The impacts of land use and cover changes on ecosystem services value in urban highland areas

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Abstract. Land use and cover (LUC) changes are one of the main factors in global environmental change. It directly affects the welfare of society through changes in environmental conditions, such as land degradation and ecosystem services value (ESV). These ecosystem services have a large impact on quality of life in urban areas in the highlands, such as the region of Takengon, and must be addressed in land use planning. The purpose of this study is to identify the impact of LUC on ESV in 2009 and 2014.Both LUC maps divided into four categories, namely built-up area, water body, forest, and non built-up area, using the ArcGIS®10.1, with a supervised classification. Furthermore, an assessment of several environmental service variables was carried out, namely gas regulation, water supply, waste treatment, food production, raw material, and recreation. The classification results show that the LUC2009 and LUC 2014 were dominated by forests, with 10,064 ha of forest in 2009 and 8,959 ha of forest in 2014. The decrease in forest area from 2009 to 2014 also reduced the ESV by 12.33%. The government needs to consider landscape conservation and sustainable urban development planning.

1. Introduction

Land use and cover (LUC) changes are one of the main factors in global environmental change[1, 2]. LUC changes directly affect the welfare of the community through changes in environmental conditions, such as land degradation [3] and ecosystem services value (ESV) [4-6]. Monitoring LUC is very important in order to increase understanding and assessment of the level, dimensions, consequences, and causes of LUC changes, which can be used to predict future change trends [6, 7].

With the increasing number of residents and activities, Takengon, an urban area of Aceh Tengah, Aceh Province, has also experienced LUC [8]. These changes are marked by land is now being used for housing and trade, especially in the city center and the eastern part of the city which is directly adjacent to Laut Tawar Lake. This change is a result of increasing human activity and affects ESV [2, 5].

Ecosystem services are defined as benefits, both tangible and intangible, that ecosystems can produce and provide for the community [5, 9]. These ecosystem services have a large impact on the quality of life in urban areas such as Takengon, and must be handled in land use planning [10]. One of the ecosystem services that appears to be declining due to LUC is the function of Laut Tawar Lake, which

is in a condition of succession, meaning that it is changing from an aquatic ecosystem to a land ecosystem [8]. This results in decreasing groundwater reserves in region that will threaten the availability of clean water for humans and other living things, which is considered unsustainable. The highlands play an important role in water supply for the downstream watershed [11].

Regional economic growth has increased, which is marked by increasing a number of important indicators for determining economic conditions and development performance, namely Gross Regional Domestic Product (GRDP). The business sector of the construction sector and services experienced a significant increase during 2010-2013. It generally indicates that additional land has been built on to accommodate existing activities. Some of the existing protected lands have the potential to shift into built-up areas. This has attracted attention, both from the government and the private sector, who want conservation to be prioritized in development. This is also a big challenge for urban planners and policy makers [12]. Assessment of ESV in LUC is needed to restore critical land and protect high-value areas [13].

Based on the description above, the authors are interested in examining the impact of LUC in ESV regions, which are focused in urban highland area. The results can be used as a basis for determining city development policies, determining new growth centers, and activities that can support growth for community welfare and disaster mitigation, through sustainable space planning. This study will be the baseline for future related studies in Aceh, the territory of Sumatra, and Indonesia. Theoretically, the resulting prediction model will contribute to introducing the LUC changes analysis method using Geographic Information System (GIS) and Remote Sensing (RS), combined with identifying the impact of the LUC on the ESV. For this reason, data is needed to identify patterns of land use over the past several years in a spatial-temporal manner [14-16].

2. Materials and methods

2.1 Study location

This research was conducted in the urban highland area of Takengon, which consists of the subdistricts Bebesan, Lut Tawar, and Kebayakan [8]. Takengon is a urban area in the Gayo highlands, Aceh Tengah, Aceh Province, Indonesia (Figure 1), which is geographically located between 4°10’30”- $05^0$07’40”N and 95°13’02”- $95^0$22’36”E, with a population in 2014 of 72,646 people [17]. The Takengon has an area of 16,024 ha and the average height of the urban area is about 1,200 meters above sea level. Takengon consists of 84 villages. The boundaries of the area surrounding Takengon are as follows:

a. the north is bordered by Bener Meriah Regency;
b. the south is bordered by the District of Pegasing and Bies;
c. the west is bordered by the District of Bintang; and
d. the east is bordered by the District of Silih Nara.

2.2 LUC changes

Using SPOT 5 satellite imagery in 2009 and SPOT 6 in 2013, Takengon land use was classified into four land use categories [18], which is a modified result adapted to the conditions in Takengon. The categories are: 1) built-up area, 2) water body, 3) forest, and 4) non-built-up area. These LUC classifications were made using the ArcGIS®10.1 application. The classification method was a supervised classification using maximum likelihood [18].

