Land use changes impact on water quality in Jeneberang Watershed, South Sulawesi, Indonesia

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Abstract. Land use change and water quality problems occur in most watersheds in Indonesia, which are also resulted by climate change phenomenon. One of the watersheds that have a critical status but have an important role in South Sulawesi, Indonesia is the Jeneberang watershed, which is included in 15 national priority watersheds for restoration and conservation. The purpose of this study is to analyze the impact of land use changes in watersheds over the last 20 years on water quality. This research is a descriptive study using quantitative and qualitative methods. In this study, Land Change Modeler (LCM) module was used in Idrisi Terrset software to analyze changes in used/covered by comparing the imagery of 2000 and 2020, while water quality analysis using the pollution index method on 7 key parameters of water quality. The results showed a decrease in forest area cover in the upstream part of the watershed with an increase in the area of agricultural areas and settlements. Water quality was classified as lightly polluted with the pollution index values increased from upstream (2.04), middle (2.12,) to downstream (2.83). Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Coliform concentrations were higher than national standards of water quality. Changing land use into agricultural areas and settlements has contributed to increased water pollution in the Jeneberang watershed.

1. Introduction

A Watershed is an area that is prone to changes in land use due to the high rate of development and population pressure. Watershed has a strategic role in supplying human needs so that it becomes an area that is rapidly changing. Increasing land requirements as a result of the increasing population are a factor in the occurrence of changes in land use in the watershed area. Forest areas become areas that are prone to conversion to other land uses so that they have an impact on the hydrological conditions of a watershed. The reduction in forest area also causes an increase in greenhouse gases, which has an impact on climate change. This is indicated by the increasing incidence of natural disasters (floods, drought and landslides), and threats to biodiversity [1].

Currently, most of the watersheds in Indonesia are damaged and their carrying capacity has decreased. This imbalance in function in the use of the watershed is triggered by a land use change that is not following spatial rules, which causes the emergence of critical lands in the watershed area. Critical...
indicators of a watershed can be indicated by changes in the hydrological cycle, such as the high frequency of flood events (peak flow) and increased erosion and sedimentation processes and decreased water quality [2]. Water quality is one of the national strategic issues that is a component in calculating the environmental quality index in Indonesia. Water quality includes physical, chemical and biological conditions that are stated with certain parameters based on applicable regulations [3]. Water quality is strongly influenced by the type of land use or land cover that exists. In addition, human activities in utilizing lands such as agriculture, settlements, and industry have the potential to produce waste that can pollute water bodies if not managed properly before being discharged into the environment [4].

The Jeneberang Watershed is one of the critical watersheds in South Sulawesi which has an important role in community life. The Jeneberang watershed has an area of ± 78,000 hectares which has an upstream in Gowa Regency and the downstream is in Takalar Regency and Makassar City. The Jeneberang watershed area is currently experiencing a decline in the carrying capacity and carrying capacity of the environment. The decrease occurred because forest cover changed its function to dry land agriculture, rice fields, settlements and plantations [5]. The change in land use in the Jeneberang watershed has affected the hydrological aspects, especially water quality. Based on the description above, a study is needed to analyze the impact of land use change on water quality in the Jeneberang watershed.

2. Method
This research was conducted in the Jeneberang watershed, which is one of the national priority watersheds for restoration. This research is a descriptive study using quantitative and qualitative methods. In this study, Landsat 5 TM 2000 and Landsat-8 OLI / TIRS 2020 imagery were used to create land cover maps for 2000 and 2020. In making the land change map, several stages were carried out, namely pre-processing, image classification, and post-processing. Pre-processing is the initial image processing stage before the classification process includes correcting geometric and radiometric images using the ENVI 5.3 application. Geometric corrections are made to correct inconsistency between location coordinates image data and coordinates of actual location in the field [6], while radiometric corrections are carried out to correct pixel values that do not match the value of object reflection due to atmospheric effects to improve the visual quality of the image [7-8]. At the image classification stage, the supervised Maximum Likelihood Classification (MLC) method is used. This method is a method for determining the distribution class based on the pixel value in the training sample for each land cover object [9]. In the Post-Processing stage, an accuracy test is carried out using the confusion matrix method to obtain indicators of accuracy and error in the classification results.

