Land use cover changes and water quality of Cipunten Agung Watershed Banten

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Abstract In general, the land and natural resources utilization of Cipunteng Agung Watershed could be classified into protected and cultivated region. Based on satellite imagery classification, protected region covers 885.76 ha (22.71%), while cultivated region occupied 3,041.69 ha (77.29%) in 2011. It means that the land use and covers change (LUCC) to be cultivated rapidly increase. Those conditions had impacted positively to the local economy development, however it had negatively degrades water quality in Ciputen Agung river. Therefore, the purpose of this research is to analyze LUCC impacts to the water quality (WQ) in Cipunten Agung watershed. Supervised classification method and Water Pollution Index (WPI) approach were correlated to define the optimal solution to reduce the rate of LUCC. The result shows that area of cultivation tree and paddy field are higher than others in midstream, and settlement is higher in downstream, particularly at riparian landscapes. The concentration of total phosphate, nitrite, and nitrate which indicated from agriculture land were complies with WPI class 2 until 4 standard. The rate of LUCC of Cipunten Agung watershed and the density of settlement are potential to be the driving factor of water quality degradation. Regional planning with ecology approach was recommended for sustainable development of Cipunten Agung Watershed.

1. Introduction
Land conversion into agriculture land or settlement was occurs gradually in many watershed in Indonesia. The one of negative impact from land conversion is water quality degradation in main watershed river. The impact of Land Use Cover Changes (LUCC) to water quality has been become the main issue in several landscape architecture dan hydroecology research within a few decades, such as Kaswanto (2012), Xia (2012), and Firdaus (2013). It also occurs in Cipunten Agung Watershed, Pandeglang Regency, Banten. Downstream community continues to build dense settlements and facilities for the fishing industry without proper planning. Improper planning can bring about watershed degradation such as barren land, critical land, and slope erosion. Eventually, the degradation process can occur such as flooding in rainy season, lower water discharge and less soil humidity, forest fires in dry season, sedimentation, and water quality degradation (Directorate of Forestry and Water Resources Conservation of Indonesia).

The evaluation of LUCC and water quality has been known as the critical point in determine pollution source and watershed management. Land use cover type and water quality degradation shows significant relation [1]. Point source and non-point source pollution which become the main factor of water pollution will affect water quality [2]. The greater the percentage of man made landscape such as construction and agricultural land, the water quality
will become worse [3]. Cipunten Agung watershed environment problem become obstacles and challenge for stakeholders. Therefore, LUCC is necessary to analyze for determining the impact of its into water quality. So it can be considered on watershed management for the sustainability of landscape development.

2. Methodology

2.1 Location, tools, and materials
This study was located at Cipunten Agung watershed, Pandeglang Regency, Banten Province with coordinate of 6°17'30" to 6°22'30" Latitude and 105°50'0" to 105°55'0" Longitude, seluas 3979.9 Ha (figure 1). The tools used in this study consist of hardware, such as digital camera, GPS, and several Geography Information System (GIS) softwares. In water sampling process, this study use tools such as temperature meter, pH meter, DO meter, and water tube. Materials of this study are Landsat imagery of year 195, 2005, 2015 (table 1). Sub-district administration map, watershed boundary map, precipitation map, digital elevation model (DEM), and soil type map. Water sampling was tested by Environmental Productivity Laboratorium of Bogor Agricultural University.

Table 1. Landsat data acquisiton

| Landsat data          | Acquisition date |
|-----------------------|------------------|
| Landsat 5             | Sept 16th, 1995  |
|                       | Path 123 Row 64  |
| Landsat ETM + 7       | May 30th, 2005   |
|                       | Path 123 Row 64  |
| Landsat 8             | Sept 23th, 2015  |
|                       | Path 123 Row 64  |
| Landsat ETM + 7       | July 31th, 2004  |
|                       | Path 123 Row 64  |

