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Land Cover Changes and Its Effect to Sediment Growth in Cacaban Reservoir, Tegal District, Central Java Province, Indonesia

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Abstract. This research aims to determine changes in land covers and its effects on the growth of sediment in Cacaban Reservoir, Kabupaten Tegal, Jawa Tengah. Descriptive method with random sampling is used to determine land cover changes and purposive sampling is used to determine water sampling on 3 inlets and water body. Remote sensing analysis with multi temporal data are used to identify land cover changes using supervised classification method and sediments growth using TSS spectral transformation method by Budiman to determined sediment growth. The result indicates dry land farming became the largest land cover in 1990, dry land farming growth in 2000, it's shrinks and mixed garden was growth with rubber trees and jati trees in 2010. And jati trees became dominant and changed into forest in 2015. The land covers change followed by TSS. From 1990 until 2010, TSS was stable on water body but growth in inlets and shrink in 2015.

1. Introduction

Geomorphology is a discourse on earth forms and it is the study of earth's physical land surface features. Many geomorphic processes affect, and are affected by, human activities that responsible for landform development. Process geomorphology have contributed to the investigation of worrying problems associated with the human impacts on landscape. In environmental planning, it is considered the interaction between geomorphology and public policies that contributions on rural land-use and soil erosion, urban land use, slope management, and policy formulation. Environmental change associated with global warming may well increase of natural hazards of geomorphic origin, landslides and debris flows may become more common, soil erosion may become more severe and sediment load of some rivers increase. Water, vegetation, crops, and so on as natural resources effected by and become worrying aspect of global warming [1].

Land cover including natural resources and variety of buildings as an ecological status become worrying aspect of global warming that change due to human interventions ([1], [2]). The impact of human activity on the landscape has increased at an accelerating rate, especially since the introduction of modern farming techniques and the creation of new features in the landscape include reservoirs formed by the construction of dams [3]. Agriculture and the construction of settlements cause dramatic changes in land use, and its make greatly change the susceptibility of the land surface to erosion and led to some dramatic change in the quantity of sediment being transported by rivers in areas affected. Human activities affect land used change ([2], [4], [5], [6], [7]). Human activities increased agriculture area [2] and increased settlement areas [7]. It's have major cause of land cover change without fundamental change to the farming systems [4], which lead to further degradation of water quality [5]. Therefore, forest land cover can be used as a predictor [8].

Improper land use caused soil degradation [9]. Catchment area that dominated by agriculture activities causes soil degradation [8]. Soil erosion has been considered as one of the most influential causes of land degradation due to losses of surface soil [10]. As a result of erosion, numbers of sediment will increase [6].

Land use, which relates to land cover, is one of the influential factors that affect soil erosion [10]. Land use design which is less attention to land condition will guide damage to the hydrological system, including water quantity and quality [7]. Runoff and sediment loss decrease as the percentage of vegetation cover increases. It verifies that vegetation and land use become important factors controlling erosion [11].

Sedimentation is the entry of sediment load and suspended in the water body [6]. Suspended solid carried by all streams under natural conditions [12]. However, if concentrations are increased will lead to changes of water quality, such as infilling of channels and reservoir when solids are deposited, higher cost of water treatment, decreased longevity of dams and reservoirs ([6], [12]).

Remote sensing is a technology to obtaining information about an object, phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation [13]. Digital land use and land cover change detection is the process of determining and describing change in land cover and land use properties based on remote sensing data [14]. Manual study for measured sediments take a long-time period ([15], [16]). One of the monitoring of sedimentation in remote sensing used TSS algorithm in water body [16].

This study aims to determine changes in land cover and its effects on the growth of sediment in Cacaban Reservoir, Tegal District, Central Java.

2. Methods

Geomorphology is a discourse on earth forms and it is the study of earth's physical land surface features. Many geomorphic processes affect, and are affected by, human activities that responsible for landform development. Process geomorphology have contributed to the investigation of worrying problems associated with the human impacts on landscape. In environmental planning, it is considered the interaction between geomorphology and public policies that contributions on rural land-use and soil erosion, urban land use, slope management, and policy formulation. Environmental change associated with global warming may well increase of natural hazards of geomorphic origin, landslides and debris flows may become more common, soil erosion may become more severe and sediment load of some rivers increase. Water, vegetation, crops, and so on as natural resources effected by and become worrying aspect of global warming [1].