2.3 ESV

There are several environmental service variables adapted in this study [9, 19, 20] : 1) gas regulation (GR), 2) water supply (WS), 3) waste treatment (WT), 4) food production (FP), 5) raw material (RM), and 6) recreation (RC).

$$\text{ESV} = \sum_{i=1}^{m} \sum_{j=1}^{n} A_i \text{ x } VC_{ij} \quad \text{..... 1)}$$

where $A_i$is the area of class i land use, VC_{ij} is the ecosystem services coefficient value for type j (rupiah/ha) combined with the type i land use class. From the results of the analysis, the impact of LUC

on regional ecosystem services can be identified, which in turn will suggest relevant policies to be proposed to balance development for community welfare and environmental sustainability. The average ESV per unit area (rupiah/ha) is used for each land use category.

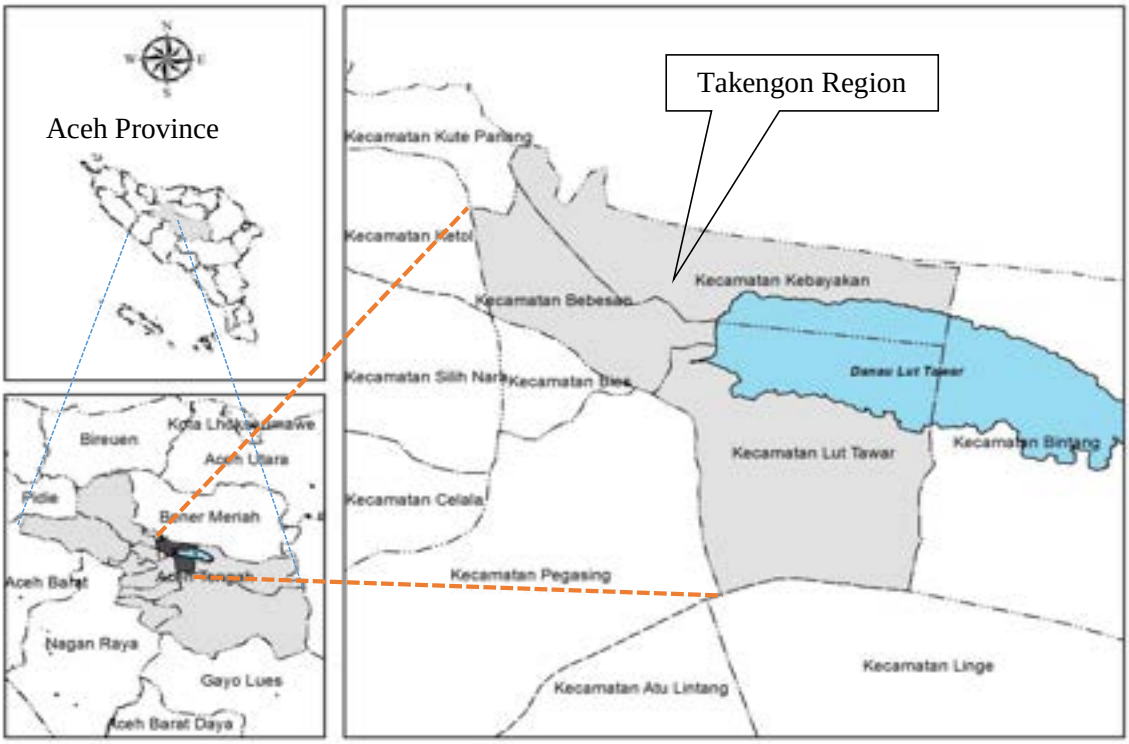

Figure 1. Study location[18]

3. Results and discussion

The magnitude of the changes that occurred can be seen in Table 1. From the table it can be concluded that built-up land increased by 90.80%, and vegetation land decreased by 13.13%. Water bodies also decreased as much as 54.16%, while wetlands have increased 10.23%. In each land category, there is extensive loss and gain, while the biggest gain occurs in the forest category [18].

This shows that population growth, the need for activities, settlements, and other needs also have an influence on the increase of built-up area. In terms of conservation of water areas, water bodies are well conserved. Only a few changes have occurred within five years. However, forest area has decreased by 1,000 ha, leaving only 8,960 ha of forest land. Most forest lands have changed into non-built-up areas and built-up areas. Non-built-up area has experienced a significant increase from 861 ha to 2,672 ha [18]. This change is estimated to come from increasing community needs for activities, such as opening forest land for fields and gardens.

Table 1. Changes in LUC 2009 and 2014 [18]

LUC category	Area (ha)	Change (ha)

	2009	2014	2009-2014
Built-up area	466.968	702.175	235.207
Water body	3,055.802	3,062.266	6.464
Forest	10,063.962	8,959.342	-1,104.620
Non-built-up area	1,811.078	2,672.27	861.192
Total	15,397. 811	15,397. 811	

The socio-economic aspects reviewed in this study are aspects of population and GRDP. Population growth and GRDP are used as variables related to changes in land use in Takengon. Based on data obtained from the Central Statistics Agency, Takengon has experienced population growth from 2009 to 2015 as shown in Table 2.

