The Effect Of Land Cover Changes On Landslides In Grindulu Watershed, Pacitan Regency, East Java

Raka Achmad Fauzi[1], Rika Harini[2], R. Rijanta[3]*

[1 2 3] Department environmental science, Graduate School, Univ Gadjah mada

Abstract. This research was conducted in the Grindulu River Watershed, Pacitan Regency. The Grindulu River is included in the Bengawan Solo river area. The Grindulu River Watershed is located in three areas, namely Pacitan Regency, Ponorogo Regency and Community Districts along the River Watershed use the grindulu river water for various activities, such as bathing, washing, and for agricultural irrigation purposes. This study aims to determine changes in land cover in the Grindulu river watershed and the distribution of landslides in the Gindulu river area. The data used in this study is information consisting of: data on landslide events in 2022 obtained from the Pacitan Regency regional disaster management agency; land cover data for the grindulu river watershed in 2018 and 2022 identified from Copernicus Sentinel-2; basic maps, such as road network maps, contour maps, river network maps and administrative maps obtained from the Indonesian Land map.Based from the spatial analysis, it was found that 67 points of landslide events that occurred during 2022 were spread throughout the river watershed. The landslide occurrence points have patterns or clusters located on the banks of the river and close to residential areas. Landslide points are found in different land covers based on spatial analysis of the distribution of landslide points with land cover maps. Most landslides occur in agroforestry land cover.

1 Introduction

The number of landslides in 2020 has reached 387. Based on data from the National Disaster Management Agency (BNPB), landslides are often the deadliest disasters in Indonesia. In 2014, BNPB recorded 354 people died due to landslides. A year later, landslides killed 174 people and in 2016 landslides occurred 599 times, killing 186 people. In 2017 as many as 15.6 people died due to landslides and 221 others died in various other disasters [1].

Landslide as an exogenic process causes the movement of soil mass down the slope due to the force of gravity and high rainfall. The other factors that cause landslides are soil type, geological factors, land cover, seismic factors and land slope [2]. Landslides in Indonesia mostly occur in areas with high rainfall and in hilly or mountainous geomorphological conditions. The highest occurrence of landslides in Indonesia occurs in areas with rainfall of more than 2000 mm and topography with steep slopes. Considering that there are many hilly or mountainous areas with rainfall > 2000 mm in Indonesia, landslides are classified as dangerous events and therefore need to be anticipated in order to prevent greater losses [3].

A watershed is a land area that is topographically bounded by mountain ridges which collect and store rainwater and then channel it to the sea via the main river [4]. The watershed can be viewed as a system consisting of input, process and output. The input is in the form of rainfall, the process is in the form of the watershed itself which consists of biotic and abiotic components, and the output is in the form of production, runoff, erosion and so on [5]. The watershed has an important role for the community, especially in terms of providing water, managing water quality, preventing floods, and as a livelihood for the community. At this time many watersheds in Indonesia are damaged. Some things that prove that are the occurrence of land erosion and its sedimentation, landslides, decreased water quality and quantity, and others [3].

Based on the topographic map issued by the National Coordinating Survey and Mapping Agency, the Grindulu river is a river on the island of Java with a geographical location of 110° 55' – 111o 25' East Longitude and 7o 55' - 8o 17' South Latitude. The Grindulu Watershed starts from Mount Gembes (1,200 meters above sea level) on the border of Jeruk Village and Bangunsari Village in Bandar District and then passes through Tegalombo District, Arjosari District, Pacitan District and empties into the Indian Ocean, precisely in Ploso Village.

Communities along the River Watershed use Grindulu river water for various activities, such as bathing, washing, and agricultural irrigation purposes more in areas with flat soil textures, for example the Tegalombo sub-district and Pacitan sub-district. Whereas areas with hilly soil textures, only stone and sand are used as materials for building houses or buildings. The grindulu river is also used for fishing by the local community. The fish that are often found include tilapia, catfish, eel, carper, wader, nyek, fresh shrimp and so on [6].

