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Land Vulnerability Analysis for Determining Land Rehabilitation Directions for Soil Conservation in Conservation District: Case Study of Tamansari District, Boyolali Regency

Alvian Febry Anggana[1], Endang Savitri[2], S. Andy Cahyono[2], Rahardyan Nugroho Adi[2], Pamungkas Buana Putra[2], Mahardhika N. R. P[1], Rama Zakaria[3], Muslim Afandi[4]

[1] Balai Penerapan Standar Instrumen Lingkungan Hidup dan Kehutanan Solo, Indonesia.
[2] Badan Riset dan Inovasi Nasioal, Indonesia.
[3] PT. Tirta Investama-AQUA Factory Klaten, Indonesia.
[4] Lembaga Pengembangan Teknologi Pedesaan, Indonesia.

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Corresponding Author:
Alvian Febry Anggana
angga.kshe43@gmail.com

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Abstract: Land vulnerability is a condition where a land is sensitive to environmental changes or human pressure. This certainly affects the productivity, quality, and sustainability of the land to recover from the impacts that may occur due to land changes. This problem certainly has a direct or indirect effect on the socio-economic life of the community. The purpose of this study is to map and recommend directions for Land Rehabilitation and Soil Conservation (RLKT) in Tamansari District, which in its development is in the Klaten Regency area, Subdas Pusur DS. The analysis method uses overlay of erosion land vulnerability, flood vulnerability, land cover, and land use capability. The results of the study indicate that the area of vulnerable land that needs to be RLKT is 4,375.7 ha covering 10 villages. The largest village that needs to be RLKT is Jemowo Village (668.9 ha) and Mriyan Village (644.7 ha). Land Rehabilitation and Soil Conservation Directions in the form of Reforestation with vegetation, cover crops, compost, reservoirs, rorak, terrace reinforcement, ridges, SPA, infiltration wells. The RLKT Direction is expected to be able to control land vulnerability to erosion, land vulnerability to flooding and water management so that it is expected to be able to improve the welfare of the community in the Tamansari District area.

Keywords: Conservation district; Land vulnerability; Rehabilitation

Introduction

Indonesia is a disaster supermarket because of the many disasters that occur (Sumasto & Wisnu, 2020). A total of 3,544 disaster events occurred throughout 2022, flood disasters (1,531 events), extreme weather (1,068 events), and landslides (634 events) dominated disaster events in Indonesia (Badan Nasional Penanggulangan Bencana, 2022). Floods, droughts and erosion dominate in many river basins (DAS) (Basuki et al., 2022; Nugroho et al., 2023; Shrestha et al., 2019) and cities in Indonesia (Habibie et al., 2020; Handayani et al., 2019; Handayani et al., 2020). Referring to the disaster level set by BNPB, land vulnerability is one of the components of the risk index. Land vulnerability is always closely related to damage and losses that

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include physical, economic, and social aspects. Not only that, disaster events affect the psychology of the community around the affected land area. This is often felt by communities who do not yet have a mitigation scenario in disaster management efforts. In addition, protecting natural areas is considered an important strategy for environmental conservation (Escobedo-Monge et al., 2022). Environmental conservation needs to consider the vulnerability of the land that occurs. However, land vulnerability has received relatively little attention in development planning (Coluzzi et al., 2022; Egidi et al., 2022; Kujur et al., 2020) and agriculture so far (Schwab et al., 2021).

Land vulnerability analysis has been widely carried out to analyze landslides (Indahsari et al., 2022; Putra & Wardika, 2021; Putri & Tjahjono, 2023; Saputra et al., 2022), floods (Riadi, 2018), land (Muminin et al., 2021), disasters (Nugraha et al., 2022), socio-economic (Yusliana, 2022), erosion (Dinata, 2020), critical land (Kubangun et al., 2019) and so on. To determine the level of land vulnerability, a land assessment is needed. Land assessment is needed for various activities such as mining (Carlo et al., 2019; Wang et al., 2020; Woodbury et al., 2020; Worlanyo & Jiangfeng, 2021), soil conservation (Abdiyani et al., 2021; Hassen & Bantider, 2020; Moreno-de-las-Heras et al., 2019; West et al., 2020), environmental services (Wu et al., 2019), Mangrove (Domínguez-Domínguez et al., 2019).