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2.1. Pre- Image Processing

- Image Geometric Correction
  The geometric correction of Landsat images uses Ground Control Point (GCP) that acquired from survey data. The coordinate system used is Universal Transverse Mercator 49 South Zone with World Geodetic System 1984 (WGS 1984) as reference.
- Image Radiometric Correction
  The radiometric correction of Landsat image use method from Landsat handbook that changing digital number value to radiance value and then change it to reflectance value.
  The algorithm converting DN value to radiance value:

$$L_\lambda = \left(\frac{L_{max} - L_{min}}{Qcal_{max} - Qcal_{min}}\right) \times (Qcal - Qcal_{min}) + L_{min} \quad (1)$$

Where:
L_λ : Spectral Radiance at the sensor's aperture
Qcal : The quantized calibrated pixel value in DN
L_{max} : Maximum value of spectral radiance
L_{min} : Minimum value of spectral radiance
$Qcal_{max}$: Maximum pixel value referring to L_{max}
$Qcal_{min}$: Minimum pixel value referring to L_{min}

The algorithm converting radiance value to reflectance value:

$$\rho_p = \frac{\pi \times L_\lambda \times d^2}{ESUN_\lambda \times cos\theta_S} \quad (2)$$

Where:
ρ_p : Unit less planetary reflectance
L_λ : Spectral radiance at the sensor's aperture
d : Earth–Sun distance value
$ESUN_\lambda$: Mean solar spectral irradiances
θ_s : Solar zenith angle

2.2. Land Cover Changes

Supervised classification used to analyze land cover change in catchment area. It is a classification method that gives guidance to the computer in the process that requires training area which represents specific classes. The training areas can be used as the basis during classification process for similar and identical image [2]. The land covers classes that are used in this study as in Table 1.

Table 1. The description of land cover classes

No.	Land Cover Class	Description
1.	Rice field	Land planted with rice, cultivated throughout the season for irrigation rice field and on rainy season for rain-dependent rice field due to waterlogged requirement to grow rice.
2.	Dry land Farming	This class describe an area where crop cultivation depends on rainfall. Crops are usually short-term rotation plants such as corn, soybeans, vegetables, etc.
3.	Mixed Garden	This class includes area which area planted with hardwoods and fruits.
4.	Forest	Refers to areas dominated with vegetation (primary and secondary forest) and stand structure was filled with large and dense canopy.
5.	Barren land	Non-vegetated areas or areas of very little vegetation cover where substrate of soil exposure is clearly apparent.
6.	Settlement	Land covered with buildings, either permanent or semi-permanent. This group includes residential, offices, schools, public facilities, roads and industries.
7.	Water body	This class describes areas that are entirely covered by water, such as reservoirs.

2.3. Sediment Growth
TSS algorithm by Budhiman was adopted to analyze sediment growth in reservoir. The model itself was adopted from a model developed in Mahakam Delta ([16], [17], [18]).

$$TSS\ (mg/l) = A * \exp(S * R(0\text{-})\ \text{red band}) \qquad (3)$$

Where:
TSS : Total suspended solid
R(-0) : Irradiance reflectance

Based on model, TSS algorithm for each satellite image data are represented in Table 2.

Table 2. TSS algorithm

Image	Algorithm
Landsat 5	TSS (mg/l) = 8.2054 * $\exp^{(23.769 * \text{red band})}$
Landsat 8	TSS (mg/l) = 8.1429 * $\exp^{(23.704 * \text{red band})}$

3. Results and Discussion

3.1. Land Cover Change
Maximum likelihood method was used in supervised classification technique. The classification test result of Landsat image using confusion matrix obtained overall accuracy and the kappa coefficient as shown in Table 3.

Table 3. Overall Accuracy and Kappa Coefficient Result

Image	Overall Accuracy	Kappa Coefficient
1990	86.11%	0.8282
2000	90.28%	0.8783
2010	93.06%	0.9128
2015	93.06%	0.9131

