Identification of the agricultural land conversion rate in Sleman regency using remote sensing

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Abstract. Lack of information concerning the conversion rate of agricultural to non-agricultural land in the last decade has become an important issue in Sleman Regency. The aim of this study was to determine the changes in land use and the land conversion rates in five years for three periods of 1990-1995, 2000-2005, and 2010-2015. The study was conducted using descriptive methods which were analyzed spatially using Landsat imagery of 1990, 1995, 2000, 2005, 2010, and 2015. Identification of the land conversion rate covered 17 districts by comparing the land use classification data. The results showed that land use in Sleman Regency cover paddy fields, moorlands, yards, forests, barren land, and other land uses. The highest rate of land conversion occurs in groundwater bodies, paddy fields, and plantation area in different periods. The highest rate of land conversion in Sleman Regency in period 1 (1990-1995) was in paddy fields, which was 8,953.04 ha or 1,790.61 ha/year. In period 2 (2000-2005), the highest land conversion rate was in groundwater bodies, which was 3,471.44 ha or 694.29 ha/year. Meanwhile, in period 3 (2010-2015), the highest land conversion rate was in plantation areas, which was 7,767.33 ha or 1,553.47 ha/year.

1. Introduction
Land is a natural resource, can't be depleted, with unique characteristics [1]. However, the availability is fixed, and the location isn't able to be moved. Land as the main natural capital that underlies life activities has two basic functions. The first is the function of cultural activities, meaning of an area that can be used for various uses, such as settlements, both as urban and rural areas, plantations, production forests, and others. The second is the protection function, meaning of an area determined by its main function to protect the preservation of the existing environment, including natural resources, artificial resources, and historical values and national culture that can support the function of cultural activities. Noticing the current development, not only the industrial sector starting to rise and grow but also the housing, health, education, and tourism sectors. All sectors also need land as one of the requirements that must be fulfilled so that business aspects can run well. As a result, a lot of agricultural lands are converted into non-agricultural land. The conversion of agricultural to non-agricultural land also occurs in the Special Region of Yogyakarta (DIY), especially in Sleman Regency. During the 10-year period (2005-2015), agricultural land in Sleman Regency declined. The decline in the area of non-paddy agricultural land is 14,403 ha (25.23%), while in the paddy fields is 1,284 ha (5.54%) [2].

The existence of agricultural land needs to be maintained to meet food needs. In addition, paddy fields also play the ecological functions, namely as water catchment areas, green open spaces, water balance control, and buffer for the surrounding area. The use of remote sensing satellite data is needed to determine land use and change from year to year. The data can be used as a source of information for evaluating policies applied in land use. Several studies have been conducted to utilize remote sensing
Satellite data to determine changes in paddy fields and determine ecological values by monitoring changes in agricultural land [3; 4; 5]. Renewal of information needs to be done in order to know the developments that occur. The previous research was conducted a long time ago, henceforth, the latest research activities need to be carried out to obtain information that is up to date. This research used Landsat imagery captured in 1990, 1995, 2000, 2005, 2010, and 2015 in identifying the land use in Sleman Regency, which has 17 sub-districts. The broad scope of the study area will have various types of land use.

Conversion of paddy fields to non-paddy fields as a result of the increasing population will cause imbalances, where food production will be reduced due to land conversion. Increasing land conversion will cause increasing people's food consumption. This can be a threat to the ability of the region to provide food needs for its population. Based on this description, the problems studied in this study were the conversion in land use and the rate of conversion of agricultural land in Sleman Regency in 1990, 1995, 2000, 2005, 2010, and 2015, analyzed using Landsat images. This research was conducted to determine the changes in land use and the rate of conversion of agricultural land in Sleman Regency using Landsat imagery.

2. Material and methods

The study was conducted using descriptive methods that were analyzed spatially. The research method consists of pre-image processing, namely the merging of image and image cutting. Image merger was performed using 3, 4, 5 bands on Landsat 7 and 6, 5, 4 band on Landsat 8 Collection-1 Level 2. Meanwhile, image cutting was performed using ArcMap 10.3 software, in accordance with the administrative boundaries of Sleman Regency. A visual image interpretation method was carried out to identify the land cover seen in the image. Digital image analysis was done using the Supervised Classification method, comprising the determination of the training area, the classification of land cover with maximum likelihood method, the transformation of the data format from vector to (.shp), performing majority to execute small polygons and the overlay of each classified image. Analysis of changes in land use was done by comparing (classification comparison) the classified image of each time separately.

