Environmental damage study based on intensive land use activities in Widoro Sub-watershed of Patuk, Gunungkidul, Yogyakarta, Indonesia

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Abstract. The criticality of watersheds in Indonesia can trigger water scarcity and trigger environmental damage if it is not handled as early as possible during uncertain climate change conditions. The long-term impact of this condition, if it is not handled properly, is the damage to the ecosystem and habitat that can disrupt rainfall patterns. Regulatory issues, sub-optimal community empowerment, lack of public awareness, and the decrease of forest productivity are some of the causes. This study was aimed to find out the extent of environmental deterioration using indicators of Erosion Hazard (EH) and landslides and to formulate environmental management strategies as an effort to conserve the environment. Data collection for the first purpose was undertaken by observation, literature review, documentation, and for the second purpose was conducted by measurement, observation, and interview. The results of the analysis can be concluded that the level of environmental damage in the Widoro Sub-watershed was in the category of minor damage. It can be seen from EH and landslides that occurred in the Widoro Sub-watershed. The erosion and landslides that occurred were at a harmless level. The environmental management strategy included counseling and assistance activities, improvement of sanitation facilities, and monitoring and law enforcement on community activities related to land use, erosion, landslide and disaster, and also the selection of plants with high value economic.
1. Introduction
Currently, climate change is increasingly erratic and unpredictable, it has the potential to increase environmental damage if it is not handled quickly. The criticality of the watershed will lead to water scarcity. Several conditions that contribute to land degradation are regulatory issues, lack of community empowerment, lack of public awareness, and decreased forest productivity. These reasons are related to land degradation important to do. A Watershed is a land area that is topographically bounded by the mountain ridges that hold and store rainwater which is then channeled into the sea through the main river [1]. Watershed itself does not avoid the problem of environmental damage. The problem that has always been associated with the destruction of the Watershed is the reduction of forest area due to the cutting down of trees upstream.

According to the Ministry of Forestry and Environment at the 3rd National Seminar on Coastal and Watershed Management, it stated that Indonesia has approximately 190 million Ha with 23 million Ha of critical land located in 15 watersheds. Subscribers to damage to the Watershed are not only the responsibility of the local government but there must be cooperation from all parties to create a sound watershed. The population density in Java affects the damaged watersheds in Java Island. One of the watersheds in DIY that is known to have environmental damage in the form of landslides is the Opak-Oyo Watershed. In 2016, there were 41 landslide events in the area. The landslide occurred in the administrative area of the Gunungkidul Regency including Patuk, Gedangsari, Ngawen, and Semin. The existing watershed in the Patuk District is Widoro Sub-watershed which is part of the Opak-Oyo Watershed which empties into the Oyo River.

Land use in Widoro Sub-watershed is a settlement, similar forest, terrestrial (river) waters, irrigation rice field, rainfed rice field, and moor/field. On agricultural land, people still use traditional ways of managing land coupled with the use of pesticides. Intensive land use from land use in the Widoro Sub-watershed has caused various impacts such as erosion [2]. The previous research data in 2014 found erosion that occurred in Widoro Sub Watershed. The area of erosion that occurs in the Widoro Sub-watershed ranges from 0.11-1303.87 tons/ha/year with very mild, moderate, severe, and very severe Erosion Hazards (EH) [3]. The objectives of this study were: (1) to determine the extent of environmental damage in terms of erosion and landslide indicators on intensive land use triggering land degradation of Widoro Sub Watershed; and (2) to formulate an environmental management strategy for the control of land degradation as the basis for environmental conservation in Widoro Sub Watershed.

2. Research methods
The study areas were Nglanggeran Village, Putat Village, Nglegi Village, and Bunder Village, in Patuk District. Data were measured and selected using a sample survey, direct observation, and interview. The level of environmental degradation in terms of erosion and landslide indicators in the Widoro Sub-watershed used descriptive analysis by looking at Erosion Hazard Map, Disaster Prone Map, and Zoning Map of Damage in the Widoro Sub Watershed. The value of annual erosion in previous studies was calculated using the USLE approach whereas landslides were the result of the plot of landslide events in the study area and the measurement of the depth of lands experienced landslides. The exercise of map data and landslide data in the field was related to data of land utilization in Sub Watershed Widoro. The three data were analyzed based on environmental components and it consisted of abiotic, biotic, and culture to produce a criterion level of environmental damage. Indicators of assessment of the extent of environmental damage were shown in Table 1, Table 2, and Table 3.

