Land use change study and the increased risk of floods disaster in Jeneberang watershed at Gowa Regency, South Sulawesi, Indonesia

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Abstract. As part of the Jeneberang watershed area, Gowa Regency has an increasing trend of risk of flood disaster which has occurred globally. The high rate of population growth and the development of community economic activities are accompanied by the increasing need for space both for settlements and economic activities which results in changes in land cover land use (LULC). This study aims to conduct a study of changes in LULC that can increase the risk of flooding in Gowa regency with watershed area approaches. This study uses a descriptive analysis method with spatial analysis techniques and complemented by other data from agencies, community interviews, and location surveys. LULC data were used in this study are the conversion results from aerial photographs of Landsat 7 ETM + in 1999 and Landsat-8 OLI / TIRS in 2020 with a map scale of 1: 50,000. The result shows that during the period of study (1999-2020), there were significant changes in LULC in the Jeneberang watershed, where the Jeneberang watershed experienced deforestation of 36.67 Ha, forest degradation of 770.14 Ha and increasing of settlement areas of 3,497,47 Ha.

The interviews and surveys indicated that the flood disaster-prone areas have grown with residential areas which reduced the water catchment areas and narrowed river boundaries thus increase the potential of flood disaster risk in the future.

1. Introduction
The Jeneberang watershed, one of the national priority watersheds, has a major role in the hydrological system in Makassar City, Gowa District, and Takalar District. It has been facing the impact of global climate change [1]. The flow of urbanization in urban areas and rapid population growth have triggered the increasing vulnerability of society towards natural disasters such as the increase of flooding risk in residential areas. This is one of the effects of climate change [2]. Population growth increases along with the increase in economic, industrial, infrastructure development and provision of housing for residents has caused the degenerate environments in the watershed. Degenerate environments and decreasing of the carrying capacity in Jeneberang watershed are marked by the occurrence disasters such as floods, landslides, and drought. These natural disasters become annual problems faced by residents [3].

One of the biggest flood disasters in Gowa district and Makassar city occurred at the end of January 2019. The severe area was around the Jeneberang River area. The rise of water levels had caused the gates opening of Bili-Bili dam. As in result, the river was flooding most of the urban areas and residential areas. According to the news, this flood had caused the loss of life and materials [4].
The suspected causes of this flood disaster were weather and climate factors. During that time, there was extreme rainfall along with high intensity as the impact of climate change. Other factors were changing in land use land cover (LULC) caused sedimentation in the Bili-Bili dam and erosion in the upstream watershed area [5], so it is necessary to have a study of LULC changed and the potential for an increased risk of disaster from these changes.

Danial et al. [6] developed a management strategy for the Jeneberang watershed using data on LULC changes in the upstream part of the Jeneberang watershed. However, to develop a management strategy for the Jeneberang watershed related to the flood disaster, LULC change data as a whole is needed not only in the upstream but also in the downstream part of the watershed. Knowing the complete condition of LULC changed and its relationship to disasters makes it easier for the government to develop appropriate flood mitigation strategies. This study aims to analyze the changes in LULC and its impact on the increasing flood risk in the Jeneberang watershed area. The results of this study are supposed to become a source of data and information for assisting the government in determining watershed management policies and flood disaster mitigation efforts.

2. Methodology

The method of this research is descriptive analysis with spatial approach. It was divided in three steps:

- Convert aerial/imagery data. This step was purposed to convert Landsat imagery data into LULC maps. This research used Landsat 7 ETM image data in 1999 and Landsat-8 OLI/TIRS in 2020. Landsat imagery data was transformed into LULC maps in 1999 and 2020 with a map scale of 1: 50,000. We combined supervised and unsupervised classification method to obtain more optimal interpretation results.

- Overlay analysis. Overlay analysis was aimed to analyse the changes in LULC maps that occurred from 1999 to 2020. Overlay method combines multiple map layers from the same area in order to obtain combination data for further analysis [7].

- Discover the relation between spatial approach result and supporting data. In this step, we collected supporting data such as secondary data, observation in prone areas, interviews, and literature studies. These supporting data was used to discover the relation between the changes in LULC and the increased risk of flooding in the Jeneberang watershed.

2.1. Study area

The study area was in Jeneberang watershed area as shown in Figure 1, a total area of approximately 78,853.15 Hectares. It is located in South Sulawesi Province, Indonesia where it covers half of Gowa district, Takalar district, and Makassar City.

