A Preliminary Study of Land Use Change and Hydro-meteorological Disaster in The North Coast of Central Java

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Abstract. The upstream-downstream area of the north coast of Central Java is categorized as a rapid development area that results in changes in land use and land cover. This region is also prone to floods, landslides, and drought. Land-use change contributes to climate change, increasing disasters such as sea-level rise, erosion, rising surface temperatures, floods, landslides, and droughts. Moreover, hydrometeorological disasters caused by human activity damages the river basin ecosystems, especially land use and land cover changes. This study aims to prove that land-use difference does matter for hydrometeorological disasters in the North Coast River Basin of Central Java in terms of the upstream and downstream areas using a quantitative method and GIS. The river basins are Jratunseluna, Bodri Kuto, Pemali Comal, and Wiso Gelis. The results indicate that from 2009 to 2018, the midstream and upstream river basins areas show the highest land use change compared to downstream. This study also finds that forests reduced significantly in the Central Java river basin, one of the disaster drivers. Above all, through this research, hydrometeorological disaster mitigation efforts in the north coast river basin in Central Java can be appropriately identified.

1. Introduction

Urbanization is the leading cause of changes in the hydrology process, loss of existing drainage capacity, and flooding in urban areas [1]. It raises the total runoff volume and peak discharge of storm runoff events. Land-use change potentially has a powerful effect on floods as humans have heavily modified natural landscapes [2]; [3]. As one of the essential drivers leading to hydrological and ecological change, land-use change may influence canopy interception, evapotranspiration eventually causes flood-drought disasters or environmental problems [4]. It is also known that the difference in the land use pattern due to rapid urbanization negatively influences the hydrological processes in a catchment, leading to a degrading water environment [5]. Liu, Wang, and Li [6] mention that land-use changes caused by human activities have influenced the characteristics and pattern of flooding or increased the risk of flood for the inner urban human sphere.

Land cover variables and rainfalls are several variables related to flooding. Rain is input from the hydrological cycle that occurs on earth, while the land cover can describe the relationship of the earth’s surface objects with water mass motion. These variables can affect the amount of surface flow debit,
more significant water debit, resulting in flooding and impacting losses [7]. It is proven by a study from Melillo [8] that climate change shifts the frequency and intensity of precipitation, resulting in more extreme rainfall events. Another study explains that high rainfall causes a greater water flow and runoff with the flat topography dominated in the area [9]. Moreover, a study from Helmi, Basri, and Sufardi [10] demonstrates that rainfall, temperature, and land use, while additional components such as soil infiltration and slope, are the components that affect the flood phenomenon in Krueng Jreue Sub-Watershed, Aceh Besar.

Besides, hydrometeorological disaster is one of Indonesia's common natural disasters, and it includes floods, droughts, landslides, and cyclones [11]. In the coastal area, floods account for the majority of disasters because of extreme rainfall, which leads to flash floods and sea-level rise, promoting tidal flooding. During the last ten years, floods in Indonesia's territory due to damaged land and watersheds occur in succession, with the intensity, frequency, and distribution or area affected by the disaster increases and expands [12]. The previous study by Rudiarto, Handayani and Setyono [13] depicts flood events mostly found in Central Java's coastal settlement, followed by tidal flooding and droughts. As the most developed area in Central Java, urbanization has contributed to rapid urbanization in this area, which 40% of people live in the north coastal area of Central Java.

The upstream-downstream area of the north coast of Central Java Province, a coastal region, also experienced two phenomena: land cover change and climate change. The high level of regional development drives this phenomenon. One of the leading causes of the region's high development is the high level of urbanization in several cities and the northern coastline's existence, which is one of the veins of economic growth in the island of Java and even nationally [14]. The main route on the island of Java is getting significant government attention to continue developing infrastructure. The existence of the North Coast Line and infrastructure development that triggers the development of an area in the future can have several impacts that need to be avoided. The rapid growth of an area can increase the likelihood of land cover changes to meet the increasing needs. This condition can influence the area to be more vulnerable to environmental degradation, leading to disasters arising from changes in land cover and climate change.

The land conversion growth rate in each river basin based on its geographical location shows that the North Coast of Java has become one of the strategical locations for human activities. Furthermore, river basins in the northern coast of Central Java Province are considered critical for hydrometeorological disasters, including floods. However, it includes one of the strategic river basins in Java Island, according to the Ministry of Public Works and Public Housing. Disaster data from 2014 to 2018 shows that 368 cases of flooding in the Central Java Province, and the number has been continuously rising [15]. Accordingly, urban areas near the coast have suffered from high flood events, such as in Semarang and Pekalongan. As a part of the river basin system, land-use changes upstream of the basin altered hydrological behavior and may flood downstream [16]; [1]. Nevertheless, it is also essential to correlate the land-use change and rainfalls components into the analysis of disaster phenomena in this area to make it a more comprehensive understanding.

