Spatial Analysis of Critical Land in Sub-Watershed of Lawe Pakam, Mardingding District, Karo Regency, North Sumatra Province

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Abstract. The Lawe Pakam Sub-watershed, Mardingding Sub-district, Karo Regency is the upstream area of the watershed. It is dominated by protected forests, which will result in significant natural disasters in the watershed downstream such as flash floods, landslides, and drought. The objectives of this study were to analyze the criticality level of land and its changes. The research method used was the critical land spatial analysis with primary data from 2019, to make comparison of secondary data from 2013 sourced from BPDA S Sei Wampu Ular to find out the changes in the critical land, and to have field examination. The results demonstrated changes in the critical land. The criticality level of the land in Lawe Pakam Sub-watershed, Mardingding District in 2013 was categorized into very critical covering an area of 2,155.47 Ha, critical 4627.93 Ha, rather critical 6,019.72 Ha, critically potential 2,307.35 Ha and not critical 3,788.04 Ha, whereas that of in 2019 was categorized into very critical covering an area of 8,014.23, critical 1,226.77 Ha, rather critical of 8,462.19 Ha, potentially critical of 268.87 Ha and not critical at 926.44 Ha. The results showed that changes in the criticality level of the land were caused by changes in the land cover. it is recommended that the critical land be rehabilitated, especially that of in protected forest areas.

1. Introduction

Lawe Pakam Sub-watershed, Mardingding Subdistrict, Karo Regency, is an upstream part of Singkil watershed. The function of a sustainable watershed in this sub-watershed is absolutely necessary because it affects the stability of the watershed downstream ecosystem. The disasters such as flash floods, landslides, erosion, drought and others in the downstream area of the watershed were caused by the land criticality in the upper watershed. Therefore, it is necessary to reduce as minimum as possible the existence of critical land to function as before.

Experts have made various definitions of watersheds Asdak, C (2010) classified watersheds into 3 regions, namely upstream, middle and downstream. Upstream area is forested and conservation areas, the topography is more than 15%, the drainage density is higher, and it is not the flood area. The middle part of the watershed is a transitional area between the upstream and downstream areas of the watershed, there is an interaction of biophysical and chemical environments that take place dynamically, so that there is a balance among material and energy outflows with the place where the organism resides. The downstream area of the watershed is a utilization area with a relatively little topography (less than 8%), in some places it is a flood
area. The regulation on water use is determined by irrigation buildings, while vegetation is dominated by pine forests and smallholder plantations.

Ramdan, 2006 stated that the determinants of flood discharge are the form of watersheds and river network systems. The more round the shape of the watershed, the shorter the concentration of rainwater falls and flows to the outlet and the higher the fluctuations of incidence of flood will be. Conversely, the oval shaped watershed will require some time of rainwater concentration which falls relatively long so that the fluctuations in the incidence of flood will be lower.

Some definitions of the watershed can be concluded that the sustainability of the upstream watershed function is the most important part of its existence, especially as a water management area in the other parts of watershed. The correlation between the upstream and downstream areas of the watershed is that the upstream area is the conservation area of water management utilized by the downstream watershed. Erosion occurring in the upper watershed will cause sedimentation in the downstream watershed. Agricultural or plantation markets from upstream watersheds will occur in the downstream watershed.

Some experts and government regulations stipulated the emergence of critical land and its causes. Arsyad (1989) states that critical land is the land condition occurring due to incompatibility between land and its use, resulting in physical, chemical and biological land damage.

Critical land is a form of land degradation. Land degradation is a decrease in the land quality or productivity. This decrease can be seen physically, by the damage of the land leading to high rates of erosion resulting in flood, landslides, sedimentation, and accumulation of toxic substances. Likewise, the function of water management will be disrupted (Director General Regulation on the Management of Watershed Management, 2013).

