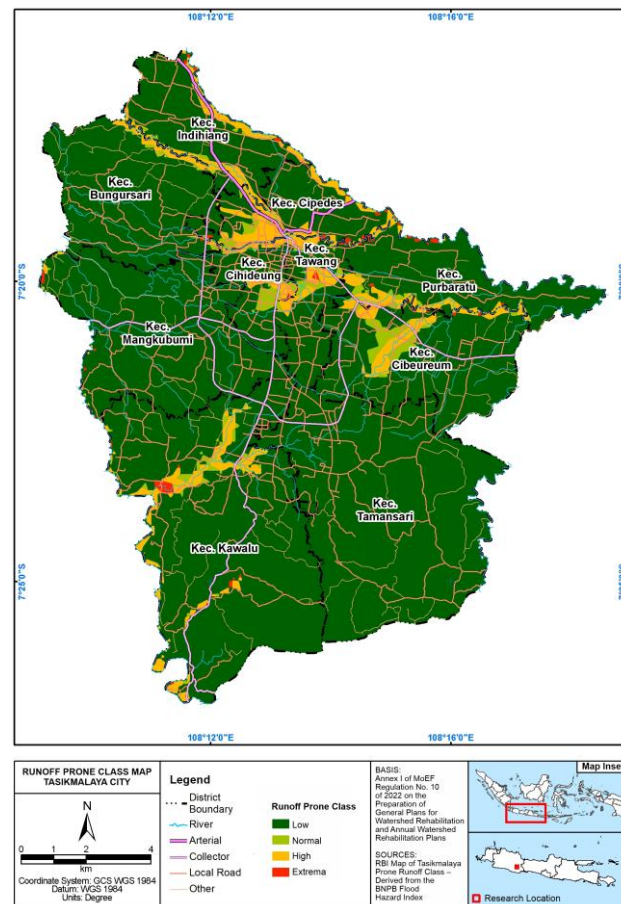


Fig. 8. Tasikmalaya City runoff vulnerability map

3.2.4 Recommendations for land rehabilitation activities

After conducting the analysis using various matrices, three main categories of land rehabilitation recommendations were identified for Tasikmalaya City (Table 17 and Figure 9): community forest and agroforestry; community forest, slope reinforcement (non-structural), and agroforestry; and environmental greening. Kawalu District recorded the highest total land rehabilitation recommendation, amounting to 1,258.0 hectares, dominated by the category of community forest, slope reinforcement, and agroforestry with 615.9 hectares. This indicates that the area is facing significant challenges related to slope erosion. On the other hand, Tamansari District has a total recommended rehabilitation area of 1,144.6 hectares, with 719.5 hectares also falling under the category of community forest, slope reinforcement, and agroforestry.

Table 17. Recommendations for land rehabilitation in Tasikmalaya City

District	Community Forest, Agroforestry	Community Forest, Slope Reinforcement (Non-Structural), Agroforestry	Greening the Environment	Grand Total
Bungursari	595.3	142.1	234.5	971.9
Cibeureum	145.4	43.7	379.9	569.0
Cihideung	72.3	-	356.1	428.4

Cipedes	230.6	13.9	439.5	684.0
Indihiang	78.0		274.6	352.6
Kawalu	293.0	615.9	349.1	1,258.0
Mangkubumi	174.2	98.2	516.3	788.7
Purbaratu	122.6	220.9	230.1	573.6
Tamansari	238.0	719.5	187.1	1,144.6
Tawang	158.1	1.8	452.7	612.6
Grand Total	2,107.5	1,856.0	3,419.9	7,383.4

Taken together, the three recommended interventions are not interchangeable options but a graded response calibrated to how many of the assessed risk layers coincide in a given location. Community forest and agroforestry alone is prescribed where critical land or infiltration deficits exist without severe slope hazard; the addition of non-structural slope reinforcement, concentrated in Kawalu and Tamansari, responds specifically to the co-occurrence of critical land, poor recharge condition, and elevated landslide susceptibility documented in Sections 3.1–3.2.3; and environmental greening, which dominates the citywide total (3,419.9 ha), addresses the more diffuse, lower-severity degradation spread across the remaining districts. This graduated logic is well supported by the wider rehabilitation literature. Agroforestry's effectiveness is not automatic: outcomes track closely with whether programs prioritize multipurpose trees suited to erosion control and food security and invest in sustained community capacity rather than one-off planting (Sukamdani & Sukwika, 2023), a design principle reflected in Tasikmalaya's pairing of agroforestry with community forest management. Beyond flood and landslide mitigation, this combination also carries co-benefits for land cover recovery and carbon sequestration at the landscape scale.

