Study of climate and land use change as considerations for sustainable agricultural land in the Saddang watershed

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Abstract. Saddang Watershed is one of the watersheds in South Sulawesi, which supplies water for agricultural land. However, the current challenge is climate change and land-use change that affect the sustainability of agricultural land. As a response, land analysis in the Saddang watershed needed starting with climate change analysis with rainfall projected in 2040, continued by land-use change analysis, land condition based on erosion rates, and sustainable agricultural land analysis directions. Rainfall projection using CSIRO general circulation model (GCM) CSIRO Mk3-6-0 climate model. Landuse change analysis using remote sensing methods with Landsat Imagery in 2000 and 2020. Landuse calculated as land condition based on erosion rate with USLE (Universal Soil Loss Equation) methods. Land conditions are a necessary consideration to formulate directions for sustainable agricultural land. The results of the rainfall projection in 2040 showed an increase in rainfall. It has an impact on land conditions. The rainfall increase occurs during the rainy season (October to January), while the rainfall decrease occurs during the dry season (July to September). Climate change was changed farmers’ cropping patterns, which usually started in October. As a response, it is necessary to increase the farmers’ adaptation by selecting plant types and mitigation activities by making reservoirs a source of water and preparing to enter the dry season. Land-use change showed a significant increase in agricultural lands, such as rice fields, agricultural and plantation land. The increase of agricultural land was converted from dry land to mixed agricultural brushwood. Most of the land conditions from dry land agricultural and dryland agricultural mixed brushwood have a high erosion level. High erosion level caused by slope conditions (rather steep, steep and very steep) and high rainfall also affects. Preserving agricultural land can be carried out through vegetative techniques. Vegetative techniques are helpful in reduced erosion levels because they didn't require a large amount of money. Vegetative techniques applied in the Saddang watershed are agroforestry, alley cropping, and strip planting along the contour.

1. Introduction

South Sulawesi is one of the regions in Indonesia as a food producer and also centre of agriculture. The agricultural sector is the cornerstone of economic growth in South Sulawesi. South Sulawesi has arable land and farming communities and is supported by water sourced from the watershed. Saddang Watershed is one of the watersheds in South Sulawesi, which supplies water for agricultural land. The water source came from direct rain and several existing rivers.

Saddang river provides benefits to farmers in North Toraja Regency, Tana Toraja Regency, Enrekang Regency, Pinrang Regency, and Sidrap Regency. Saddang River that flows in the area forms a watershed, and it’s called Saddang watershed. Several Saddang watershed locations have experienced
floods and landslides, such as in the Rantepao, Makale, and Enrekang. Disaster events, especially floods, are caused by the accumulation of climatic conditions, topography, and land cover [1].

Assessment Reports sourced from Intergovernmental Panel on Climate Change (IPCC) shows different conditions from the last few decades. The IPCC explains Earth's temperature has increased by about 0.8°C over the past century. At the end of the 21st century, global temperatures are expected to be 1.8 - 4°C higher than average temperatures in the previous century [2]. This condition has an impact on human life, especially the availability of water on earth. This condition will have a major impact on the economic conditions around Saddang Watershed, South Sulawesi, in the agricultural sector.

Apart from climatic conditions, the rapidly growing population will increase food demand, and land conversion to agricultural land will become uncontrollable [3, 4]. Landuse/land cover change are dynamic aspects that reflect socio-economic activities or community interactions in utilizing land resources [5]. Conversion of land to agriculture is the choice of most people to increase income [6]. Watershed exploitation through land-use increases erosion and sedimentation as a sign of land degradation [7].