By knowing the level of land vulnerability, it can be decided what kind of land conservation land rehabilitation direction should be carried out to be an example of the importance of proper land management according to the level of land vulnerability so as not to trigger disasters, so it is necessary to develop areas that administratively also consider conservation. These areas develop from conservation provinces, conservation districts and conservation villages. In addition, conservation sub-districts have also developed, including in Lindu Sub-district, Central Sulawesi (Acciaioli & Nasrum, 2020), Muara Gembong Sub-district, Bekasi (Fawaz & Nababan, 2021). Tamansari Sub-district was also developed by Boyolali Regency into a conservation sub-district.

Administratively, Tamansari District is located in Boyolali Regency (Hulu). From a river basin (DAS) perspective, Tamansari District is part of the upstream Pusur DAS. Pusur DAS borders directly with Mount Merapi, making the area a Water Catchment Area. The area is also a recharge area for springs (recharge area) which affects the springs (Hendrayana, 2013). The hydrogeological influence in the Pusur DAS area also affects the management of 3000 ha of land carried out by the community (Hamdani et al., 2021). The majority of upstream communities make a living as dry land farmers and livestock breeders, so it is very possible that land vulnerability occurs, especially in areas with a fairly high land slope.

To carry out an effective and efficient land vulnerability assessment, an appropriate assessment method is needed. One of the tools that can be used for this is the Geographic Information System (GIS). This system will provide a transformation in the form of spatial data input into decision-making output. The combination of geographic analysis supports the preferences of each decision maker (Malczewski, 2004). Several studies have stated that the use of GIS helps in solving environmental issues (Devianto et al., 2019; Taki, 2022) in Indonesia, for example waste (Novriansyah et al., 2023), drought, slums (Buana et al., 2022).

Research on land vulnerability and directions for land rehabilitation and soil conservation in Tamansari District has not been mapped to date. In fact, the results of the study are very much needed to support Tamansari as a Conservation District that plays an active role in conservation activities and can be used as an example for other areas. This study aims to determine the condition of land vulnerability and the right direction for RLKT activities in Tamansari District.

Method

This research was conducted in August - October 2022 in Tamansari District, Boyolali Regency, Central Java. The average rainfall for the period 1981-2020 in the upstream area of Tamansari District was 2,581 mm/year, based on the Schmidt and Ferguson climate system analysis that the climate type of the upstream area is type B (Anggana & Mujiyo, 2022).

The materials used are daily rainfall data obtained from direct measurements in the field and data from rainfall downloaded from CHIRPS (Climate Hazards Group Infra-Red Precipitation with Station data) at the link https://data.chc.ucsb.edu/products/CHIRPS-2.0/. The digital maps used are: RePPProT map published by BIG, land cover map, land criticality and area function from the Ministry of Environment and Forestry. The software used is spreadsheet and ArcGIS.

Rain Data Analysis

The rainfall data collected is daily rainfall data. To be able to determine whether an area has the potential to cause flooding, the rainfall data required is the maximum daily rainfall data (Paimin et al., 2012) combined with information on erosion vulnerability (See Figure 2). The rainfall map in the study area was created based on rainfall data from CHIRPS from 1981-2020. From this period, the maximum daily rainfall data for 30 years was obtained.

Erosion Data Analysis

Land vulnerability to erosion is the land response to its land cover. Land systems are grouped into 5 classes, namely: swamps and beaches; alluvial plains and valleys; plains; terraces, fans and lava; hills and mountains. This land system is obtained from the RePPProT map, each land unit of which has information on land form, geological conditions, slope gradient and climate (Paimin et al., 2012). Meanwhile, the land cover map was obtained from the Directorate General of PKTL (Forestry Planning and Environmental Management), KLHK. Like the land system, land cover is also grouped into 5 classes, namely: water bodies, watertight buildings, protected and conservation forests; production forests and plantations; rice fields, grass and shrubs; settlements; and dry fields and rocky soil. The result of the overlap of the land system with land cover is the vulnerability of the land to erosion, with 5 classes of vulnerability, ranging from not vulnerable to very vulnerable.

