The Impact of Urbanization to Forest Degradation in Metropolitan Semarang: A Preliminary Study

A W Sejati[1,2,3], I Buchori[1,2], and I Rudiarto[1,2]

[1]Department of Urban and Regional Planning, Universitas Diponegoro, Indonesia
[2]Center of Geomatic's Application for Sustainable Development, Universitas Diponegoro, Indonesia
[3]Doctoral program in Architecture and Urbanism, Universitas Diponegoro, Indonesia

Email: anangws@undip.ac.id

Abstract. This paper aims to examine the relationship of urbanization and the consequences of environmental impacts, especially the availability of forests. The analysis used remote sensing data ie Landsat 7 ETM (1990), Landsat 7 ETM (2000), and Landsat 8 OLI (2015). Analysis of forest availability used green vegetation cover parameters with NDVI techniques, while urbanization was measured by looking at the built-up area growth with NDBI techniques. The detection result in 1990 area of urban area was 74.85 km^2, in 2000 was 130.83 km^2, and in 2015 was 292.74 km^2. Given the overall size of the metropolitan area of Semarang (932.14 km^2), the proportion of the built up area in 2015 was 31% with an average of 6% per year change in 1990-2000 and 8.2% per year in 2000-2015. Urbanization in this region is characterized by forest conversion into residential and industrial buildings. With increasing area and built-up density, NDBI is found to be proportionately increasing, while NDVI decrease is significant. The results show that NDBI-NDVI correlation is negative (-0.99). It is very important for policy makers to formulate land use control policies in Metropolitan Semarang particularly in responding to the issue of forest conversion.

Keywords: Urbanization, Forest Degradation, NDBI-NDVI, Metropolitan Semarang

1. Introduction

In the era of urban century, where half of the world's population lives in urban areas [1], new challenges arise, namely the impact of urbanization on the environment, especially in Asia [2–5]. The pattern of urbanization of Asian countries like Indonesia is very different from the urbanization pattern in the Western countries in general and it is very special [6–10]. "Kotadesasi" (urbanization), urban sprawl, and economic growth on transportation routes are characteristic in which investment and industrialization can make rural areas into urban area [8,9,11–13].

After the decentralization era in Indonesia, government policies in each region became uncontrolled, especially in urbanization and industrialization control [14]. Furthermore, the increasing growth of Asean economy has further encouraged industrialization and development of built-up areas in metropolitan cities in Indonesia such as metropolitan Jakarta [15–19],Semarang [5,11,20,21], and Surabaya [22]. Like the two sides of coin, on one side of urbanization becomes an opportunity for

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economic growth, but on the other side, improper control policy can lead to new problems, especially environmental sustainability in the metropolitan area [23–25].

One of the environmental impacts of urbanization is the conversion of land especially on forest land. The study of land conversion by various methods has been widely conducted [26–28] but a special study of the relationship between urbanization and forest land loss especially in tropical regions like Indonesia still needs to be done. Based on this, the researchers conducted a study on urbanization relations and forest degradation with the study area in Metropolitan Semarang. The purpose of this study is to see the extent of forest conversion as a result of urbanization.

2. Data and Methods

2.1 Study Area

The study area of this paper is Metropolitan Semarang (latitudes 60 580 S and longitude 1100 250E), Semarang City and three districts affected by urbanization are: Kendal (District Kaliwungu and Boja), Demak (Sayung and Mranggen), and Semarang Regency (West Ungaran, East Ungaran, Pringapus, and Bergas) (Figure 1). Slightly different from Handayani and Rudiarto [21] that defined Metropolitan with the area affected by urban expansion in Semarang regency only in West Ungaran and East Ungaran District. Furthermore, this study area is part of Kedungsepur which is also defined as Metropolitan Semarang in the context of regional cooperation [5].

Statistical data on area studies are processed from the Center of Statistic Agency in each city and district area. The data of population growth in metropolitan Semarang used data from 1990, 2000, and 2015 (Table 1.) Statistical data was processed to provide evidence of urban growth, one of which is seen from population growth data.

