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Land use/land cover change detection in an urban watershed: a case study of upper Citarum Watershed, West Java Province, Indonesia

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Abstract

Upper Citarum Watershed is critically threatened by LULCC especially due to rapid urbanization, forest conversion and agricultural expansion. Such changes have degraded the watershed and significantly impacted on the water quality in the upper Citarum River. In order to prevent such degradation, periodic LULCC monitoring is paramount. This study employed GIS and RS techniques to detect LULCC in Upper Citarum Watershed between 1997 and 2014. The results revealed a significant change in the proportions of the various LULC types of the study area from the year 1997 to 2014. Forest decreased by 41% between 1997 and 2005, and by 35% between 2005 and 2014. In the same time period, agricultural land increased by 8% and 2% from 1997 to 2005 and from 2005 to 2014 respectively. On the other hand built-up increased by 100% between 1997 and 2005, and by 65% between 2005 and 2014. Bare land increased by 56% between 1997 and 2005 but declined by 15% between 2005 and 2014. Bush land cover decreased by 14% between 1997 and 2005 and by 4% between 2005 and 2014. Water body decreased by 12% between 1997 and 2005, and 10% between 2005 and 2014. The study revealed that rapid urbanization was the change initiator and the major force driving LULCC in Upper Citarum Watershed.

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Keywords: land use/land cover change; urban watershed; Citarum; GIS; RS.

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1. Introduction

Land use and land cover change (LULCC) is one of the major environmental changes occurring around the globe today. The interaction of LULCC with climate, ecosystem processes, biogeochemical cycles, biodiversity as well as human activities is of paramount importance [1, 2]. However, in the last two decades the magnitude and spatial reach of human impacts on the earth's land surface is unprecedented [3]. Changes in land use and land cover has been accelerating as a result of socio-economic and biophysical drivers [4] and are closely linked with the issue of the sustainability of socio-economic development since they affect essential parts of our natural capital such as vegetation, water resources and biodiversity [5]. Improper practices of LULC including deforestation, uncontrolled and excessive grazing, expansion of agriculture, and urban development are deteriorating watershed conditions [6], at various temporal and spatial scales [7-9].

Citarum Watershed is one of the severely threatened watersheds in the world and the most degraded watershed on Java Island, having an Environmental Quality Index of less than 40% [10]. The upper Citarum Watershed is experiencing rapid LULCC especially due to rapid urbanization, forest conversion and agricultural intensification. Such changes have degraded the watershed and caused deterioration of water quality in Citarum River. To prevent such degradation, monitoring of LULCC in a watershed is very important. Therefore this study was intended to employ GIS and remote sensing techniques to detect LULCC in upper Citarum Watershed between 1997 and 2014.

2. Methods

2.1. Study area

The study was conducted in Upper Citarum Watershed from September 2015 to November 2015. The Upper Citarum Watershed is the uppermost part of the whole Citarum Watershed located on Java island of West Java province, Indonesia. Upper Citarum is divided into eight sub watersheds which include; the Cikapundung Cipamokolan, Cikeruh, Cisangkuy, Citarik, Cirasea, Ciwidey, Ciminyak and Cihaur (Fig. 1). The Upper Citarum Watershed is the water reservoir and electricity source of the capital Jakarta, which is situated on the coast of the Java Sea. There is 56% of the Upper Citarum Watershed belongs to the administrative district of Bandung. The watershed is embedded in a hilly landscape of the backcountry of Jakarta. The whole area is 230,802 ha and 26,000 km wide [11]. The spatial distribution of the rainfall is not consistent [12]. Due to the extremely mountainous terrain and its topographic effect, the average annual rainfall varies from 1,966 mm up to 2,600 mm.

The study area lies in tropical rain forest climate despite a short dry season. However, some parts at the highest altitude experience warm temperate climate; moist, with precipitation in all months, with a hot summer, warmest month over 22°C [12]. The rainy season in the Upper Citarum Watershed is from November to April and the remaining months are the so-called transition or dry season. There is a huge amount of rainfall from the beginning of March until April and the second peak is from November until December [13]. According to the Ministry of forestry of Indonesia [14], the daily average temperature is between 22°C and 23°C and the average wind speed in a month lie between 23 and 106 km per hour while the atmospheric humidity is between 25% and 83%.