3. Results and discussion

3.1. Characteristics of the studied area

Sleman Regency is located at 110°13′00″ - 110°33′00″ E and 7°34′51″ - 7°47′03″S with altitude ranging from less than 100 to more than 1000 meters above sea level. The total area of Sleman Regency is 57,482 ha or about 18% of the area of the Special Region of Yogyakarta. The land condition in Sleman Regency, in the southern part, is relatively flat except the hilly area. Going to the north, land conditions tend to slope. The upper the slope, the land condition is increasingly steep. The soil in Sleman Regency is classified into litosol, regusol, grumosol and mediterranean. Most of the area in Sleman is dominated by regusol soil type, covering a total area of 49,262 ha (85.69%) [6]. According to data from the Meteorology and Geophysics Agency (BMKG) Yogyakarta [7], in 2017, the average air temperature in Sleman Regency was a minimum of 24.0°C and a maximum of 29.4°C. The minimum humidity was 70%, and the maximum was 95%. The minimum and maximum air pressure was 976.9 mb and 1004.7 mb, respectively. The minimum wind speed was in the East, and the maximum was in the North East region. Meanwhile, the rainfall was 0 mm (minimum) and 135 mm (maximum) with minimum rainy days of 12 times a month and a maximum of 26 times.

3.2. The types of land use in Sleman Regency

Based on the data of Central Bureau of Statistics (BPS) of Sleman Regency from 1990-2015, the land use is divided into paddy field, moorland, yards, others, forest, and barren land (Table 1).
Table 1. The types and area of the land use in Sleman Regency in 1990-2015

| Year | Paddy field | Moorland | Yards | Others | Forest | Barren land | Total |
|------|-------------|----------|-------|--------|--------|-------------|-------|
| 1990 | 25,832      | 5,323    | 17,725| 8,602  | 0      | 0           | 57,482|
| 1995 | 24,662      | 6,184    | 18,461| 8,175  | 0      | 0           | 57,482|
| 2000 | 23,291      | 6,394    | 18,772| 8,833  | 0      | 0           | 57,482|
| 2005 | 23,191      | 6,433    | 18,986| 8,872  | 0      | 0           | 57,482|
| 2010 | 22,819      | 6,197    | 10,446| 8,020  | 0      | 0           | 57,482|
| 2015 | 24,628      | 3,921    | 18,627| 8,988  | 530    | 1,263       | 57,482|

Source: [8]

In the period of 1990-1995, land use in Sleman Regency was changing. Paddy fields in Sleman Regency decreased by 1.17 ha or by 4.5%. On the other hand, the area of barren land, yard, and other land use was increasing, which was increasing between 3 - 8% of the previous land area (Table 1). The decline in the paddy field area and the increase in land area for other uses continued until 2005. In 2010, the area of paddy fields, barren lands, and yards decreased, but other land uses increased. The area of yards decreased significantly, which amounted to 8.181 ha or by 44.98%. In contrast, other land uses increased quite a lot, reaching 44%. In 2015, the paddy field area experienced an increase of 1,809 ha or 7.9% compared to the paddy field area in 2010. The area of yards also experienced a substantial increase, namely 8,181 ha or 78%. However, dry land and other land use decreased by 36.72% and 50%. In 2015, the area of forest and barren land were recorded 530 ha and 1,263 ha, respectively. Land use of Sleman Regency in 1990-2015 can be seen in Figure 1.

