

Spatial Analysis to Determine Paddy Field Changes in Indonesia: A Case Study in Suburban Areas of Jakarta

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Abstract. Karawang, a suburban area of Greater Jakarta, is known as the second largest rice-producing region in West Java, Indonesia. However, expansion of urban sprawl and industrial area from Greater Jakarta have created rapid agricultural land use/cover changes, especially paddy field, in Karawang. This study analyzed the land use/cover changes of paddy field from 2000 to 2016. Landsat 4-5 TM and Landsat 8 OLI/TIRS images were acquired from USGS Earth Explorer, UTM zone 48 south. Satellite image pre-processing, ground truth data collection, supervised maximum likelihood classifications, and Post-Classification Comparison (PCC) were performed in ArcGIS 10.3®. It was observed between 2000 and 2016, urban area increased 4.46% (8530 ha) from initial area of 10,004 ha. Meanwhile paddy field decreased 3.18% (6091 ha) from initial area of 115,720 ha. The spatial analysis showed that paddy field in the fringe of urban area are more susceptible for changes.

1. Introduction

Agriculture is one of the primary sectors in Indonesia. Relying on natural and human resource potential, the government of Indonesia has made agricultural sector as one of the pillars for promoting economic development of a country. Increasing food self-sufficiency on targeted commodities like rice, corn, soybean, and sugar has been considered as priority program constructed on National Long Term Development Plan 2015-2019.

Food self-sufficiency defines as dependency on domestic production to meet consumption needs of country's population [1]. Prior to promote rice self-sufficiency, Directorate General of Food Crops [2] has made target on paddy production up to 81.9 million tons in 2019. West Java is therefore targeted to produce 13.4 million tons of paddy, equal to 16.4% of total national target production. Land protection and utilization has been considered as one of the solution to increase rice production particularly in West Java [3]. It has been a concern since rapid paddy field changes dominantly occurred around suburban areas of Greater Jakarta.

The development of Jakarta as the capital city of Indonesia has led to the emergence of megacities known as Greater Jakarta which covers Jakarta and adjoin cities. Jakarta and its expanding urban regions are the most urbanized region with 12.41% of Indonesia total population in 2016. Rapid population growth have resulted in urbanization beyond municipal boundaries (also known as suburbanization) prior to accommodate the need of growing population [4]. The inevitable consequences from expansion of urban sprawl in suburban areas of Greater Jakarta is land use/cover changes, particularly paddy field.



This is due to the high economic development that lead to excessive migration across the cities, which significantly contributes to the population growth in suburban area of Greater Jakarta [5]. Therefore, the suburban areas have a significant contribution in food production scheme in the West Java and Greater Jakarta.

Therefore the objective of this research is understanding the pattern and the factor behind the higher rates of paddy field changes. This study used integrated satellite remote sensing and GIS approach to develop geo-spatial model and analyzed paddy field changes between 2000 and 2016 in Karawang. Karawang, a suburban area of Greater Jakarta, currently attracts considerable attention due to land use/cover changes.

2. Geographical Extent of Study Area

Karawang is located between longitude 107°02'E to 107°40'E and latitude 5°56'S to 6°34'S in the suburban areas of Greater Jakarta. Karawang consists of 30 districts and bordered by Bekasi and Bogor on the west, Subang on the east, and Java Sea on the north. Located in relatively flat terrain with 0-5 m above sea level has made Karawang becomes a potential area for irrigated paddy field.