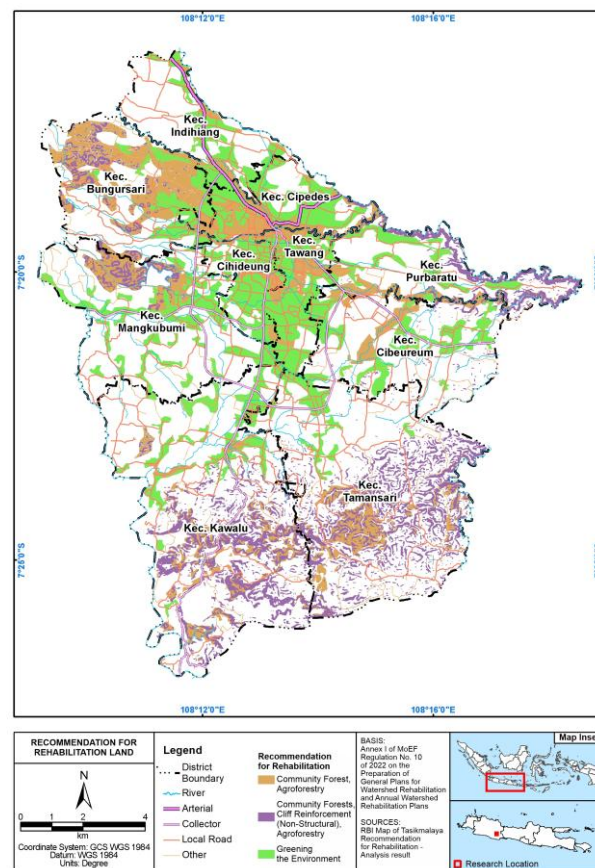


Fig. 9. Recommendations for land rehabilitation in Tasikmalaya City

Two limitations qualify these recommendations. First, in line with the "for simplification purposes" assumption stated in the Methods, this study treated the entire city as cultivation zone except for defined protected buffers (railway, lake, river, and high-voltage transmission corridors); any critical land or poor-recharge condition that happens to fall within an unmapped micro-scale protected feature would not be distinctly flagged in the final recommendation output, so the recommendation map should be read as a planning-level guide rather than a parcel-level prescription. Second, and more fundamentally, applying the RHL-DAS scoring procedure within an administrative boundary rather than its intended watershed unit means the resulting critical-land and infiltration classes for districts along Tasikmalaya City's edge are shaped by hydrological processes that continue beyond the city limits; upstream or downstream conditions in the adjoining DAS Cimanuk-Citanduy watershed are not captured. This is precisely the jurisdictional mismatch the Introduction identifies as the motivation for this adaptation: city governments regulate land use and disaster mitigation within administrative, not watershed, boundaries (Hidayat et al., 2025), and the trade-off in hydrological completeness is deliberately accepted in exchange for a rehabilitation output the city government can act on directly. Realizing that benefit in practice still depends on institutional follow-through: sustained monitoring of land-use compliance, supported where possible by periodic remote-sensing checks on whether the recommended interventions are being implemented and are working over time.

4. Conclusions

Based on the analysis of critical land delineation, water infiltration conditions, and disaster vulnerability levels, the land rehabilitation recommendations for Tasikmalaya City include three main programs: (1) Community forest and agroforestry, (2) Community forest, slope reinforcement (non-structural), and agroforestry, and (3) Environmental greening. Kawalu and Tamansari are the priority areas. Both have the largest critical land (420.7 ha and 387.9 ha) and the largest very vulnerable landslide areas. Their actual infiltration also falls well below natural potential because of dryland agriculture and settlement cover. Together they account for 2,402.6 ha of the 7,383.4 ha recommended for rehabilitation, including 1,335.4 ha of the 1,856.0 ha that needs slope reinforcement. Environmental greening covers the largest area citywide (3,419.9 ha) and targets more scattered, less severe degradation. The scoring was applied within the city boundary rather than a watershed, and all areas outside the mapped protected buffers were treated as cultivation zones, so the map can guide planning but should not be used for parcel-level decisions. City authorities can use it to rank rehabilitation sites and link them to land-use permitting and disaster mitigation, with periodic remote-sensing checks on implementation. Further work should account for upstream and downstream conditions beyond the city limit and verify the classes in the field.