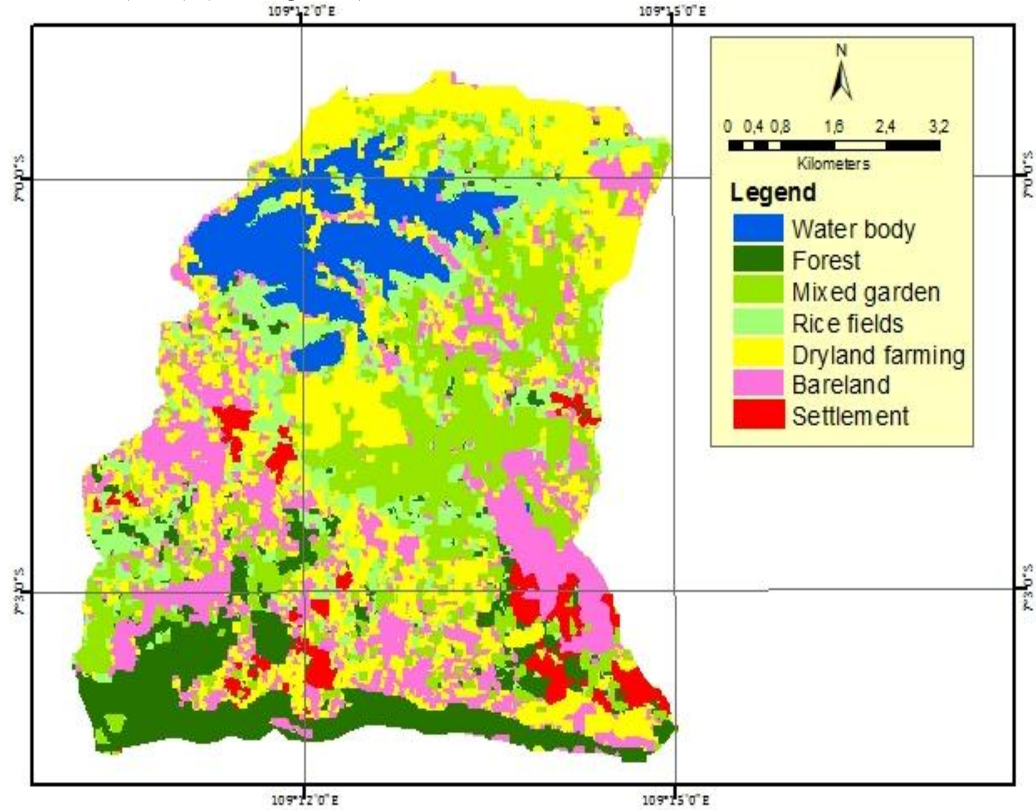
The classification indicates good classification because the overall accuracy above 85% and Kappa coefficient above 0.81.

3.1.1. Land cover area in 1990–2015. Land cover in catchment area of Cacaban Reservoir divided into 7 classes including rice fields, dry land farming, mixed garden, forest, barren land, settlement and water body. The dominant land cover class of 1990–2015 varies, as shown in Table 4.