2.2. Materials

- Satellite data
  Landsat images of path/row 121/65 and 122/65; Landsat 5 TM for 1997 and 2005, and Landsat 8 OLI for 2014. The satellite acquisition date for the images was July to September.
- Vector data
  (i) Upper Citarum Watershed boundary (Obtained from Regional Environment Management Agency, "BPLHD" -West Java province).
  (ii) Land cover map of West Java province (1990-2013), obtained from Baplan, Ministry of Forestry. [Scale:1:250.000]
- Software
  ERDAS IMAGINE 9.1 and Arc GIS 10.2.

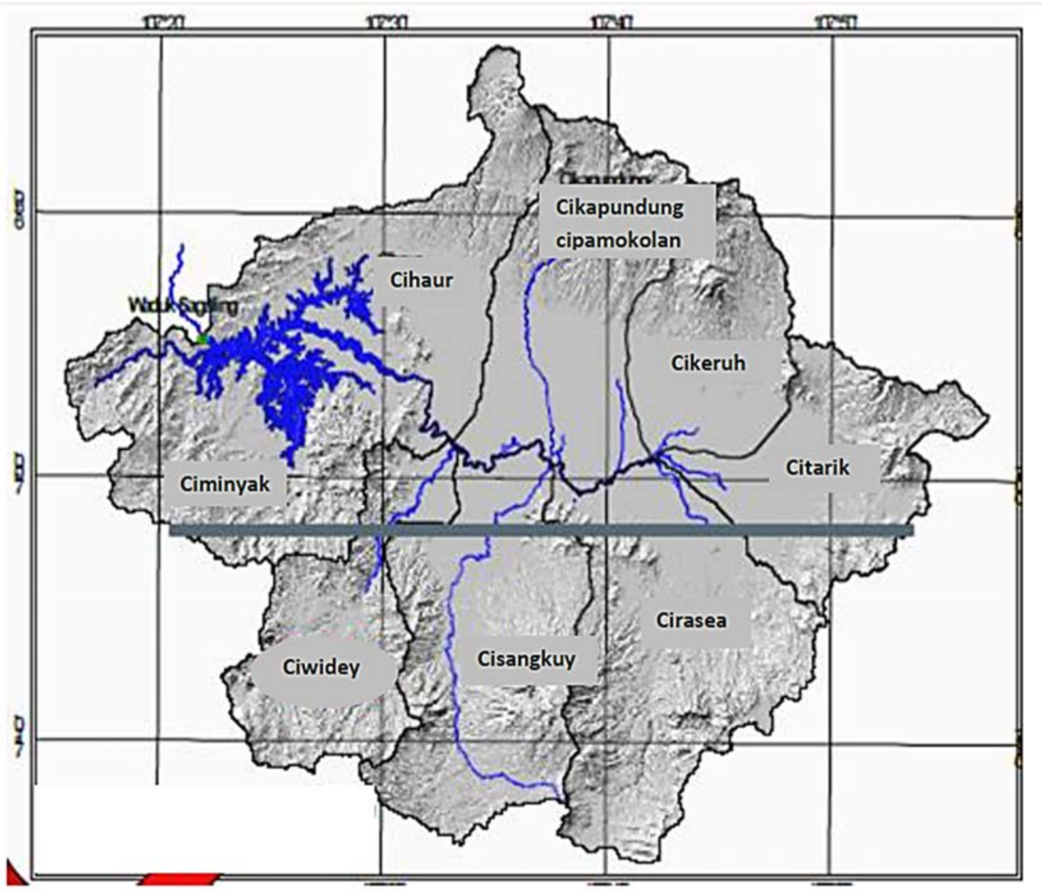

Fig. 1. Map of Upper Citarum Watershed.