Acknowledgement

The author would like to express his sincere gratitude to the government agencies and institutions for their support and for providing access to the spatial, climatic, and geological data used in this study.

Author Contribution

The author solely conducted the research, performed data analysis, and prepared the manuscript.

Funding

This research received no external funding.

Ethical Review Board Statement

Not available.

Informed Consent Statement

Not available.

Data Availability Statement

Not available.

Conflicts of Interest

The author declare no conflict of interest.

Open Access

©2026. The author. This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author and the source, provide a link to the Creative Commons license, and indicate if changes were made. The images or other third-party material in this article are included in the article's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this license, visit: <http://creativecommons.org/licenses/by/4.0/>

References

- AbdelRahman, M. A. E. (2023). An overview of land degradation, desertification and sustainable land management using GIS and remote sensing applications. *Rendiconti Lincei. Scienze Fisiche e Naturali*, 34(3), 767–808. <https://doi.org/10.1007/s12210-023-01155-3>
- Abirami, R., Srija, J., Thomas, N. J., Varghese, A., & Patil, A. (2024). *Evaluating the impact of a bus bay in order to decrease the amount of traffic*. 020016. <https://doi.org/10.1063/5.0222304>
- Direktorat Jenderal Bina Pengelolaan Daerah Aliran Sungai dan Perhutanan Sosial. (2011). *Sistem standar operasional prosedur (SSOP) pengendalian banjir dan tanah longsor*. Direktorat Jenderal Bina Pengelolaan Daerah Aliran Sungai dan Perhutanan Sosial.
- Ersoy Mirici, M., & Berberoglu, S. (2024). Terrestrial carbon dynamics and economic valuation of ecosystem service for land use management in the Mediterranean region. *Ecological Informatics*, 81, 102570. <https://doi.org/10.1016/j.ecoinf.2024.102570>
- Chow, V. T. (Ed.). (1964). *Handbook of applied hydrology: A compendium of water-resources technology*. McGraw-Hill.
- Febi, E., Putri, S., Murdjoko, A., & Raharjo, D. S. (2024). Dinamika deforestasi dan degradasi hutan di Provinsi Papua [Dynamics of deforestation and degradation of forests in Papua Province]. *Cassowary*, 7(2), 30–41. <https://pasca.unipa.ac.id/>
- Hidayat, Y., Suheri, A., Dewi, R. C., & Sudirja, R. (2025). Forest and land rehabilitation engineering using the SWAT model approach in the Citarik sub-watershed. 020052. <https://doi.org/10.1063/5.0240967>
- Hakim, L., Mulyati, M., Iemaaniah, Z. M., & Rachmadi, A. (2023). Sosialisasi rehabilitasi hutan dan lahan dengan menggunakan metode konservasi sipil teknis dalam pengendalian tanah di Desa Rembitan Kecamatan Pujut Lombok Tengah. *Jurnal SIAR Ilmuwan Tani*, 4(1), 112–117. <https://doi.org/10.29303/jsit.v4i1.97>
- Hilalia, N. N., Warsono, H., & Astuti, R. S. (2024). *Efektivitas program rehabilitasi hutan dan lahan agroforestri di Kecamatan Bringin Kabupaten Semarang*. Universitas Diponegoro.
- Irawan, P., Handiman, I., Sari, N. K., Nurrahma, F. A., Herianto, Setiawan, J., & Hidayat, A. K. (2024). Efektivitas kolam retensi untuk pengendalian banjir di ruas Jalan Dr. Moh.

