Role of land cover change to landslides susceptibility in agricultural catchment

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Abstract. Physical and hydrometeorological properties of Karangkobar Catchment combine with poor land management cause landslide is commonly occurred in Karangkobar Catchment. This research is aiming to proof the role of land cover change to landslide susceptibility in Karangkobar Catchment. We use LULC change detection and landslide susceptibility analysis in this research. Main data use in this research is Landsat imagery from 1990 to 2018. LULC change detection is done using supervised classification to divide the land cover in the research area. Landslide susceptibility analysis was done using overlaying parameters then the landslide susceptibility analysis divides into 3 classes of susceptibility. Land cover in the research area tends to shift from agroforestry land to agricultural area or built up land. This affected the landslide susceptibility, it shifted from medium in 1990 to high susceptibility for almost 3 decades later. This analysis is proof of the role of the land cover change to landslide susceptibility in the research area. Furthermore, this phenomenon should be a warning to maintaining the land better and reducing the landslide susceptibility in the future.

1. Introduction
Karangkobar Catchment is an upper part of Serayu Watershed, located in Central Java Province, Indonesia. Serayu Watershed is one of priority watershed in Indonesia according to the Ministry of Forestry's Letter No. 328/2009 [1]. This watershed is prioritized because it is considered to have important value but is threatened with environmental degradation. As an upstream part of the priority watershed, the Karangkobar Watershed is important to be managed properly. Hilly land characteristics and high rainfall during rainy season combine with lithology and soil properties making Karangkobar Catchment very fragile. This condition causes frequent landslides event in Karangkobar Catchment and its surrounding. Mountain farming is widely practiced in various places in the world [2]–[5] including Karangkobar. Due to its fertile soil which highly supports agricultural activities, mostly of local people in Karangkobar Catchment utilize land to do agricultural activities. They convert agroforestry land to intensive farming land to ensure they can provide farm product to the market. This condition are exacerbated with human activities in land utilization and make landslide worst. This research is aiming to proof the role of land cover change to landslide susceptibility in Karangkobar Catchment.
2. Methodology

2.1. Research Location
Karangkobar catchment (7°16’00.00”S 109°43’39.02”E) is located in Karangkobar Sub-District, Banjarnegara District Central Java, Indonesia. Karangkobar Catchment is a 4th Strahler’s river order catchment and encompassed 1,047 hectares area. Agriculture is the main activity of the catchment dwellers.

![Figure 1. Karangkobar catchment location](image)

2.2. LULC Change Detection
Land use land cover changes occurred in Karangkobar Catchment are identified using multitemporal Landsat imageries. Landsat imageries were obtained from USGS’ Earth Explorer (http://earthexplorer.usgs.gov). We are detected LULC change in the research area for over almost 3 decades, 1990, 2000, 2011, and 2018 using supervised classification. The supervised classification is one type of multispectral image classification. This classification uses pixel categorization made by the user and the algorithm classifies the pixels that have similarities with the sample data [6]. Land cover in the research area was divided into 3 classes; agricultural area, agroforestry/mix plant, and built up land.

2.3. Landslide Susceptibility
Landslide susceptibility defined as a physical and social condition which causing landslide event. Paimin et al [7] describe landslide susceptibility using several parameters; 3 Days accumulative rainfall (25%), slope (20%), lithology (10%), faultline (5%), solum depth (5%), LULC (30%), and infrastructure (5%).

2.4. Comparing with Landslide Events
To describe further about the role of land use land cover (LULC) to landslide, we are comparing landslide susceptibility with landslide event. We do a comparison of the data using spatial analysis,
thus the distribution of landslide events against landslide susceptibility can be analyzed spatially. Ideally, both data have more than one year of data. Unfortunately, we can only have the latest landslide events data (2017-2018). Landslide events data are collected by census landslide in the field, we do it in June 2018. Furthermore, we also compare the types of land use with landslide events. Thus, it can be clearly known what type of use has a close relationship with landslide events.

3. Result & Discussion
3.1. Spatial Distribution Land Use Type
Karangkobar Catchment is an agricultural catchment which encompasses 2 Sub District with 1,047 Hectares of total area. Most of the land in the Karangkobar watershed is used by local residents for agricultural activities (90%) both in the form of irrigated fields, agricultural land, and agroforestry while the rest is used for settlements and built land (10%). The spatial distribution of land use along with the appearance of land use in the field is presented in Figure 2.