Figure 1. The land use in Sleman Regency in 1990-2015

3.3. Characteristics of land cover in visual image
Visual land cover characteristics in Sleman Regency were identified using Landsat 8 Collection 1 Level 2 and Landsat 7 ETM imagery. The bands or canals used were 3, 4, 5 and 6, 5, 4 on Landsat 8 Collection 1 Level 2. Each image taken in 1995 to 2015 was combined first (composite), while the images taken in 1990 had been combined before. Visual land cover characteristics are presented in Figures 2-5.
Figure 2. Characteristics of land cover in 1990 and 1995

Figure 3. Characteristics of land cover in: (a) 2000; (b) 2005
Figure 4. Characteristics of land cover in 2010: (a) based on Landsat image; (b) based on Google Earth

Figure 5. Characteristics of land cover in 2015: (a) based on Landsat image; (b) based on Google Earth
3.4. Digital classification of land cover

Based on information from the National Land Agency (BPN) of Sleman Regency [8], the analysis of land use was carried out using assumptions due to differences in classification systems. Non-agricultural land use includes industries, roads, education services, sports fields, residential areas, housing, accommodation and recreation, airports, health services, government services, graves/tombs, golf courses, markets, stadiums, terminals, and Mt. Merapi shelters. Paddy fields cover irrigated rice fields and rainfed rice fields. Barren land comprises bushes, emplacements, rocky soils, moorings, sandstone, degraded land, open land, and grasslands. The plantation area includes mixed crop plantation and snake fruit plantation. Groundwater bodies cover lakes/ponds, freshwater ponds, and rivers. Meanwhile, forest land is the forest area itself. Maps of land use in 1990 and 1995 can be seen in Figure 6.

![Maps of land use in Sleman Regency in: (a) 1990 and (b) 1995](image)

**Figure 6**. The map of the land use in Sleman Regency in: (a) 1990 and (b) 1995

According to the digital land cover classification, the land use in Sleman Regency is divided into groundwater bodies (LBA), forest (LH), barren land (LK), non-agricultural land (LNP), agricultural land (LP), and paddy field (LS). The total area from the digital classification of land cover can be seen in Table 2 and Table 3. Land use in 2000 and 2005 are presented in Figure 7, while land use in 2010 and 2015 are presented in Figure 8.
Table 2. Total area of districts in Sleman Regency

| Year | LBA  | LH   | LK   | LNP  | LP   | LS   | Total  |
|------|------|------|------|------|------|------|--------|
| 1990 | 1,146.18 | 2,403.74 | 1,686.44 | 13,659.09 | 17,751.63 | 18,062.85 | 54,709.92 |
| 1995 | 157.03 | 11,933.16 | 3,724.07 | 7,450.25 | 23,607.70 | 9,109.81 | 55,982.02 |
| 2000 | 3,641.05 | 3,190.63 | 5,288.80 | 11,752.34 | 16,707.16 | 15,059.51 | 55,639.49 |
| 2005 | 169.62 | 5,389.02 | 4,297.58 | 9,025.50 | 21,830.88 | 15,611.57 | 56,324.15 |
| 2010 | 266.14 | 4,658.58 | 858.42 | 13,527.31 | 22,588.35 | 14,496.80 | 56,395.61 |
| 2015 | 62.76 | 2,834.88 | 2,762.9 | 19,846 | 15,838.55 | 14,330.33 | 55,675.43 |

Remarks: LBA= Groundwater bodies, LH= Forest, LK= Barren land, LNP= Non-agricultural land, LP= Plantation area, LS=Paddy fields

Table 3. Percentage of total area of districts in Sleman Regency

| Year | % LBA | % LH | % LK | % LNP | % LP | % LS | Total |
|------|------|------|------|------|------|------|-------|
| 1990 | 2.1 | 4.39 | 3.08 | 24.97 | 32.45 | 33.02 | 100  |
| 1995 | 0.28 | 21.32 | 6.65 | 13.31 | 42.17 | 16.27 | 100  |
| 2000 | 6.54 | 5.73 | 9.51 | 21.12 | 30.03 | 27.07 | 100  |
| 2005 | 0.3 | 9.57 | 7.63 | 16.02 | 38.76 | 27.72 | 100  |
| 2010 | 0.47 | 8.26 | 1.52 | 23.99 | 40.05 | 25.71 | 100  |
| 2015 | 0.11 | 5.09 | 4.96 | 35.65 | 28.45 | 25.74 | 100  |

Remarks: LBA= Groundwater bodies, LH= Forest, LK= Barren land, LNP= Non-agricultural land, LP= Plantation area, LS=Paddy fields

Figure 7. The map of the land use in Sleman Regency (a) 2000 and (b) 2005
Figure 8. The map of the land use in Sleman Regency (a) 2010, (b) 2015