Farmers need easy and inexpensive innovations to solve problems caused by climatic conditions and degradation of land resources. The first step in overcoming climate change is to simulate climate change to determine the climate variability [8]. The construction of water storage can be physically done to overcome drought due to climate change [9]. Regarding land degradation, vegetative conservation techniques effectively control erosion and surface runoff, increase land productivity and low costs [10] [11]. The research analysed climate change, land-use/land cover changes, and land conditions in the Saddang watershed. Assessment of land conditions by knowing the level of erosion. This value becomes a reference in making policies towards sustainable agricultural land

2. Materials and methods
This study focused on formulating steps in achieving sustainable agricultural land based on an assessment of changes in rainfall patterns, changes in land use, and land conditions in erosion classes. This research includes:

2.1. Determining the boundary of research location
The boundaries of the Saddang watershed are the study boundaries in this study. Also, as the outer limit of all types of data used for analysis purposes. The Saddang Watershed has an area of 661,926.96 hectares which is classified as a large watershed. Administratively, it consists of two provinces with five regencies. Five regency consist of Tana Toraja, North Toraja, Enrekang, and Pinrang Regencies in South Sulawesi Province, and Mamasa Regency in West Sulawesi Province. It is made Saddang watershed very strategic. The location of the Saddang watershed can be seen in figure 1.

2.2. Collecting research data
This research generally uses the Geographical Information System (GIS) method combined with changing rainfall patterns and remote sensing methods. Basic data includes watershed boundaries from the Ministry of Environment and Forestry in 2018, river data, administrative boundaries from the Geospatial Information Agency in 2020. Daily rainfall data were obtained from the MERRA 2 (Modern-Era Retrospective analysis for Research and Applications, Version 2) Satellite, NASA, United States of America 2000-2019. Landsat 7 imagery 2000 and Landsat 8 imagery 2017 for image interpretation analysis to obtain land cover maps. The data requirements for erosion analysis are soil classification data from RePPProt [12] and Aster DEM data for slope classes.
2.3. The processing and analyzing research data

2.3.1. Rainfall projection analysis. Rainfall data for 2040 were obtained from the CSIRO general circulation model (GCM) climate model CSIRO Mk3-6-0 from the Commonwealth Scientific and Industrial Research Organization, Australia, with a horizontal resolution of 14 km [8]. Estimated climate data for 2040 are obtained by multiplying the actual climate data for 2000-2019 with the CSIRO climate change model. In climate change analysis, it is assumed that two different periods between the present and the future. Between 2000-2019 and 2020-2040 periods will be compared. 200-2019 is called Period I, and 2020-2040 is called Period II.

The analysis begins by multiplying the monthly average value by the number of rainy days to get the monthly rainfall on obtaining the climate change value. The next step is to average the monthly rainfall over the 20 years, between 2000-2019 and between 2020-2040. Furthermore, calculating the changes that occurred between Period I and Period II with the equation: \( \text{Change} = \frac{\text{Period II} - \text{Period I}}{\text{Period I}} \). Positive (+) indicates an increase in rainfall and temperature, a negative (-) shows a decrease in rainfall.

2.3.2. Landuse change. Temporal and spatial land-use changes were analyzed by integrating remote sensing. Analysis using Geographic Information Systems (GIS) proved efficient and low cost [13]. Land cover change analysis is carried out in four stages, starting from pre-image processing using Landsat 7 imagery in 2000 and Landsat 8 imagery in 2020. The next step is to interpret the Landsat imagery. Interpretation of Landsat images begins with a composite band, then digitizes it using the visual manual method. Land cover classification is determined based on patterns and characteristics, namely hue, colour, and image texture. An accuracy test carries out the results of land use interpretation. Accuracy is a comparison between the results of image classification with an existing condition in the field. The accuracy testing process is called overall accuracy with the following equation.
Overall Accuracy Calculation = \( \frac{X}{N} \times 100\% \)  

where:
X: The corresponding number of points
N: The sum of all points

2.3.3. Land conditions. Land conditions were identified by predicting erosion rates using the USLE (Universal Soil Loss Equation) method. The factors in predicting erosion using the USLE method consist of rainfall, soil type, slope, and land use. The USLE method has been detailed in Minister of Forestry Regulation No. P.32/MENHUT-II/2009 concerning Procedures for the Technical Plan for the Rehabilitation of Forest and Watershed Lands (RTKRHL-DAS) [14]. The USLE Method equation is stated as follows:

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

A: amount of land loss (ton/ha/year)
R: rain erosivity factor
K: soil erodibility factor
LS: length and slope factor
C: vegetation cover factor and crop management
P: land management factor/soil conservation action

2.3.4. Sustainable agriculture land directives. The direction for sustainable agricultural land is based on land conditions in the Saddang watershed. Land conditions that show a heavy level of erosion and very heavy are directed at some vegetative treatment. This treatment maintains land conditions to reduce the possibility of greater erosion.

