Impact of climate and land use change on the erosion of the upstream Kelara Watershed

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Abstract. South Sulawesi has been affected in recent years by natural disasters. One of the areas affected by the flood disaster is the Jeneponto District, which is included in the Kelara Watershed ecosystem's boundary. Extreme weather conditions cause flood disasters, and land use in the upper reaches of the Kelara watershed do not match its designation, which causes an increase in the rate of erosion. Climate change analysis with projected precipitation from the CSIRO General Circulation Model Mk3.5. The estimated land cover change uses a combination of the Geographic Information System, remote sensing, and Markov Chain Cellular Automata method with Landsat images. Prediction of erosion rates using the Universal Soil Loss Equation method. The annual rainfall of 2026 has decreased due to a significant decrease in rainfall during the dry season. In 2006-2016, changes in land use were not significant. In the land-use projection for 2026, there will be significant changes in land use. The use of paddy fields has increased over a wider area, while other land uses continue to follow the previous trend of reducing the surface. The prediction of future erosion will only increase by one ton/ha/year. Intense erosion classes will experience a reduction in the area of about 200 hectares in 2026. Based on this, the land is not a problem in the future, but an issue that must be prepared for its management is a drought when considering climate change conditions.

1. Introduction

Natural disasters such as floods, landslides, and whirlwinds have occurred in recent years at regencies/cities in South Sulawesi Province. Jeneponto regency, which is located in Kelara Watershed, is one of the affected areas. Where upstream of Kelara watershed located in Gowa Regency and Jeneponto Regency itself, this incident caused human casualties and material loss [1].

Disasters that occur due to extreme weather marked by rainfall reaching 197 mm/day [1]. Disasters that occur due to extreme weather characterized by rainfall reaching 197 mm/day. Rainfall and temperature conditions in an area will affect the hydrological state to cause abnormal conditions [2]. Global temperatures have also been predicted to be higher than average temperatures in the previous century [3]. Thus, this extreme weather condition in the future will have a major impact on the biophysical conditions on earth, including the land cover. Therefore, climate change simulation is needed to determine the climate variability [4].

Apart from the extreme weather conditions, the disasters around Kelara Watershed were caused by many forest conversions to agricultural land [1]. The increasing population will increase uncontrolled land conversion [5]. Exploitation by converting land cover type from forest to agricultural has led to increased erosion and sedimentation. This causes land degradation [6].
Land-use change in an area can estimate by combining remote sensing and Geographic Information Systems (GIS) [7, 8]. Future land use projections can be made using the CA-Markov model [9]. This model is the result of cellular automata integration and Markov chain analysis that can predict future land use trends based on the results of past land-use changes [8]. This will help to predict and determine future planning and policies.

Land-use change conditions have occurred a lot. Of course, this causes the land condition in a watershed to become critical [1]. Erosion is an important parameter in determining critical land [10]. The event of soil transport from one place to another by natural media is called erosion [11]. Soil displacement will have several impacts. Erosion will open up the soil and reduce the nutrients needed by plants since most of the soil's nutrients have been eroded.

Based on this, it is necessary to determine the impact of climate change and land-use change on erosion in the upstream Kelara Watershed. The erosion assessment is focused on the upstream Kelara watershed as a source of erosion while sedimentation to the main river of Kelara Watershed. This assessment will form the basis for determining adaptation, mitigation activities, and arriving at the form of planning.

2. Materials and methods
This research measures the impact of climate change and land-use change impacts on erosion, which begins with analyzing rainfall projected land-use change and predicting future erosion. The research boundary used is in the upstream Kelara watershed area. This study included:

2.1. Determining the boundary of research location
The Upstream Kelara watershed boundary is the outer boundary of all types of data used to analyze the research location. Administratively, the Kelara boundary is in two regencies, namely Gowa district and Jeneponto Regency, South Sulawesi Province, which can be seen in figure 1.

![Figure 1 Location research map.](image-url)
2.2. Collecting research data
To describe climate change (rainfall Projected), land-use change, and erosion predictions in this study using the geographic information system (GIS) and remote sensing method. Data collected in this study consisted of primary data and secondary data. Preliminary data collected is an image of 2006, 2011 and 2016 Landsat OLI recording to analyze image interpretation that issues a land-use map. Besides, a land-use survey was also conducted at the research location. Secondary data includes boundary watershed data, rainfall data, 30 meters DEM daisies, soil type maps from RePPProt 1987.