The various challenges faced in the context of the use and management of land resources are increasingly complex, including: (1) population pressure on land,

*Corresponding author: raka.achmad.f@mail.ugm.ac.id

(2) land conservation and land conversion, (3) forest degradation and land damage. , (4) environmental damage and natural disasters. Therefore, in the future the concept of sustainable land resource management by taking into account the aspects of resource and environmental sustainability as well as the various challenges that need to be formulated on a national, regional and local scale must become the main reference [7]. This study aims to prove the role of land cover change on landslides in the grindulu watershed.

2 Methods

2.1 Location

The Grindulu River Watershed is located in Pacitan Regency. The Grindulu River Watershed which is the largest watershed in Pacitan Regency, has an area that is mostly composed of limestone hills. From the data released by the Pacitan Regency Regional Disaster Management Agency (BPBD) until the end of December 2021, at least 441 disaster events had been recorded. Of that number, around 75% were dominated by landslides with 330 incidents. BPBD Pacitan said that the impact of the disaster throughout 2021 included 354 houses affected.

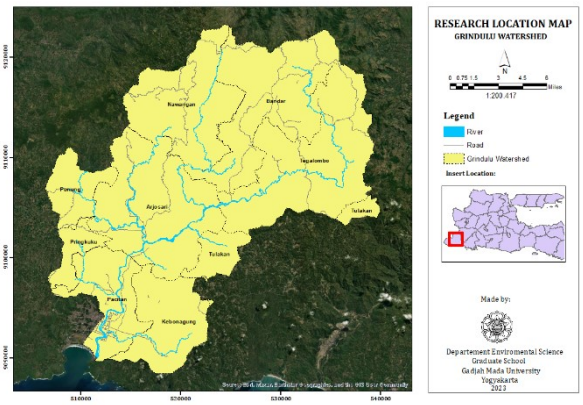


Figure 1. Map of Research Location.

2.2 Data

The data used in this study is information consisting of:

1. Data on landslide events in 2022 obtained from the Pacitan Regency regional disaster management agency
2. Land cover data for the grindulu river watershed in 2018 and 2022 identified from Copernicus Sentinel-2
3. Basic maps, such as road network maps, contour maps, river network maps and administrative maps obtained from the Indonesian Rupa Bumi map.

2.3 Research methods

In this research, the method employed is satellite image analysis. All satellite image processing and analysis were carried out using Google Earth Engine, and the stages of satellite image analysis can be observed in the research method flowchart. After the area was clipped based on the Grindulu River watershed, image sharpening, and mosaic creation, image interpretation was conducted. Image interpretation is a process used to classify objects in the image by identifying their color patterns or appearances on the image. Image interpretation and band combinations provide characteristics of land use.

In Google Earth Engine, land cover classification was performed using supervised classification to characterize each land cover type. Land cover classification served as a guide or reference in the remote sensing image interpretation process for land cover mapping purposes. Furthermore, in this classification stage, digitization processes were employed to further clarify objects in the research area, such as settlements, plantations, rivers, and study area boundaries.

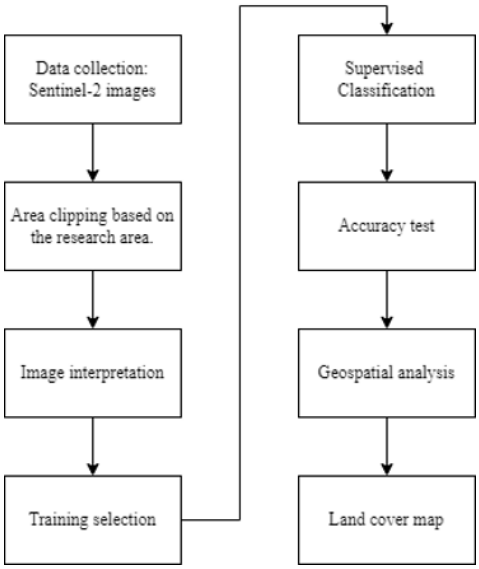


Figure 2. Research Method Diagram

Below is an explanation of the research stages from the research methodology diagram.

