The Effect of Changes in Land Cover on Total Sediment Yield in Peusangan Watershed, Aceh Province

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Abstract. The watershed is an area above or higher than a river whose topographical boundaries cause water to flow into the same river. The river flow carries sediment particles that potentially cause silting of the estuary area. The sediment carried by the river flows from the erosion process that occurs in the watershed. Changes in land cover potentially affect the rate of sediment export to rivers due to changes in surface roughness and water infiltration rate to the ground. This study aims to identify the effect of the land cover change on the total sediment yield from the Peusangan Watershed, Aceh Province. The sediment yield is calculated from the erosion rate and the sediment delivery ratio. The erosion rate is modeled using the revised universal soil loss equation, while the sediment delivery ratio is calculated based on the function of the watershed area. From the results of the calculation, in general, the rate of erosion is at a very level where the average erosion rate in 1995 is 26,715 tons/ha/year, in 2005 it is 26,886 tons/ha/year, in 2015 it is 24,959 tons/ha/year and in 2018 amounted to 26,771 tons/ha/year. With a sediment delivery ratio value of 0.180, the total sediment yield was 1,083,148.20 tons in 1995, 1,090,047.94 tons in 2005, 1,011,920.71 tons in 2015, and 1,085,398.35 tons in 2018. The identification results show that the changes in land cover affect the total sediment yield that comes out of the watershed.

Keywords: soil, erosion rate, sediment, modelling

1. Introduction

1.1. Background

Watersheds are defined as areas above rivers whose topographical boundaries make water flow into the river [1]. The environmental dynamics of watersheds and coastal areas are strongly influenced by climate change and rapid land changes [2]. Land cover is a line that describes the boundary of the sixfold cover area above the earth's surface consisting of landscapes and/or artificial landscapes [3]. Land cover and its changes will affect the rate of erosion and sedimentation of a watershed because land cover will determine the rate of erosion as a result of the speed of rainwater falls. The speed at which rainwater falls will slow down when it hits vegetation or canopy before it hits the ground so that the erosion generation force is reduced. [1]. Changes in land cover that occur in upstream watersheds,
especially in forest areas will make the land open, degraded and critical so that it will be easily eroded.

[4] Changes in land cover in the watershed area will affect hydrological characteristics such as erosion and sedimentation of the watershed [5]. The conversion of land from forest to open land is a very influential factor in the increasing rate of erosion that occurs in watersheds [6].

Changes in land cover significantly affect sediment exports to rivers as a result of changes in surface roughness, water-to-soil infiltration rates and hydraulic links to watersheds [7]. Sediment exports can be described as the amount of sediment from the source location that actually reaches the catchment outlets that can be in the form of dams, reservoirs, and river estuaries. Sediment export can be determined from soil erosion at the source land surface as a result of rainwater runoff as a sediment delivery process based on land connectivity [8]. Therefore, the effect of land cover changes on sediment exports can be divided into two parts: the influence on sediment sources and the influence on sediment delivery. Previous research on watersheds indicated that sediment exports were influenced by changes in land cover, soil and water conservation measures, and anthropogenic activities [9].

The effects of climate change and land cover change led to changes in the environmental dynamics of watersheds and beaches, for example, affecting temporal and spatial patterns of sedimentations [10], higher soil loss in areas with high rainfall and runoff variability [11], coastal flooding, and submerged coastal and estuary areas [11]. However, studies on the potential impact of land cover changes on watershed interactions and coastal dynamics are still limited, especially in terms of changes in coastline and maritime boundaries due to watershed sedimentation.

Potential changes in maritime boundaries can cause significant legal problems related to sedimentation in watersheds due to climate change. The United Nations Convention on the Law of the Sea (UNCLOS) does not explicitly mention the normal baseline, and maritime boundaries will change due to coastal dynamics, such as through watershed sedimentation, coastal erosion, and sea level rise [12]. However, legal experts interpret that normal baselines may change as a result of environmental changes caused by human activity or [12]. In addition, UNCLOS allows areas formed by coastal dynamics to claim maritime zones, if the shoreline changes due to erosion and sedimentation according to the definition of an island that naturally forms a land area and is above water at high tide [12].

1.2. Purpose
Based on the background, the purpose of this study is to identify the effect of land cover changes on the amount of annual sediment exported (total sediment export rate) of Peusangan watershed through the implementation of spatial models of erosion processes. From this purpose, it is lowered into the following objectives:

- Detect changes in land cover that occurred in the Peusangan Watershed area for 4 periods, namely in 1995, 2005, 2015 and 2018.
- Estimating the rate of erosion in Peusangan Watershed with variations in land cover for 4 periods namely 1995, 2005, 2015 and 2018. The result of the estimated erosion rate will be presented in the form of spatial distribution map of erosion rate in Peusangan Watershed.
- Calculate the sediment delivery ratio (SDR) based on watershed area function and estimate the total sediment export rate and the total sediment yield of Peusangan Watershed for 4 periods (1995, 2005, 2015 and 2018).
- Identify the effect of land cover changes on changes in total sediment yield.