2.3. Data analysis

- Image classification

Classification of LULC was conducted using supervised classification in ERDAS 9.1 IMAGINE software. LULC reference points were generated from Baplan LC Map (1990-2013) in ArcGIS 10.2 software. The classification process produced LULC maps for the years 1997, 2005 and 2014. Six LULC classes were generated which included; forest, water body, built-up, bush, bare-land and agricultural land.

- LULCC detection

LULCC detection was conducted by Post-classification comparison change detection using ERDAS modeller. This was achieved by comparative analysis of the 1997-2005 LULC maps and 2005-2014 LULC maps to detect LULCC between 1997 and 2005, and 2005 and 2014 respectively (Fig. 2). In Image interpreter change matrices were then generated for each two adjacent time periods (1997-2005 and 2005-2014).

2.4. Research procedure

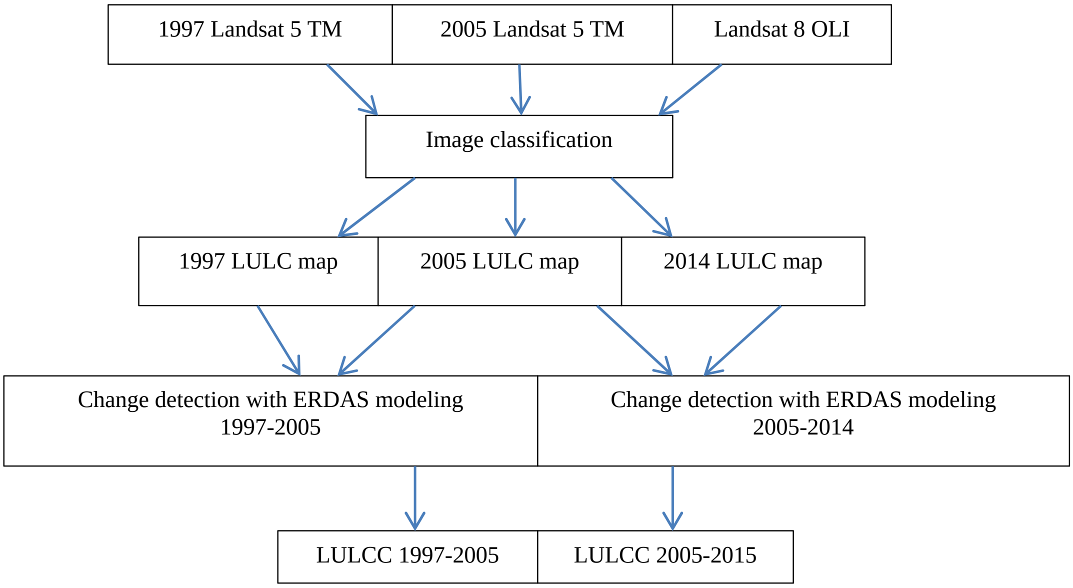

Fig. 2. Image analysis and change detection process.

3. Results and Discussions

Six LULC classes were produced. These included; forest, water body, built-up, agriculture, bare-land and bush. LULCC from 1997 to 2014 is shown in Fig. 3, 4 and 5. Analysis revealed a significant change in the proportions of the various LULC types of the study area from the year 1997 to 2014 (Table 1). Forest decreased from 63,966 ha in 1997 to 37,789 ha in 2005, indicating a 41% forest loss (Fig. 6). From 2005 to 2014 forest decreased from 37,789 ha to 24,590 ha representing a 35% forest loss. In the same time period, agricultural land increased from 138,741 ha in 1997 to 149,410 ha in 2005, indicating an 8% increase. From 2005 there was an increase from 149,410 ha to 152,492 ha in 2014, representing a 2% increase. Built-up land on the other hand increased from 10,319 ha in 1997 (Fig. 3) to 21,232 ha in 2005 (Fig. 4), representing a 100% increase in built-up area. And from 2005 to 2014 built-up increased from 21,232 ha to 34,904 ha, indicating a 65% increase in built-up area (Fig. 5).