a. Data Collection: The research begins with the collection of relevant data, which likely includes satellite images and other necessary information. Sentinel-2 (S2) is a wide-swath, high-resolution, multispectral imaging mission with a global 5-day revisit frequency. The S2 Multispectral Instrument (MSI) samples 13 spectral bands: visible and NIR at 10 meters, red edge and SWIR at 20 meters, and atmospheric bands at 60 meters spatial resolution. It provides data suitable for assessing state and change of vegetation, soil, and water cover.
b. Area Clipping Based on the Grindulu River Watershed: The research focuses on a specific area, and in this step, the area is clipped or delineated according to the Grindulu River watershed. This ensures that the analysis is conducted within the desired geographical boundaries.
c. Image Interpretation: Image interpretation is a crucial step where the researcher visually analyzes

the images to identify and classify objects or land cover types within the study area. This process involves recognizing color patterns and appearances of objects in the images. Digital remote sensing data interpretation essentially involves classifying pixels based on their spectral values. Each class or group of pixels is then analyzed in relation to objects or phenomena on the Earth's surface. In other words, each class reflects what objects or phenomena they represent. Digital interpretation involves analyzing the digital values contained in each pixel column, making the interpretation of images relatively more objective. Digital interpretation also allows for more complex image analysis, considering several spectral channels, multi-temporal data, and multi-spatial data.

d. In this process, methods are employed to determine which method can be used when testing an image. The testing method utilized is the supervised method, where several best accuracy measures will be obtained from the method.
e. Supervised Classification: images that have been classified through supervised classification for land cover are then converted from raster to vector format, enabling them to be overlaid with other vector map data.
f. Accuracy Assessment: fter obtaining pixel values for the training areas from the image data, it is necessary to evaluate the spectral response patterns for each land cover category, particularly their ability to differentiate each spectral signature. The accuracy assessment used in this research involves measuring or evaluating the spectral separability using an error matrix or confusion matrix. This matrix helps quantify discrepancies, including an excess of pixels assigned to other classes (commission) or a shortage of pixels assigned to different classes.
g. Geospatial analysis involves the spatial aspect that indicates the location, placement, and position of an object or event both below and above the Earth's surface, expressed in a specific coordinate system. Geospatial data refers to data about geographic location, dimensions or sizes, and/or characteristics of natural and human-made objects that exist on or above the Earth's surface.
h. Mapping: Once the land cover is classified and the necessary digitization is completed, the research likely involves creating maps to visually represent the results of the analysis. These maps provide valuable information about the distribution of land cover types within the study area.

2.4 Data Analysis

2.4.1 Land Cover Change

Land cover changes that occur in the Grindulu watershed are identified as multitemporal Sentinel image. Sentinel imagery obtained from Google Earth Engine (https://code.earthengine.google.com). We detected land cover changes in the study area over 2 years, namely 2018 and 2022, using supervised classification. Supervised classification is one type of multispectral image classification. This classification uses the pixel categorization created by the user and the algorithm classify pixels that are similar to the sample data. The scope of the research area is divided into 6 classes; river, agricultural areas, agroforestry, forest, residential and pasture.

To analyze and create land cover maps using Google Earth Engine is explained in the following steps:

a. Cutting image area based to research area. The cutting area is based on the size of the Grindulu river basin. Area cutting using ArcGis software and displayed on Google Earth Engine.
b. Image interpretation using Google Earth Engine begins with the technique of providing sampling data by providing color in each feature collection that represents sampling data in Google Earth Engine software. The image sharpening results are applied to the RGB 654 color composite image, namely sharpening low-pass filtering before the supervised classification process is carried out. In the image data there are high frequency of data variability with heterogeneous characteristics of landscape features. Technique Lowpass filtering has been widely used to reduce visible spatial frequencies in Figure 3.
c. Image interpretation is conducted using supervised

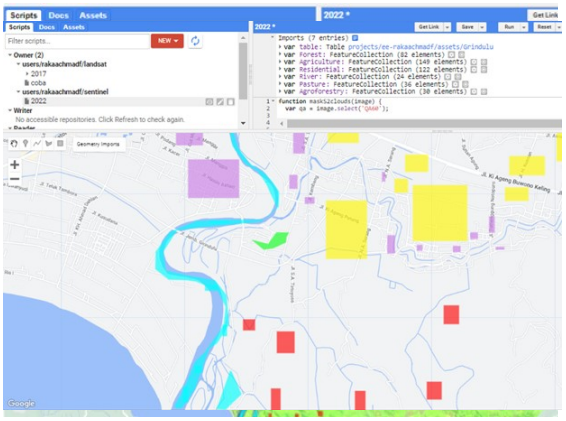
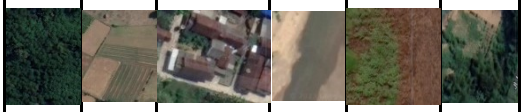