The preparation and formulation of an environmental management strategy based on Government Regulation no. 37/2012 concerning Watershed Management. The analytical technique used in the preparation and formulation of environmental management strategies was the relationship matrix method. The relationship matrix method is a concept contained in the table to identify, explore, and describe in detail all the causes associated with a problem. This method is commonly used at the stage of identifying the problem and determining the cause of the problem [6]. The environmental
management strategy which was the result of the analysis of the data and information obtained results in the recommendation with three categories: minor, moderate, and severe damage.

Table 1. Classification of erosion hazard level (EHL)[4].

| No. | Class | Lost land (ton/ha/thn) | Large (ha) | Percentage (%) | Description |
|-----|-------|------------------------|------------|----------------|-------------|
| 1   | I     | <15                    | 115        | 7.86           | Very Light  |
| 2   | II    | 16-60                  | 322        | 21.99          | Light       |
| 3   | III   | 60-180                 | 630        | 43.03          | Medium      |
| 4   | IV    | 180-480                | 307        | 20.97          | Heavy       |
| 5   | V     | >480                   | 90         | 6.15           | Very Heavy  |

Table 2. Classification of soil lands depth [5].

| No. | Type            | Description | Depth (m) |
|-----|-----------------|-------------|-----------|
| 1   | Surface slide   | Very light  | <1.5      |
| 2   | Shallow slide   | Light       | 1.5–5.0   |
| 3   | Deep slide      | Medium      | 5.0–20    |
| 4   | Very deep slide | Heavy       | >20       |

Table 3. Elements of assessment of social environment components.

| No. | Social aspect research parameters                                                                 |
|-----|---------------------------------------------------------------------------------------------------|
| 1   | The dominant livelihood in the Widoro sub watershed                                               |
| 2   | Utilization of dominant land in Widoro Sub Watershed                                                |
| 3   | Effect of land use with erosion and landslides                                                      |
| 4   | Tradition of the people in Widoro Sub Watershed                                                    |
| 5   | Institution in Widoro Sub-watershed related to agriculture and conservation activities as an effort to preserve the environment |

3. Research result and discussion

3.1. Types and forms of intensive land use

Land use in the Widoro Sub-watershed includes forest, settlement, rainfed rice field, irrigated rice field, moor, and damaged soil. Types and forms of intensive land use also a trigger environmental damage. Bhan [7] also said that land uses influence the flow of water, nutrients and sediments in coastal areas. These issues lead to give the impact on rainfall patterns which can automatically increase the temperature as well that can affect climate change. In order to know the proper land use, it is necessary to identify land uses such as follows.

a) Types of intensive land use activities include: agricultural land, agricultural land, settlements, tourist attractions, economic support facilities, public facilities, farms, and sources of clean water.

b) Forms of intensive land use activity:

- Rainfed rice paddies and irrigated paddy fields with cropping pattern 1Xrice, 1Xpalawija.
- Mixed gardens, fruit orchards, chocolate gardens, and commodity plantation gardens.
- Permanent settlements, semi-permanent settlements, and wood-paneled settlements.
- Forest Park (Tahura), Tourism Village, Ecotourism, and waterfall.
- Economic support facilities: shophouses, restaurants, markets, department stores, banks, and supermarkets.
- Public facilities: five schools, one refueling station, one market, one post office, cemetery, sports field, and seven places of worship.
- Livestock: chicken farms, quail farms, and cattle farms
• Source of clean water: springs and rivers.

Types and forms of land use in the Widoro Sub-watershed that trigger of environmental damage. The types and forms of utilization are as follows.

a) **Paddy field**

Red Latosol and Litosol, the change of rainfall intensity since 2015, most of the paddy field has a depth of land of 1.5 meters, and the erosion and landslide occurrence in paddy field.

b) **Mooring field**

An area with a slope of 25% - 40%. It can be detected from the roots of the plants that appear due to the ground has been eroded by water. The moor has a soil thickness of 0.5-1 meters.

c) **Settlement**

Can trigger the occurrence of environmental damage due to the process of land conversion and utilization that is not in accordance with the efforts of environmental conservation.

d) **Places of interest**

The trigger of environmental degradation in the tourist spots more lead to human intervention. Habits brought by the society in disposing of garbage and maintaining the environment became the main trigger.

e) **Source of clean water**

The clean water facilities of Local Water Company still cover areas with easy accessibility especially along Yogy-Wonosari Street. The northern part has a water depth of more than 15 meters. But not all sources of clean water free of domestic waste left by the community itself, both solid and liquid waste.