Figure 1. The study area of Cipunten Agung

2.2 Method
The main method used in this study was supervised classification for LUCC analysis and Water Pollution Index for water quality analysis. Land use and cover was classified into five classes, namely water bodies, forest, cultivated tree, settlement and paddy field. Water quality parameter that used in this study are Total Suspended Solid, Total Dissolved Solid, Temperature, Dissolve Oxygen (DO), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Nitrite (NO₂), Nitrate (NO₃), Ammonium (NH₄), Phosphate (PO₄), pH, and, Total Coliform. Water quality standart threshold which used in this study following Indonesian Goverment Decree No. 82 of 2001 for classifying water quality into four classes. Water Pollution Index (WPI) analysis which used in this study, following Environmental Ministry of Indonesia decree No. 115 of 2003, with some criteria of WPI such as:
0 ≤ WPI ≤ 1.0 = not polluted,
1.0 ≤ WPI ≤ 5.0 = lightly polluted,
5.0 ≤ WPI ≤ 10. = moderate polluted,
and WPI > 10.0 = heavy polluted.
The relationship between LUCC and WPI was identified by spatial correlation between LUCC map and water sample point at radius 1 km (figure 2).

3. Result and discussion

3.1. Land use cover changes
Land Use Cover classification use classes namely, water bodies, forest, cultivated tree, settlement, and paddy field. There were 75 training area which used for accuracy test of classification. Accuracy standard that used in this classification is 75% following minimal standart of National Institute of Aeronautics and Space of Indonesia. Land Use Cover classification from Landsat Image of 1995 result (Figure 3) shows that, the widest class of land use cover is cultivated tree 2570 ha and paddy field 793.63 ha, while the smallest class is water bodies 38.98 ha or 0.98% of total area. Land utilization as cultivated tree and paddy field was intensive for daily needs supply. In 1995 at downstream, settlement area was developed 20 m near the river, which was one of inundation and flooding area.

Land Use Cover classification from Landsat Image of 2005 result (Figure 3) shows that the widest class of land use cover is cultivated tree 2286.01 ha. Cultivated tree area was decreasing while paddy field area was increasing to 969.9 ha or 24.37% of total watershed area. Settlement area not too expanded, the total area is 114.44 ha or 2.88% from total watershed area. There was a stripping landsat image problem and it solved by gap filling. The material used for gap filling was landsat imagery of 2004, with assume there was no significant LUCC in one year. Gap filling process result was added two classes of Land Use Cover such as cloud and shade. The classification result shows people tend to built residential area at downstream since 1995.

Landsat imagery of 2015 Land Use Cover classification result (Figure 5), the widest area is cultivated tree 2420.5 ha or 61.41% of watershed total area, while the smallest area is water bodies 46.69 ha or 1.19% from watershed total area. Classification in 2015 was tested with accuracy assessment of classification in 2015 result is 82.67%, more than the minimum threshold 75%. The increases of paddy field and decreases of cultivated tree occur especially at Jiput Districts (Mid stream). LUCC into paddy field many occur at 1995 to 2005 period with 591.66 ha area, while LUCC into settlement many accour at 2005 to 2015 period with 195.21 ha area.
Figure 3. Land use cover of Cipunten Agung Watershed in 1995

Figure 4. Land use cover of Cipunten Agung Watershed in 2005
3.2. Cipunten Agung water quality

Water sampling location was determined based on accessibility, watershed character, and land use cover of Cipunten Agung Watershed. Station (ST) 1 and 2 were located at the middle stream which surrounded by paddy fields, precisely at Sikulan and Bangkuyung village. ST 3, 4, and 5 were located at downstream which surrounded by settlement area, precisely at Sukawati, BTN, and Teluk village. The observation shows that, Cipunten Agung water recently was used for washing, irrigation, and livestock. Water quality sampling test result presented descriptively at Table 2 it shows the minimum, maximum, and the standard deviation of eleven parameters.