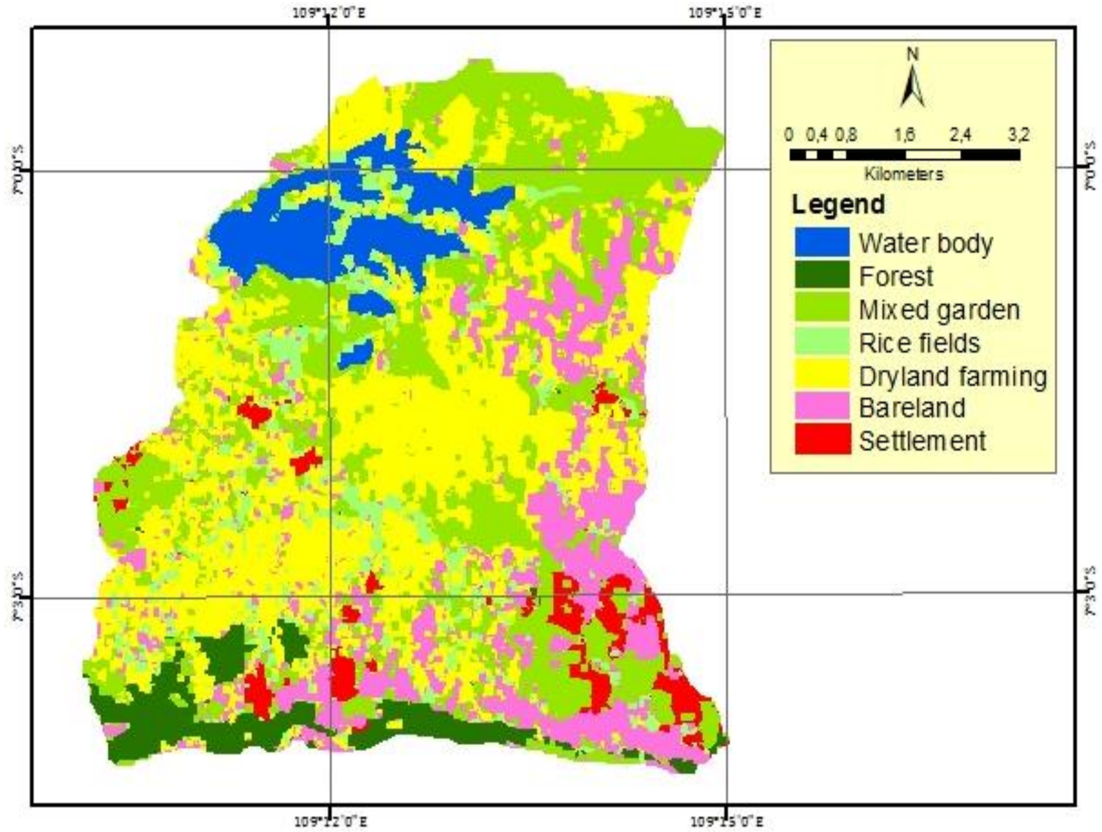
Table 4. Land cover area in 1990–2015

Land Cover	1990		2000		2010		2015	
	ha	%	ha	%	ha	%	ha	%
Rice fields	807.39	13.26	470.22	7.72	331.96	5.45	756.52	12.42
Dry land farming	1,569.89	25.77	2,048.58	33.63	1,949.78	32.01	871.64	14.31
Mixed garden	1,163.75	19.11	369.56	6.07	1,602.58	26.31	294.81	4.84
Forest	700.70	11.50	325.16	5.34	341.10	5.60	2,348.14	38.55
Barren land	1,121.66	18.41	893.95	14.68	976.41	16.03	984.94	16.17
Settlement	197.81	3.25	211.44	3.47	233.90	3.84	254.61	4.18
Water body	530.42	8.71	411.90	6.76	655.41	10.76	580.49	9.53
TOTAL	6,091.16	100.00	6,091.16	100.00	6,091.16	100.00	6,091.16	100.00

In 1990, land cover was dominated by dry land farming (26%) with area 1,569.89 ha and mixed garden with area 1,163.75 ha (19%). In 2000, dry land farming grew 2,048.58 ha and still dominated (43%) the catchment area. In 2010, dry land farming shrink 1,949.78 ha (32%) and mixed garden grew (26%) with total area of 1,602.58 ha. In 2015, forest grew and became dominant land cover with total area 2,348.14 ha (39%) (See Figure 1).



(a)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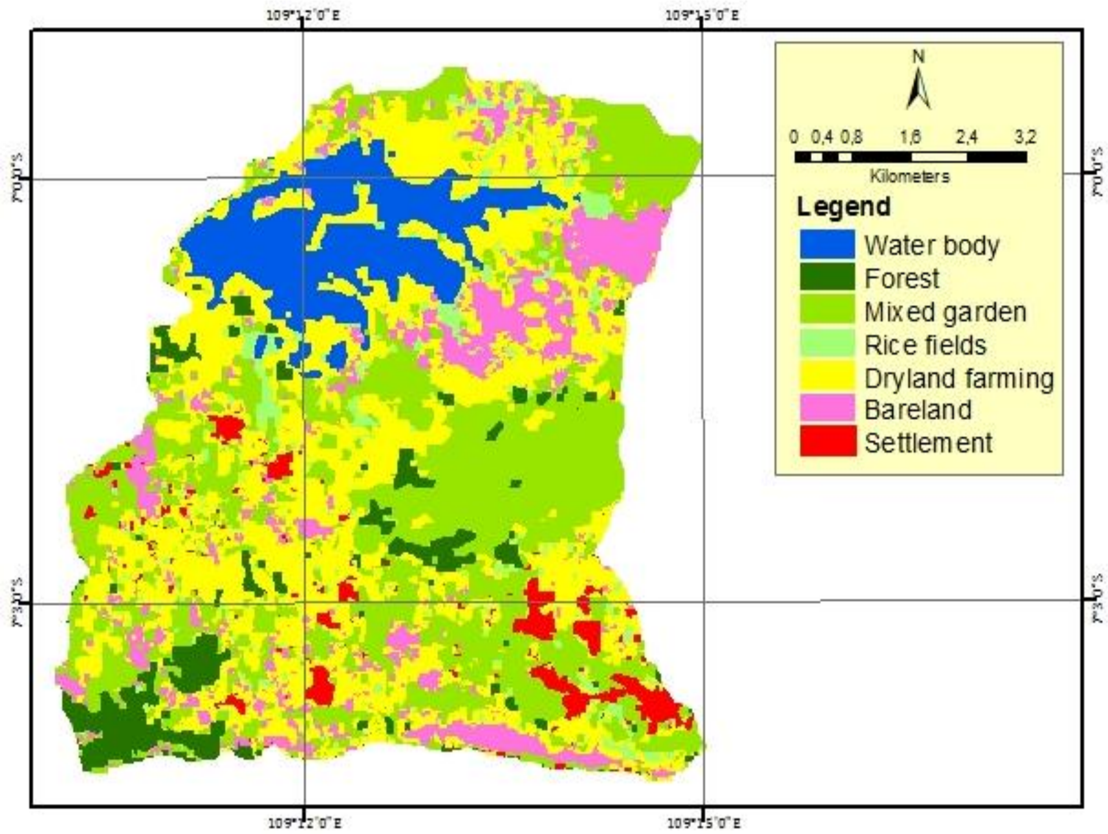
Water body
Forest
Mixed garden
Rice fields
Dryland farming
Bareland
Settlement