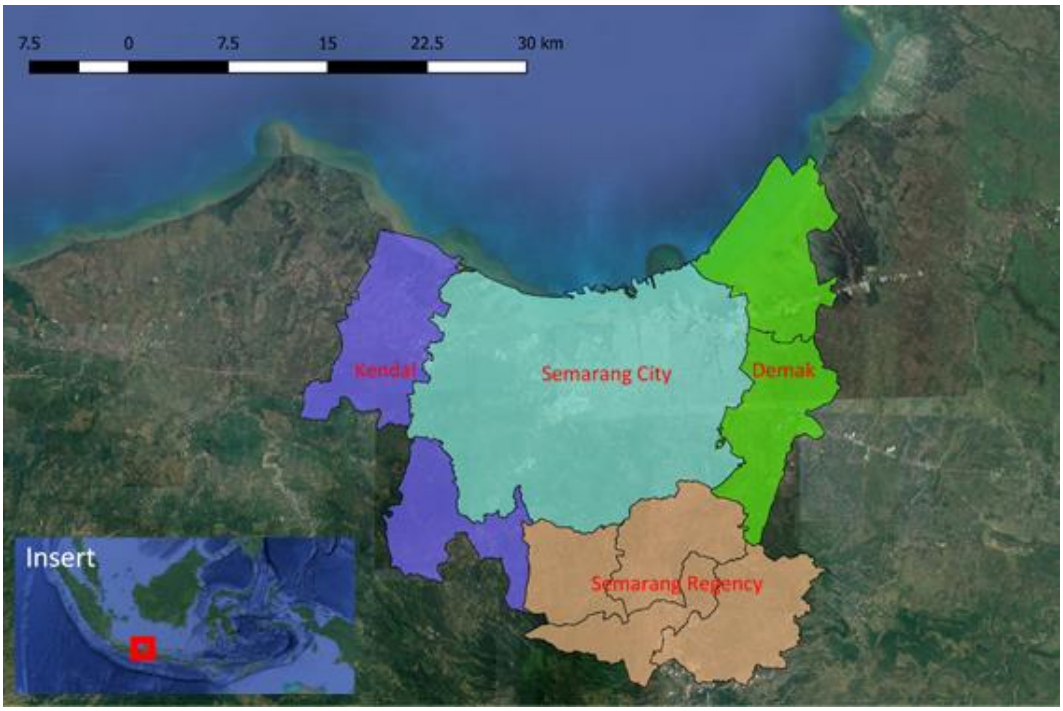

Figure 1. Metropolitan Semarang

Table 1. Population data of Metropolitan Semarang year 1990, 2000, 2015

Region	Year		
	1990	**2000**	**2015**
Semarang City	1,146,931	1,368,803	1,595,187
Kaliwungu	74,991	88,025	102,574
Boja	51,567	61,898	69,219
Ungaran Barat	54,886	67,353	77,758
Ungaran Timur	44,372	58,576	69,895
Pringapus	29,763	41,297	51,772
Bergas	30,374	41,987	72361
Sayung	68,340	78,699	103,932
Mranggen	82,785	125,575	180,152
Total Population	**1,584,009**	**1,932,213**	**2,322,850**
% Growth (per year)		2.2	1.4

Source: Center of Statistic Agency and Analysis

2.2 Image Analysis

In this paper, satellite image analysis used data from Landsat with different years ie 1990, 2000, and 2015 (Table 2). Likewise, Landsat is very useful for studying large areas, especially to measure land cover such as built-up area and vegetation canopy [29–34]. The type of Landsat used in accordance with the data of the year of satellite imagery. In 1990 and 2000 the analysis used Landsat 5 TM and Landsat 7 ETM which had 7 Bands. In 2015, the analysis used Landsat 8 OLI. Special year 2015 Landsat image has experienced a lot of sharpening so that the result was better than the previous Landsat because it has 11 bands.