| Parameter                        | Unit   | Min  | Max   | Mean  | St.dev |
|----------------------------------|--------|------|-------|-------|--------|
| **Physics**                      |        |      |       |       |        |
| Temperature                      | °C     | 27.00| 31.90 | 28.56 | 2.11   |
| Total Suspended Solid (TSS)      | mg/L   | 9.00 | 18.00 | 13.00 | 4.24   |
| Total Dissolved Solid (TDS)      | mg/L   | 20.00| 4232.00| 1012.80| 1826.79|
| **Chemical**                     |        |      |       |       |        |
| pH                               | -      | 6.35 | 7.18  | 6.91  | 0.35   |
| Dissolved Oxygen                 | mg/L   | 4.60 | 6.90  | 5.66  | 0.99   |
| Biological Oxygen Demand         | mg/L   | 3.00 | 5.80  | 3.68  | 1.20   |
| Chemical Oxygen Demand           | mg/L   | 25.68| 35.56 | 27.91 | 4.29   |
| Total Phosphate                  | mg/L   | 0.03 | 0.35  | 0.12  | 0.14   |
| Ammonium (NH₄)                   | mg/L   | 0.01 | 0.45  | 0.11  | 0.19   |
| Nitrate (NO₃-N)                  | mg/L   | 0.18 | 0.43  | 0.33  | 0.10   |
| Nitrite (NO₂-N)                  | mg/L   | 0.01 | 0.02  | 0.01  | 0.00   |
| **Microbiology**                 |        |      |       |       |        |
| Total Coliform                   | MPN/100mL | 17000| 43000 | 29000 | 10319 |
The average value of physics parameters such as temperature and TSS are 28.56 mg/L and 13 mg/L were below the threshold of class 1 until 4. Meanwhile, the average value of TDS is 1012.8 mg/L overpass the threshold of class 3. It indicates, the Total Dissolved Solid concentration in water is still good, but its not drinkable. The average value of chemical parameter such as pH, DO, and BOD were below the threshold of class 1 until 4. pH of Cipunten Agung river is neutral from 6.35 to 7.18. DO, BOD, and COD never reach out the threshold standart. The DO concentration average is 5.66 mg/L, it indicates the water was good enough for human and aquatic organism. The BOD concentration average is 3.68 mg/L. It indicates, the biological activity in water ecosystem are still in good condition.

Another chemical parameter such as Total Phosphate, Ammonium, Nitrate, Nitrite was measured in small quantities with an average value are, 0.12; 0.11; 0.33, and 0.01 mg/L below the standart threshold from class 1 until 4. Regarding to the result, the concentration of those parameter are still in permitted level. The chemical parameter was important to analyze due to its possibility to predict the water pollution point source from agriculture land such as, chemical fertilizer, excrement, and erosion [4].

One of microbiolgy parameter is Total Coliform which has value from 17000 to 43000 and high average value 2900 MPN/100mL. That value had overpass the Total Coliform thershold standart at class 4. It indicates a high potential of pathogenic bacteria in Cipunten Agung River water. Total Coliform is a group of bacteria commonly found in the environment, e.g in soil or vegetation, mammals, including human. Coliform bacteria had small potential to become a source of disease, but the presence of these bacteria indicates that the water supply is vulnerable to contamination by the microorganism which more dangerous (www2.gnb.ca). So, its not recommended to use Cipunten Agung water for consumption.

3.3. **LUCC and water quality correlation**

The impact of LUCC to the water quality was identified by the land cover variety analysis which surrounding the sample stations in radius 1 km. Water Pollution Index analysis refers to Environmental Ministry of Indonesia decree No. 115 of 2003. In WPI calculation process, each parameter in 5 station was compared with four water quality standart. ST 1 (Figure 6) and ST 2 (Figure 7) located at middle stream, 13.77 and 7.72 km from the estuary area. In radius 1 km, ST 1 was dominated with cultivated tree and paddy field with the size of area are 150.8 ha and 141.4 ha. The result shows, ST 1 has the highest concentration of COD 35.56 mg/L, it indicates the potential of the organic material which not degraded properly, and it potentialy occur muddy areas.