Based on Table 2, the population is mostly concentrated in the Bebesan District. The Kebayakan District has the smallest population compared to the other two districts in Takengon. The average population growth between 2009 and 2014 is very small, only 0.42%. Even though there are many methods used to assess ESV, both implicitly and conceptually [21],research by Liu et al, 2012) refers to the coefficient of ESV proposed by Costanza et al. [9], and also adapted by Estoque and Murayama [19]. The equivalence value can be seen in Table 3.

The equivalent values in Table 3 were applied to the LUC of Takengon to obtain ESV in each LUC category. The ESV in each land use category was generated by using Equation 2 to multiply the ESV coefficient with the area of each LUC category. The ESV coefficient value was one hectare per year, as adapted from Costanza et al. [9] as shown in Table 4. The total ESV numbers combined with the LUC are fully shown in Table 5 and Table 6. The type of ESV was chosen according to available GRDP data.

Table 2. Population growth of Takengon in 2009 up to 2015

No.	District	Year						
		2009	2010	2011	2012	2013	2014	2015
1	Bebesan	36,825	34,342	35,129	36,060	36,340	37,606	38,366
2	Kebayakan	13,798	14,041	14,362	14,742	14,857	15,374	15,685
3	Lut tawar	19,174	17,960	18,372	18,858	19,005	19,667	20,065

The total ESV of Takengon between 2009 and 2014 decreased by 5.56% (Table 7). The decrease in ESV only occurred in the forest category (12.33%), while for other categories it increased, except for built-up areas that did not have ESV in any ESV variables (category). The ESV water body (Laut Tawar Lake) has not undergone significant changes. The change in ESV water body numbers in Table 7 is more due to a slight error in the LUC classification.

Ecosystem services often have little impact on policy making because they are not fully depicted in commercial markets and are very infrequently used in economic and manufacturing services [9, 20]. This has become a dilemma for urban planners and policy makers in the Central Aceh District, so a scientific guide is needed to determine the ecological issues related to urbanization and to achieve sustainable development.

Table 3. Equivalent value of one unit area of ecosystem services [9].

Category	Forest	Grassland	Farmland	Wetland	Lake	Desert
Food production	0.80	1.24	1.00	4.74	0.76	0.00

Category	Forest	Grassland	Farmland	Wetland	Lake	Desert
Raw materials	2.56	0.00	0.00	1.96	0.00	0.00
Gas regulation	0.00	0.13	0.00	2.46	0.00	0.00
Climate regulation	2.65	0	0.00	0.08	0.00	0.00
Hydrological regulation	0.09	0.06	0.00	0.35	0.14	0.00
Waste treatment	1.61	1.61	0.00	0.08	12.31	0.00
Soil formation and conservation	8.65	0.56	0.00	0.00	0.00	0.00
Biodiversity maintanance	0.33	0.89	0.70	5.63	0.00	0.00
Providing aesthetic value	1.26	0.04	0.00	26.94	4.26	0.00
Total	17.95	4.53	1.70	42.24	17.47	0.00

Table 4. ESV (rupiah ha^{-1} $year^{-1}$) in several categories of land use and cover

	Built-up area	Water body	Forest	Non built-up area
Gas regulation	-	-	-	-
Water supply	-	28,401,672.00	40,248.00	-
Food production	-	550,056.00	576,888.00	724,464.00
Raw material	-	-	1,851,408.00	-
Recreation	-	3,085,680.00	885,456.00	-

Table 5. Total ESV year 2009 (rupiah x 10^6 $year^{-1}$)

	Built-up area	Water body	Forest	Non built-up area	Total
Gas regulation	-	-	-	-	-
Water supply	-	12,150.58	36.45	-	12,187.03
Food production	-	1,260.65	4,644.62	1,312.06	7,217.33
Raw material	-	-	47,699.19	-	47,699.19
Recreation	-	40,168.48	11,228.10	-	51,396.59
Total	-	53,579.70	63.608,37	1,312.06	118,500.14

Table 6. Total ESV year 2014 (rupiah x 10^6 $year^{-1}$)

	Built-up area	Water body	Forest	Non built-up area	Total
Gas regulation	-	-	-	-	-
Water supply	-	12,176.30	32.45	-	12,208.76
Food production	-	1,263.31	4,134.83	1,935.96	7,334.11
Raw material	-	-	42,463.73	-	42,463.73
Recreation	-	40,253.53	9,995.71	-	50,249.24
Total	-	53,693.15	56,626.72	1,935.96	112,255.83