Figure 3. Image interpretation results

classification techniques within the Google Earth Engine software. Before the interpretation process, sampling areas are determined based on the features observed in the image. The creation of training areas is based on the desired number of land cover classes, which include forest, river, residential, agriculture, pasrture, and agroforestry area. This process can be visualized in Figure 4.

The following table shows the training and validation areas for each cover class.

Table 1. Image Interpretation Geometry

Geometry Type	Forest	Agri-culture	Residential	River	Pasture	Agro-forestry
Color						
Area						

In Table 1, a geometry data sampling category is created which is used to declare an area intended for sampling which is used as a pixel used when classifying data. From the data that has been turned into pixels, the data is classified based on the land that fits the existing categories
converted into pixels

d. Supervised Classification: after using the Feature Collection, extract the reflectance values of each pixel from each band. Create training data by assigning training points on the image. This approach will provide training data with the pixel values for each point. After running the script, the training data will be printed to the console. Note that the 'properties' information has now been changed to land cover, and there are now reflectance values at each point. Six land cover classes were used based on the map, as explained in the image below.

Here are the results of land cover classification for Sentinel-2 Year 2022 and Sentinel-2 Year 2018 images in the Grindulu Watershed, as shown in Figure 4 and Figure 5.

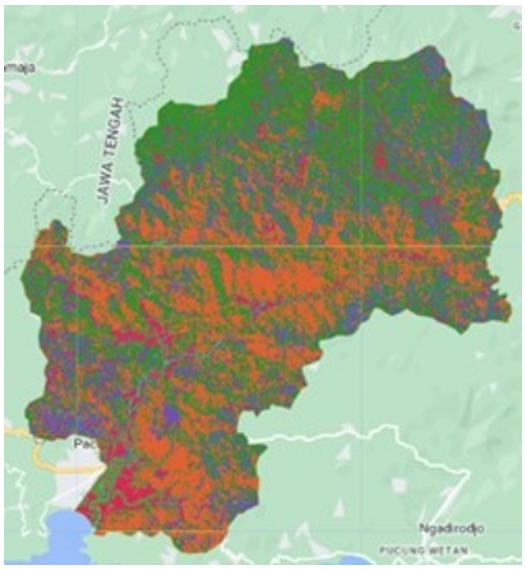


Figure 4. Results of Supervised Land Cover Classification in 2022

2.4.2 Landslide Distribution

Landslide distribution points obtained from secondary data and primary data. Secondary data is initial data obtained from the Pacitan Regency regional disaster management agency. This data contains the number of landslide events, disaster victims, incident locations, affected buildings, losses and coordinates. Primary data was obtained from field surveys to determine the location and coordinates of the required landslides. the coordinates obtained during 2022 from January to December are then collected and displayed on a map spatially.

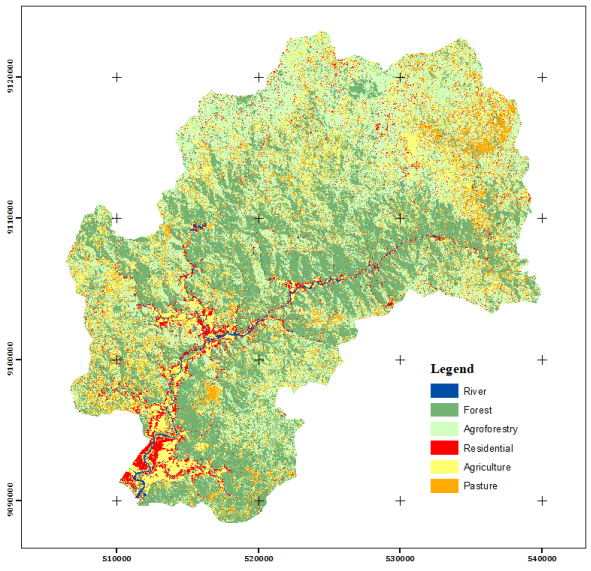
2.4.3 Analysis Landslides by Land Cover Change

To elaborate further on the role of land cover against landslides. We compared the data using spatial analysis, so that the distribution of landslide events to landslide points can be analyzed spatially. Data on landslide events was collected through a landslide census in the field, we did it from January to December 2022. Furthermore, we also compared the types of land cover with landslide events. Therefore, it can be seen clearly what types of utilization have a close relationship with the occurrence of landslides.