Various studies have been done previously regarding urbanization, land use and land cover change effects on flooding. There are several studies confirmed that, for example, the correlation between urbanization to climate-related disaster in the coastal area of Central Java [13]; land-use changes in Ciliwung River Basin that resulted in flooding in Jakarta [16]; land-use changes lead to the higher flood debit in Malalayang River Basin [17], and increasing in urban areas that give significant contribution to flood exposure and flood event in Yangtze River Basin [6]. However, they evaluate it in land-use phenomena at whole or specifies cities/districts, while this study wants to analyze more in the context of river basin system including upstream, midstream and downstream in some periods to examine the linkage between them. The condition then leads to an essential research question about how land-use change and extreme precipitation impact the hydrometeorological disaster in Central Java's North Coast River Basin. Using the climate and land use data in some period time will be useful for
further flood control system planning and implementation. Through this research, hydrometeorological disaster mitigation efforts in the north coast river basin in Central Java can be obtained.

2. Literature Review

2.1. Coastal Regional Development

The dynamism that is owned makes the coastal area the primary goal of humans to live and all their activities so that human settlements tend to be concentrated in this area. This also happens in developing countries, where big cities grow in areas near the sea, especially in Indonesia [18]. The rapid growth in coastal areas characterized by high population density and the increased built area, influences climate change and other development phenomena. The rapid growth and high demand for land have implications for changing the shape of land cover. This has an impact on the environment that is adding pressure to the environment [18]. This pressure is proven by the change in environment or climate change, rising sea levels, erosion, salinization, land subsidence, and massive deforestation. The rapid growth in the coastal area results in the coastal area being an area that is vulnerable to the effects of climate change. Explanation of facts based on some previous literature shows that coastal areas are mostly categorized as developed areas. Accordingly, coastal areas in Indonesia tend to be centers of growth and human activity. This results in pressure on the environment that may influence land-use change and disaster. As in the north coast of Central Java, population, activities, and development make the region vulnerable to disasters [13]; [19].

2.2. Land-Use Change

The land is characterized as a location where all human action is carried on. Human activities, powered primarily by socio-economic forces, resulting in shifts in unconstructed and built-up land given physical constraints [20]. Presently, land use/land cover changes encompass the human population's environmental concerns, including climate change, biodiversity depletion, and pollution of water, soil, and air [21]. A form of land cover can change in a place due to the consequences of regional development. One area's development is marked by population growth. The population growth will also increase the need for land to carry out various activities, but the problem is the limited land area that can not develop quickly. This has become an issue in the development of several regions in Indonesia. The issue has a consequence that is the expansion of the built area and causes changes in land cover [18]; [13]. Changes in land cover are defined as changes in the form of land users or land cover due to growth and development in an area so that this phenomenon is an undeniable event [22]; [23]. Land-use change may link to the environmental impacts of land-use change and their contribution to global change that occur through physical processes associated with land-cover change. Land-use and land-covered change (LUCC) has increasingly been seen as the leading cause of global environmental transition, such as greenhouse gas emissions, global climate change, biodiversity loss, and soil resource degradation [24].

2.3. Hydrometeorological Disaster

Hydrometeorological disasters account for the most significant number of natural disasters worldwide and affect more people than any other natural disaster type. Hydrometeorological hazards include cyclones, drought, floods, heatwaves, heavy snowfall, storms, and storm surges, but can also influence other hazards, such as epidemics, landslides, locust plagues, and wildfires. They comprise a dominant fraction of natural hazards and exist in all regions of the world, although the frequency and severity of such hazards and society's susceptibility to them differ between regions. Severe storms, strong winds, floods, and droughts develop at different spatial and temporal scales, but they can all become disasters that cause significant damage to infrastructure and cause hundreds of thousands of lives worldwide every year. Multiple hazards may also coincide or cause cascading impacts from one extreme weather event [25].
2.4. Disaster and Land Use Change
Population growth and human activity cause changes in land use and land cover. However, changes in land cover that tend not to consider the impact will result in several disasters [1]. Human activities can lead to anthropogenic disasters, namely, disasters caused by human activity. Changes in land cover can cause a decrease in the ability of land related to the environment's carrying capacity, causing a decrease in environmental quality that results in anthropogenic disasters. Disasters that can occur include floods, landslides, and drought [25]. It is also important to note that land cover changes can affect runoff [26]; [27]. Rainwater that falls to the ground will become a surface runoff that will go to the river, and some will seep into the ground. If an area has dense vegetation, then the surface water flow will decrease and increase the water volume that seeps into the ground, which can increase groundwater reserves. If converted into a residential area, an area of vegetation increases surface runoff leading to rivers, as well as a decrease in water infiltration into the ground. This can cause drought disasters. The high surface runoff leading to the river can increase large river discharge. Therefore, if the surface flow is high, the maximum flow of the river will also increase. The impact of changes in the magnitude of the maximum discharge from the river is the higher the potential for landslides and floods in the rainy season, and in the dry season, the potential for drought disaster will also be even more enormous [28].