2.3. The processing and analyzing research data

2.3.1. Rainfall projection. Climate change is a rainfall projection taken from the Global Climate Model (GCM) with a horizontal resolution of 14 km. The global climate model used is CSIRO-MK 3.5 [4]. Rainfall projections in 2026 are obtained from the product of the actual rainfall from BMKG Maros and the CSIRO rainfall change model. In the analysis of rainfall projections, two different periods are determined between the past and the future; in this case, a comparison is made between the period 1976-1996 (1986) and 2016-2036 (2026). The year 1986 is after this referred to as Period I and the year 2026 is called Period II. This means that the rainfall value obtained in 2026 is always relative to 1986. So, to get the change value in the CSIRO model, it is necessary to analyze the following data:

a. Multiplying the monthly average value by the number of rainy days to get the month concerned.

b. Average monthly rainfall over 20 years, between 1976-1996 and between 2016-2026.

c. Calculate the changes between Period I and Period II with the equation: Change = (Period II - Period I) / Period I. A positive value indicates an increase in rainfall, and a negative value indicates a decrease in precipitation.

d. Multiplying the value of changes between periods with actual rainfall to predict rainfall in Period II, assuming that value said that the precipitation is relative to Period I.

2.3.2. Projected land use in 2026. Projected land-use change in 2026 uses a combination of the Information System approach Geographical, remote sensing, and Markov Chain Cellular Automata with Landsat image processing in 2006, 2011, and 2016. First, land use change analysis used Landsat 7 imagery in 2006 and 2011 and Landsat 8 imagery in 2016. Land cover change with Image interpretation performed using the visual delineation method. The results of determining land use classes based on patterns and characteristics in the form of hue, color, and texture in the image adjusted to the Directorate General of Planning and Environmental Management, Ministry of Environment Forestry.

Land use projections were analyzed using the method Cellular Automata Markov Chain (CA Markov). The CA Markov method was carried by comparing changes between 2006 and 2016. The Markov Chain model will produce a transitional / probability area matrix, a transition matrix for changes from the previous year to the projection year. The Markov equation is using the distribution of land use at the beginning and the end of the observation represented in a vector (one column matrix) and transition matrix as follows:

\[
M_{t+1} \cdot M_t = M_{t+1}
\]

\[
\begin{pmatrix}
LU_{uu} & LU_{ua} & LU_{aw} \\
LU_{au} & LU_{aa} & LU_{aw} \\
LU_{wu} & LU_{wa} & LU_{ww}
\end{pmatrix}
\begin{pmatrix}
U_t \\
A_t
\end{pmatrix}
= 
\begin{pmatrix}
U_{t+1} \\
A_{t+1}
\end{pmatrix}
\]

(1)

The probability of each point clarified as class U at time t. LC_{uu} shows the probability of one class U becoming another class at a certain time [12].

The model is Cellular Automata used to predict land use in 2026. The data entered is in the form of a transition matrix, land use in 2016, and land suitability. Model validation is also done to find out how accurate the projection is. Then projections are also carried out in the actual year (2016) based on data
for 2006 and 2011. Validation will then be done by comparing the land use simulation results with land use results from field observations based on the kappa value with the Kappa value equation as follows:

\[
K = \frac{\sum_{i} X_{ii} \times \sigma_{II}^2 - \sum_{i} X_{ii} \times X_{ii+}}{N^2 \sigma_{II}^2} \times 100\%
\]

(2)

Description:

- **K**: Kappa Value
- **X_{ii}**: area of type i land use simulation results that correspond to an area of type i of land use observation results
- **X_{ii+}**: area of type i land use simulation results
- **X_{ii}**: area of land use type i observation results
- **N**: the total area of all types of land use
- **Z**: Total land-use types

If the calculation result from the kappa value (K) obtained 0.9 or 90%, the match between the simulation results and the observation results is 90%. An acceptable condition is the percentage level of minimum accuracy of 85% [13].