2.2. Aerial imagery data processing and analysis

In processing and analyzing the Landsat 7 ETM images in 1999 and Landsat-8 OLI / TIRS images in 2020 into LULC maps, several phases were performed, as well as: image correction, image interpretation, surveys, and accuracy test. In the image data correction steps, we performed radiometric correction and geometric correction by using Envi 5.1 and Arc Gis 10.4 softwares from the environmental system research institute (ESRI).

Image interpretation was performed by combining supervised and unsupervised classification methods to optimize interpretation results [8]. The supervised classification method used the maximum likelihood classification (MLC) algorithm [9]. In MLC process, we combined several bands from Landsat satellite image which is called natural color as shown in Figure 2.
For better results, the outputs from the MLC method were processed using an unsupervised method. This was intended to ensure accuracy in determining LULC by referencing several combinations of other bands from Landsat imagery such as false-color band, infrared band, and other images with higher resolution. The high-resolution image used is an open-source image from Google Earth Pro. The software application used in the image data interpretation process is ArcGis 10.4. There were twelve classes identified as the final class type from the LULC map with a scale of 1:50,000, which were primary forest, secondary forest, settlements, meadow, dryland agriculture, plantation, paddy field, shrub, pond, cleared land, mixed gardens, and waterbody.

\[ N = \frac{4pq}{E^2} \] (1)

To ensure the quality of the LULC result interpretation, verification and validation were carried out using a field survey method accompanied by a thorough test of the results of the classification of LULC. Determination of the number of samples for the accuracy test used the equation (1) from Anderson in Lo [10]:

**Figure 1.** Research location map.

**Figure 2.** Landsat image (combination of natural color bands) in the Jeneberang watershed area (Source: United States Geological Survey (USGS), http://earthexplorer.usgs.gov/)
where:
- \( N \) = Number of samples
- \( p \) = Expected accuracy
- \( q = 100 - p \)
- \( E \) = Acceptance of errors

Accuracy test based on the specified samples. These samples were calculated using an error matrix or confusion matrix on each form of land cover or land use from the results of the image interpretation. Mapping accuracy according to Short in [11] can be made in several class X which calculated by the equation (2).

\[
MA = \frac{X_{cr \text{ pixel}}}{X_{cr \text{ pixel}} + X_{o \text{ pixel}} + X_{co \text{ pixel}}} \tag{2}
\]

where:
- \( MA \) = Mapping accuracy
- \( X_{cr} \) = Number of corrected class X
- \( X_{o} \) = Number of class X that goes to another class (omission)
- \( X_{co} \) = Number of additional X classes from other classes (commission)

The accuracy of all classification results (KH) in image interpretation can be calculated using the equation [10]:

Equation. 3. Formula of Accuracy for All Classification Results

\[
KH = \frac{\text{The Number of pure pixels of all classes}}{\text{The Number of all pixels}} \tag{3}
\]

where:
- \( AR \) = accuracy results

3. Results and discussion

3.1. LULC condition in year of 1999 until 2020 at Jeneberang Watershed

From the interpretation process of Landsat satellite image, a map of LULC was produced in the Jeneberang watershed area in 1999 and 2020 with a scale of 1: 50,000. The LULC data are presented in map form in Figure 3 and Table 1. From the analysis of LULC data in the Jeneberang watershed from 1999 to 2020, there have been changes in LULC, where some have experienced increases and decreases. It was found settlement, plantation, and dryland agriculture have increased meanwhile primary dryland forest, secondary dryland forest, paddy field, shrubs, pond, cleared land, mixed garden, meadow, and waterbody have decreased.

![Figure 3. Land use map of Jeneberang Watershed at 1999 and 2020.](image-url)
Table 1. Area distribution of LULC in year of 1999-2020 at the Jeneberang Watershed.

| No. | Land cover and use         | Area (Ha) 1999 | Change (Ha) 2020-1999 | (% Change) |
|-----|---------------------------|----------------|------------------------|------------|
| 1   | Primary Forest            | 2,840.28       | -1,028.24              | -36.20%    |
| 2   | Secondary Forest          | 12,159.36      | -864.58                | -7.11%     |
| 3   | Settlement                | 1,417.66       | +3,497.47              | 246.71%    |
| 4   | Meadow                    | 180.50         | -24.51                 | -13.58%    |
| 5   | Plantation                | 861.72         | +1,258.98              | 146.10%    |
| 6   | Dryland Agriculture       | 16,495.50      | +7,265.22              | 44.04%     |
| 7   | Paddy Field               | 21,751.26      | -3,022.47              | -13.90%    |
| 8   | Shrub                     | 17,774.28      | -5,782.65              | -32.53%    |
| 9   | Pond                      | 544.29         | -282.19                | -51.85%    |
| 10  | Cleared land              | 815.75         | -243.58                | -29.86%    |
| 11  | Mixed Garden              | 852.21         | -234.99                | -27.57%    |
| 12  | Waterbody                 | 3,160.35       | -538.46                | -17.04%    |
|     | **Total**                 | **78,853.15**  | **78,853.15**          |            |