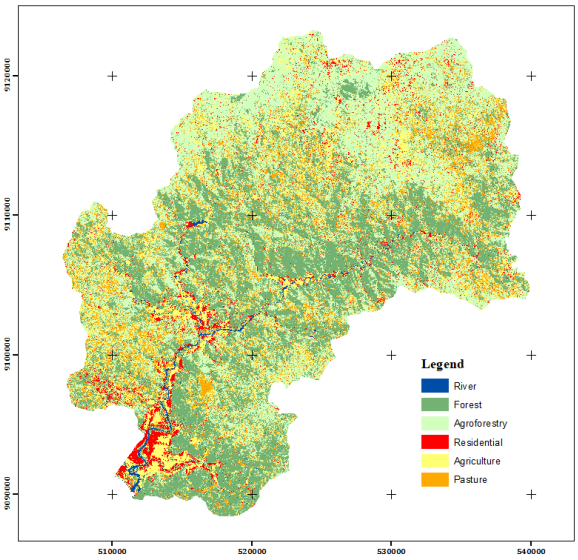
3 Result and Discussions

3.1 Spatial Distribution Land Cover Type

The Grindulu River stretches from the north of Pacitan Regency to empties into the southern sea. Nearly 80% of Pacitan district is included in the grindulu river watershed. The distribution of land cover in the Grindulu watershed is divided into 6 land cover classes. The land cover is in the form of agricultural areas, agroforestry, forests, rivers, shrubs and settlements. The land cover classes are displayed spatially in the following two maps.



(a)



(b)

Figure 5. Land Cover 2018 (a); Land Cover 2022 (b).

Figure a and figure b show the difference between the land cover of the grindulu watershed in 2018 and 2022. The five year difference in the map shows spatially how the land cover in the grindulu river watershed has changed.

Table 2. Land Cover Ratio

Land Cover Area Ratio		
Land Cover	**2018**	**2022**
Agriculture Area	6614 Ha	7471 Ha
Agroforestry	26226 Ha	25795 Ha
Forest Area	22741 Ha	21400 Ha
Residential	3131 Ha	3075 Ha
River	456 Ha	511 Ha
Pasture	7271 Ha	8517 Ha

Source: Data Analysis

It can be seen from the table of differences in land cover from 2018 and 2022 that experienced several changes in the area of land cover. the agricultural area increased from 6614 hectares to 7471 hectares. this can be illustrated that during the last five years there has been a change in land cover in terms of human activity in farming.

The increase in area has also occurred in pasture land cover where in 2018 it was 7271 hectares to 8517 hectares in 2022. This is related to reduced land productivity. agriculture. In contrast, forest land cover has decreased in area from 2018 by 22741 hectares to 21400 hectares in 2022. The reduction in forest area has changed in various other land covers, especially into agriculture and pasture areas. In other land covers, such as settlements, rivers, agroforestry, the land cover area tends to be stable or nearly the same for five years.

Changes in land cover over the five years from 2018 to 2022 are due to various factors. the most common factor is community activities in meeting their needs such as opening gardens, rice fields, settlements, and other built areas. Changes due to human activities are most visible on the banks of the Grindulu river which can be seen from the land cover map. This is due to various reasons, especially the need for water to irrigate rice fields and for the daily needs of the community. other activities in the form of sand and stone mining in the river by the community, where these things can cause landslides.