### 2.3.3. Erosion Prediction

The rate of erosion is predicted by analyzing the determinants of erosion, namely **R** (erosivity index), **K** (erodibility index), **LS** (length and slope index), **C** (Index of vegetation cover and crop management), and **P** (index of land management/soil conservation measures) for each land use. Erosion projection in 2026 is carried out using rainfall projection data and projected land use in 2026. The equation used in erosion prediction based on the USLE method is as follows:

\[
A = R \times K \times LS \times C \times P
\]

(3)

The **R** value with the average monthly rainfall in this method is obtained by averaging the actual rainfall data and analyzing the rainfall projection for 2026 through the CSIRO model. Values obtained by the formula R Lenvain as follows:

\[
R = 2.21 \times (\text{Rain})^{1.36}
\]

(4)

Description:

- **R** = index rain erosivity,
- **Rain** = Monthly rainfall (cm)

The **K** value is obtained by matching soil types at the research location with existing soil erodibility values (table 1). The soil type map from RePPProt 1987 shows that the soil type in the upstream Kelara watershed is the same as the soil type from the Jeneberang watershed. The **LS** value was obtained from the slope class data from the Aster DEM 30 m analysis. Slope classes are adjusted to the existing LS values (table 2). The **C** and **P** values were obtained by conducting land use surveys and conservation techniques undertaken by the community. The survey results adjusted to **C** and **P**'s values from the Ministry of Forestry [13]. Based on the erosion value obtained through the analysis stage, the level of erosion can determine by referring to the erosion level classification by the Ministry of Forestry.

**Table 1.** Value of the **K** factor for soil types in the sub-watershed Jeneberang.

| No. | Soil type     | K Value |
|-----|---------------|---------|
| 1   | Dystrandepts  | 0.31    |
| 2   | Dystropepts   | 0.21    |
| 3   | Tropaquepts   | 0.32    |

Source: Indrowanto, et al (2012) [15].

**Table 2.** LS values based on slope class.

| No. | Class slope | Slope (%) | LS value |
|-----|-------------|-----------|----------|
| 1   | I           | 0–8       | 0.40     |
| 2   | II          | 8–15      | 1.40     |
3. Result and discussion

3.1. Projection rainfall in 2026

Actual rainfall data were obtained from five BMKG rainfall estimating stations around the upstream Kelara Watershed. The five stations are Bungaya Station (x: 119,733 ; y: -5,368), Paledingan Station (x: 119,806 ; y: -5,373), Malino Station (x: 119,861 ; y: -5,265), Malakaji Station (x: 119,845 ; y: -5,444), and Kelara Station (x: 119,816 ; y: -5,529). Rainfall projection for the year 2026 by linking the monthly actual average rainfall data with the CSIRO-MK3.5 model data. Rainfall station and grid model CSIRO-MK3.5 model can be seen in figure 2.

|   |   |   |
|---|---|---|
| 3 | III | 15–25 | 3.10 |
| 4 | IV | 25–40 | 6.80 |
| 5 | V | > 40 | 9.50 |

Source: Sutapa (2010) [16].

Figure 2. Area of rainfall station in the upstream Kelara Watershed.

Figure 2 shows a polygon represented by a rainfall measurement station where a different model grid represents each rainfall station. This means that the trend of change between each rainfall estimating
station will be different. The analysis results of the trend change in rainfall for the model can be seen in tables 3 and 4.

Based on the results of the projected rainfall in the upstream Kelara Watershed, the average rainfall has decreased. The decrease in rainfall that occurs almost every month will change the rain pattern in each month. This will affect erosivity as a predictive factor for erosion and will reduce the rate of erosion. It should be noted that the dry season is long around the upstream Kelara Watershed, so it takes a form of adaptation and mitigation to climate change. Combining agricultural, plantation, and forestry crops in an agroforestry system will increase climate resilience and increase carbon stocks in the soil. [17].

**Table 1.** Actual predicted, period I, period II, change and rainfall in 2026 in neighborhood stations upstream Watershed Kelara.

| Times/Period | BMKG Station | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Des |
|--------------|---------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Actual year  | Paledingan    | 724.33 | 512.25 | 286.92 | 398.42 | 331.58 | 422.20 | 190.60 | 87.25 | 92.50 | 241.50 | 417.00 | 448.38 |
| Period I     | Period II     | 369.27 | 298.46 | 263.81 | 119.24 | 41.69 | 14.35 | 11.14 | 9.02 | 16.65 | 52.00 | 106.12 | 255.40 |
| Change       |               | -0.09 | 0.04 | -0.18 | -0.15 | -0.12 | 0.04 | -0.35 | -0.57 | -0.24 | -0.20 | 0.00 | -0.04 |
| 2026         |               | 676.32 | 535.20 | 234.13 | 338.08 | 292.25 | 439.85 | 124.58 | 37.39 | 70.02 | 193.86 | 418.26 | 429.14 |