Bare land increased rapidly (by 56%) between 1997 and 2005 but decreased by 15% between 2005 and 2014. The rapid increase in bare land between 1997 and 2005 could be attributed to the rapid clearing of forest land for agriculture and the massive construction development that occurred in that time period. The decline in bare land between 2005 and 2014 was due to its conversion to built-up. Bush land cover decreased by 14 % between 1997 and 2005 from and decreased by 4% between 2005 and 2014. This was due to conversion to agricultural land. Water body decreased by 12% between 1997 and 2005, and by 10% between 2005 and 2014. This was due to conversion of watered areas to agricultural land through land reclamation and intensified irrigation.

Analysis of the change matrix revealed that LULCC in the study area was initiated by the conversion of agricultural land to built-up (Fig. 7). This change was then propagated into the conversion of forest land to agricultural land. Direct conversion of forest land to built-up was negligible. The findings also showed that bare land is was more prone to conversion to built-up. Bush seems to be a transition from forest to agriculture. The area of the Bandung city witnessed the greatest change in LULC. This was due to rapid urbanization of the Bandung city. Another major in LULC occurred in the forested areas due to conversion to agricultural land.

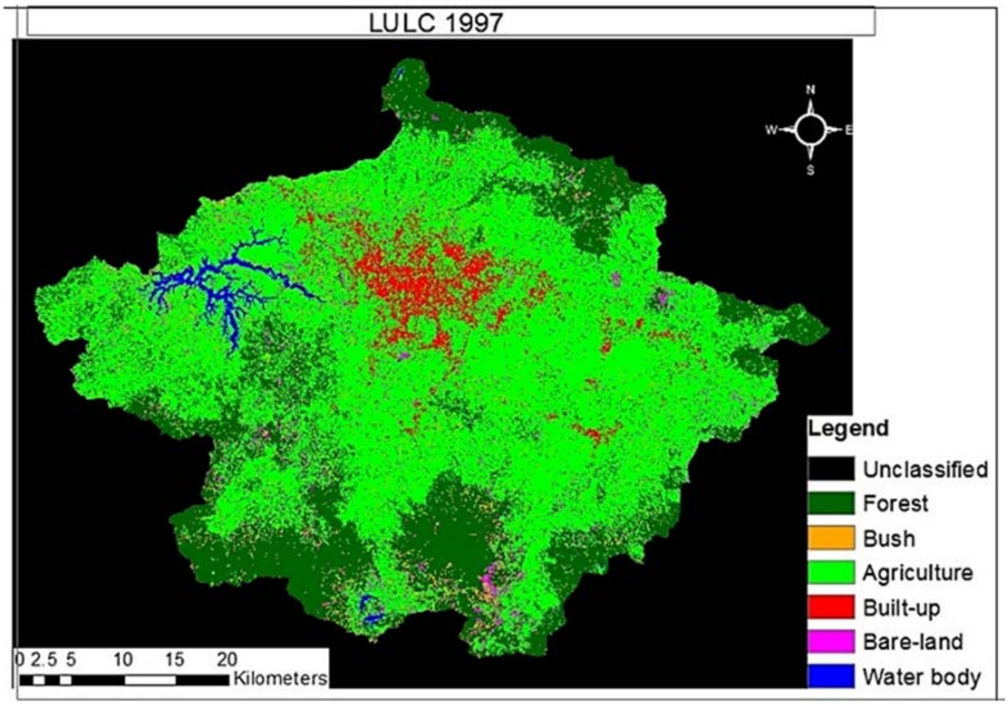

Fig. 3. Land use and land cover map of Citarum Watershed in 1997.