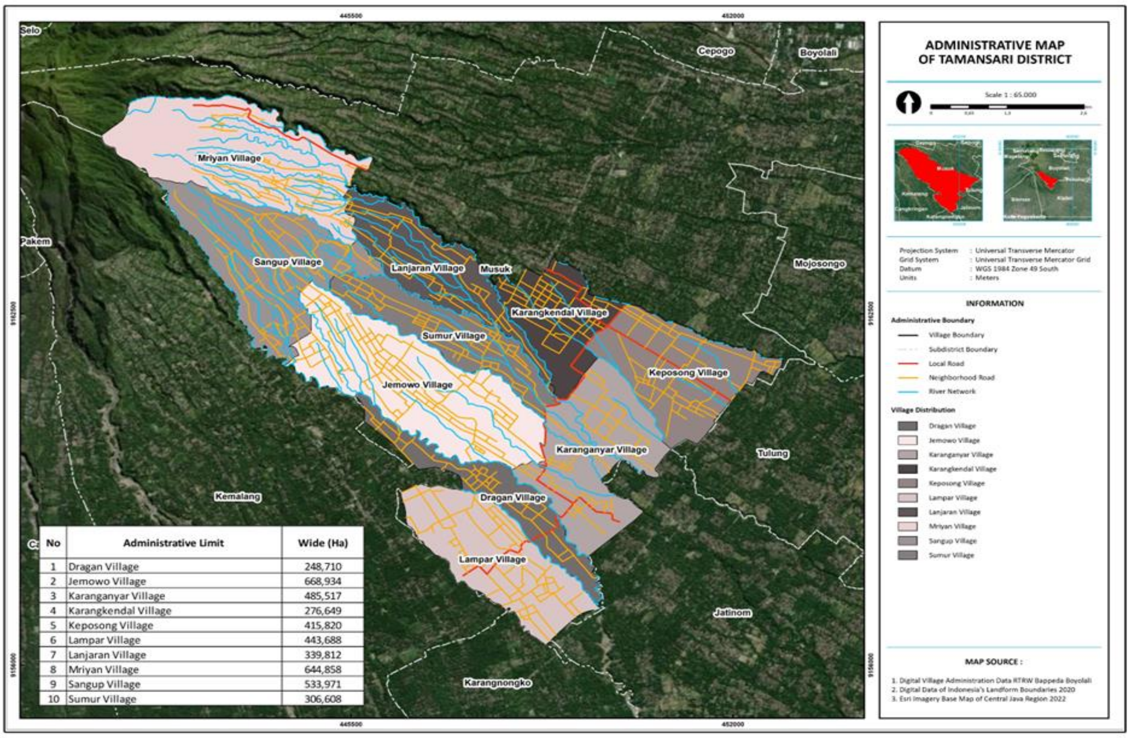

Figure 1. Administrative Map of Tamansari District

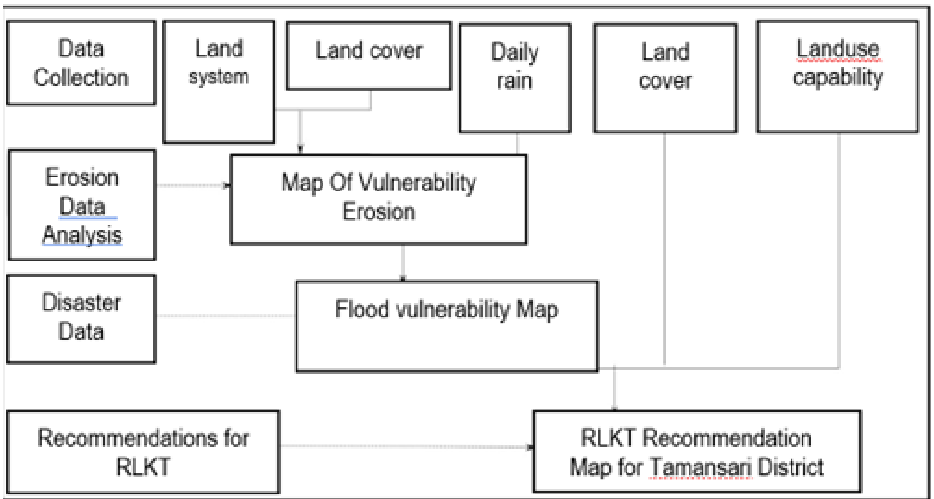

Figure 2. Land vulnerability analysis flow

Disaster Data Analysis

Areas that experience flooding are usually flood plains or flood plains which in the land system are swamps, beaches, river bends or alluvial areas (Paimin et al., 2012). This area is not affected by the amount of rain, but only by its position in a landscape. In contrast, the flood supply area is an area that produces a lot of runoff, which can cause the area below to flood. This flood supply area is affected by the amount of rain and its vulnerability to erosion. The more susceptible to erosion, the more erosion and runoff occurs (Gayen et al., 2019; Halder et al., 2021; Quan et al., 2020). Flood control in floodplain and flood supply areas is different, because the causes are different. Floodplain areas prioritize civil technical handling, while flood supply areas prioritize runoff reduction through various vegetative or civil technical KTA techniques.