| Times/Period | BMKG Station | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Des |
|--------------|---------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Actual year  | Malino        | 855.50 | 498.33 | 508.17 | 367.67 | 189.00 | 214.83 | 140.17 | 42.60 | 63.40 | 93.20 | 270.20 | 520.00 |
| Period I     | Period II     | 82.66 | 90.02 | 82.56 | 60.79 | 28.17 | 20.62 | 16.96 | 14.33 | 12.20 | 33.87 | 60.06 | 81.52 |
| Change       |               | -0.11 | -0.08 | -0.11 | -0.10 | 0.37 | -0.35 | -0.03 | -0.55 | -0.37 | -0.19 | -0.01 | 0.11 |
| 2026         |               | 763.65 | 457.97 | 450.54 | 331.30 | 258.08 | 140.71 | 136.47 | 19.20 | 39.76 | 75.36 | 268.68 | 578.46 |

**Table 2.** The percentage change in rainfall from 2016 to 2026.
3.2. Land use projection

Land use projection is carried out by interpreting the actual image. Interpretation of Landsat 7 satellite imagery in 2006 and 2011, and Landsat 8 satellite imagery in 2016 (Table 5). The image interpretation results of the actual year (2016) are the basis for seeing field conditions. The land uses consist of secondary dryland forest, plantation forest, plantations, secondary dryland agriculture, rice fields, and water bodies.

| No. | Land Use                | LU 2006 (ha) | LU 2011 (ha) | LU 2016 (ha) | Change in 2006 (ha) |
|-----|-------------------------|--------------|--------------|--------------|---------------------|
|     |                         | (%)          | (%)          | (%)          | (%)                 |
| 1.  | Secondary dryland forest| 6,448.39     | 6,226.82     | 5,862.64     | -585.75 -2.08       |
|     | Plantation forest       | 943.29       | 918.31       | 736.96       | -206.33 -0.74       |
| 2.  | Orchard                 | 12,021.05    | 11,661.41    | 11,856.71    | -164.34 -0.58       |
| 3.  | Dryland agriculture     | 4,746.46     | 4,476.8      | 4,732.55     | -139.19 -0.05       |
| 4.  | Rice field              | 3,994.52     | 4,870.37     | 4,964.85     | 970.33 3.44         |
| 5.  | Water                   | 31.76        | 31.76        | 31.76        | 0.11 0.00           |
|     | Total                   | 28,185.47    | 28,185.47    | 28,185.47    | - -                  |

Based on the land use data for 2006, 2011, and 2016 above, it can be used as the basis for projections of land use in the year 2026. Before projecting land use in 2026, projections made to determine how much the projection results in 2026 can be received. The validation test was carried out by projecting land use in 2016 based on land use in 2006 and 2011. The results of the 2016 projection were then adjusted to the 2016 land use. The results of the 2016 projection validation test showed a kappa value of 0.89. This used to project land use in 2026 [13] (Table 6).

| No. | Land Use                | 2016 (ha) | 2026 (ha) | Change (ha) |
|-----|-------------------------|-----------|-----------|-------------|
|     |                         | (%)       | (%)       | (%)         |
| 1.  | Secondary dryland forest| 5,862.64  | 4,530.27  | -1,332.37 -4.73 |
| 2.  | Plantation forest       | 736.96    | 489.56    | -247.40 -0.87 |
| 3.  | Orchard                 | 11,856.71 | 11,528.85 | -327.86 -1.17 |
| 4.  | Dryland agriculture     | 4,732.55  | 4,113.50  | -619.05 -2.20 |
| 5.  | Rice field              | 4,964.85  | 7,499.90  | 2,535.05 9.00 |
| 6.  | Water                   | 31.76     | 23.39     | -8.37 -0.03 |
|     | Total                   | 28,185.47 | 28,185.47 | 28,185.47 - - |

Projected use land use in 2026 shows a greater change compared to land use in 2016. The land use that has decreased significantly is secondary dryland forest, while the land use increased significantly is...
rice fields. This shows the greater use of land by the upstream community. Kelara Watershed changes in land use indicate socio-economic activities or community interaction in utilizing land resources [6].