The combination of composite image bands for each type of analysis is critical to the interpretation of image data. The combination of bands for urban interpretation is as shown in Figure 2. To determine urban and non-urban, the false color combinations used were 7, 5, 3 for 1990 and 2000. As for 2015, the combination used 7, 6, 4. For urban classification, analysis using the NDBI formula (Eq.1) [34–36] and supervised classification [32,37,38]. NDBI used Band 5 SWIR (Short Wave Infra-Red) and Band 4 NIR (Near Infra-Red) for 1990 and 2000, while in 2015, NDBI analysis used Band 6 for SWIR and band 5 for NIR.

$$NDBI = (SWIR-NIR)/(SWIR+NIR) \quad \text{(Eq. 1)}$$

Furthermore, to see the condition of vegetation as the impact of urbanization, the RGB band configuration is different from urban area. The analysis used 4, 3, 2 (figure 3) band configuration, so that sharpening was more on infra-red (RED) and Near Infra-Red (NIR) sensors. The infrared sensor is getting sharper (red) when it met chlorophyll, so it can be used for green vegetation detection (Figure 3). Vegetation detection used the NDVI formula [39–42] (Eq. 2) where the RED band used band 3 and NIR bands used band 4 for Landsat 1990 and 2000, while for 2015 RED band used band 4 and NIR bands used Band 5.

$$NDVI = (NIR-RED)/(NIR+RED) \quad \text{(Eq.2)}$$

Table 2. Dataset for Image Analysis

Data	Type	Year	Source
Satellite imagery	multi spectral		
	landsat 5 TM	1990	USGS
	landsat 7 ETM	2000	USGS
	landsat 8 OLI	2015	USGS