3. Material and Methods

3.1. Study Area
The study area is located in the North Coast Central Java river basin, including Pemali-Comal, Bodri-Kuto, Jratun Seluna, and Wiso-Gelis river basin. Central Java river basin is one of the critical river basins according to Ministry Decree that many main activities are taking place in the river basin. The total area of the river basins is 16.403 sq. km. The study area includes Tegal, Pekalongan, Semarang, and Salatiga City, and other 17 regencies.

Figure 1. Study Area
3.2. Data and Method

This study used both spatial data and non-spatial data obtained by secondary data collection. Spatial data includes Landsat satellite image, slope, elevation, and watershed delineation. Besides, non-spatial data includes rainfall intensity, disaster events, and river debit. Land use data derived from the Landsat Image of 2009 and 2018 to assess the land use-land cover change in Central Java's upstream-downstream areas. This study uses data from 2009 and 2018 based on the availability of the disaster data and land use data, since the Disaster Management Board in Indonesia established on 2008. For the analysis part, it will employ land use data in shapefile format. Moreover, terrain data process to slope and elevation to define four river basin characters in Central, slope, and elevation data will process from terrain data.

Non-spatial data includes disaster events, rainfall intensity, and river debit. The disaster data obtained from the Disaster Management Board (online source: dibi.bnpb.go.id), Public Works Agency, and online newspapers to make disaster data more complete. Meanwhile, for rainfall intensity and river debit obtained from MCGA and River Management Board respectively. The rainfall data obtained from several Meteorological, Climatology, and Geophysics stations in Central Java, namely Semarang Station and Tegal Station, provide rainfall data covering 21 cities/regencies study area.

Spatial data processing is the main stage of this study. This stage processes spatial data of slope, elevation, and Central Java river basin delineation. The output is the map of river basin area which consist of upstream, midstream, and downstream area. Furthermore, to achieve the first objective in this research, it will use spatial land-use change analysis to analyze the study area's land use condition in 2009 and 2018. The land use will be divided into several kinds of land use, for example, built-up area, industrial areas, and paddy field. The output of land use analysis is then combined with the river basin delineation using the overlay method. From this analysis, it can be inferred the land use condition of the river basin.

Disaster data used as variables in this study are floods, landslides, and drought. The data needed to be related to these variables is the location and frequency of disaster events. The data was obtained through secondary data from the disaster data of BPBD of Central Java Province in 2009-2018, news of disaster events quoted from the national news website, and Public Works Agency. The data is then analyzed using description analysis to explain the location of the disaster event and the area with the highest number of disasters using graphs and tables. Besides that, a trend analysis is also conducted to find out the time series of disaster conditions. After that, there is an overlay process of disaster data with the classification of upstream, midstream, and downstream areas, resulting in the distribution of floods and landslides in the upstream, middle and downstream areas of the study area.

4. Results

4.1. Land Use Change in Central Java

Central Java, with all its developments, has caused the area of built land to increase, which can change the land cover. The existence of support for the "North-coast" or Pantura route and the activities of various big cities located in the northern coastal area add to the area's development. This region's growth can be seen from the population, which is increasing from year to year. Thus, this growth can lead to changes in the land cover into built-up land. This is easily known by looking at the area and percentage of the residential land area against other land cover areas. It is known that the land cover in the Upstream-Downstream North Coast of Central Java is very diverse. Although experiencing reasonably rapid development, the dominant land cover in the entire area is rice fields. However, the distribution of rice fields with a large area is only in a few districts, while settlements dominate urban administrative areas such as Semarang City, Tegal City, Pekalongan City, and Salatiga City. This distribution indicates that human activities related to built-up land tend to focus on urban areas.

The land use is dominated by mixed cropland cover. This type of land cover dominates around the middle areas between hills or mountains with coastal or coastal areas with a spreading pattern. When
viewed from the area of mixed cropland cover, it has a total area around 30% of the total area, meaning that one-third of the area's land area has the land cover of various types of vegetation with varying density levels with low to moderate vegetation heights. Judging by administrative boundaries, the regency or city with the largest mixed crop area is Grobogan Regency, with an area of 55,001 hectares. The high area of mixed cropland cover in Grobogan Regency is partly due to the largest administrative area among other districts/cities.