3. Results and discussion

3.1. Rainfall projection 2040
Climate change projection 2040 used the general circulation model (GCM) of CSIRO Mk3-6-0. Based on the Merra Satellite data, the average rainfall in the Saddang watershed in the period 2000 to 2019 is 209.46 mm/month. Rainfall projection results in 2040 indicate that the overall monthly rainfall in the Saddang watershed has fluctuated. Graph of the average monthly rainfall in the 2000-2019 period and climate projection in 2040 is presented in figure 2.

Climate projections show an increase in rainfall, especially at the beginning of the rainy season, October to January. Decrease in rainfall during the dry season from July to September. In addition, there was also a decrease in rainfall from February to April (wet month), but there was an increase after that, May and June.

Rainfall projection data for 2040 shows an increase in rainfall which will have an impact on the land. Climate change is changing farmers’ cropping patterns which can start in October. Based on differences in rainfall in the future, the farming community must adapt to selecting types of plants and mitigation activities by making water storage a source of water entering the dry season. Climate change mitigation involves setting plant species and creating a seasonal crops combination, fruit trees, and timber in agroforestry systems. The construction of water storage is also a climate change mitigation activity to overcome the dry season's decreasing rainfall [9].
3.2. Landuse change

Land cover change is the observable biophysical cover on the earth's surface. The land cover also represents human regulation, activity and treatment on the earth's surface. Land use and land cover are substantially different even though they describe the earth's surface's physical condition [15]. Land use and land cover are aspects that are dynamic over time. It is a picture of human activities in utilizing natural resources [5].

The interpretation of Landsat imagery, followed by a ground check, indicates 14 types of land use/land cover in the Saddang watershed. The results of the land use/land cover 2020 classification were then tested for accuracy. An accuracy test is performed to determine the data's confidence level from the interpretation land use/land cover obtained based on the overall accuracy equation. The number of sample points following the field's actual situation is divided by the total number of sample points (figure 3 and table 1). The results will show the level of accuracy of land use/land cover interpretation performed.
Based on Accuracy testing with overall accuracy, the confusion matrix table shows 68 points corresponding between sample points and conditions in the field, while 6 points do not correspond. The interpretation accuracy results of land use/land cover obtain the value of 91.89%, which shows that the classification results can be acceptable [15]. Accuracy of land use/cover interpretation provides
legitimacy to use. Land use/land cover change in Saddang Watershed can be seen in table 2, table 3, and figure 4.

Table 2. Landuse/land cover in 2000 dan 2020.

| No  | Type of Land Use/Land Cover                  | Area (ha) 2000 | Area (%) 2000 | Area (ha) 2020 | Area (%) 2020 | Difference 2000-2020 (ha) |
|-----|---------------------------------------------|----------------|---------------|----------------|---------------|--------------------------|
| 1   | Airport                                     | 60.64          | 0.01          | 60.64          | 0.01          | -                        |
| 2   | Primary Dryland Forest                      | 48,787.10      | 7.37          | 48,761.78      | 7.37          | -25.32                   |
| 3   | Secondary Dry Land Forest                   | 109,348.15     | 15.95         | 105,547.01     | 15.95         | -3,801.14                |
| 4   | Plantation Forest                           | 1,467.23       | 0.22          | 104.68         | 0.02          | -1,362.55                |
| 5   | Meadow                                      | 44,466.50      | 6.71          | 41,797.37      | 6.31          | -2,669.13                |
| 6   | Orchard                                     | 481.25         | 0.07          | 6,155.41       | 0.93          | 5,674.16                 |
| 7   | Settlement                                  | 2,273.66       | 0.34          | 7,221.10       | 1.09          | 4,947.44                 |
| 8   | Dryland Agriculture                         | 7,612.16       | 1.15          | 40,972.62      | 7.20          | 33,360.50                |
| 9   | Dryland Agriculture Mixed in Bush           | 282,255.25     | 42.64         | 235,982.77     | 35.65         | -46,272.48              |
| 10  | Rice Fields                                 | 44,468.96      | 6.72          | 64,534.56      | 9.75          | 20,065.60                |
| 11  | Shrubs                                      | 111,885.60     | 16.90         | 100,750.23     | 15.22         | -11,135.37              |
| 12  | Pond                                        | 4,497.75       | 0.68          | 4,497.54       | 0.68          | -0.02                   |
| 13  | Open field                                  | 1,077.12       | 0.16          | 587.82         | 0.09          | -489.30                 |
| 14  | Water                                       | 3,264.59       | 0.49          | 3,331.87       | 0.50          | 67.28                   |