Recommendations for RLKT Activities

The selection of the type of RLKT activity is highly dependent on the condition of the location where it will be implemented and the problems that occur. Problems on the land in question can be seen from the land use capability map, land vulnerability map to erosion and flood vulnerability map, while the types of plants to be used are adjusted to the current land cover. From the land use capability map, the ability of the land to produce normally and its inhibiting factors can be seen. Determination of the land use capability class and its inhibiting factors is determined by erosion, drainage, soil conditions, climate and slope (Wahyuningrum & Basuki, 2019). In addition, community norms and perceptions are also considered in choosing conservation and its implementation (Burivalova et al., 2019; Dobson et al., 2019; Niemiec et al., 2020; Thomas et al., 2019). RLKT activities are limited to areas that have land vulnerability to erosion in class 3-5 or moderate to very vulnerable, while non-vulnerable and slightly vulnerable classes are not considered a priority for handling.

Result and Discussion

Rainfall Distribution Point

Rainfall is an important natural parameter in the hydrological function of a terrestrial ecosystem on earth which is related to the availability of water resources on a regional scale to support basic elements of life, understanding the dynamics of land resource utilization and environmental management, understanding the dynamics of hydrometeorological disasters related to future climate change risks (Gao & Jin, 2022). Surface rainfall data is needed for several studies but there are limitations in provision so that the use of satellite rainfall data obtained from the extraction of the CHIRPS data set is a solution (Bai et al., 2018; Okal et al., 2020). The data set for the period 1981-2020 was used in this study which was then analyzed for monthly average rainfall, classifying the Schmidt and Ferguson climate system (Rafi'i, 1995).

Distribution points of rainfall data observations by considering the regional distribution in the Pusur sub-DAS, Babang sub-DAS, and Dengkeng sub-DAS on a grid per pixel CHIRPS data. The rainfall data obtained includes 18 points. The presentation of rainfall histogram data is grouped based on the most upstream watershed area (point b2), upstream (points p1, d1, and b3), middle (p3, and b1), and downstream (p6 and d5). Figure 3 shows the difference in histogram colors which indicate data grouping based on elevation. The average rainfall for the period 1981-2020 at point b2 (upstream of the Babang sub-DAS) was recorded at 2,956 mm/year, the highest among other observation points, including the upstream points of the Pusur sub-DAS (p1) and Dengkeng sub-DAS (d1).

Table 1. Parameters for determining land vulnerability to erosion

Parameter		Vulnerability Class
Land Closure	Water bodies, buildings	Not vulnerable
	Protected forests, conservation forests	Somewhat vulnerable
	Production forests, plantations	Medium
	Rice fields, grass, bushes	Vulnerable
	Settlements	Very vulnerable
Land System	Tegal, open land	Not vulnerable
	Swamps, beaches	Somewhat vulnerable
	Alluvial plains, alluvial valleys	Medium
	Plains	Vulnerable
	Fans and lava, terraces	Very vulnerable

(Paimin et al., 2012)

Table 2. Land vulnerability to erosion in Tamansari District

Vulnerability Class	Area (ha)	Percentage%
Medium	272.884	6.24
Vulnerable	1,090.319	24.92
Highly Vulnerable	3,012.634	68.85
Total		100

The average rainfall for the period 1981-2020 in the upstream area was 2,581 mm/year, while the average distribution per month is presented in Figure 3. In the upstream area which is the location of Tamansari District on the morphological unit of the peak and slopes of Mount Merapi, it has high rainfall compared to the middle and lower areas. Therefore, this area is very important because it is a recharge area that requires conservative land resource management. Meanwhile, based on the analysis of the Schmidt and Ferguson climate system, Tamansari District which is in the upstream area has a B climate type as well as the middle area, while the downstream area includes a climate type of C. Paying attention to the average monthly rainfall distribution graph forming a "V" model, it can be said that the entire Pusur DS sub-DAS area is influenced by monsoon winds.