3.2. **Identify the level of environmental damage**

Land policies also affect environmental damage because several land use policies have created a mentality of open access to resources such as forests, water, etc., which makes local communities compete for reckless exploitation of resources in watershed with a loss of ownership [8]. The level of environmental damage at each land use is the result of identification of the damage, suitability of land use, type of land cover present in each land use. The following in Table 4 presents the analysis of the level of damage to each land use in the Widoro Sub-Watershed.

| Land Use               | Land Utilization          | EH   | Landslide Classification | Conclusion                                                                 |
|------------------------|---------------------------|------|--------------------------|-----------------------------------------------------------------------------|
| Land water (River)     | Source of clean water     | Medium | There was no landslide   | Heavy Damage (Low erosion hazard, waste and water pollution problems)       |
|                        | Irrigation water sources  |      |                          |                                                                             |
|                        | Washroom                  |      |                          |                                                                             |
| Similar Forest         | Similar Forest            | Very Mild | There was no landslide | Heavy Damage (Vegetation cover and land utilization support environmental sustainability) |
|                        | Place for Educational Tour|      |                          |                                                                             |
| Irrigated rice field   | Paddy rice field          | Mild  | Very heavy               | Heavy Damage (Landslides that occurred a surface landslide)                 |
| Rainwater crops        | Rice field and rice crops | Mild-Medium | There was no landslide | Heavy Damage (rice fields are well managed, EH is still within the permissible stage because it does not fall into the heavy and very heavy EH classification) |
### Land Use and Land Utilization

| Land Use       | Land Utilization         | EH        | Landslide Classification | Conclusion |
|----------------|--------------------------|-----------|--------------------------|------------|
| Settlement     | • House                  | Mild      | Light (depth of 1.5–5.0 meters) | • In settlements with mild-moderate EH have mild damage (the settlements are managed in accordance with the way erosion and landslide prevention such as mechanical erosion handling by making a barrier on the cliffs using a pile of stones until cemented). |
|                | • Food stalls            | Heavy     |                          |            |
|                | • Store                  |           |                          |            |
|                | • Tourist attractions    |           |                          |            |
| Tackle/ fields | • Mixed garden          | Light     | Heavy (depth of 1.5–5.0 meters) | Heavy Damage (damage that occurs in this area is relatively mild because of landslides that occur away from the settlements, but there must be handling in areas that have moderate EH with the type of cliff erosion). |
|                | • Homogeneous garden     | Medium    |                          |            |
| Ground broken  | • Tourist sites          | Medium    | There was no landslide   | Heavy Damage (this location goes into the complex of Gunung Api Purba Nglanggeran, volcanic parent material with a height between 550–600 m asl). |

Source: Field observation and library review (2017).

### 3.3. Widoro Sub-watershed environmental management strategy for environmental sustainability

Human activities such as agriculture, deforestation, and urbanization can generate severe disruption to water resources [9] and it has been shown in the previous section. Environmental management strategy is a continuation of the environmental damage level that has occurred. Strategy as a cultivated effort to prevent and mitigate the occurrence of environmental damage due to intensive land use activities by the community. The result of the identification analysis of environmental damage trigger shows that environmental destruction trigger that affects environmental sustainability at all observation points are surface erosion and some landslide events. Referring to the result of analysis of research variables related to abiotic and biotic components which are measured by Erosion Hazard Level (EHL) and depth of landslide, it can be concluded that almost the entire Widoro Sub-watershed region experienced erosion from very light to very heavy category and the landslide that happened have a depth less than five meters. Dealing with the findings of the problems, the environmental management strategy is prepared for each land use in the research area covering the problem, classification of damage, determining the extent of environmental damage, and management strategies. The recommendations matrix of the environmental management strategy is presented in Table 5.
Table 5. Widoro Sub-watershed Environmental Management Strategy