Total Area (ha) 661,926.96

Table 3. Landuse/land cover change in 2000 dan 2020.

| Code LC | Land Cover 2000 | Land Cover 2020 | Total |
|---------|-----------------|-----------------|-------|
| LC 1    |                 |                 | LC 1  |
| LC 2    | 0.00            |                 | 0.00  |
| LC 3    | 45.782.24       | 2,089.84        | 47.95 |
| LC 4    | 2,681.09        | 95,873.71       | 1,302.15 |
| LC 5    | 1,041.68        | 1,041.68        | 1,041.68 |
| LC 6    | 56.77           | 105,252.85      | 20.33 |
| LC 7    | 2,173.66        | 1,196.63        | 1,196.63 |
| LC 8    | 352.30          | 1,041.68        | 1,041.68 |
| LC 9    | 254.77          | 1,041.68        | 1,041.68 |
| LC 10   | 546.84          | 3,331.87        | 3,331.87 |
| LC 11   |                 | 4,497.54        | 4,497.54 |
| LC 12   | 47.24           | 0.00            | 47.24 |
| LC 13   | 0.00            | 0.00            | 0.00  |
| LC 14   | 23.37           | 56.77           | 56.77 |
| Total   | 0.00            | 661,926.96      | 661,926.96 |

LC 1: Airport
LC 2: Primary Dryland Forest
LC 3: Secondary Dryland Forest
LC 4: Plantation Forest
LC 5: Meadow
LC 6: Orchard
LC 7: Settlement
LC 8: Dryland Agriculture
LC 9: Dryland Agriculture Mixed in bush
LC 10: Rice Fields
LC 11: Shrubs
LC 12: Pond
LC 13: Open Field
LC 14: Water
Figure 4. Land cover/land-use change (a) 2000 (b) 2020.

Land-use change indicates a significant increase in agricultural land, starting from rice fields and dryland agriculture. Increasing rice fields and agricultural land converted from dryland agriculture mixed in the bush. It shows that the community is more intensive in expanding land for agriculture in the Saddang watershed. Clearing land for agriculture is one of the community's choices to fulfill their daily needs due to food demand and increased population [14].

Apart from agricultural land, a significant increase occurred in settlements. The increase in settlements is more than double what it was in the early 20th century. The increase in settlements is the impact of the increasing population. Central Bureau of Statistics and National Planning Agency Republic Indonesia [16] stated that in 2045 the projection of Indonesia's population would experience a very high population growth (24.7%).

3.3. Agricultural land conditions

The land is a physical environment consisting of climate, relief, soil, water and vegetation, and objects on top of it as long as there is an influence on land use, including human activities. Erosion is one of the parameters to determine land's criticality because it describes the damage to the soil's physical and chemical properties [17]. Erosion is the event of transporting soil or other soil parts from one place to another by natural media. Erosion factors in the form of erosivity, erodibility, slope, and land cover/use (figure 5) are overlaid. Land conditions by knowing the erosion level in the Saddang watershed are focused on agricultural land ranging from plantations, dryland agriculture, dry land mixed with shrubs, and rice fields. The condition of agricultural land in the form of erosion levels can be seen in table 4 and figure 6.
Figure 5. Erosion factors, (a) erosivity (b), erodibility, (c) slope, and (d) land cover/land use.
Table 4. Erosion classification in agricultural land in 2020.