Land degradation in Indonesia tends to increase in forest areas that were previously heavily forested. However currently the forests are covered residential land, agricultural crops or plantations, and shrubs are deforested. Forests that are intentionally cut down and shift their functions into other uses in the upstream area have caused increasing forest degradation. This can increase sedimentation in the downstream area and the incidence of flash floods. Changes in land cover due to forest encroachment are found in almost every province in Indonesia. Likewise, the development of the condition of the forest area in North Sumatra Province is that its area has been decreasing from 3,689,188 ha (SK. 44 / Menhut-II / 2005), 3,055,795 Ha (SK. 579 / Menhut-II / 2014) to 3,010,160, 89 Ha (SK. 1076 / MenLHK-PKTL / KUH / PLA.2 / 3/2017). According to Hutabarat (2008), the causes of degeneration of watersheds in Indonesia are geomorphological conditions (geology, land, and topography), high rainfall (erosion), and community activities (Illegal logging, forest burning, forest encroachment, forest exploitation, and excessive land use and not applying soil and water conservation). The rate of deforestation is increasing but the rate of rehabilitation is relatively low, which is only 500 thousand to 700 thousand ha per year so the forest will be increasingly critical. The determinant of critical land is based on the procedures for compiling spatial data of critical land determined based on the Director General Regulation of Control of Watershed and Protection Forest Number: P.3/PDASHL/SET/KUM.1/7/2018, consisting of land cover maps, erosion maps, slope maps, Forest Zone function maps, and updated critical land maps.

From some of the above definitions, it can be concluded that the hydrological process that occurs in the upstream watershed is related to the erosion, transportation and sedimentation in the downstream watershed, so it is necessary to pay attention to land use by considering soil
and water conservation to avoid the expansion of critical land. The land use neglecting principles of soil and water conservation can cause land degradation which will eventually lead to critical land. In addition, it is also necessary to consider the type of vegetation with a strong root system growing on the land, especially in the upper watershed to reduce the land criticality. Studies on critical land have been done in recent years. Indrihastuti (2016) conducted a study entitled Analysis of Critical Land and Direction of Land Rehabilitation in the Development of Kendal District Area, Central Java. The results showed that the area of critical land measured by parameters from the Regulations of Directorate General of BPDAS PS Number P. 4 / V-Set / 202013 was 19,535.96 ha, and was 34,317.87 ha by modified parameters including 4,678.92 ha of protected area and 29,638.95 ha of cultivation area.

Melo (2018) conducted a study entitled Analysis of Factors Causing Changes in the Critical Land Area in Tateli, Mandolang District. The results showed that the dominant factor causing critical land was land cover, followed by erosion hazard level and slope, while land management had little effect on land.

Limbong et al (2010) conducted a study entitled Mapping the Criticality Level of Land in Protected Areas in Aek Raisan Sub-watershed, Batang Toru Watershed. The results showed that the criticality level of land in Aek Raisan sub-watershed was dominated by a potentially critical level. Efforts made to overcome it were Forest and Land Rehabilitation by observing principles of soil and water conservation to prevent critical land expansion. Several study also was conducted in the different watershed using GIS, such as: Rahmawaty et al. (2011), Rahmawaty et al. (2015), Satriawan et al. (2015) and Rahmawaty et al. (2019).

Some of the studies above show that there have been no studies done on the analysis of critical land in the Lawe Pakam Sub-watershed, Mardingding District, Karo District. This study analyzes critical land in the area. The objective was to determine the influence of criticality level of land on land conversion in Lawe Pakam Sub-watershed, Singkil Watershed, and to find out the distribution of critical land in Sub-watershed in Lawe Pakam, Singkil Watershed based on the parameters of Director General of Control of Watershed and Protection Forests (PDASHL) Number: P.3/PDASHL/SET/KUM.1/7/2018 dated July 9, 2018 concerning Technical Guidelines for Preparation of Critical Land Spatial Data. It is recommended to perform rehabilitation of critical land, especially in protected forest areas that have been damaged or have converted to oil palm, maize or seasonal crop plantations.

2. Method
Critical land spatial method was employed to analyze the primary data from 2019 by applying the application of Geographic Information Systems, comparing secondary data from 2013 sourced from BPDAS Sei Wampu Ular to observe the changes in land criticality (land area and soil criticality), and field examination. Primary data were analyzed by firstly processing the critical land data of Lawe Pakam watershed, Mardingding Subdistrict, Karo Regency in 2019 using parameters in accordance with the Regulation of Director General of the Control of Watershed and Protection Forests Number: P.3/PDASHL/SET/KUM.1/7/2018 including land cover, erosion, slope, and forest area function maps. The changes found in the criticality level of the land became the samples selected for field examination as verification and validation of critical land analysis by observing field conditions, taking documentation, and interviewing informants who were aware of land cover changes leading to critical land.