2. Method

2.1. Location
This research was conducted in Peusangan Watershed, Aceh Province, Indonesia as shown in Figure 1. Peusangan Watersheds are in the coordinate range of 4°30'00” North Latitude (N) to 5°17'30” N and 96°27'00” East Longitude (E) to 96°27'00” E. Peusangan Watershed has upstream rivers located in
mountainous areas and crosses five districts/cities until finally reached the sea Bireun. The upstream river is located in Lake Laut Tawar, Central Aceh Regency, while the river network flows through the administrative areas of Bener Meriah, North Aceh, Bireuen, and Lhokseumawe. The area of Peusangan watershed reaches 238,550 hectares. The length of the main river from Lake Laut Tawar to the Bireuen coast reaches 128 kilometers. The area around Peusangan Watershed is dominated by dense forests. The main upstream of Peusangan watershed is in the Gayo Plateau in Takengon City while the estuary is in the Strait of Malacca in Bireuen Regency [13].

![Figure 1. Peusangan Watershed boundary map](image)

2.2. Data
In this study, data is needed that determines the results of this study. The data used is secondary data. Here's the data used in this study:

a. Digital Elevation Model data
Digital elevation model (DEM) data is used to define topography, watershed boundaries, river order, as well as observation area characteristics. The data information is obtained from dem data degradation results. Dem data used is DEM HydroSHEDS data with a horizontal resolution of 90
meters and a vertical resolution of 1 meter. DEM HydroSHEDS is an improvement of DEM SRTM (Shuttle Radar Topography Mission). The final data quality of HydroSHEDS products has not been systematically evaluated but regional comparisons with other global hydrographic data sets support the following conclusions [14]: (1) HydroSHEDS shows much better accuracy than other global river network representations derived from altitude data. This is because the underlying DEM is superior; HydroSHEDS is a clear improvement of HYDRO1k (an earlier global hydrographic data set and widely used at a resolution of 1 km) [14]. (2) HydroSHEDS tends to show better accuracy compared to the 1:1 million Digital Chart of the World mapping product hereinafter referred to as DCW (VMAP-0); however, the accuracy of both data sets varies by location. On some areas of HydroSHEDS are very prone to errors, such as floodplains are veering, DCW quality can be superior to HydroSHEDS. (3) As a global product, HydroSHEDS does not achieve the accuracy of high-resolution local river networks (e.g., those described on the 1:50,000 national hydrographic map). Recommended to further improve the quality of HydroSHEDS through the incorporation of local information [14].

b. Rainfall data

Rainfall data obtained from the official page of the University of Santa Clara from global circulation modeling (GCM): IPSL-CM4 with each pixel has a coverage of 0.5 degrees latitude-longitude. GCM rainfall data: IPSL-CM4 has a relatively high correlation compared to field size data from several locations in the world with a Pearson correlation coefficient of 0.85 [15].

c. Land cover data

Land cover data are classified into 22 classes with reference United Nations Food and Agriculture Organization's (UN FAO) Land Cover Classification System (LCCS) from Copernicus, a spatial resolution of 300 meters. Land cover data used is land cover data in 1995, 2005, 2015, and 2018. Land cover data in 1995, 2005, and 2015 have overall accuracy of 71.45% [16], while land cover data in 2018 has overall accuracy of 70.82% [17].

d. Soil type data

Soil type data from Soilgri with classification system World Reference Base for Soil Resources 2006 (WRB 2006) which has a spatial resolution of 250 meters with overall accuracy of 70% [18].

2.3. Erosion Rate

The rate of erosion is the mass rate of soil or rock particles raised from their source caused by a force. In this study the value of erosion rate will be calculated using the equation of revised universal soil loss equation (RUSLE) for the estimated amount of soil loss in the entire watershed area [19]. The RUSLE equation is an empirical model for calculating the soil that is detached from the source. The RUSLE equation is the result of an improvement of the USLE equation developed by Renard [20].

RUSLE equations and USLE equations take into account climate factors (erosiveness of rainfall), soil (soil erodibility), topography, land cover, and land conservation practices prepared within the scope of geographic information systems hereinafter referred to as GIS. Improvement of RUSLE equation to USLE equation is to change the energy factor of rainwater blow (rainfall energy factor) into erosive factor of precipitation in lifting soil particles or rocks due to collision with rain granules and surface flow that transports soil particles as a surface flow factor (runoff factor) as a function of surface flow volume and peak surface flow rate (peak runoff rate). Here is the RUSLE equation used to calculate the erosion rate value [19]:

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

where:

\(A\) = rate of erosion,
\(R\) = annual rainfall erosive factor,
\(K\) = soil type erodibility factor,
\( C = \) land cover factor,  
\( LS = \) slope length and slope factor, and  
\( P = \) factors of land conservation practices.