| Land cover/land use          | Erosion Levels (ton/ha/year) |       |       |       |       | Total  |
|------------------------------|------------------------------|-------|-------|-------|-------|--------|
|                              | I (< 15 ton) | II (15-60) | III (60-180) | IV (180-480) | V (> 480) |       |
| Orchard                      | 1,049.39     | 14.43      | -        | -       | -        | 1,063.82 |
| Dryland Agriculture          | -             | 4,265.35   | 15,472.89| 16,551.09| 11,958.13| 48,247.45|
| Dryland Agriculture Mixed in Bush | -       | 11,996.95 | 40,260.08| 113,642.74| 71,613.15| 237,512.92|
| Rice Fields                  | 64,680.47    | 559.87     | -        | -       | -        | 65,240.33 |
| **Total Area (ha)**          | 65,729.86    | 16,836.59  | 55,732.97| 130,193.83| 83,571.28| 352,064.53|

Based on table 4, most dryland agriculture and dry land mixed with shrubs have a high erosion level. The level of heavy erosion is influenced by high rainfall, topography, and open agricultural land. Managing agricultural land problems varies widely, starting from sloping land to erosion [18]. Saddang watershed is dominated by steep slopes and hilly to mountainous landforms. The soil erosion rate on sloping agricultural land between 3-15% is high [19]. It is exacerbated by the conditions of open and homogeneous agricultural land. High erosion impacts land users’ negligence in applying soil and water conservation principles [19].

3.4 Sustainable agricultural land directive
The condition of agricultural land in the Saddang watershed is in the very bad category 60% of agricultural land is heavily eroded. In the future, this condition will be exacerbated by higher rainfall. It will also lead to increased erosion. It is an essential concern to keep agricultural land sustainable.
According to the community's habits around the Saddang watershed, actions to overcome severe erosion levels are agroforestry planting system. Agroforestry systems can be land use application that can solve ecological problems and overcome food problems [11]. Saddang watershed, which has steep land conditions and hills, requires an agroforestry system combined with alley cropping techniques and planting in the contour's direction. The combination of conservative techniques with alley cropping is an alternative for agricultural land in the upstream watershed to control erosion [20].

The agroforestry system is a land-use pattern characterized by multi strata of vegetation with a combination of trees, fruit crops and seasonal crops. The system broadly creates buffer conditions in land use patterns. Besides, agroforestry produces biomass that can increase carbon stocks in the soil. Furthermore, it will reduce the release of CO₂ into the atmosphere so that the increase in air temperature decreases. The combination of agroforestry with alley cropping contributes to increased carbon stocks in the soil [21]. The direction of sustainable agricultural land using agroforestry systems addresses land degradation and supports climate change mitigation actions.

4. Conclusions
The projected rainfall in 2040 has fluctuated from month to month in the Saddang watershed. Climate change is characterized by an increase in rainfall which will affect land. The increase in rainfall occurs at the beginning of the rainy season, from October to January, while during the dry season, the rainfall decreases, from July to September. Climate change is changing farmers' cropping patterns which can start in October. Meanwhile, there must be mitigation activities by constructing water storage as a water source entering the dry season. Climate change mitigation is also carried out by selecting plant types with a combination of seasonal crops, fruit trees, and timber as an agroforestry system.

Land-use change indicates that there has been a significant increase in agricultural land into rice fields, dryland agriculture, and agricultural land use has been converted from dry land agriculture mixed in the bush. The communities around the Saddang watershed have intensified their agriculture. Besides, it is also encouraged by an increase in population, which stimulates growth in food demand.

Most of the land conditions of dryland agriculture and dryland agriculture mixed bush farming have heavy erosion rates. The slope conditions that cause heavy erosion are rather steep, steep, and very steep and have high rainfall. It is exacerbated by very open agricultural land and more homogeneous. In maintaining sustainable agricultural land, vegetative techniques do not require large costs to reduce heavy erosion. The vegetative technique applied in the Saddang watershed is agroforestry with a combination of alley cropping and planting in the contour's direction. Agroforestry systems are also sustainable as a pattern of land use to mitigate climate change.

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