2.1 Materials and Tools
The materials used in this study are as follows:
1. Spot Imaging Map 6/7 recorded in 2017
2. The RBI map in 2015 on scale of 1: 50,000.
3. Archmap 10.1
4. Map of the boundaries of Lau Pakam Sub-District of Karo Regency and the Watershed Management Center (BPDAS) Wampu Sei Ular
5. The land cover map in 2017 on a scale of 1: 250,000
6. The slope map on a scale of 1: 250,000
7. The Area Map in Decree No. 579 of 2014 in conjunction with 1076 in 2017
8. The Critical Land Map on a scale of 1: 250,000
9. The Global Positioning System (GPS)

2.2 Research Procedure

The research procedures are as follows:
1. Delineation of the boundary map of Lawe Pakam Sub-watershed, Mardingding District, Karo Regency.
2. Making spatial analysis of the critical land area in 2019 using parameters according to the Regulation of the Directorate General of PDASHL Number P.3/PDASHL/SET/KUM.1/7/2018.
3. Detecting changes in the Critical Land Map in Lau Pakam Sub-watershed Map from 2013 until 2019
4. Choosing a sample of Critical Land Change Detection results
5. Examining or Conducting a field survey on selected samples.
6. Having interviews with informants who were aware of the changes in land cover causing land criticality.

![Figure 2.1 Research Procedures](image-url)

- Delineation of the Lau Pakam watershed boundary map
- Critical Land Map Data Processing in 2019
- Change Detection
- Critical Land Map of 2013
- Critical Land Map in 2019
- Selected sample: Critical Land Change
- Field Check and Interview

Parameters according to P.3 / PDASHL / SET / KUM.1 / 7/2018, namely:
1. Land Closure Map in 2017
2. Erosion Map
3. Map of Regional Functions
   a. In the Forest Zone
   b. Outside the Forest Zone
4. Slope map

1. Spatial analysis of the relationship between the critical level of land and land use change
2. Distribution of critical land based on the parameters of the PDASHL Regulation Number: P.3 / PDASHL / SET / KUM.1 / 7/2018
3. Results and Discussion

The overlay results of the latest thematic maps demonstrate that the critical land area in Lawe Pakam Sub-watershed, Mardingding District, Karo Regency indicated an increase in the area of critical land with very critical category. In 2013, the area of very critical land was 2,155.47 Ha, but it increased to 8,014.23 Ha in 2019 or 5,858.76 Ha has been expanded to the map.

The distributions of the critical land area in Lawe Pakam Sub-watershed, Mardingding District, Karo Regency from 2013 until 2019 are presented in Table 3.1, Figure 3.1 to Figure 3.4.

Table 3.1 Changes in Critical Land Area from 2013 until 2019

| Number | Land Criticality Level | Area (Hectare) | Area of Change (hectare) |
|--------|------------------------|----------------|-------------------------|
|        |                        | Year 2013      | Year 2019               |
| 1.     | Very Critical          | 2.155,47       | 8.014,23                | 5.858,76                |
| 2.     | Critical               | 4.627,93       | 1.226,77                | 3.400,23                |
| 3.     | Slightly critical      | 6.019,72       | 8.462,19                | 2.442,47                |
| 4.     | Potentially critical   | 2.307,35       | 268,87                  | 2.038,48                |
| 5.     | Not Critical           | 3.788,04       | 926,44                  | 2861,60                 |
|        | Total                  | 18.898,50      | 18.898,50               |

Figure 3.1 The Distribution of Critical Land Change in Lawe Pakam Sub-District, Mardingding District, Karo Regency between 2013 and 2019
Figure 3.2 Critical Land Map of 2013

Figure 3.3 Critical Land Map in 2019
Figure 3.4 Critical Land Change Map in Sub-Watershed in Lawe Pakam Mardinding District, Karo Regency, North Sumatra Province from 2013 until 2019