Erosion rate calculation is done by overlaying the constituent factors and then conducting spatial analysis on raster data in the form of mathematical operations on rasters. The raster pixel value of each constituent factor is reclassified into the rated value of each factor based on the division of each class. After reclassifying, then a mathematical operation is performed on raster data using spatial analysis. The erosion rate modeling results are divided into 5 (five) classes that are very low, low, medium, heavy and very heavy [21]. The division of the erosion rate class can be seen in Table 1.

| Class Division  | \( A \) (ton/Ha/year) |
|-----------------|------------------------|
| Very Light      | <15                    |
| Light           | 15-60                  |
| Medium          | 60-180                 |
| Heavy           | 180-480                |
| Very Heavy      | >480                   |

Source: Ministry of Environment and Forestry, 2017

Erosive factor of annual rainfall (\( R \)) states the physical influence of precipitation that causes erosion. The influence of fisking occurs when the falling raindrops pound the soil causing the soil particles to peel off so that they are carried away by the flow of groundwater. Equation 2 displays the equation in the calculation of erosive factors based on annual rainfall compiled by DHV Consulting Engineers [22]. DHV Consulting Engineers states the formulation of the calculation of precipitation erosive factors in the following equations:

\[
R = 2.21P^{1.36}
\]

where:  
\( P = \) annual rainfall (mm).

Erodibility factor (\( K \)) states the properties of the soil, namely infiltration, permeability, and soil capacity in holding water. These properties affect the durability of the structure at the time of receiving erosion from the fall of rain grains as well as the erosion of the surface [23]. Wischmeier & Smith states that the erodibility factor is the rate of erosion of each unit of erosion index of a soil or rock on a standard experimental homogeneous plot with a length of 72.6 feet (22 meters) and located on a slope that has a slope of 9% without plants [20]. The value of the erodibility factor used in this study can be seen in Table 2.

| Soil Type | ID | \( K \) |
|-----------|----|--------|
| Acrisol   | 0  | 0.26   |
| Andosol   | 3  | 0.26   |
| Grumosol  | 6  | 0.26   |
| Latosol   | 10 | 0.23   |
| Fluvisol  | 11 | 0.20   |
| ID  | Soil Type       | K    |
|-----|----------------|------|
| 12  | Gleysol        | 0.20 |
| 14  | Histosol       | 0.31 |
| 17  | Lixisol        | 0.20 |
| 22  | Plinthosol     | 0.26 |

Source: Kartasapoetra, 1991 in Asdak, 2010

The land cover factor (C) states the relationship between the amount of land eroded on land cover in the form of a certain type of crop with erosion that occurs on land that is not covered by vegetation [24]. C values range from 0 to 1. The value of C that is getting closer to the value of 1 indicates that the easier the soil or rock is eroded with the relatively barren surface of the soil. While the value of C that is getting closer to the value of 0 indicates that the soil is increasingly difficult to erode because of the presence of plants that cover the soil so that the soil has a stronger defense against erosion. The value of land cover factors used in this study can be seen in Table 3.

### Table 3. The value of the land cover factor.

| ID  | Types of Land Cover                                                                 | C   |
|-----|------------------------------------------------------------------------------------|-----|
| 10  | Cropland, raingrains                                                              | 0.005 |
| 11  | Herb cover                                                                         | 0.002 |
| 12  | Tree or bush cover                                                                 | 0.003 |
| 20  | Agricultural land, irrigation or post-flood                                        | 0.005 |
| 30  | Mosaic of cropland (> 50%) / natural vegetation (trees, shrubs, cover plants) (<50%) | 0.002 |
| 40  | Mosaic of natural vegetation (trees, shrubs, cover plants) (> 50%) / agricultural land (<50%) | 0.002 |
| 50  | Tree cover, broad-leaved, year-round green, covered to open (> 15%)                 | 0.003 |
| 150 | Sparse vegetation (trees, shrubs, cover plants) (<15%)                              | 0.005 |
| 170 | Tree cover, waterlogged, salt water                                                | 0.001 |
| 190 | Urban area                                                                         | 0.0007 |
| 210 | Body of water                                                                      | 0.0001 |

Source: Trahan, 2003

Slope factor and slope length (LS) consists of constituent components in the form of slope length and slope. The length of the slope is the length of the slope measured from where the water flow begins to its outlet. The slope is the slope level of a slope expressed in the degree of angle of the slope or percent [1]. Calculation of LS factor can be derived from digital elevation model data (DEM) that no longer has sinks. Here are the equations for LS calculation compiled by Wischmeier & Smith [20]:

\[ L_S = \left( \frac{L}{K} \right)^m \left( k_1 \sin^2 s + k_2 \sin s + k_3 \right) \]  \hfill (3)

with:
- \( m = 0.2 \) for \( 0 \leq s < 1 \)
- \( m = 0.3 \) for \( 1 \leq s < 3 \)
- \( m = 0.4 \) for \( 3 \leq s < 4.5 \)
- \( m = 0.5 \) for \( s \geq 4.5 \)

where:
- \( L \) = slope length on DEM surfaces greater than 122 meters,
- \( m \) = slope index,
- \( s \) = percent slope, and
$k$ = empirical constants.