Table 7. Total ESV for each LUC category

LUC Category	ESV(Rupiah x 10^6 $year^{-1}$)		Changes (2009-2014)	
	2009	2014	x 10^6 rupiah	%
Built-up area	-	-	-	-
Water body	53,579.70	53,693.15	113.44	0.21
Forest	63,608.37	56,626.72	-6.981.65	-12.33
Non-built-up area	1,312.06	1,935.96	623.90	32.23
Total	118,500.14	112,255.83	-6.244.31	-5.56

The forest has an important role as a counterweight to cultivated land. Based on the results of the ESV analysis, forest is the biggest contributor to ESV compared to the other three LUC categories. The decrease in forest area from 2009 to 2014 also reduced the ESV by 12.33%. Based on this trend, it is estimated that the forest area will continue to decline, which also decreases the ESV.

The decrease in ESV is not only focused on the forest, but the total ESV assessment, calculated by integrating all LUC categories and six ESV variables, shows that the ESV decreased by 5.56%. Other study results show the same thing [20, 22, 23]. LUC also influences ESV, specifically the decline in the LUC categories that have a large contribution to ESV, such as the forest and water body. The LUC forest category contributes to the supply of O_2, water supply, and recreation.

Forest cover also helps absorb CO_2 and maintain the air quality of the city. The occurrence of urbanization, along with the continuous loss of forest cover, has contributed to the decline in air quality in the city. Forest cover also plays an important role in regulating clean and fresh water supplies in Takengon. Pine trees also offer green space that is very valuable in city forest parks, for recreation, and even along roads and within the central business district. Forest cover also has value for ecotourism, aesthetics, inspirational and educational values, and contributes to a sense of place and cultural heritage, in a highland city in Aceh.

Growth must be balanced with economic development, social welfare, and environmental protection and conservation [20, 24]. For the urban highland area of Takengon, creating a sustainable city is also related to earthquake and volcano eruption mitigation.If the city is expected to grow to be able to 1) accommodate the growing needs of the population, 2) invite the flow of investment in the trade and services sector, 3) be a tourism area that is integrated with the preservation of cultural heritage areas, and 4) become an ecological city and based on disaster mitigation, the regulations that are made must be able to improve the quality of life for the city community. This requires strict regulation and careful planning of the use of protected areas and cultivation areas, including providing open space in coastal areas, green open spaces in city areas, controlling population density in areas prone to tsunami disasters, and encouraging growth of potential areas for development offices, trade, and services.

For the Aceh Tengah District Government, this study serves as a reference in revising the 2008-2028 Aceh Tengah Spatial Plan (SP) to produce relevant development policies by placing greater emphasis on the conservation of the natural environment and disaster mitigation along with social development economy. Urban planners can utilize the results of this research to plan new growth areas and activities that can support growth for the welfare of the community.From a scientific point of view, this research has contributed not only to understanding the future and potential of the urban landscape and LUC changes, but also methods, techniques, and variables related to modeling urban growth and driving growth factors (driving factors).

4. Conclusion

The classification results show that the LUC 2009 and LUC 2014 were dominated by forests, which respectively had an area of 10,064 ha and 8,959 ha. This forest cover has decreased in size, even though it is very helpful in absorbing CO_2 and maintaining the air quality of the city. The continuous loss of forest cover has contributed to the decline in air quality in the city. Water bodies or Laut Tawar Lake

did not experience significant changes, so they are well conserved. Built-up area increased by 50% within 5 years. Non-built-up areas experienced a significant increase, which also almost reached 50%.

The forest category is the biggest contributor to ESV compared to the other three LUC categories. The decrease in forest area from 2009 to 2014 also reduced the ESV by 12.33%. Based on this tendency, it is estimated that the forest area will continue to decline year after year, which also decreases the ESV. The decrease in ESV not only focuses on the forest, but the total ESV assessment, by integrating all LUC categories and six ESV variables, showing that the ESV decreased by 5.56%. LUC changes also influenced the ESV, specifically the decline in the LUC category which has a large contribution in ESV, such as the forest and water body. The forest category, in general, contributes to the supply of O_2, water supply, recreation aspects, and the beauty of the city.

In preparation of the Aceh Tengah Spatial Planning revision, we should consider the urban growth model found in this study, which tries to review the changes in land use and their relationship with ESV to direct sustainable development in areas that are expected to develop, and protect regions that need to limit growth and be used as a green space. For future urban development, a balance is needed between environmental protection, mitigation, economic development, and social welfare as a vision of the Aceh Tengah Spatial Plan revision. The Aceh Tengah region, especially the urban area of Takengon, faces challenges in promoting sustainable development in the future, so the government needs to consider landscape conservation and urban development planning on a broader scale.

Acknowledgments
We thank Universitas Syiah Kuala for supporting this research.

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