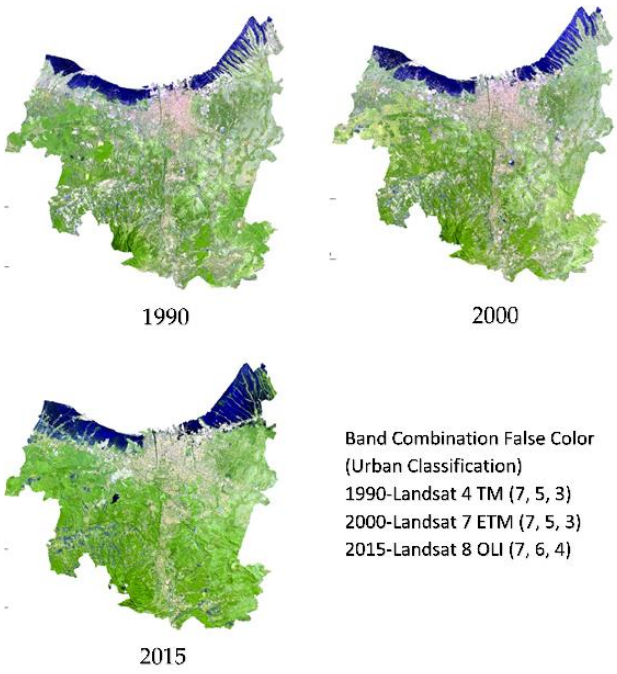

Figure 2. Landsat Band Configuration for Defining Urban Area

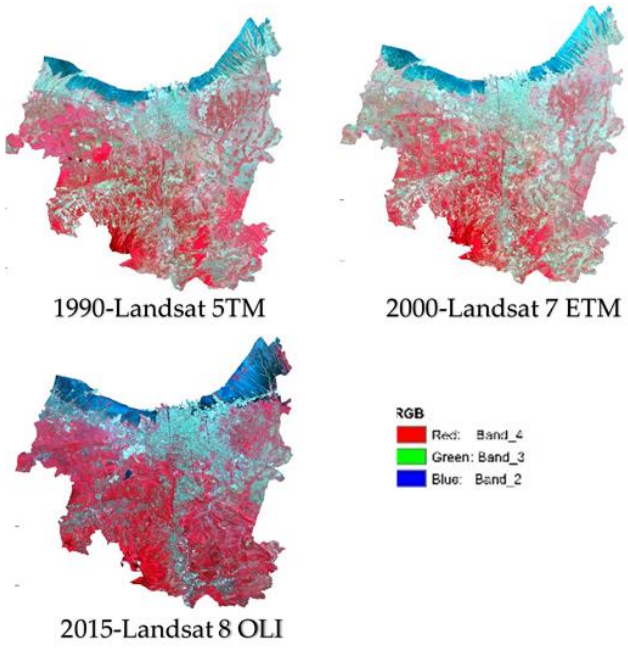

Figure 3. Landsat Band Configuration for Defining Canopy Vegetation

3 Results and Discussion

3.1 Urbanization in Metropolitan Semarang

Detection of urbanization patterns using temporal satellite images is one of the concrete steps in seeing urban development spatially. The results of image interpretation (Figure 4) show that in 1990 the urban area was 74.85 km^2, in 2000 was 130.83 km^2, and in 2015 was 292.74 km^2 (Table 3). Given the overall size of the metropolitan area of Semarang (932.14 km^2), the proportion of the built-up area in 2015 was 31% with an average of 6% per year change in 1990-2000 and 8.2% per year in 2000-2015. This change was so significant, so that the direction of urbanization can be determined from the growth direction of the built-up area.

According to Handayani and Rudiarto [21] the built-up area grows linearly with the population, so it needs a comparison with the population growth. Population growth in metropolitan Semarang from 1990-2000 were averaged 2.2% per year and in 2000-2015 an average of 1.4% per year (Table 1). Compared to the built-up area that rises up to 8.2% per year, there is a tendency that urbanization is largely not due to meeting the needs of the population but there are other factors. These factors can be seen from the growth in peri urban as an expansion area of urban Semarang.

Figure 5 shows the growth comparisons of peri-urban areas affected by urban expansion. From the figure, it is clear that Mranggen, Kaliwungu, Sayung, and Bergas are fast-growing peri-urban areas in the metropolitan urbanization of Semarang. To prove the result of NDBI calculation model and Built-up area, then field calibration is done. The calibration results show that four rapidly growing peri-urban areas are Mranggen, Kaliwungu, Sayung, and Bergas. It turns out that the distribution of the industry in the four urban areas makes the number of built-up areas grow and the growth rate is greater than the population growth rate in Metropolitan Semarang.

The phenomenon of surging areas for industry and population growth is a clear proof of the rapid urbanization process in rural areas that causes built-up land to grow rapidly and convert non-built-up land [24,43,44]. Moreover, from this growth it can be seen that the direction of metropolitan growth of Semarang tends to be evenly distributed but the dominant moment is to the east of expansion to Demak district where Mranggen and Sayung as fast-growing peri-urban triggers. This is consistent with the prediction that the urbanization of an industrialization not only gives rise to economic growth, but also gives effect to the spatial pattern of space [2,5,16]. The spatial pattern evolves due to the need for spatial development to meet the needs of industrial workers, such as residential and other supporting facilities, so that it needs to be well planned.

Table 3. Built-up area in Metropolitan Semarang (Km^2)

	1990	**2000**	**2015**
Semarang City	56.31	89.44	180.53
Kaliwungu	5.58	7.29	19.04
Boja	1.60	4.68	11.57
Ungaran Barat	2.46	5.08	10.55
Ungaran Timur	1.65	4.83	11.66
Pringapus	3.53	3.59	9.93
Bergas	1.96	4.76	12.04
Sayung	2.24	3.50	13.92
Mranggen	3.33	7.66	23.50
Total Built-up area (Km^2)	78.65	130.84	292.75