| Problems                                                                 | Classification of Environmental Damage | Determination of the Level of Environmental Damage | Management Strategies |
|--------------------------------------------------------------------------|-----------------------------------------|---------------------------------------------------|-----------------------|
| • Damage to river lip biota due to garbage caught in plants              | Heavy Damage                            | • The amount of garbage caught in pandan-pandan plants is small | • Increase public awareness on the importance of tackling environmental damage especially as a result of household waste. |
| • Reduced river water quality due to household waste                     |                                         | • Areas that have less than 20 meters of polluted waste | • Management of environmentally friendly river water cultivation |
| • Lack of public awareness of environmental hygiene                      |                                         | • Type of waste in the form of plastic waste and can still be taken | • Waste management in the sub watershed. |
| • Community's habitual factors that still use the river as a place of disposal |                                         |                                                   |                       |
| • Heavy Damage                                                           |                                         |                                                   |                       |
| • The amount of garbage caught in pandan-pandan plants is small          |                                         |                                                   |                       |
| • Areas that have less than 20 meters of polluted waste                  |                                         |                                                   |                       |
| • Type of waste in the form of plastic waste and can still be taken      |                                         |                                                   |                       |
| • Increase public awareness on the importance of tackling environmental damage especially as a result of household waste. |                                         |                                                   |                       |
| • Management of environmentally friendly river water cultivation         |                                         |                                                   |                       |
| • Waste management in the sub watershed.                                |                                         |                                                   |                       |
| • Lack of knowledge about waste and the environment                     | Heavy Damage                            | • Activities are conducted on the downstream of the river | Build environmental sanitation facilities and infrastructure |
| • Difficult to get clean water during the dry season                     |                                         | • Conducted by people with middle to lower economic levels | Build environmental sanitation facilities and infrastructure |
| • Community's habitual factors that still rely on river water as water needs. |                                         | • The existing sanitation system has not reached the riverside area |                       |
| • Lack of sanitation                                                     |                                         | • Type of waste is household wastewater           |                       |
| • River contamination due to household wastewater                         |                                         |                                                   |                       |
| • Heavy Damage                                                           |                                         |                                                   |                       |
| • The soil is easily saturated with water                               | Heavy Damage                            | • The location of the landslide is in the rice fields | Increase public awareness of hazards and losses in the presence of erosion and landslides. |
| • Tilt slope between 25-40%                                              |                                         | • The depth of the landslide is less than five meters | Selection of plants that have strong roots to bind the soil. |
| • High swales over 1 meter                                               |                                         |                                                   | Creation of erosion and landslide controls naturally and mechanically |
| • Lack of public knowledge about erosion and landslides, especially farmers. |                                         |                                                   |                       |
| • Lack of public knowledge, especially farmers regarding the loss and danger of erosion and landslides. |                                         |                                                   |                       |
| • Heavy Damage                                                           |                                         |                                                   |                       |
| • The soil is easily saturated with water                               | Heavy Damage                            | • The landslide depth is less than 5 meters      | Increase public awareness of losses from erosion and landslides. |
| • Tilt slope between 25-40%                                              |                                         | • Location is not adjacent to residents' houses | Selection of high value economic plants that can cope with erosion and landslides. |
| • Located at an altitude of more than 2 meters from the road            |                                         | • Landslides are caused by natural factors such as high rainfall and erosion-free soils | Increase community awareness about environmental sustainability. |
| • Plant species not planted strongly rooted.                            |                                         | • Plants grown at this location have not been able to bind soil particles. |                       |
| • Lack of public awareness of landslide hazards                          |                                         |                                                   |                       |
| • Generally, landslides are planted with maize, peanut and cassava.      |                                         |                                                   |                       |
Problems Classification of Environmental Damage Determination of the Level of Environmental Damage Management Strategies

- Land is at an altitude of > 500 m asl
- Cliff erosion occurs on the only access road to the residents' settlement.
- Lack of illumination and difficult terrain associated with positions on the slope of 25-40%.
- Most of the land is a plantation production plant such as teak and mahogany trees.

Medium Damage
- Erosion lasts for a long time
- The eroded cliff reaches approximately 25 cm
- Erosion will continue if not addressed further
- Landslide occurs with a depth of less than 5 meters.