3.5. Land conversion rate

The rate of land conversion in Sleman Regency was analyzed based on the conversion period, namely period 1 (1990 to 1995), period 2 (2000 to 2005), and period 3 (2010 to 2015). The rate of land conversion in Sleman Regency can be seen in Figure 9. Based on this Figure, paddy fields experienced the highest conversion rate in period 1, which reached 8,953.04 ha. This conversion of paddy fields can be used in the form of other land uses. Irawan [3] argued that the conversion of agricultural land was greater in paddy fields compared to barren land because it is influenced by three factors. First, the development of non-agricultural activities such as housing, shops, offices, and industrial estates is easier to be carried out on flatter paddy fields compared to dry soil in the barren land. Second, due to the past development focusing on efforts to increase rice products, economic infrastructure is more available in paddy fields than in barren land. Third, paddy fields, in general, are closer to consumer areas or relatively densely populated urban areas compared to barren land areas which are mostly located in hilly and mountainous regions.
Remarks:
Period 1 = Land conversion from 1990 to 1995;
Period 2 = Land conversion from 2000 to 2005;
Period 3 = Land conversion from 2010 to 2015.
LBA= Groundwater bodies, LH= Forest, LK= Barren land, LNP= Non-agricultural land,
LP= Plantation area, LS=Paddy fields

**Figure 9. Land conversion rate in 1990-2015**

An increase in population will increase the need for settlements, which becomes one of the reasons for land conversion. Conversion of agricultural land into non-agricultural land in the form of settlements or built-up land causes the remaining agricultural lands to be unproductive because they are located around settlements or built-up land. As a result, eventually, the remaining agricultural lands will also be converted. The rate of land conversion per year can be seen in Table 4.

**Table 4. Land conversion rate per year**

| Period    | LBA   | LH    | LK    | LNP   | LP    | LS    |
|-----------|-------|-------|-------|-------|-------|-------|
| Period 1  | 201.39| 8.55  | 22.76 | 1,242.59| 733.97| 1,790.61|
| Period 2  | 694.29| 259.93| 296.48| 662.19| 322.87| 228.44|
| Period 3  | 47.41 | 407.46| 0.00  | 184.09| 1,553.47| 525.49|

Remarks:
LBA= Groundwater bodies, LH= Forest, LK= Barren land, LNP= Non-agricultural land, LP= Plantation area, LS=Paddy fields

Table 4 shows that paddy fields have the highest conversion rate in period 1, which is 1,790.61 ha/year or 45% of total land use. In period 2, the highest conversion rate is on groundwater bodies, reaching 694.29 ha/year or 28%. Meanwhile, the highest conversion rate in period 3 occurred in plantation areas, which reached 1,553.47 ha/year or 57%.

Groundwater bodies area has the highest land conversion rate. The conversion of groundwater bodies is possibly due to the increasing area of agricultural land in Sleman Regency every year. Sleman Regency is an upstream region that functions like a rain catcher. If land conversion continues, water conservation can be threatened. As a result, an area is needed that can be used as a water absorber. Another factor is the occurrence of siltation of the river or the conversion of groundwater bodies area to paddy fields. The volume of groundwater reserves due to land conversion is influenced by the amount of land converted and the amount of infiltration in the unit area. Some districts in Sleman Regency
experienced a conversion of 245,929 m$^2$ of land, resulting in a decrease in groundwater reserve volume of 263,961 m$^3$.

In period 3, the land that experienced the highest conversion rate was the plantation area. The plantation area has been converted by up to 57%. This plantation area is likely to be converted to a settlement or tourist place. The need for land conversion occurs because of two main things. The first is a need to meet the increasing needs of the population, and the second is related to the increasing demand for a better quality of life [10]. In addition, stakeholders are inconsistent with regional regulations that have been made and stipulated.

Besides experiencing land degradation or conversion, Sleman Regency has also experienced an increase in the area of land use. The increase in the area of land use in Sleman Regency can be seen in Figure 10. In period 1 and 2, the highest increase in the area of land use was in forest and plantation areas. Meanwhile, in period 3, the significant increase in the area of land use was observed in non-agricultural land.