Erosion Data Analysis

Land susceptibility to erosion is influenced by land cover and land systems (Ferreira et al., 2015), land with a higher slope is followed by increasingly open land cover so that the sensitivity of the land is more easily eroded. Table 1 shows the parameters used to determine land susceptibility to erosion, while Table 2 presents the distribution of land susceptibility in Tamansari District. Land susceptibility to erosion in Tamansari District is dominated by the Very Vulnerable Class (68.85%).

This is based on the predetermined parameters in the form of land cover and land systems. In the land cover parameters, the Tamansari area is dominated by dry fields, open land. While in the land system parameters, Tamansari is included in the category of mountains and hills. This is also reinforced in research Wahyuningrum & Basuki (2019) which states that the hilly and mountainous land systems are only found on the watershed boundaries and in mountainous areas such as the Merapi, Merbabu, and Lawu Mountains. In addition, based on observations in the field, the majority of people grow vegetables and tobacco on private agricultural land. It should be noted that the Tamansari area is geographically located between the boundaries of the Pusur Sub-basin and Dengkeng Sub-basin. The land cover that is dominated by dry fields with a combination of land systems in the form of mountains and hills, it is understandable that the land vulnerability class to erosion of the very vulnerable class dominates the area.

Land Vulnerability to Flood Supply

Land vulnerability to water supply is the vulnerability of land to erosion combined with maximum daily rainfall and results in surface flow (runoff). The higher the rainfall, the more vulnerable the area is to surface flow. Rainfall observation is very necessary because rainfall is one of the triggers for erosion and landslides (Naryanto et al., 2019). Table 3 shows the relationship between maximum daily rainfall and land vulnerability to erosion. This condition can cause an increase in river flow discharge which has an impact on flooding.

Table 3. Relationship between maximum daily rainfall and land vulnerability to erosion

Maximum daily rainfall (mm)	Land vulnerability to erosion				
	Not vulnerable	Somewhat vulnerable	Moderate	Vulnerable	Very vulnerable
≤ 20	Not vulnerable	Not vulnerable	Somewhat vulnerable	Somewhat vulnerable	Moderate
21 – 40	Somewhat vulnerable	Somewhat vulnerable	Somewhat vulnerable	Moderate	Moderate
41 – 75	Somewhat vulnerable	Moderate	Moderate	Moderate	Vulnerable
76 – 150	Medium	Moderate	Vulnerable	Vulnerable	Vulnerable
> 150	Medium	Vulnerable	Vulnerable	Very vulnerable	Very Vulnerable

(Paimin et al., 2012)

Table 4. Land vulnerability to flood supply in Tamansari District

Vulnerability Class	Area (ha)	Percentage%
Not Vulnerable	-	-
Somewhat Vulnerable	-	-
Moderately	-	-
Vulnerable	272.88	6.24
Highly Vulnerable	4,102.95	93.76
Total	4.375.84	100

Areas with high flood supply need to implement soil and water conservation activities to reduce surface flow, and ultimately reduce flooding downstream (Maryono, 2014). Soil conservation activities in areas that are vulnerable and very vulnerable to flood supply are focused on efforts to put as much water as possible into the soil, such as making infiltration wells, rorak or reservoirs. Reducing the volume of surface runoff can be done by adding perennial plants to agricultural/forest areas and making infiltration wells in settlements (Savitri & Pramono, 2017). Table 4 presents the distribution of land vulnerability to flood supply in Tamansari District.

Almost 100% of Tamansari area is very vulnerable to flood supply. This can be explained that more than 68% of the land in Tamansari is very vulnerable to erosion, while the maximum daily rainfall in the area is quite heavy, which is more than 150 mm. As a result, Tamansari District is very vulnerable to flood supply.

Table 5. Flood vulnerability in Tamansari District

Vulnerability Class	Area (ha)	Percentage%
Not Vulnerable	438.730	10.03
Somewhat Vulnerable	3,909.447	89.34
Moderate	27.660	0.63
Total	4,375.84	100

Tamansari District, which has a relatively small flood potential because it is located in the upstream area (Table 5). With the potential for high rainfall, the community in Tamansari is also expected to manage their land by paying attention to the principles of land rehabilitation and soil conservation activities so that the potential for disasters can be minimized.

Recommendations for Land Rehabilitation and Soil Conservation (RLKT) Activities

Recommendations for RLKT activities are based on land vulnerability to disasters and current land cover. Recommended RLKT activities are only for land with class 3 (moderate), 4 (vulnerable) and 5 (very vulnerable) vulnerabilities so that not all land is determined to have RLKT. It is hoped that these recommendations can be used as a basis for determining RLKT activities which can then be agreed upon together with the community. Shows the distribution of RLKT activities in Tamansari District.