The resulting land cover classification is sometimes imperfect and has low accuracy so that it needs to be improved by filtering and editing [10]. The resulting land cover map is then processed using the Land Change Modeler (LCM) module in the Terrset software to analyze land use changes that have occurred in the Jeneberang watershed during the 2000-2020 period.

The water quality data used is secondary data from the results of monitoring and laboratory analysis of the Dinas Pengelolaan Lingkungan Hidup of South Sulawesi in 2020. Water quality data is taken at 3 points representing upstream, middle and downstream as in Table 1.

Table 1. Locations of 2020 water quality monitoring.

| No. | Point      | Location                   | Coordinate          |
|-----|------------|----------------------------|---------------------|
| 1.  | Upstream   | Desa Bolutana, Kecamatan Tinggi Moncong, Gowa | S 05°17’55,626” N E 119°53’20,286” E |
| 2.  | Middlestream | Kelurahan Bontoparang Kecamatan Parangloe, Gowa | S 05°15’31,08” N E 119°34’58,22” E |
| 3.  | Downstream | Benteng Sombaopu, Makassar | S 05°13,05’ 2” N E 119°27’24,3” E |
Determination of water quality status is calculated using the Pollution Index method for 7 parameters, namely TSS (Total Suspended Solid), Total Phosphate, BOD (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand), DO (Dissolved Oxygen), Fecal Coliform and Total Coliform. The calculation formula using the Pollution Index Method is as follows [11]:

\[
IP_j = \sqrt{\left(\frac{C_i}{L_{ij}}\right)_m^2 + \left(\frac{C_i}{L_{ij}}\right)_r^2}
\]  

Information:
- Li: Concentration of water quality parameters stated in the water quality standard (j)
- Ci: Concentration of water quality parameters (i)
- PIj: Pollution Index for designation (j)
- (Ci/Lij) M: Maximum Ci/Lij value
- (Ci/Lij) R: Average Ci/Lij value

The pollutant index values are categorized into 4 classes as follows Table 2.

| No. | IP Score        | Quality Status        |
|-----|-----------------|-----------------------|
| 1.  | 0 ≤ IP ≤ 1,0    | good                  |
| 2.  | 1,0 < IP ≤ 5,0  | slightly polluted     |
| 3.  | 5,0 < IP ≤ 10   | fairly polluted       |
| 4.  | IP > 10         | heavily polluted      |

3. Result and discussion

3.1. Land use in Jeneberang watershed

The results of the image classification process using the supervised maximum likelihood method obtained land use maps for 2000 and 2020 as shown in Figure 1. There are 13 land use classes in the Jeneberang watershed with an area as shown in Table 3.

![Land Use 2000 and Land Use 2020](image)

**Figure 1.** Land use map for 2000 and 2020 in Jeneberang watershed.
The results of the classification of land use are tested for accuracy using confusion matrix tables. The results of the overall accuracy test from the confusion matrix table obtained the image accuracy results of 92.32%. This shows that the results of image interpretation carried out can be accepted in accordance, that acceptable image classification is a minimum level of accuracy of 85% [12].