**Figure. 3** Land use change (a) 2016 (b) 2026 in the upstream Kelara Watershed.

### 3.3. Erosion level prediction

#### 3.3.1. Erosivity index ($R$). Erosion prediction is carried out twice, namely in the actual year (2016) and the projection year (2026). The erosivity factor is determined by the actual, and projected rainfall. The calculation of the erosivity factor ($R$) is carried out using the Lenvain equation. The Lenvain equation is used because of the availability of monthly rainfall data. The $R$ value for actual and projected rainfall in 2026 presented in table 7.

**Table 7. Erosivity (R) value in the upstream Kelara Watershed.**

| Station   | Actual R Value 2016 | Projection of R Value 2024 | (ha)  | (%)  |
|-----------|---------------------|----------------------------|-------|------|
| Bungaya   | 3,061.78            | 2,731.76                   | 219.69| 0.78 |
| Kelara    | 1,311.37            | 1,284.00                   | 3,506.65| 12.44|
| Malakaji  | 1,907.63            | 1,964.29                   | 16,061.87| 56.99|
| Malino    | 3,252.25            | 2,996.05                   | 544.17| 1.93 |
| Paledingan| 3,521.77            | 3,159.47                   | 7,853.08| 27.86|
| **Total** | 28,185.47           |                            | **100.00**|

Erosivity shows provide information that the higher the rainfall, the greater the erosion in an area. The Malakaji rainfall station has the most extensive influence in the upstream Kelara Watershed. The Malakaji rainfall projection has increased slightly so that it will impact increasing the Erosivity value. The Paledingan and Kelara rainfall stations, which have sufficient influence on the upstream Kelara Watershed, will decrease the value of erosivity in the future.
3.3.2. Crop management index (C) and conservation (P). Crop management index (C) and soil conservation action index (P) are based on actual and projected land use data (table 8). This factor is quite dynamic following the pattern applied by the community on land. The greater the vegetation that covers the soil, the less erosion it causes. This also applies in treating soil conservation.

**Table 8. Value of plant management and conservation measures upstream Kelara Watershed.**

| No. | Land Use                     | C Factors                  | C Value       | P Factors                  | P-Value | Area (ha)  |
|-----|------------------------------|----------------------------|---------------|---------------------------|---------|------------|
|     |                              |                            |               |                           |         | 2016       | 2026       |
| 1   | Secondary Dryland forest     | 0.005                      | without action| 1                         | 5,862.64| 4,530.27  |
| 2   | Plantation Forest           | 0.1                        | without action| 1                         | 736.96  | 489.56    |
| 3   | Orchard                     | 0.2                        | without action| 1                         | 11,856.71| 11,528.85 |
| 4   | Dryland Agriculture         | 0.64                       | Terrace Benches| 0.15                     | 4,732.55| 4,113.50  |
| 5   | Rice Field                  | 0.01                       | Terrace Benches| 0.15                     | 4,964.85| 7,499.90  |
| 6   | Water                       | 0                          |               |                           | 1       | 31.76      | 23.39      |
|     | Total                        |                            |               |                           |         | 28,185.47  |            |

Vegetation ground cover has an enormous influence on runoff and erosion. The effect of soil cover vegetation on erosion is to protect the soil surface from the collision of rainwater, reduce water flow velocity, hold soil particles in place, and maintain the soil's stability to absorb water [11]. The value of the human action factor in soil conservation is the ratio between the amount of land erosion with a certain conservation action to the amount of erosion on land without conservation action. [14]. The use of land in the form of Orchard dominates the upstream Kelara Watershed. The Orchard is high enough to cause erosion. Also, dryland agriculture based on field survey results is maize. Corn plants have a high sensitivity to erosion because they don't cover the soil well. The projection results for 2026 show an increase in land use in the form of rice fields. Rice fields have a low sensitivity to erosion [14].

3.3.3. Erodibility index (K), and slope index (LS). Erodibility is a soil factor against erosion (table 9). The slope is the ratio of land conditions that cause erosion (table 10). In a short period of time, both of these factors do not change, in contrast to the very dynamic rainfall and land use.