3.2 Landslides by Land Cover Change

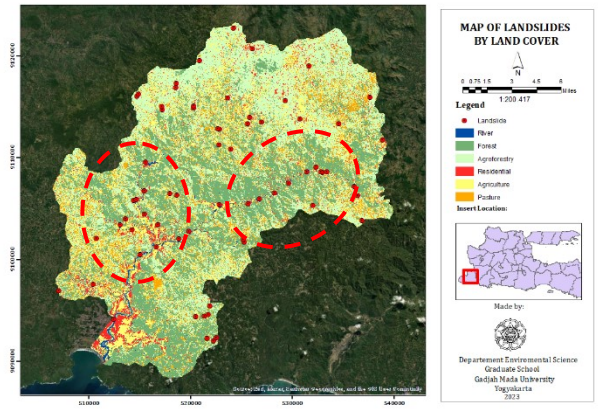


Figure 6. Map of Landslides Distribution

The distribution of landslides is depicted on the map along with the land cover. In 2022 there were 67 landslide events. All of these landslides were spread in the grindulu river watershed and spread over various existing land covers. The landslide incident mostly affected houses and public facilities.

Through spatial analysis, it can be determined whether there are clusters or groups of events that have patterns within the existing land cover, as indicated by circles on the map.It can be seen that the clusters of these incidents mostly occurred on the banks of the Grindulu river, which incidentally is the area that is most frequently used both for rice fields, roads and settlements

Table 3.Number of landslides on land cover

Land Cover	Number of Landslide Points
Forest	17
Agroforestry	25
Residential	11
Agriculture	5
Pasture	9
River	0

In detail, most landslides occur in forest land cover, agroforestry, and settlements. even so based on the data, these incidents were all close to homes and public facilities. From the closeness of land cover to houses and land changes, it can be seen that human activities in the form of development and clearing of defensive land are spatially visible patterns related to landslides.

4 Conclusion

Based from the results of the analysis it can be concluded that land cover changes for five years. that is, from 2018 to 2022 there have been changes in several land covers. The main land cover that has increased is the area of agriculture and pasture which is closely related to human activities in the Grindulu river watershed.

Based on spatial analysis, 67 landslide points were found that occurred throughout 2022, spread throughout the river watershed. Landslide occurrence points have patterns or clusters located on riverbanks and close to residential areas. Landslide points are found in different land covers based on spatial analysis of the distribution of landslide points with land cover maps. Most landslides occur in agroforestry land cover.

Acknowledgement

The author expresses his deepest gratitude to RTA-UGM 2023 with the Grant Number 5075/UN1.P.II/Dit-Lit/PT.01.01/2023, which has funded this research. And also really appreciate reviewers for suggestions to make this article better. without all the support given, this research would not be possible. Hopefully this research is useful for many people.

References

1. [BNPB] National Disaster Management Agency. 2020. A total of 2,925 Natural Disasters Happened in 2020 in the country, Hydrometeorological Disasters Dominate. [Internet]. [accessed September 28, 2022].

2. Purnamasari DC. 2007. Application of remote sensing and geographic information systems (GIS) in the evaluation of landslide-prone areas in Banjarnegara District. [Thesis]. Bogor(ID): Department of Forest Resources Conservation and Ecotourism, Faculty of Forestry, Bogor Agricultural University.

3. Naryanto HS, Prawiradisastra F, Kristijono A, Ganesha D. 2018. Spatial planning after the landslide disaster in Puncak Pass, Cipanas District, Cianjur Regency March 28 2018. Journal of Natural Resources and Environment Management. 9(4):1053–1065. doi: 10.29244/jpsl. 9.4.1053-1065.

4. Asdak, C. 2010. Hydrology and Watershed Management: Fifth Revised Edition. Gadjah Mada University Press.

5. Paimin, Sukresno, and Purwanto. 2010. Rapid Imprint of Sub Watershed Degradation (Sub DAS). Forest Research and Development Center and Nature Conservation, Bogor.

6. Wijayanti, T. 2017. Profile of Heavy Metal Pollution in the Waters of the Grindulu Pacitan River Watershed (Das). Scientific Journal of Science Vol. 17 No. 1. Biology Education IKIP Budi Utomo Malang

7. Worosuprojo, Suratman. 2007. Spatial-Based Land Resource ManagementIn Sustainable Development In Indonesia. Yogyakarta: Faculty Geography. Gadjah Mada University.