- Hatta Sukamanah Kota Tasikmalaya. *Jurnal Rekayasa Sipil*, 20(2), 120–135. <https://doi.org/10.25077/jrs.20.2.120-135.2024>
- Jiang, K., Teuling, A. J., Chen, X., Huang, N., Wang, J., Zhang, Z., Gao, R., Men, J., Zhang, Z., Wu, Y., Cai, L., Huang, Z., Ma, Z., & Pan, Z. (2024). Global land degradation hotspots based on multiple methods and indicators. *Ecological Indicators*, 158, 111462. <https://doi.org/10.1016/j.ecolind.2023.111462>
- Jinger, D., Kaushal, R., Kumar, R., Paramesh, V., Verma, A., Shukla, M., Chavan, S. B., Kakade, V., Dobhal, S., Uthappa, A. R., Roy, T., Singhal, V., Madegowda, M., Kumar, D., Khatri, P., Dinesh, D., Singh, G., Singh, A. K., Nath, A. J., Joshi, N., Joshi, E., & Kumawat, S. (2023). Degraded land rehabilitation through agroforestry in India: Achievements, current understanding, and future perspectives. *Frontiers in Ecology and Evolution*, 11. <https://doi.org/10.3389/fevo.2023.1088796>
- Mangela, D., Muis, H., Rahman, A., Naharuddin, N., Massiri, S. D., Maiwa, A., Paramitha, T. A., & Istiqamah, N. (2024). Analisis spasial tingkat kekritisian lahan di Sub DAS Wimbi, Kelurahan Sawidago, Kecamatan Pamona Utara, Kabupaten Poso. *Savana Cendana*, 9(1), 1–5. <https://doi.org/10.32938/sc.v9i1>
- Monsaputra, M. (2023). Analisis perubahan penggunaan lahan pertanian menjadi perumahan di Kota Padang Panjang. *Tunas Agraria*, 6(1), 1–11. <https://doi.org/10.31292/jta.v6i1.200>
- Munir, N., & Rinduwati. (2023). Analisis lahan kritis dalam mendukung ketersediaan hijauan pakan: Review. *Buletin Nutrisi dan Makanan Ternak*, 17(2), 93–103. <https://journal.unhas.ac.id/index.php/bnmt/article/view/32124>
- Ningrum, M. H., Fahmi, S., & Laksmi, A. N. (2024). Analysis of the environmental damage and agricultural utilization in Forest Area of Dieang Plateau, Central Java, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 1315(1), 012049. <https://doi.org/10.1088/1755-1315/1315/1/012049>
- Nurdin, I. (2022). Pemetaan lahan kritis menggunakan sistem informasi geografis di Kecamatan Sumalata Provinsi Gorontalo. *Geodika: Jurnal Kajian Ilmu dan Pendidikan Geografi*, 6(2), 232–243. <https://doi.org/10.29408/geodika.v6i2.6531>
- O'Kelly, M., & Bryan, D. (1996). Agricultural location theory: Von Thünen's contribution to economic geography. *Progress in Human Geography*, 20(4), 457–475. <https://doi.org/10.1177/030913259602000402>
- Paimin, Sukresno, & Purwanto. (2006). *Sidik cepat degradasi sub daerah aliran sungai (Sub DAS)*. Balai Penelitian Kehutanan Solo, Pusat Penelitian dan Pengembangan Hutan dan Konservasi Alam, Badan Penelitian dan Pengembangan Kehutanan.
- Parris, K. M. (2016). *Ecology of urban environments*. Wiley Blackwell.
- Putri, A. V. Y., Sadono, R., & Sutata, D. F. (2024). Enhancing land cover and carbon storage through rehabilitation of degraded lands into Wono: A case study of a small-scale private forest in Dengok Village, Gunungkidul, Yogyakarta, Indonesia (1972-2021). *Journal of Degraded and Mining Lands Management*, 11(2), 5105–5117. <https://doi.org/10.15243/jdmlm.2024.112.5105>
- Rahmadani, D. A., Wati, D. T. A., Hanifah, N. W., & Fauziyah, N. M. (2024). Analisis mitigasi bencana banjir di Indonesia berbasis pendekatan kuantitatif dalam studi literatur. *Jurnal Matematika dan Ilmu Pengetahuan Alam*, 2(3), 21–32. <https://doi.org/10.35580/lageografia.v22i3.64637>
- Ramli, I., Nabila, F., Satriyo, P., & Jayanti, D. S. (2023). Model pengelolaan lahan kritis pada daerah aliran sungai Krueng Peusangan menggunakan sistem dinamik. *Jurnal Ilmiah Rekayasa Pertanian dan Biosistem*, 11(1), 44–55. <https://doi.org/10.29303/jrpb.v11i1.469>
- Ravera, O. (Ed.). (1989). *Ecological assessment of environmental degradation, pollution and recovery*. Elsevier Science Publishers.
- Ridhoi, R. (2023). Menggaungkan pendekatan ekologis dalam historiografi perkotaan di Indonesia pasca reformasi. *Jurnal Sejarah Indonesia*, 6, 74–90. <https://doi.org/10.62924/jsi.v6i1.32606>