3.2. Deforestation and forest degradation at Jeneberang Watershed

According to the Minister of Forestry Regulation No. 30/2009, deforestation is defined as the conversion of natural forest cover becomes the land cover other than forest (non-forest) category which only occurs once in a certain area. Forest degradation is defined as the change in primary forest class, which including the primary dryland forest into secondary forest classes. The types of LULC in the Jeneberang watershed are grouped into forest land are primary forest and secondary forest, others beyond those two groups are categorized into non-forest. The results from analysis of overlay maps from 1999 to 2020, the Jeneberang watershed experienced degradation and deforestation. The number of degradation area is 770.14 hectares and deforestation area is 1,122.68 hectares as showed in Table 2 and Figure 4.

Table 2. Distribution of deforestation and degradation events in the Jeneberang Watershed

| Incident | Type of LULC | Year 1999 | Year 2020 | Area (Ha) |
|----------|--------------|-----------|-----------|-----------|
| 1. Degradation | Primary forest | Secondary forest | 770.14 |
| Forest degradation area | 770.14 |
| 2. Deforestation | Primary forest and secondary forest | Meadow | 7.33 |
| Plantation | 9.80 |
| Dryland agriculture | 560.23 |
| Paddy field | 37.75 |
| Shrubs | 466.27 |
| Clear land | 41.30 |
| Deforestation area | 1,122.68 |
3.3. Increasing of settlement

Based on the LULC data from 1999 to 2020 there was an increase of settlement area of approximately 3,497.47 Ha (246.71%). The average in each year showed the increasing of the area settlement is 167.89 Ha. Completed data can be seen in Table 3 and the location of changes in the area of settlement in the Jeneberang watershed can be seen in Figure 5.

Table 3. Types of land cover and land use that change to settlement from 1999-2020.

| Land cover and use    | (Ha)  | (%)  |
|----------------------|-------|------|
| Secondary Forest     | 1.54  | 0.04%|
| Plantation           | 0.18  | 0.01%|
| Dryland agriculture  | 23.65 | 0.68%|
| Paddy field          | 1179.76 | 33.73%|
| Shrubs               | 1444.37 | 41.30%|
| Pond                 | 164.79 | 4.71%|
| Cleared land         | 218.30 | 6.24%|
| Mixed Garden         | 392.98 | 11.24%|
| Waterbody            | 71.85  | 2.05%|
| **Total**            | **3497.47** | **100.00%**|

3.4. Condition of flood disaster prone-areas at Gowa Regency

According to the regional disaster control agency of Gowa District, Sombaopu and Palangga sub-districts were the most flood-affected areas. The villages in Sombaopu and Palangga sub-districts that were affected until 2019 by the flood disaster in the Jeneberang watershed area in Gowa District can be seen in Figure 5. The list of rural/urban villages affected by the flood included Bontoramba, Bonto-botoa and Pangkabinanga villages which were in Sombaopu sub-district; while in Palangga Sub-district were: Tetebatu, Panakukkang, Bungaejaya, and Palangga villages.

The data from the regional statistical agency of Gowa District about the internal disasters which recorded for 5 (five) years from 2014 to 2019, shows the flood affected villages in Gowa district increased from 6 (six) villages in 2014 to 43 villages in 2019 [10]. Previously, there was no flood events...
until 2014 in Palangga subdistrict. However, in 2019, there were to 4 (four) villages that experienced flood disasters. In Sombaopu sub-district, the flood affected villages were increasing from 1 (one) village to 7 (seven) in 2019.

According to the survey and interviews with several local residents, the cause of the flood was categorized into two types. These two types are flash flood due to overflowing of the Jeneberang river and flood puddle due to land conversion and poor drainage systems. The residential development closer to the river border in the Sungguminasa, Tetebatu and Pangkabinanga villages has cause local residents more vulnerable toward the flooding risk.

Formerly infiltration areas such as in Bonto-Bontoa, Tetebatu, Palangga, Panakkukang, and Bungaejaya villages were also in great risk of flooding. Previously, they were originally swamp or agricultural areas, but currently have been converted into residential. The reduction of infiltration areas increases the risk of flood puddle in the rainy season.

Figure 5. The distribution map settlement growth in Jeneberang watershed.