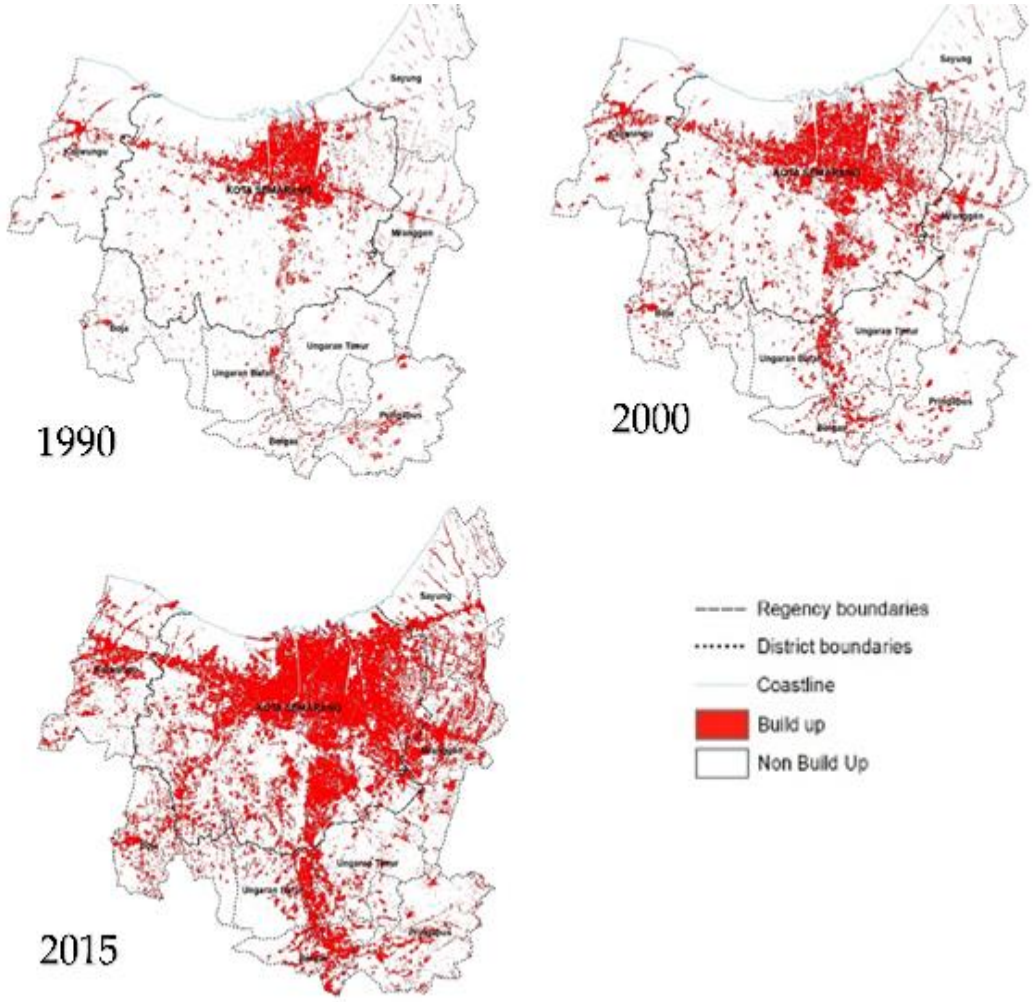

Figure 4. Built-up and non-Built-up Area 1990-2015

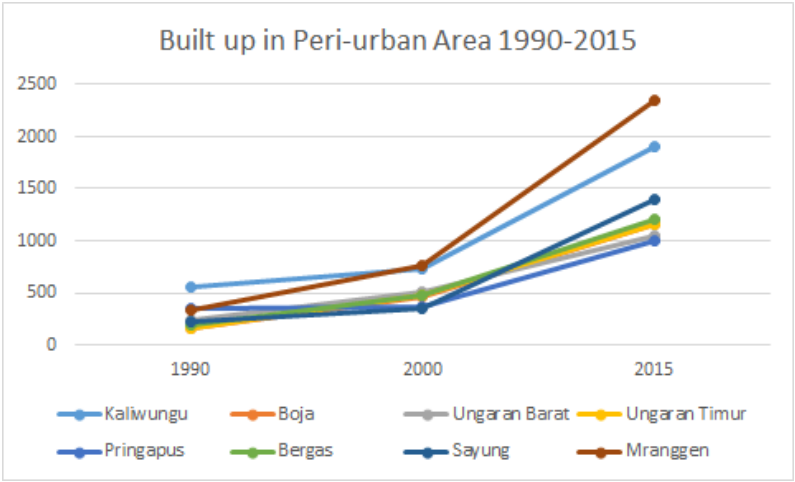

Figure 5. Comparison Built-up in peri-urban area

3.2 Forest Degradation in Metropolitan Semarang

Discussing the problem of urbanization certainly cannot be separated from land conversion. Land conversion in this paper is the reduced land cover of green vegetation that turns into a Built-up area. From the calculation with the NDVI formula (Figure 6) was the area with high vegetation density ie for the NDVI value above 0.4 decreases (Figure 7). In 1990 the number of high-density vegetation was 391.23 Km^2, in 2000 was 264.24 Km^2, and in 2015 was 242.14 Km^2. This proves that the decline is quite significant; especially in the period 1990-2000 was reduced by 32% and in 2015 decreased 8%. This characteristic was in line with the research of Sharma & Joshi [45] showing a negative relationship between built-up