Table 6. Recommendations for Village RLKT in Tamansari District

Village	RLKT Activities (ha							Grand Total
	B1. 4. 11	B1. 4. 25	B11 (pollutant) 12. 18	B11. 13. 18	B12. 13. 21. 27	B12. 13. 27	B24. 25	B4. 11. 24	
Dragan	183.5	-	-	-	-	-	-	70.3	253.9
Jemowo	282.0	-	-	-	-	-	172.9	214.0	668.9
Karanganyar	287.5	-	-	11.1	-	-	-	186.9	485.5
Karangkendal	140.3	-	-	-	-	-	-	136.4	276.7
Keposong	285.0	-	-	0.2	-	-	-	130.6	415.8
Lampar	235.2	-	10.7	0.0	-	-	-	197.8	443.7
Lanjaran	82.8	-	-	-	-	-	224.3	32.7	339.9
Mriyan	-	121.6	-	-	2.7	217.3	303.1	-	644.7
Sangup	-	53.0	-	-	-	44.2	442.9	-	540.1
Sumur	140.1	-	-	-	-	-	91.0	75.5	306.6
Grand Total	1,636.4	174.5	10.7	11.2	2.7	261.5	1,234.3	1,044.3	4,375.7

The RLKT program is expected to have a positive impact on the community. Currently, the community only sees one side, namely the economic aspect compared to the environmental impacts obtained. This is in accordance with research conducted by Jariyah (2014) on land rehabilitation and soil conservation in the Keduang Sub-basin that the farming community only sees one economic side (tangible benefits) and has not seen the environmental impact (intangible benefits). However, business development to encourage restoration and rehabilitation is important as shown by Ulya et al. (2022). Furthermore, Kartasasmita (1996) and Raharjo et al. (2019) state that the RLKT program can be successful if the involvement of the surrounding community is required through the adoption of community potential mapping which is then linked to business groups and then the implementation of RLKT activities.

The classification of RLKT activity recommendations in villages in the Tamansari District (Table 6). Some areas in Tamansari are recommended to carry out RLKT activities in the form of: Reforestation with a mixture of cover crops, construction of infiltration wells, construction of reservoirs and development of agroforestry. Reforestation aims to restore the main function of the upstream area as a life support system (Indahsari et al., 2022). Land use needs to be balanced with soil and water conservation efforts. The construction of water infiltration and reservoirs helps accelerate the process of water entering the soil. In accordance with research by Riastika (2012) which states that the more water that enters the soil can increase aquifer filling and reduce surface flow. Based on the results of the RLKT analysis, it shows that the majority of villages in the Tamansari District area of 4,375.7 ha are expected to be able to carry out RLKT activities. There are at least 3 villages that are prioritized for implementing RLKT, including Jemowo Village with an RLKT land area of 688.9 ha, Mriyan Village with an RLKT land area of 644.7 ha, and Sangup Village with an RLKT land area of 540.1 ha. This finding is quite in line with that carried out by the Conservation District (Kurniawan, 2023) including vegetative conservation with coffee of economic value; technical civil conservation in the form of rainwater harvesting; Orchid conservation; and as a model for a conservation district. Although Kurniawan's study is not yet in-depth and less detailed.

Conclusion

Distribution of land vulnerability in Tamansari District. Dominated by the Very Vulnerable Class (68.85%). The results of the analysis show that the area of land that needs to be repaired is 4,375.7 ha covering 10 villages. The largest villages that need to be RLKT are Jemowo Village (668.9 ha) and Mriyan Village (644.7 ha). The recommended RLKT activities are only on land with vulnerability classes 3 (moderate), 4 (vulnerable) and 5 (very vulnerable) so that not all land is determined for RLKT. It is hoped that these recommendations can be used as a basis for determining a repair activity plan that can be agreed upon with the community. Shows the distribution of RLKT activities in Tamansari District. Directions for Land Rehabilitation and Soil Conservation in the form of Reforestation with vegetation, cover crops, compost, reservoirs, rorak, terrace reinforcement, ridges, SPA, infiltration wells. The RLKT directive is expected to be able to control land vulnerability to erosion, land vulnerability to flooding and water management so that it is expected to be able to improve the welfare of the community in the Tamansari District area.

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The authors declare no conflict of interest.

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