(b)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Mixed garden
Rice fields
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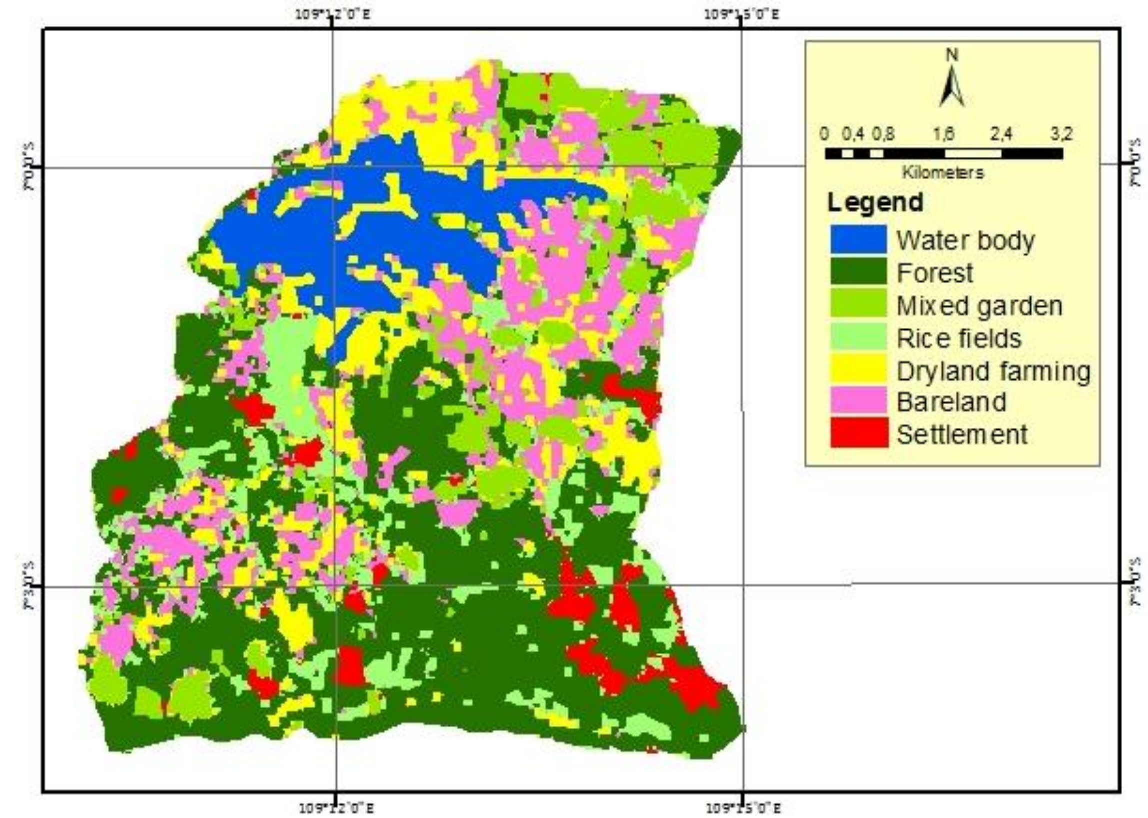

(d)

Figure 1. (a) Land cover map of 1990; (b) Land cover map of 2000; (c) Land cover map of 2010; (d) Land cover map of 2015

3.1.2. Rate of land cover change 1990–2015. During the period 1990–2015 there was a change of land cover in the Cacaban Reservoir. Area that initially had a certain land cover turned into other types of land cover with high rate of addition and substantial reduction (See Table 5).

Table 5. Total land cover change 1990–2015

Land Cover	Year		Change	
	1990	2015	Ha	%
Rice fields	807.39	756.52	-50.87	-6.30
Dry land farming	1,569.89	871.64	-689.25	-43.90
Mixed garden	1,163.75	294.81	-868.94	-74.66
Forest	700.70	2,348.14	1,647.44	235.11
Barren land	1,121.66	984.94	-136.72	-12.19
Settlement	197.81	254.61	56.80	28.71
Water body	530.42	580.49	50.07	9.44

During the period 1990–2015, rice fields, dry land farming, mixed garden, and barren land has decreased but forest and settlements has increased. The forest experienced the greatest change in the research area during the period because jati tree were planted since 2010.

3.2. Sediment Growth

According to Budhiman [17] condition of TSS from satellite image recording is not influenced by season. In 1990, the lowest TSS value of 50.5 mg/l and the highest TSS 192.2 mg/l. In 2000, the lowest TSS value of 65.9 mg/l and the highest TSS 194.8 mg/l. In 2010, the lowest TSS was 47.4 mg/l and the highest TSS was 251.8 mg/l. In 2015, the lowest TSS score of 46.6 mg/l and the highest TSS 559.3 mg/l. (See Figure 2).