- Rijal, S., Nursaputra, M., & A, C. (2025). Evaluating Forest and Land Rehabilitation Using Remote Sensing: A Case Study in Maros Regency. *Jurnal Penelitian Kehutanan Wallacea*, 14(1), 35–44. <https://doi.org/10.24259/jpkwallacea.v14i1.36726>
- Rizki, M. Y. (2023). Rehabilitasi lahan terbengkalai sebagai solusi kekeringan kota padat penduduk. *International Journal of Evaluation and Research in Education (IJERE)*, 0–11. <https://doi.org/10.11591/ijere.v9i1.paperID>
- Salsabil, R., Bagus Wibowo, R., & Rahayu, R. (2024). Kerusakan ekosistem akibat penambangan pasir di kawasan Gunung Merapi Kabupaten Sleman, Yogyakarta. *Jurnal Ekologi, Masyarakat dan Sains*, 5(1), 122–129. <https://doi.org/10.55448/jbn5pr88>
- Sihombing, L. A., & Utami, C. F. (2023). Hirarki dan distribusi kota penyebaran, dan kepadatan penduduk serta implikasinya terhadap infrastruktur. *Jurnal Ilmiah Sosial Teknik*, 5(2). <https://doi.org/10.59261/jequi.v5i2.159>
- Singh, M. C., Sur, K., Al-Ansari, N., Arya, P. K., Verma, V. K., & Malik, A. (2023). GIS integrated RUSLE model-based soil loss estimation and watershed prioritization for land and water conservation aspects. *Frontiers in Environmental Science*, 11. <https://doi.org/10.3389/fenvs.2023.1136243>
- Sukamdani, N. B., & Sukwika, T. (2023). Erosion prevention through empowerment of human resources to support food security around the Kambaniru watershed, East Nusa Tenggara. *IOP Conference Series: Earth and Environmental Science*, 1133(1), 012061. <https://doi.org/10.1088/1755-1315/1133/1/012061>
- Supandi, S., Saputra, Y. H. E., Yuliadi, Y., Nasrulloh, R. S., & Muafi, M. (2025). Carbon Reserved Measurement as a Sustainability Strategy for Land Rehabilitation Program in Menoreh Hill Watershed, Central Java, Indonesia. *International Journal of Sustainable Development and Planning*, 20(3). <https://doi.org/10.18280/ijstdp.200307>
- Tupanno, C. E., Talakua, S., Soplanit, R., & Osok, R. M. (2023). Analysis of physical characteristics and soil degradation due to erosion and rehabilitation recommendation based on GIS in protected forest area of Mount Sirimau. *Jurnal Budidaya Pertanian*, 19(1), 58–68. <https://doi.org/10.30598/jbdp.2023.19.1.58>
- Wahyunto, & Dariah, A. (2014). Degradasi lahan di Indonesia: Kondisi existing, karakteristik, dan penyeragaman definisi mendukung gerakan menuju satu peta. *Jurnal Sumberdaya Lahan*, 8(2), 81–93. <https://doi.org/10.21082/jsdl.v8n2.2014.81-93>
- Yang, L., Zhao, G., Mu, X., Lan, Z., Jiao, J., An, S., Wu, Y., & Miping, P. (2023). Integrated assessments of land degradation on the Qinghai-Tibet plateau. *Ecological Indicators*, 147, 109945. <https://doi.org/10.1016/j.ecolind.2023.109945>
- Zachrani, A. O., Rayes, M. L., & Sulaeman, Y. (2024). Identifikasi lahan kritis skala 1:25.000 berbasis citra Sentinel 2 dan DEMNAS resolusi 8 meter (Studi kasus Sub DAS Cikapundung Jawa Barat). *Jurnal Tanah dan Sumberdaya Lahan*, 11(2), 327–338. <https://doi.org/10.21776/ub.jtsl.2024.011.2.4>
- Zildan, H. S., & Marhaento, H. (2025). Land Suitability Analysis of Different Plant Species to Rehabilitate Landslide Prone Areas in Merawu Catchment, Indonesia. *BIO Web of Conferences*, 167, 03005. <https://doi.org/10.1051/bioconf/202516703005>

Biography of Author

Chandra Egy Setiawan, Department of Environmental Science, School of Environmental Science, Universitas Indonesia, Central Jakarta, DKI Jakarta 10430, Indonesia.

- Email: chandra.egy@ui.ac.id
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A