The high land cover for settlements in urban areas is also directly proportional to urban areas' population density. The four cities have an average population density of 5,235 people/km². Pekalongan City has the highest population density, with a population density of 6,656 people/km². Meanwhile, the city with the lowest population density is Salatiga City, with a large population density of 3,327 people/km². Meanwhile, with the highest residential land cover area, Pati Regency has a population density of 829 people/km², and this is because the administrative area of Pati Regency is quite large compared to the administrative area of urban areas. Based on the appearance of residential land cover and more population concentration in urban areas, this is in line with Mikovits et al. [29] that the population will tend to be concentrated to live in urban areas. This opinion is evident from the land cover in urban areas dominated by settlements and the very high level of population density in urban areas. Then for a comparison between built and non-built land cover, it is still seen that the non-built up area, which consists of ponds, rice fields, reservoirs, forests, mixed plants, and vacant land, still dominates the entire study area with an area of around 86% in 2018.

Meanwhile, the built-in land cover consisting of industries, settlements, and toll roads has 230,000 hectares or 14% of the research area's total area. From the perspective of the river basin, Figure 2 illustrates the land-use changes based on its types, namely housing and settlement, industry, rice field, forest, and mix plantation in 2009 and 2018. In general, land-use in 2009 and 2018 is still dominated by the rice field, forest, and mixed plantation. Meanwhile, most of the housing and settlement allocation is located in the downstream area, specifically as the urbanized area's contribution, such as Semarang City, Pekalongan City, and Tegal City.

![Figure 2. Land-Use Change from 2009-2018](image-url)
Figure 3. Built-up Area in Coast of Central Java 2009 - 2018

4.2. Hydrometeorological disaster events in Central Java
The phenomenon of climate change has contributed to several disasters in the northern coastal areas of Central Java. Almost all districts or cities located on the north coast of Central Java have experienced the impact of climate change in the form of disasters. Disasters that occur include floods, landslides, tornadoes, drought, and tidal waves. The average occurrence of these disasters from 2009 to 2018 in each type of disaster occurred with a frequency of more than one event a year. Disasters in each region are not always the same; each district or city on the North Coast of Central Java has different disaster incidents.

The dominant type of disaster is determined based on the largest number of disasters in one regency or city, available data from the Disaster Management Board of Central Java. The impact arising from the various disasters varies. Meanwhile, the flood disaster inundated residents' houses with a height of 20-100 cm; it could cause damage residents' houses and cause embankments to burst [30], [31]. As a result, landslides can cause people's houses and several facilities to collapse [32], [33]. The hydrometeorological disaster (i.e., flood, landslides, drought) occurred evenly in almost all research areas. However, several districts are included in the research area where certain disasters did not occur, such as cyclone that does not occur in Semarang City, Tegal City, and Pekalongan Regency. The incidence of floods and landslides in the study area tends to be scattered throughout the research area. Floods and landslides that occur are identified in the administrative area unit of the village or kelurahans.
### Table 1. Dominant Disaster in Central Java

| City/Regency | Dominant Disaster               |
|--------------|--------------------------------|
| Grobogan     | Cyclone, drought               |
| Blora        | Landslides, cyclone, drought   |
| Rembang      | Flood, landslides              |
| Pati         | Flood                          |
| Kudus        | Flood, landslides, cyclone     |
| Jepara       | Cyclone, Flood                 |
| Demak        | Cyclone                        |
| Batang       | Cyclone                        |
| Pekalonggan  | Flood                          |
| Pemalang     | Cyclone, Flood                 |
| Tegal        | Flood                          |
| Brebes       | Flood, landslides              |
| Semarang City| Flood, landslides              |
| Pekalongan City | Flood, cyclone            |
| Tegal City   | Flood                          |

*Source: Disaster Management Board of Central Java, 2018*

Floods and landslides in the study area were evenly distributed throughout the study area. In general, the data presents that floods increased significantly from 2009 to 2018. The number of flood events in the study area throughout 2018 reached 128 events, while in 2009, there were 85 flood events. On the other side, landslide events in 2018 were higher than in 2009. The condition is due to incomplete data about landslide events in 2018 from several cities or regencies. In 2018, landslides in around several locations spread out in 15 regencies or cities with total disaster events of 190. Eighteen villages/kelurahans have experienced disasters and landslides. Some regencies or cities with zero landslides events are Grobogan, Salatiga, Pekalongan, and Tegal City. However, compared to 2009, Tegal City has the highest number of landslide events that reach 129 events from 221 total events in that year. Based on the figure, the occurrence of flood disasters in the study area shows that the distribution of disasters occurs in the northern part of the study area with topographic characteristics tend to be flat. The two regions with a high frequency of flood disasters have a large area of non-built land and a large area of built-up land.