Conservation practice factor ($P$) is human action in soil management. Factor $P$ states the relationship of the amount of land eroded on land with conservation actions and without conservation action on the land [24]. The $P$ factor can be derived from the slope value of the land. The value of conservation practice factors can be seen in Table 4.

| Slope (%) | $P$  |
|-----------|-----|
| 9-12      | 0.6 |
| 13-16     | 0.7 |
| 17-20     | 0.8 |
| 21-25     | 0.9 |
| >25       | 0.95|

Table 4. Value of Conservation Practices

Source: Abdulrahman, 1981 in Asdak, 2010

Calculation of erosion rate is done by overlaying the constituent factors and then spatial analysis of raster data in the form of mathematical operations on raster. The study will focus on land cover change schemes for estimated erosion rates. Estimated erosion rate values are done in a time step using land cover data in 1995, 2005, 2015, and 2018 while other data (rainfall, soil type, topography) using data in 2018.

2.4. Sediment Delivery Ratio

SDR is a comparison between the number of particle masses eroded throughout the watershed region and the number of particle masses carried out of the watershed system through watershed outlets. SDR values range from 0 to 1. An SDR value that is closer to the value of 1 indicates that almost all the eroded particles are carried out of the watershed system. Similarly, the SDR value is getting closer to the value of 0, indicating that almost all the eroded particles are not caught out of the watershed system. The calculation of SDR value is derived from watershed area function using SDR equation which is the result of processing 300 watersheds [26]. The following formula is used to calculate the SDR value of Vanoni [26]:

$$ SDR = 0.4724 A^{-0.125} $$

where:

$A = \text{Watershed area (km}^2)$.\]

2.5. Total Sediment Yield

The annual erosion rate only shows how many soil particles or rocks are chipped from the source. Eroded soil or rock particles will be moved by water flow through the slopes of the watershed and the channel system. Sedimentary particles will be deposited or deposited on the slopes of the watershed or channel system, so that sediment particles that come out to the watershed outlet will usually be much less than the number of eroded particles. To calculate how many sediment particles reach the outlet of a watershed system can be done by calculating the total erosion rate with SDR. Here is the equation used to calculate the total sediment yield ($Y$):

$$ Y = A \cdot SDR $$

where:

$Y = \text{sediment yield}$,
$A$ = erosion rate, and
$SDR$ = sediment delivery ratio.

2.6. Research Flow Chart
The steps of the research conducted can be seen in Figure 2 below,

Figure 2. Research flow chart

3. Results and Discussion
3.1. Land Cover Changes
Land cover in Peusangan Watershed changes with increasing time. To see the land change in Peusangan Watershed, land cover was chosen in 1995, 2005, 2015, and 2018. The selection of land cover in those years caused by the availability of land cover data from Copernicus which has a spatial
The addition of the area of a type of land cover is identified in Table 6 with the percentage change value in the form of a positive number and the reduction of the area of a type of land cover in the form of a negative number. A change in the area of a type of land cover can occur due to converting a type of land cover into another type of land cover.

| ID  | Types of Land Cover                                                   | Area (ha)          |
|-----|-----------------------------------------------------------------------|--------------------|
|     |                                                                       | 1995    | 2005    | 2015    | 2018    |
| 10  | Cropland, raindrops                                                   | 3,753.0 | 3,951.0 | 4,059.0 | 4,059.0 |
| 11  | Herb cover                                                            | 2,772.0 | 2,844.0 | 3,924.0 | 4,050.0 |
| 12  | Tree or bush cover                                                    | 29,304.0| 30,285.0| 34,605.0| 36,981.0|
| 20  | Agricultural land, irrigation or post-flood                           | 81.0    | 72.0    | 81.0    | 81.0    |
| 30  | Mosaic of cropland (> 50%) / natural vegetation (trees, shrubs, cover plants) (<50%) | 27,108.0| 23,346.0| 21,141.0| 21,285.0|
| 40  | Mosaic of natural vegetation (trees, shrubs, cover plants) (> 50%) / agricultural land (<50%) | 34,866.0| 34,326.0| 38,457.0| 39,816.0|
| 50  | Tree cover, broad-leaved, year-round green, covered to open (> 15%)   | 109,746.0| 112,068.0| 104,382.0| 100,422.0|
| 150 | Sparse vegetation (trees, shrubs, cover plants) (<15%)               | 234.0   | 369.0   | 549.0   | 549.0   |
| 160 | Tree cover, inundated with water, fresh water or brackish water      | 225.0   | 297.0   | 387.0   | 369.0   |
| 170 | Tree cover, waterlogged, salt water                                   | 225.0   | 216.0   | 261.0   | 234.0   |
| 190 | Urban areas                                                           | 252.0   | 288.0   | 495.0   | 495.0   |
| 210 | Body of water                                                         | 5,454.0 | 5,697.0 | 5,679.0 | 5,679.0 |