and vegetation. In addition the NDVI relationship with LST is negative, so it can be predicted that the reduced area of green vegetation cover will increase the UHI.

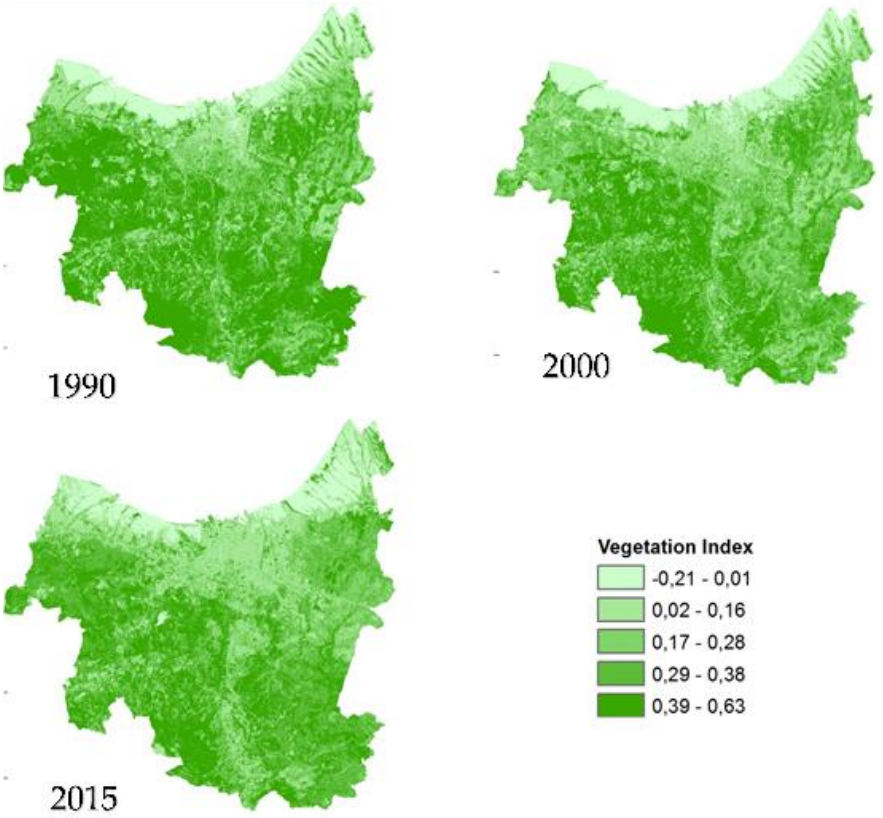

Figure 6. The NDVI result for forest detection

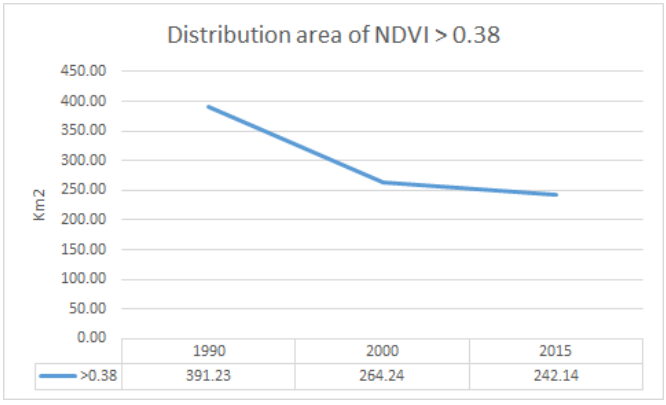

Figure 7. Degraded Green Vegetation Detection using NDVI value > 0.38

3.3 Discussion

Urban land use planning is a land use planning product that regulates land use for a period of time [46]. Planning is policy, and every policy depends on the decision maker. Policies require data and information, so that data and analysis must conform to the real conditions to support good governance systems [47]. From the analysis, it found that it was almost triple built-up growth rate for 25 years (1990-2015), it is a warning for land use planning policy makers, as the challenge of environmental issues and climate change must be responded immediately.