ST 2 was dominated by cultivated tree and paddy field with the size of area 146.6 ha and 104.9 ha. Nitrate concentration at ST 2 was increasing, it potentialy occur by the COD and Nitrate concentration which already high at ST 1 and the extension of paddy field area at the middle stream. Nitrate concentration at agriculture land significantly higher than at the riparian area [5]. Nitrate are actually not poisonous, but if it is reduced to Nitrite then it will be toxic digestion. Nitrite is one of carciogenic tumor disease source [6]. The content of N should be considered because it can damage health. The density of cultivated tree in ST 2 has potential to provide landscape services as biofilter to reduce the concentration of COD and Nitrates in ST 1 and 2 rbelow the quality standart limits. The biofilter also potentialy reduce the level of water pollution index which from agricultural land use.
ST 3, 4, and 5 was located at downstream area, with distances 3 km; 0.68 km; and 0.14 km from the estuary area. In radius 1 km, ST 3 (Figure 8) was dominated by cultivated tree and paddy field with the size of area 220 ha and 65.9 ha, smaller than at the middle stream. The concretion of Total Phosphate and Ammonium increase to 94 % and 55 % from ST 2. Those parameter is toxic metabolites due to the presence of nitrogen which can stimulate the growth of algae (algae bloom). Algae can form a layer on the water surface and prevent the penetration of oxygen and sunlight which needs by the aquatic ecosystem. When waters contain enough phosphate, algae accumulate it inside the cell and exceed its needs, its known as over consumption [7].

Figure 6. Station 1

Settlement and industry area was intensely developed at down stream area. In radius 1 km, ST 4 (Figure 9) was dominated by cultivated tree and settlement with the size of area 79.9 and 91.6 ha. BOD concentration in ST 4 is 5.8 mg/L, its higher than others. This indicates, the oxygen decreases rapidly due to the organic material degradation. LUCC with the increases of domestic activity, agriculture, and industry will influence and impact on the water quality condition, mainly the domestic activity that will increases BOD concentration [8].

In radius 1 km, ST 5 (Figure 10) was dominated by cultivated tree and settlement area with the size of the area 71.9 ha and 88.2 ha. Nitrate and Total Coliform was decreasing 45% and 63%, while the TDS concentration was higher than other ST. The TDS concentration was 4232 mg/L, its overpass the standart threshold at 2000 mg/L. This indicates, the solid material was
dissolve rapidly and impacted the water taste. Its also indicate, the presence of toxic minerals. Environmental Protection Agency (EPA) USA suggested the maximum threshold water pollutant is 500 mg/L (500 ppm).

All stations of water samples has a high concentration of Total Coliform 17000-43000 MPN/ml overpass the standart threshold at 1000 MPN/ml at class 1 until 4. This indicates the water quality and sanitation were not in good condition. Eventhough, the potential of coliform bacteria to causing disease was small, the presence of its shows the vulneralibility of water for contaminated by more dangerous microorganism (www2.gnb.ca). Water quality degradation problems was impacted by LUCC, deforestation, monoculture planting system, urbanization, industrialization, and another development activity [9].

**Figure 8. Station 3**

**Percentage of area**

- Water bodies: 70%
- Cultivated tree: 21%
- Settlement: 9%
- Paddy field: 0%

**Figure 9. Station 4**

**Percentage of area**

- Water bodies: 39%
- Cultivated tree: 34%
- Settlement: 26%
- Paddy field: 1%
The diversity of land use cover and water utilization from upstream to downstream will influence the water quality from the physics, chemical, and microbiology parameter (Figure 11). Water Pollution Index can determine the polluted degrees compared with standard threshold of class 2, based on the Cipunten Agung water utilization. Indonesia Government Regulation No. 82 year 2001 stated, water with the status of class 2, can be used as water recreation, fish cultivation, livestock, and irrigation. The pollution degrees was classified into $0 \leq WPI \leq 1.0 = \text{not polluted}; \ 1.0 \leq WPI \leq 5.0 = \text{lightly polluted}; \ 1.0 \leq WPI \leq 10.0 = \text{moderate polluted}; \ WPI > 10.0 = \text{high polluted}$. Water Pollution Index shown as Table 3.