| ID  | Types of Land Cover                                                   | Percentage (%) |
|-----|-----------------------------------------------------------------------|----------------|
|     |                                                                       | 1995 | 2005 | 2015 | 2018 | 1995-2005 | 2005-2015 | 2015-2018 |
| 10  | Cropland, raindrops                                                   | 1.75 | 1.85 | 1.90 | 1.90 | 0.09 | 0.05 | 0.00 |
| 11  | Herb cover                                                            | 1.30 | 1.33 | 1.83 | 1.89 | 0.04 | 0.50 | 0.06 |
| 12  | Tree or bush cover                                                    | 13.69| 14.17| 16.17| 17.28| 0.48 | 2.00 | 1.11 |
| 20  | Agricultural land, irrigation or post-flood                           | 0.04 | 0.03 | 0.04 | 0.04 | -0.004| 0.004 | 0.00 |
| 30  | Mosaic of cropland (> 50%) / natural vegetation (trees, shrubs, cover plants) (<50%) | 12.67| 10.92| 9.88 | 9.95 | -1.74 | -1.04 | 0.07 |
| 40  | Mosaic of natural vegetation (trees, shrubs, cover plants) (> 50%) / agricultural land (<50%) | 16.29| 16.06| 17.97| 18.60| -0.23 | 1.91 | 0.63 |
From 1995 to 2005, the largest change in land cover occurred in the type of land cover in the form of mosaics of agricultural land (>50%) with natural vegetation (trees, shrubs, cover plants) (<50%) which decreased by 1.74% of the total area of Peusangan Watershed or an area of 3,762.0 hectares. From 2005 to 2015, the largest land cover changes occurred in the type of land cover in the form of broad-leaved and green trees throughout the year from closed to open (>15%) reduced by 3.66% of the total area of Peusangan Watershed or an area of 7,686.0 hectares. From 2015 to 2018, the largest land cover changes occurred in the type of land cover in the form of broad-leaved and green trees throughout the year from closed to open (>15%) which is reduced by 1.85% of the total area of Peusangan Watershed or an area of 3,960.0 hectares. To facilitate in identifying changes in land cover that occurred in the Peusangan Watershed, a percentage graph of land cover in 1995, 2005, 2015, and 2015 is presented in Figure 3.
3.2. Erosion Rate

Erosion rate value obtained from all input parameters in the calculation of erosion rate with RUSLE equation mentioned earlier, obtained erosion rate value in Peusangan Watershed in 1995, 2005, 2015, and 2018. In 1995, the average rate of erosion obtained was 26.715 tons/ha/year and the number of soil particle mass eroded as much as 6,018,193.66 tons where the amount of soil particle mass obtained from the average value of erosion rate multiplied by the area of watershed. In 2005, the average rate of erosion obtained was 26.886 tons/ha/year and the amount of soil particle mass eroded as much as 6,056,530.05 tons. In 2015, the average erosion rate obtained was 24.959 tons/ha/year and the number of eroded particle masses as much as 5,622,439.11 tons. In 2018, the average erosion rate obtained was 26.771 tons/ha/year and the number of eroded particle masses as much as 6,030,695.97 tons. The average rate of erosion and the number of eroded particle masses in 1995, 2005, 2015, and 2018 are presented in Table 7.

Table 7. Average and total erosion in 1995, 2005, 2015, and 2018

| Year | Average (ton/ha/year) | Total Erosion (tons) |
|------|-----------------------|----------------------|
| 1995 | 26.715                | 6,018,193.66         |
| 2005 | 26.886                | 6,056,530.05         |
| 2015 | 24.959                | 5,622,439.11         |
| 2018 | 26.771                | 6,030,695.97         |