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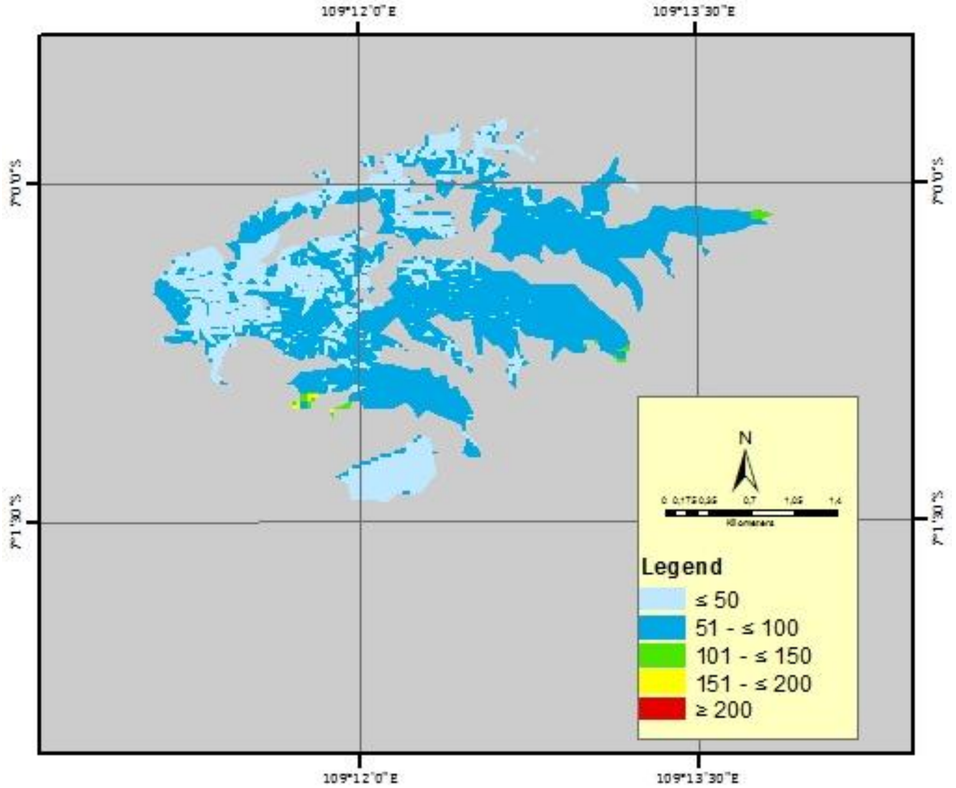
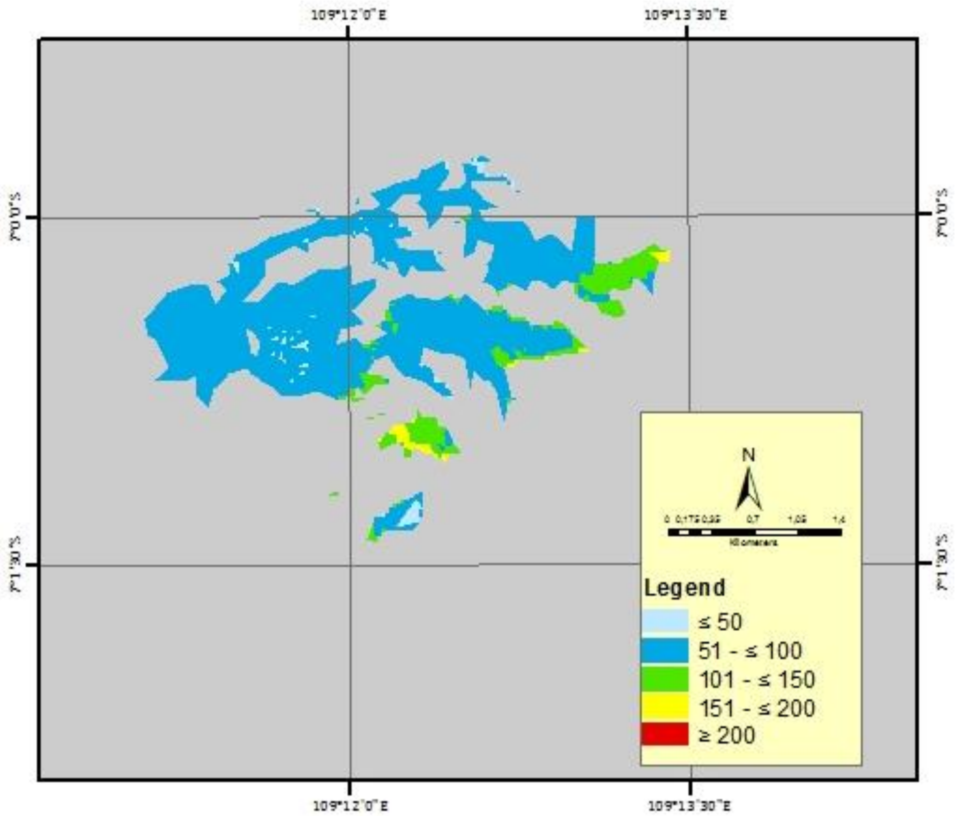
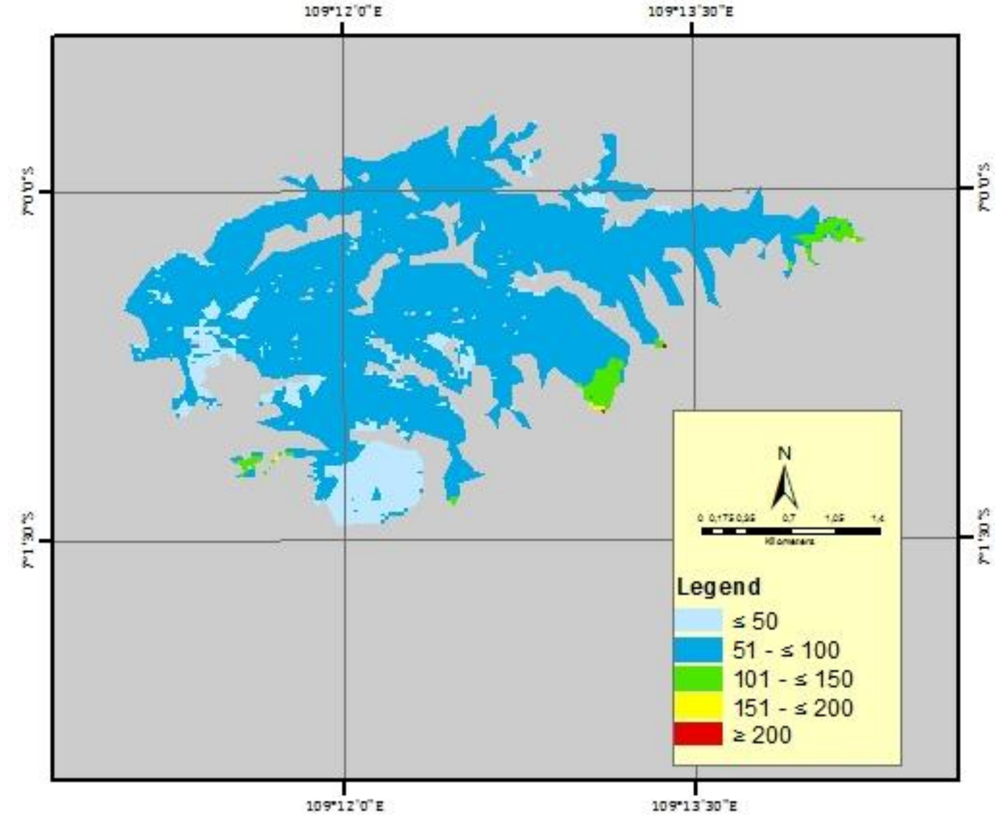