*Source: Disaster Management Board of Central Java, 2018*

**Figure 4.** Flood Events in 2009 and 2018
From the river basins perspective, most of the flood incidents, 81% or 378 events, occurred in the watershed's downstream area with a dominant slope below 8%. The downstream areas were categorized with the highest number of floods, namely the Brebes Regency with 88 incidents in 2018, during the second and third highest in Pati and Tegal Regencies with 62 and 44 incidents. Meanwhile, 12% of events occurred in the middle part, and 6% of incidents were in the upstream watershed area. The district with the most flood incidents in the middle and upstream is Pati Regency, with 17 incidents in the middle and 8 in the upstream. Flood events that often occur in the downstream part occur because of floods originating from large surface runoff from upstream or upstream areas. This finding support Halim [17] previous research, which states that there is a change in land cover in the upstream part, which causes flooding in the downstream part of the river basin. Besides that, on average, the flood height is 20-40 cm (the worst reaches 2 meters). The duration varies as it could happen so fast (less than an hour) but also, in worst situations, the inundation remains up to more than 24 hours. These phenomena may explain the intense flooding in the downstream area compared to floods in the upstream and midstream.

The distribution of landslides based on the river basin classification shows that landslides tend to occur in the upstream area with a slope level of above 15%, dominated by highlands with hilly and mountainous topography. This can be seen from landslide events in the upstream area of 154 events or 63% of the total landslide events between 2009 and 2018. The number of landslide disasters in the upstream area indicates that landslides are caused by areas with high slope levels and can also be caused by reduced vegetation that can maintain soil stability and groundwater content. The preliminary analysis shows that landslides tend to occur in dense vegetation areas (forests) in hilly or mountain areas. Landslides in the study area tended to occur in the upstream area with a slope of> 15%, and the area was dominated by land with reasonably dense vegetation.
Unfortunately, a comparison between 2009 and 2018 could not be made regarding drought disasters since there is minimal data on the drought condition. Drought disasters were identified in the sub-district administrative area unit, and the magnitude of the drought disaster was seen from the number of villages affected in the sub-district. In 2009, there were 18 drought events in Grobogan, Blora, Demak, and Tegal Regency. On the opposite, drought in 2018 raised drastically up to 555 events spread in most of the north coast of Central Java, except Batang Regency, Salatiga City, and Tegal City. Pati was the highest drought event in 2018, with the total disaster events is 122 incidents, around 20% of the total events. Besides that, Grobogan Regency and Blora Regency contribute to the highest drought events after Pati Regency with the total drought events of 94 and 86.

Meanwhile, the lowest incidence of the drought was in Semarang City, with one drought event in an urban village. These areas are considered prone to drought disasters mostly have low vegetation land, and some of them are areas far from urban centers so that they have limited access to clean water. The limited availability of clean water is obtained through drought news, which explains that most areas experiencing drought have received clean water assistance from various parties, both government and private sectors.
5. Conclusion
This preliminary study shows that there was significant expansion or built up area in north coast of Central Java that in line with the number of disaster events. Besides, flood is the primary hydrometeorological disaster that occurs in Central Java with 81% of disasters located in downstream area. The most significant flood exposure is at the downstream area that is mostly defined as the urban center. The previous study states that most tidal floods occurred in the coastal area less than five kilometers from the coastline. A flood happens as a result of various factors, and urban flooding mostly takes place because of the overflow of the water from them and because of pluvial flooding (caused due to land conversion in combination with weak drainage system). Flood tends to occur in areas with low forest land cover, and the majority occurs in downstream areas with low forest areas and flat topography areas. Moreover, landslides tend to occur in areas with low land cover and areas with high forest cover. In addition to the land cover factor, the slope level factor also affects the occurrence of landslides. This is evidenced by dominant landslides occurring in areas with slope levels above 15% or upstream areas. Areas that have a strong relationship between landslides and land cover are Jepara Regency and Semarang City which located in Jratunseluna River Basin. Besides that, the low land area cover for paddy fields, forests, and mixed crops is a potential area for drought. Drought disasters also occur in areas with minimal residential areas, which are assumed to have limited access to clean water. Since this is a preliminary study, further research on land-use change and hydrometeorological disaster is still needed to understand and analyze the relationship between several factors properly.

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