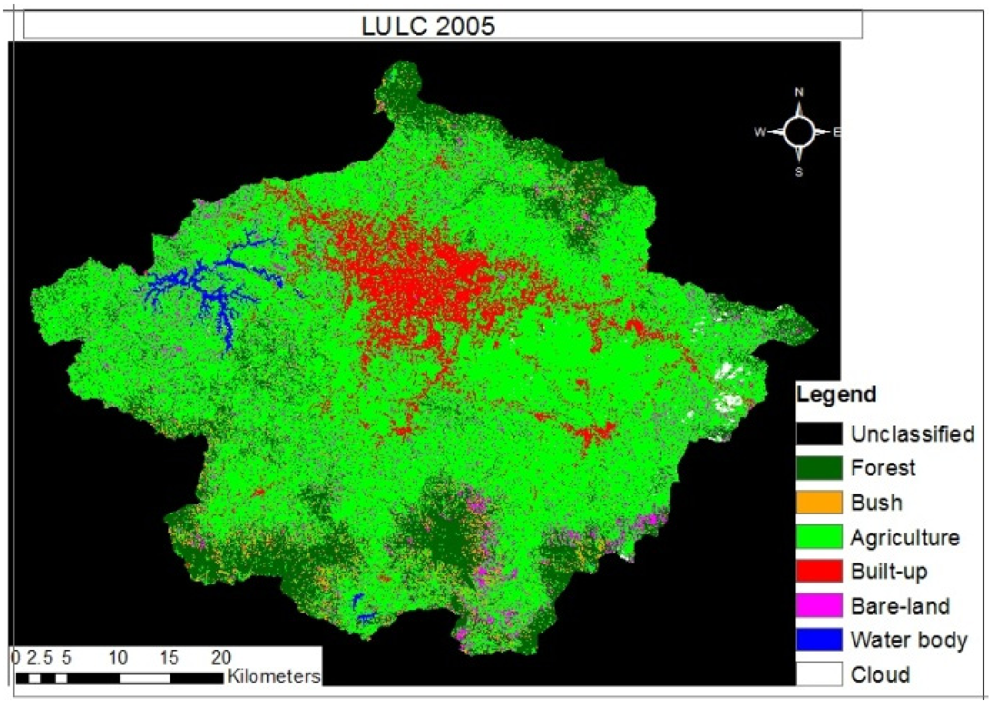

Fig. 4. Land use and land cover map of Citarum Watershed in 2005.

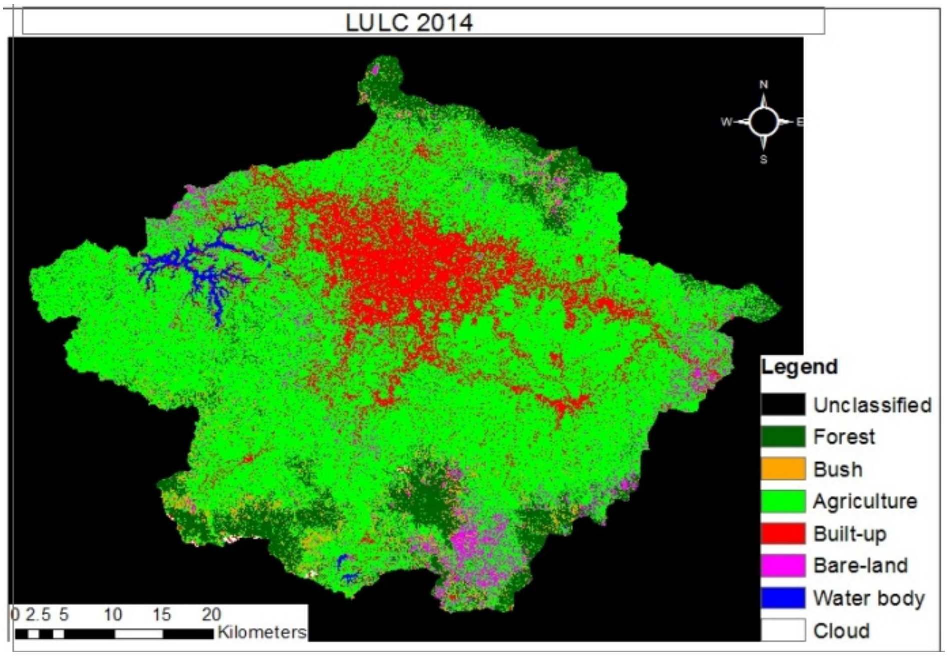

Fig. 5. Land use and land cover map of Citarum Watershed in 2014.