The estimated erosion rate is classified into 5 (five) classes i.e. very light, light, medium, heavy and very heavy [21]. From the average rate of erosion in Peusangan Watershed, in general the level of erosion hazard is in a light class based on the Ministry of Environment and Forestry [21]. The rate of severe erosion is generally located in areas with soil types in the form of latosol soil and andosol soil, the topography of steep slopes more than 25%, rainfall of 2,786.89 mm/year, and types of land cover in the form of agricultural land both rainy and agricultural land irrigation or post-flood and types of land cover in the form of rare vegetation (trees, shrubs, cover plants) (<15%). Figure 4 showing the spread of erosion rates in the Peusangan Watershed in years (a) 1995, (b) 2005, (c) 2015, and (d) 2018.
**Table 8.** Area and percentage rate of erosion rate

| Class      | Area (ha) | Percentage (%) |
|------------|-----------|----------------|
|            | 1995      | 2005 | 2015 | 2018 | 1995 | 2005 | 2015 | 2018 |
| Very Light | 139,604.20 | 139,129.90 | 143,765.00 | 139,519.70 | 62.74 | 62.53 | 64.61 | 62.70 |
| light      | 64,639.15  | 64,988.96  | 61,690.69  | 64,677.53  | 29.05 | 29.21 | 27.72 | 29.07 |
| keep       | 3,317.77   | 3,349.38   | 3,011.02   | 3,233.88   | 1.49  | 1.51  | 1.35  | 1.45  |
| heavy      | 1,200.08   | 1,200.08   | 1,068.53   | 1,187.11   | 0.54  | 0.54  | 0.48  | 0.53  |
| Very Heavy |           |         |         |         |       |       |       |      |

**Figure 4.** Erosion rate spread in Peusangan Watershed
3.3. Total Sediment Yield

In 1995 the total mass of eroded soil particles amounted to 6,018,193.66 tons, in 2005 as much as 6,056,530.05 tons, in 2015 as much as 5,622,439.11 tons, and in 2018 as much as 6,030,695.97 tons. However, the amount of mass of sediment yield coming out of the watershed system will be much less than the number of eroded soil particles [6]. The total sediment yield mass coming out of the watershed system is calculated by multiplication between the amount of erosion and the SDR. Since the SDR value will be fixed each year, the total sediment yield mass will be directly proportional to the number of masses of eroded soil particles. From the calculation, the amount of mass sediment yield obtained in 1995 amounted to 1,083,148.20 tons, in 2005 amounted to 1,090,047.94 tons, in 2015 amounted to 1,011,920.71 tons, and in 2018 amounted to 1,085,398.35 tons as stated in Table 9.

| Year | Total Erosion (tons) | SDR | Total Sediment Yield (tons) |
|------|----------------------|-----|-----------------------------|
| 1995 | 6,018,193.66         | 0.180 | 1,083,148.20               |
| 2005 | 6,056,530.05         | 0.180 | 1,090,047.94               |
| 2015 | 5,622,439.11         | 0.180 | 1,011,920.71               |
| 2018 | 6,030,695.97         | 0.180 | 1,085,398.35               |

To test the quality of modeling in this study, validation of modeling results is required against field size data. Due to the unavailability of field size data, the modeling quality in this study was conducted by comparing similar studies that have been validated against field size data. The modeling results from this study that were tested are the results of sediment yield estimates in 2018 with consideration of rainfall data used is rainfall in 2018 so that it is more in accordance with the actual conditions. The sediment yield value used as a comparison in this study is the sediment yield value of Krueng Aceh Watershed [28], Citarum Hulu Watershed [6], Cipunagara, Cimanuk, and small watersheds between Cipunagara and Cimanuk Watersheds. The comparison of the area and the total sediment yield between Peusangan Watershed and the comparison watershed are listed in Table 10.

| Watershed         | Area (km²) | Sediment Yield (x 10⁶ tons/year) |
|-------------------|------------|----------------------------------|
| Peusangan Watershed | 2,252      | 1.1                              |
| Cimanuk           | 3,660      | 9.8                              |
| Cipunagara        | 1,436      | 3.6                              |
| Upper Citarum     | 1,771      | 2.1                              |
| Krueng Aceh       | 1,734      | 2.4                              |
| Small Watershed   | 1,564      | 1.4                              |

From Table 10, it can be identified that the total sediment yield coming out of the Peusangan Watershed system is smaller than other watersheds that are comparators, but close to sediment yield from the comparison watershed and also equally in order of one million tons per year. The result of smaller sediment yield is caused by differences in research years and conditions between Peusangan Watershed and comparison watersheds. The difference in years and conditions causes differences in input parameters for erosion rate calculation. From the comparison result, the result of this smaller sediment yield is due to the input parameter in the Peusangan Watershed is smaller than the parameter.
input in the comparison watershed. In Figure 5, sediment yield between the Peusangan Watershed and the comparator watersheds is presented.