### Table 3. Land use area in 2000 and 2020 in Jeneberang watershed.

| No. | Land Use Class          | 2000         |   | 2020         |   |
|-----|-------------------------|--------------|---|--------------|---|
|     |                         | Area (ha)    | % | Area (ha)    | % |
| 1.  | Primary Forest          | 2,802.31     | 3.55 | 1,672.64     | 2.12 |
| 2.  | Secondary Forest        | 12,918.31    | 16.38 | 12,892.84    | 16.35 |
| 3.  | Forest Farming          | 936.94       | 1.19 | 1,616.23     | 2.05 |
| 4.  | Shrubs                  | 16,604.96    | 21.05 | 12,972.02    | 16.45 |
| 5.  | Grassland               | 296.87       | 0.38 | 3,891.56     | 4.93 |
| 6.  | Mixed Dryland Agriculture | 17,221.20   | 21.83 | 15,884.79    | 20.14 |
| 7.  | Dryland Agriculture     | 899.72       | 1.14 | 7,090.08     | 8.99 |
| 8.  | Paddy Field             | 21,566.73    | 27.34 | 14,108.92    | 17.89 |
| 9.  | Pond                    | 542.76       | 0.69 | 327.52       | 0.42 |
| 10. | Mining Area             | 52.47        | 0.07 | 525.97       | 0.67 |
| 11. | Settlement              | 1,600.17     | 2.03 | 4,998.55     | 6.34 |
| 12. | Cleared Land            | 266.68       | 0.34 | 915.90       | 1.16 |
| 13. | Water Body              | 3,160.35     | 4.01 | 1,973.07     | 2.50 |
|     | Total                   | 78,870.11    | 100 | 78,870.11    | 100 |

3.2. Land use change analysis

Land use changes that occurred in the Jeneberang watershed from 2000 to 2020 were analyzed using the Land Change Modeller in the change analysis feature which is presented in the diagrams and tables of land use changes (Figure 2).

![Figure 2. Land use change between 2000 and 2020 in Jeneberang watershed.](image-url)
The results of data analysis show that land use in the Jeneberang watershed has undergone extensive changes from 2000 to 2020 (Table 4). 7 land use classes have decreased in area, namely primary forest, secondary forest, Paddy fields, ponds, mixed dry land agriculture, shrubs, and water bodies, while the other 6 classes of land cover have increased, namely Forest Farming, Grassland, Dry Land Agriculture, Mining, and Cleared Land.

The decrease in the area of primary and secondary forest indicates that there had been deforestation in the Jeneberang watershed, especially in the upstream [13]. Deforestation in the Jeneberang watershed had reached 1,154 hectares within 20 years, which had been converted to other land uses as shown in Table 5.

| Land Use Classes             | Change |          |          |
|-----------------------------|--------|----------|----------|
|                             | Losses (ha) | Gains (ha) | Difference |
| Primary Forest              | -1,601 | 472 | -1,129 |
| Secondary Forest            | 5,202  | 5,177 | -25 |
| Forest Farming              | 867    | 1,107 | 240 |
| Shrubs                      | 11,857 | 8,225 | -3,632 |
| Grassland                   | 257    | 3,850 | 3,593 |
| Mixed Dryland Agriculture   | 11,679 | 10,343 | -1,336 |
| Dryland Agriculture         | 546    | 6,736 | 6,190 |
| Paddy Field                 | 12,512 | 5,055 | -7,457 |
| Pond                        | 414    | 199 | -215 |
| Mining Area                 | 46     | 520 | 474 |
| Settlement                  | 198    | 3,596 | 3,398 |
| Cleared Land                | 183    | 832 | 649 |
| Water Body                  | 1,451  | 264 | -1,187 |

Paddy fields have also decreased, reaching 7,457 hectares. There are 12,512 hectares of paddy fields converted to other land uses, while the area of new paddy fields printed is only around 5,055 hectares. The distribution of changes in the area of paddy fields can be seen in Figure 3. Most of the downstream paddy fields have turned into built-up land such as residential and industrial areas because they are close to urban areas and have a topography that is suitable for residential areas [8].
Other land use changes that have had an impact on the condition of the Jeneberang watershed are an increase in the area of settlement and dry land agriculture. The area of built-up increased by 3,596 hectares from 7 other land uses as in Table 6. The need for land for shelter and farming is the cause of this land conversion [14-15].