Figure 6. Flood disaster affected areas in the Jeneberang watershed area in Gowa Regency.
3.5. Flood disaster risk potential increase in the Jeneberang watershed

Population growth is important factor for causing the increase of land conversion, including deforestation, forest degradation, and settlement areas. These caused the reduction of vegetation cover area in the Jeneberang watershed. The decrease of vegetation cover area will cause an increase of surface runoff of the Jeneberang watershed during the rainy season and also cause drought in the dry season [6]. The upstream part of the Jeneberang watershed becomes at high risk of landslides. High rainfall in the rainy season and the landslide material continues to gather for a long time can trigger flash floods [12].

Yendri [13] explains the significant correlation between increased water discharge and land changes, especially for density of vegetated areas such as forests that have turned into non-forest (deforestation). From changes of LULC, deforestation and degradation of forest, and increasing of the settlement area have led to reduction of vegetation in entirely land cover. This reduction increased the flooding risks in disaster-prone areas around Jeneberang watershed due to the increasing landslides potential and increase of surface runoff during the rainy season.

4. Conclusion

Changes in LULC, including deforestation, forest degradation, and increasing of settlement in the Jeneberang watershed have increased the risk of flood disaster which are impact of climate change that has occurred globally. They also have a broad impact on the community, especially for those who live in disaster-prone areas such as the Sombaopu and Palangga Districts in Gowa Regency. Seeing the trend of high population growth and continuing changes in LULC, the level of community vulnerability to the impacts of climate change such as flood disaster is getting higher. Mitigation efforts based on a proper watershed management approach such as forest rehabilitation and law enforcement in forestry and environment sectors must be implemented.

References

[1] Ali S 2015 Perencanaan Penggunaan Lahan Berbasis Rendah Emisi Karbon Di Daerah Aliran Sungai Kelara Undergraduate Thesis (Makasar: Hasanuddin University)
[2] Kundzewicz Z W et al. 2014 Flood Risk and Climate Change: Global and Regional Perspectives Hydrol. Sci. J. 59(1) 1–28
[3] Pambudi A S, Moersidik S S and Karuniasa M 2020 Keterkaitan Perilaku Masyarakat Dengan Penggunaan Lahan dan Erosivitas Limpasan Permukaan di Sub DAS Lesti, Kab. Malang J. Penelit. Pengelolaan Dhr. Aliran Sungai 4(2) 155–172
[4] Thoban M I and Hizbaron D R 2020 Urban resilience to floods in parts of Makassar, Indonesia E3S Web Conf. 200 01007.
[5] Nurdin P F, Kubota T and Soma A S 2019 Investigation of flood and landslide in the Jeneberang catchment area, Indonesia in 2019 Int. J. Eros. Control Eng. 12(1) 13–18
[6] Danial M, Arsyad U and Demmallino E B 2020 Strategi Pengelolaan Hulu Daerah Aliran Sungai Jeneberang Provinsi Sulawesi Selatan J. Ecosolum 9(2) 11–31
[7] Hutagaol V, Sudarsono B and Nugraha A 2015 Penentuan Potensi Lokasi ATM BNI Menggunakan Analytical Hierarchoy Process (AHP) Dan Sistem Informasi Geografis (Studi Kasus: Kecamatan Tembalang) J. Geod. Undip 4(2) 25–32
[8] Suriana D, Barkey R A and Gou Z 2020 Analysis of Land Use/Land Cover Change and Their Effects on Spatiotemporal Patterns of Urban Heat Islands (UHI) In The City Of Makassar, Indonesia Int. J. Eng. Sci. Appl. 7(2) 113–123
[9] Jia K et al. 2014 Land cover classification using Landsat 8 Operational Land Imager data in Beijing, China Geocarto Int. 29(8) 941–951
[10] Nilasari A and Murtialaksoco K 2017 Tipologi Konflik Kawasan Hutan pada Proses Penataan Batas di Wilayah Pulau Bangka J. Sosiol. Pedesaan 5(3) 176–183
[11] Purwadi S H 2001 Interpretasi Citra Digital (Jakarta: Grasindo)
[12] Soma A S and Kubota T 2017 The Performance of Land Use Change Causative Factor on Landslide Susceptibility Map in Upper Ujung-Loe Watersheds South Sulawesi, Indonesia
[13] Yendri O, Wahyudi A and Gunawan G 2019 Perubahan Tutupan Lahan Terhadap Debit Banjir Menggunakan Model Regresi Linier Berganda Sub Das Musi Hulu Kabupaten Musi Rawas 
*Teknik Hidro* **12**(2) 32–39