![Comparison of Watersheds Area and Sediment Yield](image)

**Figure 5.** Graph comparing the area of watershed with the total sediment yield from each watershed

### 3.4. Changes in Land Cover and Its Effect on The Total sediment yield

The correlation coefficient and determination coefficient ($R^2$) is used to see the relationship between changes in land cover to changes in the total sediment yield. Land cover and sediment yield in 1995 as a baseline in calculating changes that occurred in 2005, 2015, and 2018. In this calculation, changes in land cover are made independent variables and affect erosion rates that indirectly affect the value of the total sediment yield. From the calculation result, obtained correlation value of 0.9987 which is interpreted to have a very strong unidirectional relationship rate because it is a positive value and is in the range of 0.800 - 1.000 [29]. In more detail, the results of correlation values can be seen in Table 11, with linear regression obtained the value of the coefficient of determination ($R^2$) of 0.9979 as stated in Figure 6.

| Year       | Land Cover Factor | Sediment Yield | Correlation |
|------------|-------------------|----------------|-------------|
| 1995 - 2005| 0.6370            | 0.5842         |             |
| 1995 - 2015| -6.5760           | -5.9393        | 0.9987      |
| 1995 - 2018| 0.2078            | -0.1193        |             |
Figure 6. Linear regression results

With the correlation results that show the level of a direct and very strong relationship, it can be interpreted that if there is a change in the land cover, then there is a change in the direction of the total sediment yield. From the value of the coefficient of determination ($R^2$) which is close to the value of 1(one), it can be interpreted that the change in the number of land cover factor values affects the occurrence of changes in the total sediment yield. This is supported by the identification of changes in land cover and the total sediment yield that indicates where the total sediment yield increases when there is a change from land cover with strong defense against erosion to land cover with weak defense against erosion. In contrast, the total sediment yield decreases when there is a change from land cover with weak defenses against erosion to land cover with strong defenses against erosion.

In the period between 1995 and 2005, there was an increase in the number of sediment yields by 6,899.74 tons and at the same time there was a change in land cover such as reduced Mosaic of natural vegetation (trees, shrubs, cover plants) (> 50%) / agricultural land (<50%) by 0.23%, reduced Mosaic of cropland (> 50%) / natural vegetation (trees, shrubs, cover plants) (<50%) by 1.74%, Increased Tree cover, broad-leaved, year-round green, covered to open (> 15%) by 1.15%, increased Cropland, raindrops by 0.09%, increasing sparse vegetation (trees, shrubs, cover plants) (<15%) by 0.06% and increasing Tree or bush cover by 0.48% of the total area of Peusangan Watershed as stated in Table 6. Changes in land cover make soil defense from erosion becomes weaker, this can be seen from the value of land cover factors where the higher the value of the land cover factor, the weaker the defense from erosion so that more and more soil is eroded and cleared into sediment yield. Land cover in the form of Mosaic of natural vegetation (trees, shrubs, cover plants) (> 50%) / agricultural land (<50%) as large and land cover in the form of Mosaic of cropland (> 50%) / natural vegetation (trees, shrubs, cover plants) (<50%) has a land cover factor value of 0.002, increasing the cover of Tree cover, broad-leaved, year-round green, covered to open (> 15%) has a land cover factor value of 0.003, and land cover in the form of agricultural land has a greater land cover factor value of 0.005.

In the period between 2005 and 2015, there was a decrease in the amount of sediment yield by 78,127.23 tons and at the same time there was a change in land cover such as reduced Mosaic of cropland (> 50%) / natural vegetation (trees, shrubs, cover plants) (<50%) by 1.04%, reduced cover of Tree cover, broad-leaved, year-round green, covered to open (> 15%) by 3.66%, Increased mosaic of
natural vegetation (trees, shrubs, cover plants) (>50%) / agricultural land (<50%) by 1.91%, increased herbaceous cover by 0.50%, increased tree or bush cover by 2.00%, and increased urban area by 0.10% of the total area of Peusangan watershed. In this period, the interesting thing happened, namely the type of land cover with large land cover factor values such as Mosaic of cropland (>50%) / natural vegetation (trees, shrubs, cover plants) (<50%) and Tree cover, broad-leaved, year-round green, covered to open (> 15%) which has a land cover factor value of 0.003 actually reduced in large numbers and types of land cover with smaller land cover factor values such as Mosaic of natural vegetation (trees, shrubs, cover plants) (>50%) / agricultural land (<50%) which is 0.002, herb cover with a land cover factor value of 0.002, and urban areas with a land cover factor value of 0.0007 actually increases. The increase in the type of land cover with a small land cover factor value makes the soil defense against erosion stronger so that the amount of soil that is eroded and covered into sediment yield is reduced.

In the period between 2015 and 2018, there was an increase in the amount of sediment yield of 73,477.64 tons and at the same time there was a change in land cover such as reduced Tree cover, broad-leaved, year-round green, covered to open (> 15%) by 1.85%, reduced cover of trees inundated by fresh water or brackish water by 0.01%, reduced Tree cover, inundated with water, fresh water or brackish water by 0.01, increased Tree or bush cover by 1.11%, and increased Mosaic of natural vegetation (trees, shrubs, cover plants) (>50%) / agricultural land (<50%) by 0.63% of the total area of Peusangan Watershed as stated in Table 6. In this period, there was a decrease in the area of land cover types with the value of small land cover factors and an increase in the area of land cover types with the value of large land cover factors. Land cover in the form of Tree cover, inundated with water, fresh water or brackish water has a land cover factor value of 0.001, while tree or bush cover and land cover in the form of mosaics of natural vegetation (trees, shrubs, cover plants) (>50%) / agricultural land (<50%) has a greater land cover factor value of 0.003 for tree or shrub cover and 0.002 for land cover in the form of natural vegetation (trees, shrubs, cover plants) (>50%).