### Table 3. Water Pollution Index in Cipunten Agung Watershed

| DAS Character | Station | WPI  | Class | Status          |
|---------------|---------|------|-------|-----------------|
| Mid stream    | 1       | 5.05 | 2     | Lightly polluted|
| Mid stream    | 2       | 4.03 | 2     | Lightly polluted|
| Down stream   | 3       | 2.48 | 2     | Lightly polluted|
| Down stream   | 4       | 6.18 | 2     | Lightly polluted|
| Down Stream   | 5       | 3.31 | 2     | Lightly polluted|

Land use cover and water quality analysis in 1 km radius potentialy support for pollution degree prediction of Cipunten Agung river. Land use cover composition at ST 1, 2, and 3 which dominated by cultivated tree and paddy field determine the lower pollution degree at 5.05; 4.04; and 2.48 with WPI status is lightly polluted (Figure 11). The increases of nutrient at water surface was correlated with eutrophication, which occurs in the ecosystem due to the addition of artificial or natural substance from manure or waste into water system [4]. Meanwhile, land use cover composition at ST 4 and ST 5 which dominated by cultivated tree and settlement , determine the pollution degree at 6.18 and 3.31 with WPI status is lightly polluted. ST 4 was highlighted because it surrounded by the settlement with high density and poor sanitation. ST 5 which surrounded by fish industry and settlement has lower WPI score than ST 1, because of the influence of estuary salinity and affected by sea water. Water Pollution Index result of all station was at range of $1.0 \leq WPI \leq 5.0$ determine that 80 % Cipunten Agung main river area was lightly polluted.
4. Recommendation
Material from many sources will accumulate at river, making the role of the river very crucial. Water pollutant concentration potentially increased due to the land conversion, such as agricultural land and industry areas. Based on WPI value, its important to arrange Cipunten Agung river water restoration for water quality improvement. Ecological approaches in various scales can be applied in regional water resource management with cost and energy efficiencies for environmental quality improvement. In meso scale such as Cipunten Agung watershed, agroforestry scenario can be applied for agriculture production and environmental sustainability in the same time. Other research shows agroforestry landscape provide landscape services, specifically pollutant absorption from agriculture activities such as nitrogen and phosphorus [10].

In micro scale, natural landscape engineering such as biofilter potentially improve water quality which used wet land plant such as *Typha latifolia*, *Scirpus grossus*, *Pistia straiaotes*, and *Echinodorus palaefolius*. Biofilter can be applied at some point of Cipunten Agung main river near by the agriculture, settlement, and industry outlet area. *Typha latifolia* density variation will affect the COD reduction significantly 97.18%, it will be more efficient for BOD, COD, and TSS reduction with plant density value 1 g/cm$^2$ [11]. The combination of *Scirpus grossus* and *Pistia straiaotes* effectively 70-100% for reduction the concentration of TSS, TDS, Nitrit, Ammonia, and COD [12]. Integrated emergent plant such as *Scirpus grossus* and submergent plant system were potentially remove the biological oxygen demand (BOD5), 65.7%; chemical oxygen demand (COD), 40.8%; ammonium (NH4+-N), 74.8%; nitrate (NO3--N), 38.8%; phosphate (PO43-), 61.2%; total suspended solids (TSS), 65.8%; and fecal coliforms, 94.8% [13].

The abilities to maintain the local wisdom knowledge to maintain the environmental quality are more likely the best options for achieving sustainable management in rural landscape [4]. Low Carbon Society (LCS) potentially applied to involve the communities in watershed resource management. The paradigm of water back landscape at many level of society and government should be restored to the water front landscape. The incentives should be given to LCS communities and disentive for the program offenders [14].

5. Conclusion
LUCC can support water quality and ecosystem sustainability prediction in Cipunten Agung Watershed. Paddy field was increases at 2005, its potentially increase Nitrate concentration. Meanwhile, the cultivated tree landscape at 1995 potentially influence the environmental rejuvenation, especially water quality. Cipunten Agung Watershed management with ecology approaches is important to ensure the sustainability of environment and social ecosystem.
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