**Table 6. The transition of land use to settlement**

| No. | Transition to Settlements | Area (ha) | %   |
|-----|---------------------------|-----------|-----|
| 1.  | Secondary Forest          | 3         | 0,09|
| 2.  | Shrubs                    | 106       | 3,07|
| 3.  | Mixed Dryland Agriculture | 1.805     | 52,21|
| 4.  | Paddy Field               | 1.327     | 38,39|
| 5.  | Pond                      | 167       | 4,83|
| 6.  | Cleared Land              | 17        | 0,49|
| 7.  | Water Body                | 32        | 0,93|

3.3. Water quality analysis

River water sampling is carried out at 3 points, namely upstream, middle stream and downstream [16]. Laboratory test results on 7 water quality parameters compared with class II quality standards are presented in Table 7.

**Table 7. Water quality test results in 2020.**

| No. | Parameters          | Unit      | Quality Standards | Upstream | Middle | Downstream |
|-----|---------------------|-----------|-------------------|----------|--------|------------|
| 1.  | Total Suspended Sol (TSS) | mg/L      | 50                | 42       | 48     | 21         |
| 2.  | Dissolved Oxygen (DO) | mg/L      | 4                 | 7,8      | 7,4    | 7,2        |
| 3.  | Biological Oxygen Demand (BOD) | mg/L | 3                 | 1,8      | 14,5   | 4,4        |
| 4.  | Chemical Oxygen Demand (COD) | mg/L | 25                | 2,2      | 9,1    | 24         |
| 5.  | Phosphate            | mg/L      | 0,2               | 0,19     | 0,14   | 0,20       |
| 6.  | Fecal Coliform       | Jml/100 ml | 1000              | 1500     | 193    | >11000     |
| 7.  | Total Coliform       | Jml/100 ml | 5000              | 11000    | >11000 | >11000     |

| exceed quality standards |
Based on Table 6, shows that 4 parameters exceed the quality standard, namely BOD, Phosphate, Fecal Coliform, and Total Coliform. The high concentration of BOD, Fecal Coliform, and Total Coliform parameters is influenced by the presence of domestic activities, agriculture, livestock, and industrial waste [17-18]. Rainfall factors and river physical conditions also affect the high of these parameters [18].

3.4. Water quality status
The results of calculating water quality using the pollution index method can be seen in Table 8.

| No | Point     | IP Score | Water Quality Status  |
|----|-----------|----------|-----------------------|
| 1. | Upstream  | 2.04     | slightly polluted     |
| 2. | Midstream | 2.12     | slightly polluted     |
| 3. | Downstream| 2.83     | slightly polluted     |

Table 8 shows that the Jeneberang River has a mildly polluted status at all monitoring points. The Pollution index value has increased from upstream to downstream.

3.5. Relationship between changes in land use and water quality
Changes in land use in the watershed have impacts on ecological, economic and social conditions. From an ecological perspective, land use change has the potential to become a source of pollutants for water quality. Increasing the area of residential and industrial land causes the potential for domestic and industrial waste disposal to be even higher. Domestic and industrial waste will affect the parameters of BOD, COD, and Coliform Bacteria.

Changes in land use from forest to agricultural areas, especially in the upstream area with sharp slopes, can trigger erosion and carry sediment into rivers, thereby accelerating the process of silting the river flow. The erosion process will increase phosphate and and leachate water from agricultural land can increase Nitrate.

4. Conclusion
Land use in the Jeneberang watershed has changed from 2000 to 2020. Changes in land use in the Jeneberang watershed can be seen in the reduction in forest area of about 1,154 hectares and an increase in built up land of 3,398 hectares. Decreasing of forest area has an impact on the function of the forest as a regulator of water and climate systems. The existence of climate change contributes to changes in the quantity and quality of water. The water quality in the Jeneberang watershed is classified as lightly polluted based on the calculation of the pollutant index. Bacterial parameters BOD, phosphate, and coliform are parameters that exceed the quality standard. Water quality is strongly influenced by land use and human activities in it.

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