4. Conclusion

Land cover in Peusangan Watershed within a period of 23 years from 1995 to 2018 has changed both the addition and reduction of the area of a land cover. From 1995 to 2005, the most significant changes occurred in the type of land cover in the form of mosaics of agricultural land (>50%) with natural vegetation (trees, shrubs, cover plants) (<50%) which decreased by 1.74% of the total area of Peusangan Watershed or an area of 3,762.0 hectares. From 2005 to 2015, the largest land cover changes occurred in the type of land cover in the form of broad-leaved and green trees throughout the year from closed to open (>15%) decreased by 3.66% or an area of 7,686.0 hectares. From 2015 to 2018, the largest land cover changes occurred in the type of land cover in the form of broad-leaved and green trees throughout the year from closed to open (>15%) 1.85% or an area of 3,960.0 hectares.

Peusangan Watershed in general has a light erosion rate based on the Ministry of Environment and Forestry. In 1995, the average erosion rate was 26.715 tons/ha/year. In 2005, the average erosion rate was 26,886 tons/ha/year. In 2015, the average erosion rate was 24,959 tons/ha/year. In 2018, the average erosion rate was 26,771 tons/ha/year. The low level of erosion is influenced by land cover conditions dominated by the type of land cover that inhibits erosion, soil types in the form of latosol soil that is somewhat sensitive to erosion, moderate rainfall, and topography conditions with steep slopes followed by ramps. Although topographic conditions are dominated by steep slopes, other factors have an impact in reducing the potential for erosion in Peusangan Watersheds.

The result of erosion rate in Peusangan Watershed directly affects the total sediment yield that comes out of the watershed system and reaches the Peusangan Watershed outlet. With an SDR value of 0.180 from the SDR calculation based on the decrease in watershed area, sediment export rate from Peusangan Watershed is generally in normal class according to Mulyanto, 2006 [30]. From the rate of sediment exports, the amount of sediment yield is obtained that changed from year to year. Pin 1995 amounted to 1,083,148.20 tons, then in 2005 increased to 1,090,047.94 tons, then in 2015 reduced to 1,011,920.71 tons, and in 2018 increased to 1,085,398.35 tons. The total sediment yield in Peusangan
Watershed is less than the total sediment yield from Krueng Aceh Watershed, Citarum Hulu Watershed, Cipunagara Watershed, Cimanuk Watershed, and small watersheds between Cipunagara Watershed and Cimanuk Watershed. Sediment yield is smaller due to the difference in the year and condition of each watershed so that the input parameters in the Watershed Peusangan is smaller than the input parameters in the comparison watershed.

Changes in the value of land cover factors and changes in the total sediment yield resulted in a correlation value of 0.9987 and a coefficient of determination of 0.9979. The value indicates the level of direct and very strong relationship that can be interpreted that if there is a change in land cover, then the total sediment yield will change in the same direction. This is supported by the identification results that show that the total sediment yield increases during the change from land cover with strong defense against erosion to land cover with weak defense against erosion. In contrast, the total sediment yield decreases when there is a change from land cover with weak defenses against erosion to land cover with strong defenses against erosion. From the correlation value and the results of the identification can be concluded that the change in land cover that occurred affects the total sediment yield that comes out of the watershed system and reaches the outlet of the Peusangan Watershed.

5. Suggestion
This study still has many shortcomings related to data as well as from methods. The results of this study have not been validated with field size data and are only compared to the results of other similar studies. Of these shortcomings, here are some suggestions for further research:

- To test the quality of modeling, it is necessary to validate the input data as well as the modeling results. Verification is done to determine the condition and character of the actual study area. Verification is also done to compare the results of modeling, namely the total sediment yield with the results of measurements in the field.
- Better use of resolution data can be done to improve the quality of modeling results.
- To better know the changes in land cover, it can be identified each change in land cover so that land changes can be identified more clearly rather than just detected.
- The estimated SDR value can be replaced by calculations based on the physical process of transporting sediment that occurs on the slopes of watersheds and river channel systems. Calculations based on physical processes will give better results because each pixel has different factors and will result in different SDR values for each pixel.

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There is no perfection in the world, so it is with the results of this study because perfection belongs only to Allah SWT. The author hopes that this research can be useful for readers in adding to the characteristics of science. Finally, the author humbly accepts constructive criticism and suggestions in order to be an improvement for future research.
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