The spatial analysis of thematic maps is made based on the Regulation of the Director General of PDASHL Number P.3/PDASHL/SET/KUM.1/7/2018 to determine the criticality level of land and its changes. Furthermore, analysis of spot imaging maps 6/7 was conducted to observe the type of land cover, and the results of Melo study (2018) demonstrated that the dominant factor causing critical land was land cover, then a field observation was conducted on selected samples. The development of land cover (years) and field observation is presented in Table 3.2.
Table 3.2 Development of Land Cover (Years) and Field Observation

| Number | Land Unit | Land Closure Development (Year) | 2011 Information | 2019 Information | Information |
|--------|-----------|---------------------------------|-------------------|-------------------|-------------|
| 1      | 6         | Secondary Dryland Forests are in good condition | There are logged marks | There are a number of logged (added) marks overgrown with grasses. | Not Critical - rather critical |
| 2      | 59        | Shrub shrubs and part of dryland agricultural areas | Several paths, dry land agriculture, and several land clearing areas | Widespread land clearing area | Critical potential - Very critical |
| 3      | 62        | There are several logged-over areas | There are oil palm plantations, mixed dryland agriculture | Widespread land clearing and few plants | Critical-Very Critical |
| 4      | 73        | Dryland Agriculture and few logged-over areas | Dryland Agriculture and some logged-over areas Shrub bushes, some new areas are cut down, and paths are made | Widespread Land clearing and few plants | Rather Critical-Very Critical |
| 5      | 79        | Shrub bushes, some new areas have been grassy | Shrub shrubs, increased new area felled, and paths | Shrub bushes began to be rare and new areas were cut down | Critical Potential - Rather Critical |
| 6      | 79        | Dense bushes and grassy cutting marks | Shrub bushes began to be rare and new areas were cut down | Start to grow shrubs and grassy cutting marks | Critical Potential - Rather Critical |
| 7      | 79        | Shrub bushes | Start to grow shrubs and grassy cutting marks | Paths and bushes | Critical-Rather Critical |
| 8      | 81        | Shrub bushes | Start to grow shrubs and grassy cutting marks | Paths and bushes | Field checks of the area have become dry land agriculture with |
Table 3.2 Development (*Advanced*)

|   | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 9. |  | 84 | Palm oil fields and several plots of rice fields that have just been harvested | Palm oil fields and the expansion of newly harvested rice fields | A small portion of oil palm land and the expansion of paddy fields with rice plants | The field check of the area is dry land agriculture rather than Critical - Not Critical rice fields |
| 10. |  | 97 | Secondary Dryland Forests are mostly in good condition even though there is logged over with grass | Secondary Dryland Forest has been turned into a grassy logged area | Logs have been grassy and there are several newly logged lands | Not Critical - Rather Critical |

The results of the field observation indicate that two units of land had different types of land cover as illustrated by the results of the spot imaging map analysis 6/7 in 2017, namely land unit 81 and 84. Both units of land were within the forest area. The spot imaging map 6/7 on land unit 81 was based on the type of land cover in the form of footpaths and shrubs, but the results of field observation showed that the area was apparently a dry farming land with corn, candlenut, jengkol, and orange plantations. Based on the Regulation of the Directorate General of PDASHL Number P.3/PDASHL/SET/KUM.1/7/2018, shrub land cover and dry land agriculture in the forest area have the same score of 4, so the criticality of the land remained at a critical level.

The spot imaging map analysis 6/7 on land unit 84 was made based on the type of land cover in the form of a small portion of oil palm land and expansion of rice field plots, but the results of field observation showed that the area was dry agricultural land instead of rice fields. Based on the Regulations of Directorate General of PDASHL Number P.3/PDASHL/SET/KUM.1/7/2018, rice field cover in forest areas had a score of 1, while dry agricultural land had a score of 4, so that the criticality score became 23, but the criticality remained at an uncritical level.

The difference of the results of the analysis through the desk study from the field observation was caused by the recording using high resolution 6/7 Spot Imaging Map on Earth surface objects, the type of land cover was the current condition of land cover at the research time, so it does not necessarily show similar result for the present land cover condition. The increasing density of population growth in the area has also led to an increase in community dependence on the availability of land to switch functions into other uses to meet their needs, so it has accelerated changes in land cover types that can affect the criticality level of land.

4. Conclusion
Spatial analysis of critical land by applying the application of Geographic Information Systems in Lawe Pakam Sub-watershed, Marcingding Sub-District, Karo Regency demonstrated that there has been changes in the criticality level of the land. The reason was that the recording used high resolution 6/7 Spot Imaging Map on Earth surface objects, the type of land cover applied was the condition of the current land cover at the research time so it does not necessarily show similar result for the present land cover condition. The increasing density of population...
growth in the area has also led to an increase in community dependence on the availability of land to switch functions into other uses to meet their needs, so it has accelerated changes in land cover types that can affect the criticality level of land.

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