Figure 2. Land use type in research area, a) agroforestry, b) rice field, c) farm land and settlement

Non-agricultural land in the form of settlements and built land is located in the middle region which has relatively flat slopes. Some are scattered in several hamlets, most of which are inhabited by livelihoods as farmers. Rice fields can only be found in downstream watershed areas that have relatively flat slopes. This rice field is located very close to the Telatasuron River which is the main stream of the Karangkobar watershed. Farm land can be found in the upstream (north) and also slightly in the south. Agroforestry is distributed in the southwest part of the watershed and can be found in several other areas in the Karangkobar watershed.
3.2. LULC Change Detection

Over almost 3 decades, land cover in Karangkobar Catchment are changing tremendously. Land cover type in the research area tends to shift from forested area/mix plantation (agroforestry) to agricultural area and built up land. We detect agricultural area are increasing 0.2% per period, built up land increasing 0.17% per period, while forested area/mix plantation (agroforestry) is decreasing 0.18% per period.

3.3. Landslide Susceptibility

Land cover condition contributes to landslide susceptibility. To emphasize the role of land cover to landslide susceptibility we change land cover condition per period while keeping all other variables fixed. Changes of land cover over almost 3 decades in the research area are increasing the landslide susceptibility. It shifts from medium level of susceptibility to high level of susceptibility. The area under high-level susceptibility are increasing 0.73% per period while medium susceptibility area is decreasing 0.06% per period.
Figure 5. Landslide susceptibility: (a) 1990; (b) 2000; (c) 2011; (d) 2018

3.4. Comparing with Landslide Events

Landslide vulnerability maps produced in the previous section use the model proposed by Paimin et al (2010). This model is a general model of landslide vulnerability assessment. This section tries to analyze the accuracy of the model to be applied in the study area. We tried to compare the landslide vulnerability with actual landslide events obtained through direct field surveys. Analysis of the accuracy of the model was not carried out statistically but was only done using the spatial attachment.

Figure 6. Landslide susceptibility vs landslide event in 2018
(a) spatial distribution, (b) number of landslide event per susceptibility class

Landslide in the watershed Karangkobar found through field surveys in July 2018 as many as 45 events. Figure 6 describes the location (6a) and the number of landslide events in each landslide susceptibility class (6b). The information obtained from Figure 6 explains that the most landslide events occur in the moderate vulnerability class (34 events) followed by high vulnerability classes (9
events) and low vulnerability classes (2 events). Landslide events occur more in areas with moderate vulnerability than in high vulnerability classes. This indicates that the landslide vulnerability model proposed by Paimin et al (2010) is less fit to be used for this study area and requires modification of the model. The spatial distribution of 45 landslide events is not evenly distributed throughout the watershed but tends to be concentrated in certain locations forming cluster patterns. There are at least three clusters that can be encountered, northern cluster (L1), middle (L2), and southern (L3) as described in Figure 7.

![Figure 7. Landslide event clusters](image)

To show the relationship between land use types and actual landslide events, an overlay analysis was conducted between land use and actual landslide events in the Karangkobar Watershed. The results showed that most landslides occurred on agricultural land (Figure 8a). The number of landslide events that occurred on agricultural land was 39 events, 4 events occurred on the built land and 2 events occurred in agroforestry (Figure 8b).
The agricultural area found in the study area is partly located in areas with rather steep slopes (8-15%) to steep slopes (15-45%). The agricultural area is processed intensively for agricultural activities. Agricultural land has a lot of landslides because of the decrease in slope stability due to lack of/little tree stands and increased infiltration due to intensive tillage. Increased infiltration will trigger the movement of soil in the slip plane.

Actually, the built land has the potential for landslides that are bigger than agricultural land. Nonetheless, local residents harden the land and make protective walls to reduce the potential for landslides. Agroforestry land, even though it is also used for agricultural activities, the existence of tree stands makes the conditions much different compared to agricultural land. Tree stands that exist in agroforestry have relatively deep roots compared to seasonal crops so that they are able to withstand soil aggregates which make slope stability much better.

4. Future research

Future research will be carried out to determine the effect of land cover parameters and other parameters on landslide events. In addition, it will also be modified the Paimin et al landslide vulnerability determination model by Paimin [7] to produce a more accurate landslide vulnerability model that is more in line with the characteristics of the Karangkobar Watershed.

5. Conclusion

Land cover is playing an important role in affecting landslide susceptibility. Land cover is heavily related to the land management which controlled by activities of the catchment dwellers. Karangkobar Catchment land cover which tends to converted from agroforestry to agricultural land average with rate 0.2% per period produce the shift of susceptibility level from medium to a high level. Furthermore, landslide events have most occurred in agricultural land. This condition will drive further to an alarming situation of landslide hazard in the catchment.

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