During that period, the population density was positively correlated with the probability of urban expansion, indicating that its development focused not only on the city core—with large population density—but also on fast growing areas in new growth centers. The relatively complete infrastructure and transportation in the city center provide a good opportunity for development, but investments such as industry also have a major effect on rural-urban transformation in the metropolitan Semarang.

Looking at the urbanization impact parameters from 1990-2015, the findings indicate that urban expansion in Metropolitan Semarang is growing as emerging new growth centers reinforce urban expansion into urban areas. In the context of urbanism, the growth of metropolitan Semarang with a new growth center, cultivated a new view of the concept of urbanization. Reduced numbers of movements to the city center have occurred. The distance to the city center does not significantly affect the growth, as facilities such as shopping centers and some downtown activity centers also grow in new growth centers. This is due to the availability of basic needs facilities in each area of urban expansion.

Furthermore, in 1990, Semarang City's CBD (center of Semarang) became the center of community activity, but by the year 2000 some community activities in fulfilling the needs of life had shifted to a new growth center such as east of Semarang City bordering on Mranggen and south of Semarang City bordering on Ungaran. The growth is widespread by 2015, so urban and peri-urban borders are merged, such as the Mranggen is no longer as rural area and Ungaran has become the new growth centers that merge with the southern part of Semarang.

Another character is industrialization. Industrial areas that originally grew around the port of Tanjung Emas in the coastal area of Semarang city (northern part) developed in a linear and also sprawl to some areas. Linearly, the industrial area expanded to Kaliwungu (Kendal) and Sayung (Demak). In 1990, the industrial area of Kendal advanced only in Kayu Lapis in Mororejo, but after 2013 the Industrial Park of Kendal quite rapidly even there is an integrated industrial area with national and international scale. Similarly with Sayung, the growth of food industry, livestock, and fertilizer from several foreign companies also expanded Sayung especially after 2010.

Returning to the main objective of this study is to show how the development of urbanization degrades the environment showing a correlation. It can be seen from the change of green vegetation cover (Forest) that disturbs the ecological balance (NDBI-NDVI correlation is negative -0.99). The vitality of environmental parameters such as NDVI analysis results in monitoring the status of forests in areas that have further implications for decision makers and policies in the municipal and regional planning sectors.

The analysis highlights that urbanization in Metropolitan Semarang coincides with a declining green status. This may explain that the environmental impact of urban expansion to peri-urban areas has greater possibilities, as new activity centers grow to form their own urban areas. On the other hand, it should be noted that the available land for expansion in downtown activity has been reduced and largely stagnant after rapid development, so growth moves more dynamically to peri-urban and poses a threat to the environment.

Urban landuse dynamics and environmental impacts require urban planners and decision makers to frame more sustainable practices than continue to promote urbanization and the rampant elite occupancy offerings in urban areas. Current spatial planning shows the focus of economic development. Control of utilization in rapidly growing areas has not been well anticipated, so the current challenge is limiting the growth of built-up areas especially in forest as protected areas and conservation.

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4 Conclusion and Future Work

With increasing area and built-up density, NDBI is found to be proportionately increasing, while NDVI decrease is significant. The results show that NDBI-NDVI correlation is negative (-0.99). It is very important for policy makers to formulate land use control policies in Metropolitan Semarang particularly in responding to the issue of forest conversion. The greater the level of urbanization, the greater the conversion of forests and the extent of forest degradation. Furthermore, this phenomenon is a big challenge because controlling spatial policy is not easy but it does not mean impossible to do. This provides valuable insight for planners in intervening especially in providing recommendations to control urbanization. The future work from this paper is to measure the relationship of urbanization, degradation of forest area, and Land Surface Temperature.

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