**Table 9. Soil type and K value in the upstream Kelara Watershed.**

| No. | Soil type | K value | Area (ha) | (%)   |
|-----|-----------|---------|-----------|-------|
| 1   | Dystrandepts | 0.31   | 10,814.61 | 38.00 |
| 2   | Dystropepts | 0.21   | 16,229.75 | 58.00 |
| 3   | Tropudalfs | 0.23   | 1,141.10  | 4.00  |
|     | Total     |         | 28,185.47 | 100.00|


Table 10. Slope class and LS value in the upstream Kelara Watershed.

| No. | Slope Class | LS Value | area (ha) | (%)  |
|-----|-------------|----------|-----------|------|
| 1.  | 0-8%        | 0.4      | 5,176.14  | 18.36|
| 2.  | 8–15%       | 1.4      | 2,304.89  | 8.18 |
| 3.  | 15 – 25%    | 3.1      | 4,869.03  | 17.27|
| 4.  | 25 – 40%    | 6.8      | 5,077.02  | 18.01|
| 5.  | > 40%       | 9.5      | 10,758.39 | 38.17|
|     | Total       |          | 28,185.47 | 100.00|

Figure 4. (a) soil type and (b) slope in the upstream Kelara Watershed.

The erodibility value is in the range of 0.21 - 0.31 against erosion in the upstream Kelara Watershed. In addition, steep and very steep slopes dominate the upper reaches of Kelara watershed. The slope conditions increase the possibility of erosion (Figure 4). The level of soil erosion on agricultural land with steep slopes is high [18].

3.3.4. Actual and future erosion level prediction

Erosion rate prediction using the USLE method by transferring the factors of erosivity, erodibility, slope, crop management index, and soil conservation index. The erosion rate analysis was carried out twice, namely actual (2016), and projection in 2026. First, with the erosivity factor and the actual crop management index. Second, with the erosivity factor and the projection crop management index (table 11).
Table 11. Erosion levels in the Upstream Kelara Watershed.

| Erosion Levels (ton/ha/year) | Actual 2016 | Projection 2026 | Change (%) |
|------------------------------|-------------|-----------------|------------|
|                              | Area (ha)   | Erosion (ton/ha/yrs) | Area (aa) | Erosion (ton/ha/yrs) |          |
| Very Light (< 15)            | 6,000.23    | 3.54            | 8,416.30  | 3.50              | 8.57     |
| Light (15 – 60)              | 7,671.71    | 32.46           | 5,741.65  | 20.37             | 32.09    | -6.85 |
| Moderate (60 – 180)          | 1,729.78    | 148.65          | 1,532.66  | 5.44              | 152.60   | -0.70 |
| Very Heavy (180 – 480)       | 6,661.83    | 323.97          | 6,100.94  | 21.65             | 324.12   | -1.99 |
| Very Heavy (> 480)           | 6,121.91    | 938.52          | 6,393.92  | 22.69             | 943.75   | 0.97  |
| Total                        | 28,185.47   | 100.00          | 299,13    | 100.00            | 300.13   |

Figure 5. Erosion levels (a) 2016 and (b) 2026 in the upstream Kelara Watershed

Overall, the level of erosion which is classified as heavy and very heavy, has decreased in the future. Significant changes in the rate of erosion are due to the widespread use of paddy fields and reduced rainfall in the Upstream Kelara Watershed in the future (Figure 5). Rice fields have a low sensitivity to erosion, resulting in increased runoff [14, 19]. The decrease in rainfall that occurs in most stations in the upstream Kelara Watershed will cause a decrease in the value of erosivity. In addition to the expansion of rice fields, which have a smaller erosion density than other land use classes. The concern is that rice fields cause a large amount of surface runoff to accumulate to become flood discharge in rivers [19]. This is evident from the floods Kelara watershed in 2009 and 2019 [20, 12].

4. Conclusions
The 2026 rainfall has decreased in most of the stations around the upstream Kelara Watershed. The decrease in precipitation is relatively large during the dry season, while there is an increase in rainfall
during the rainy season. The increase in rainfall is not too large when compared to the decrease in rainfall. This is a concern that the availability of water in the dry season will increasingly experience a deficit in the future. This land-use change was not very significant in 2006-2016. The use of paddy fields has increased in the area, while other land uses have decreased in the area. The projected land use in 2026 will see significant changes in land use that still follow the previous trend. The use of paddy fields has increased in a wider area, reaching 9% from the previous area, while land use has decreased in the area. The predicted level of erosion will decrease in the future. The decrease in the rate of erosion is due to an increase in the rice field area and a decrease in rainfall in the future. Based on this, the land is not a problem in the future, but a problem that needs to prepare for handling is drought by considering climate change conditions in Kelara Watershed. Also, an increase in rice fields will cause an increase in surface runoff which accumulates to become peak discharge or flooding, as happened in 2019.

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