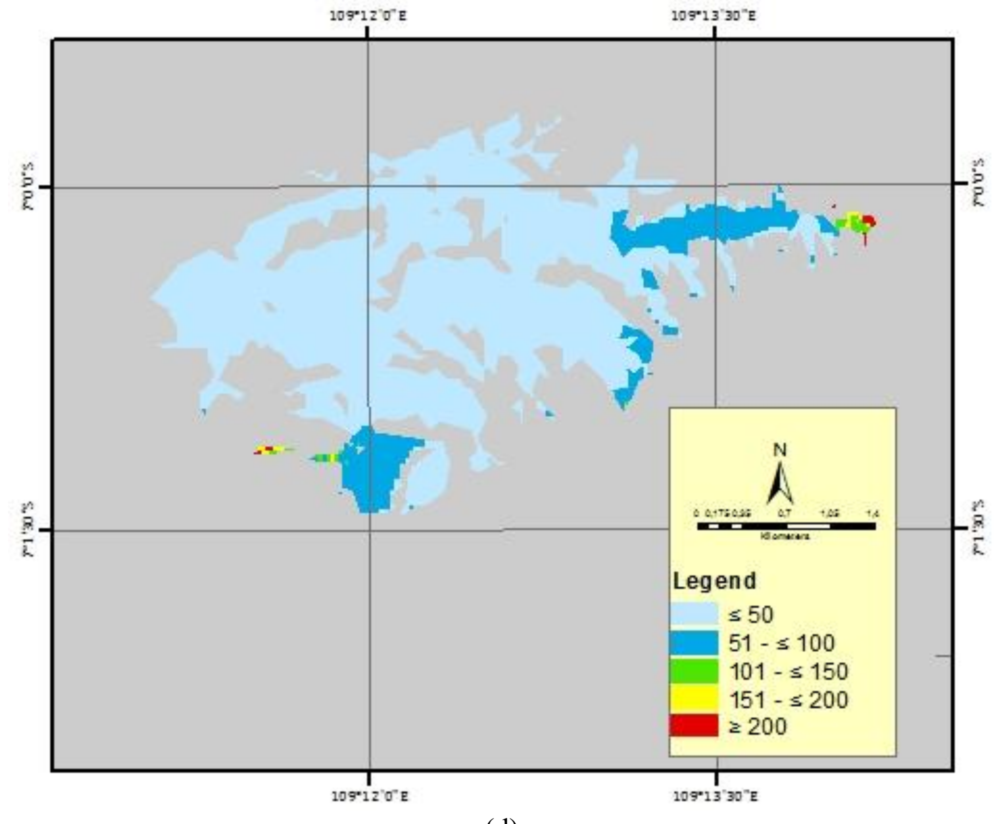
(a)