![Figure 2. The increase in land use from 1990 to 2015](image)

Changes in land use in Sleman Regency in each period can be seen in Table 5. The value (+) indicates that the land is converted, but it does not experience an increase in the area, while the value (-) shows that the land is converted, but it experiences an increase in area. Groundwater bodies experience changes in land use in each period and tend to continue to decrease, while paddy fields experience the highest conversion rate but the lowest increase in area.

| Period   | LBA  | LH    | LK    | LNP   | LP    | LS    |
|----------|------|-------|-------|-------|-------|-------|
| Period 1 | 17.84| 9572.2| 2151.5| 4.13 | 9525.8| 0     |
| Period 2 | 0    | 3498.04| 491.18| 584.1| 6738.07| 1694.24|
| Period 3 | 33.65| 213.58| 1904.5| 7239.1| 1017.5| 2461  |

**Table 5.** The change in land use in Sleman Regency

Remarks:
LBA= Groundwater bodies, LH= Forest, LK= Barren land, LNP= Non-agricultural land, LP= Plantation area, LS=Paddy fields
(+)= tend to decrease, (-)= tend to increase
4. Conclusion
Sleman Regency experiences changes in land use in each period. Land that continues to experience changes in land use and does not experience an increase in area in each period is groundwater bodies area. Meanwhile, the land that experiences the highest rate of land conversion and experiences the lowest increase in area is paddy fields. The rate of land conversion in Sleman Regency in period 1 is 1,790.61 ha/year (paddy fields), in period 2 is 694.29 ha/year (groundwater bodies), and in period 3 is 1,553.47 ha/year (plantation area). The satellite images of land cover that have the best quality for identification and data analysis were obtained in Landsat 7 and Landsat 8.

References
[1] Utomo M. 1992. Alih fungsi lahan: Tinjauan analitis. Di dalam: Utomo M, Rifai E, Thahar A, editor. Pembangunan dan Pengendalian Alih Fungsi Lahan. ISBN 979-8287-02-9. Bandar lampung (ID): Universitas Lampung. Hal. 3.
[2] Central Bureau Statistic (BPS) of Special Region of Yogyakarta (BPS DIY). 2017. Sleman Regency in Figure 2005 – 2015. https://yogyakarta.bps.go.id/. Access Mei 5th 2017
[3] Irawan, B. 2005. Konversi Lahan Sawah : Potensi Dampak, Pola Pemanfaatannya dan Faktor Determinan. Forum Penelitian Agro Ekonomi 21 (2) 145-174.
[4] Pakpahan, A., Sumaryanto, N. Syafa’at. 1993. Analisis Kebijaksanaan Konversi Lahan Sawah ke Penggunaan Nonpertanian. Pusat Penelitian Sosial Ekonomi Pertanian. Bogor.
[5] Rustiadi E, Wafda R. 2005. Masalah Ketersedian Lahan dan Konversi Lahan Pertanian. Makalah Seminar pada Seminar Penanganan Konversi Lahan dan Pencapaian Lahan Pertanian Abadi pada tanggal 13 Desember 2005, Kerjasama Kantor Kementerian Koordinator Bidang Ekonomi dan Pusat Studi Pembangunan Pertanian dan Perdesaan (PSP3) LPM IPB.
[6] Central Bureau Statistic (BPS) of Sleman Regency. 2017. Sleman Regency in Figures 2016. Sleman. Indonesia (In Indonesia: Badan Pusat Statistik.. Kabupaten Sleman dalam Angka 2016. Sleman. Indonesia) https://slemankab.bps.go.id/index.php. Access Mei 5th 2017.
[7] Meteorology and Geophysics Agency (BMKG) Yogyakarta. 2017. Data of Climate in Sleman. Yogyakarta.
[8] Central Bureau of Statistics (BPS) of Sleman Regency from 1990-2015. Sleman Regency in Figures. https://slemankab.bps.go.id/index.php. Access Mei 5th 2017.
[9] National Land Agency. 2016. Analysis of Land Use in Sleman Regency in 2016. (in Indonesia: Analisis Penggunaan Lahan Kabupaten Sleman Tahun 2016). Sleman. BPN Kabupaten Sleman
[10] Delvi. 2013. Analisis Spasial Konversi Lahan Kota Padang Tahun 2003-2012. Laporan Akhir Penelitian Dosen. Fakultas Teknologi Pertanian. Universitas Andalas.