Table 1. LULC classes and LULCC between 1997 and 2014.

LULC type (ha)	Year			% change	
	1997	2005	2014	1997-2005	2005-2014
Forest	63,966	37,789	24,590	41*	35*
Agriculture	138,741	149,410	152,492	8**	2**
Built-up	10,319	21,232	34,904	100**	65**
Bush	7,112	6,151	5,935	14*	4*
Bare land	8,735	13,614	11,391	56**	15*
Water body	2,969	2,622	2372	12*	10*

*Decreased **Increased

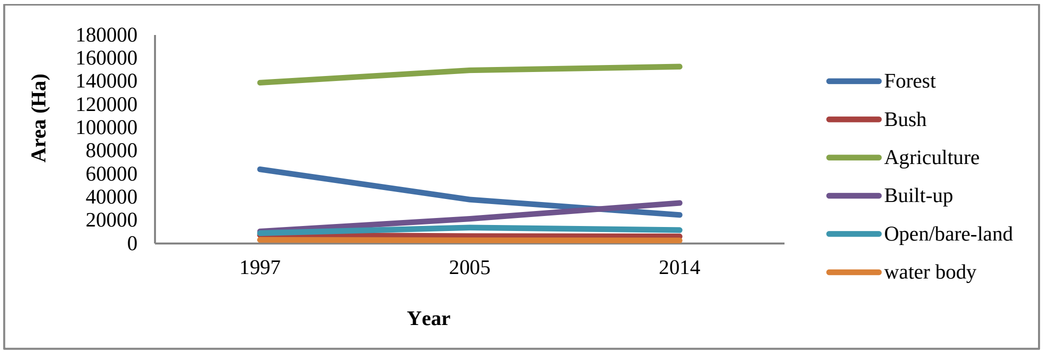

Fig. 6. LULCC in Upper Citarum Watershed between 1997 and 2014.

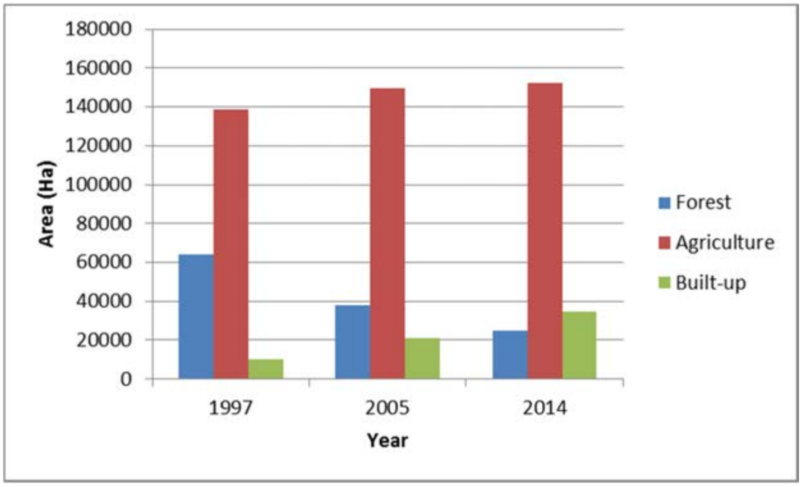

Fig. 7. Trend of LUC among the three major land use types in Upper Citarum Watershed (1997-2014).

4. Conclusions

Agriculture was the dominant land use in the study area throughout the study period covering about 65% of the entire study area. This is followed by built-up covering about 15% of the study area, forest covering 10% and others 10%. Built-up land use seems to be the main driving force behind LULCC in the study area, while forested areas were affected most due to rapid conversion to agricultural land. Major LULC change occurred in Cihaur and Cikapundung Cipamokolan sub-watersheds due to rapid expansion of the Bandung city.

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