(b)



(c)



(d)

Figure 2. (a) TSS map of 1990; (b) TSS map of 2000; (c) TSS map of 2010; (d) TSS map of 2015

Satellite image recording results show significant TSS development. In 1990, the distribution of TSS encompassed 373.27 hectares and covered 47.25% of reservoir bodies with the highest concentration at a rather low concentration level of 51-≤100 mg/l range that spread in the west of the reservoir close to the reservoir outlet.

In 2000, the distribution of TSS increased to 514.99 hectares and covered 65.19%. It contains the same concentration as in 1990, at concentrations of 51-≤ 100 mg/l. This concentration is spread throughout the body of the reservoir. Right at the reservoir inlet at Kali Wadas, moderate sediment concentrations ranged from 101-≤ 150 mg/l and were rather high with a range of 111-≤ 200 mg/l. In the Kali Glogok inlet, moderate and moderately high sediment concentrations are found in water bodies around the inlet, precisely at the inlet boundary and inlet water bodies.

In 2010 the highest concentration of TSS occurred in the range of 51-≤ 100 mg/l reaching 625.69 hectares in the reservoir body. TSS area in the reservoir body reaches 720.14 hectares and covers 91.16% of the reservoir body.

In 2015 the TSS area decreased to 644.93 hectares and covered 81.64% of the reservoir body. The highest concentration almost in the entire body of the reservoir is a low concentration with a TSS value of ≤50 mg/l. A concentration of solids ≥ 200 mg/l can be seen in inlet Kali Wadas.

3.3. Land cover change and TSS

The land cover changes occurring in the Cacaban Reservoir have a different effect on the result of overlay of land cover map and TSS. In 1990, 47% of the reservoir body was filled with sediment. The most dominant land cover in 1990 was the dry land farming. The dry land farming in catchment area that planted with row crop technique became the main contributor to the sedimentation into the reservoir body. This result indicates that the high TSS in row crop land use that similar to Miller et al. [8].

During the period of 1990-2000, the decrease of mixed garden area and the increasing of dry land farming area brought TSS change which increased as much as 65% in the reservoir body. In the period 2000-2010 there was a change of land cover from rice fields and dry land farming to mixed garden. Although the change that occurs can be categorized as small but still has an effect on the sediment that occurs in the reservoir body and is proven by increasing TSS to 91%.

In the period 2010-2015 there was a reduction of TSS cover in the reservoir body from 91% in 2010 to 82% in 2015. The growths in forest occupy the highest change in 2015. Forest area increased since 2010, helping to reduce sediment in the reservoir. The result is consistent with that expressed by Miller et al. [8], that forest land cover had strongest influence on TSS growth.

Population growth rate in Tegal District are 0,07% [19] and based on table 5, since 1990-2015 there are increase of settlement area. According to Sihotang et al. [7] people growth that affect increased of settlement area will also affect land use change.

Stakeholders in catchment area play important role in helping and maintain the sedimentation [8]. The government of Tegal District took serious action against sedimentation that occur in reservoir, such as give warning with a billboard to not randomly chop down the trees, did some sludge dredging on the stream channel leading to reservoir, and conservation in catchment area.

The government program to reduce sedimentation in Cacaban Reservoir by planting rubber tree and jati tree proved to be a real contribution [20,21].

4. Conclusions

Satellite imagery could be used to determine changes in land cover and sedimentation growth. Land cover changes affect sediment growth in reservoir. According the result in 2015, forest area had strongest influence on sediment growth. Additional sources are needed to fulfil erosion and sediment rates and further research is needed to estimate reservoir effective time.

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