- Creation of erosion and landslide controls naturally and mechanically
- Increase public awareness of hazards and losses in the presence of erosion and landslides

Source: Research Results and Analysis (2017)

3.4. Environmental management strategy to provide recommendations on land management for environmental sustainability

Land management that aims to conserve the environment should be carried out for all types of land use to create integrated environmental management. In the Widoro Sub-watershed, there are two types of damage, i.e. mild and moderate. Recommendations with minor damage refer to erosion control by vegetative methods such as: reducing runoff rate and protecting the surface from rainfall impact by planting suitable plants, increasing the capacity of soil infiltration, utilizing litter, making appropriate cropping patterns, making pattern planting alternating hoses, and planting in rotation. Several recommendations for moderate damage: closing cracks using waterproof soil, reducing soil thickness or slope of landslides prone to landslides, planting slopes with roots that can penetrate the bedrock, installing rocks on the path, and drainage channels on the slopes. The land management recommendations are based on the situation in the Widoro Sub-watershed but not all appropriate. Land management recommendations can be used in watersheds with the same physical and type characteristics. Strategies at various governance spheres should prioritize addressing the structures that impede individual pro-environmental dispositions from materializing as well [10].

4. Conclusion and recommendation

The rainfall patterns can affect climate change itself. Water infiltration that is not absorbed effectively, reduced soil nutrients, damage to ecosystems, and habitats due to errors in land use are several things that then trigger it. Types of land utilization activities in Widoro Sub Watershed, it is divided into eight, namely agricultural land, moorland, settlements, tourist attractions, economic support facilities, public facilities, farms, and sources of clean water. There are several lands uses that can trigger environmental degradation. The level of environmental degradation of Widoro Sub- Watershed is generally included in the category of minor damage with two categories of damage that is mild and moderate. This is due to differences in the number of findings of landslide events and TBE bases in two different locations. Widoro Sub-watershed's environmental management strategy to preserve sustainability by providing information to society about erosion, landslide, disaster, and environmental sustainability. It can make efforts to assist the community in environmental management that supports the perpetuity of the environment and to make the community aware of the environment. The activities covered by the government include environmental community groups, the implementation of activities under the Environmental Law Number 32/2009.
The First suggestion is necessary to study the carrying capacity of the Widoro Sub-watershed on the land utilization done by the community through environmental factors that are abiotic, biotic, and cultural factors. The study is expected to minimize environmental damage due to land use. Second, there is an effort to increase the participation and understanding of the community in maintaining the quality of the environment through counseling and assistance from the government and environmental groups to increase community understanding on land use based on environmental sustainability, erosion, landslide, and disaster. Third, further study can examine the environmental problems of the Widoro Sub-watershed concerning pollution and the amount of sediment load on the Widoro River from upstream to downstream is needed.

References
[1] Asdak C 2004 *Hidrologi dan pengelolaan daerah aliran sungai* (Yogyakarta: Gadjah Mada University Press)
[2] Arsyad S 2010 *Konservasi Tanah dan Air* (Bogor: IPB Press)
[3] Hashifah D G 2014 *Tingkat erosi Sub-das Widoro Kecamatan Patuk Kabupaten Gunungkidul* [Thesis] (Yogyakarta: Universitas Negeri Yogyakarta)
[4] Direktorat Kehutanan dan Konservasi Sumberdaya Air 2004 *Kajian modal pengelolaan daerah aliran sungai (DAS) terpadu* (Jakarta: Direktorat Kehutanan dan Konservasi Sumberdaya Air/BAPPENAS)
[5] Hardiyatmo 2006 *Penangan tanah longsor & erosi* (Yogyakarta: Gadjah Mada University Press)
[6] Farkhah Y 2016 *Kajian kerusakan lingkungan perairan Sungai Winongo akibat limbah cair di Kota Yogyakarta* [Thesis] (Yogyakarta: Universitas Gadjah Mada Yogyakarta)
[7] Bhan S 2013 Land degradation and integrated watershed management in India *Int. Soil Water Conserv. Res.* 1 49–57
[8] Desta H, Lemma B and Gebremariam E 2017 Identifying sustainability challenges on land and water uses: The case of Lake Ziway Watershed, Ethiopia *Appl. Geogr* 88 130–43
[9] Degife A, Worku H, Gizaw S and Legesse A 2019 Land use land cover dynamics, its drivers and environmental implications in Lake Hawassa Watershed of Ethiopia *Remote Sensing Applications: Society and Environment* 14 178–90
[10] Espinoza-Cisneros E and Akhter M 2020 Walking the talk” in land management: Structural factors influencing pro-environmental intention-action links in a tropical watershed *J. Rural Stud.* 79 pp 334–44