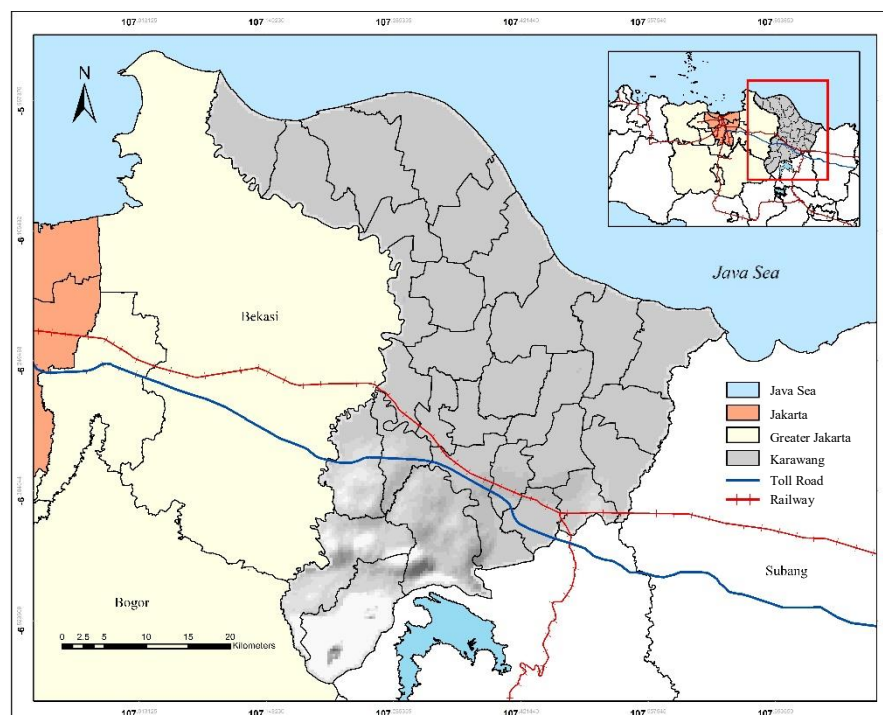


Figure 1. Land use/cover in 2000 and 2016 for Karawang areas

3. Methodology

Prior to develop spatial analysis on land use/cover changes, several methodological approaches were conducted as follows: (a) Data acquisition; (b) Ground truth data collection; (c) Image pre-processing; (d) Image classification and accuracy assessment; (e) Change detection analysis.

3.1. Data Acquisition

This study used Landsat 4-5 TM and Landsat 8 OLI/TIRS acquired from USGS Earth Explorer on September 6, 2000 and May 13, 2016 respectively. Geo-referencing was done by correctly register satellite images with reference images and projected into Universal Transverse Mercator (UTM), Datum WGS 1984 zone 48 south.

3.2. Ground truth data collection

Ground observation was conducted to identify types of land use/cover distribution in study area. The ground control points in the fields and visual observation of high resolution images on google maps were used to complete supervised classification and evaluate the accuracy of the land use/cover map. Ground control points were taken based land cover type and accessibility of the location.

3.3. Image classification and accuracy assessment

The satellite images were classified into nine classes; forest cover, mixed garden, paddy field, upland agriculture, shrub land, fallow land, aquaculture use, water body, and urban settlements (Table 2). False color composite for vegetation analysis was applied to help classification process due to contrast color between vegetation, water, and soil (Table 1). Maximum likelihood supervised classification was used to generate land use/cover from satellite images by assigning pixels of interest into defined class. All the classification methods were employed in ArcGIS 10.3®.

Multiple accuracy assessment was conducted to measure the acceptability rate of the land use/cover map. The accuracy assessment was carried out by using random sampling of reference points based on ground truth data and visual interpretation on Google Earth Pro®. The comparison data between land use/cover and reference points were served in the form of confusion matrix. The confusion matrix had been widely used to promote accuracy of the land use/cover for various analysis such as watershed analysis [6] and urban expansion analysis [7]. Series of analytical statistics such as overall accuracy, Kappa coefficient, omission error, commission error, producer's accuracy (corresponds to omission error), and user's accuracy (corresponds to commission error) were derived from the confusion matrix and generally reported to assess land use/cover accuracy.

Table 1. False color composite for vegetation analysis in Landsat 4-5 TM and Landsat 8.

| Satellite | Band combination (RGB) |
|--------------------|--------------------------|
| Landsat 4-5 TM | 5,4,3 (SWIR 1, NIR, Red) |
| Landsat 8 OLI/TIRS | 6,5,4 (SWIR 1, NIR, Red) |

SWIR: Shortwave Infrared, NIR: Near-Infrared

Table 2. Description of different land use/cover classes of study area.

| Class | Description |
|-------------------------|--|
| Forest Cover (FC) | Large area covered with dense trees, including mountainous area |
| Mixed Garden (MG) | Mixture of vegetation planted behind settlement and vegetation along the street and the river |
| Paddy Field (PF) | Field where paddy is grown, mostly dominated by irrigated paddy field |
| Upland Agriculture (UA) | Cultivated area, usually planted by maize, cassava, upland rice (non-irrigated) |
| Shrub Land (SL) | Sparse vegetation and abandon land |
| Fallow Land (FL) | Area with exposed soil surface |
| Aquaculture Use (AU) | Covered both inshore (open sea farming) and offshore (inland fishpond) fish farming |
| Water Body (WB) | Part of earth surface covered with water: river and lake |
| Urban Settlements (US) | Area dominated by human. It covers settlement, commercial building, public infrastructure, and industrial estate |

3.4. Change detection analysis

Post-classification comparison (PCC) method was used to identify the differences between two independently produced classified land use/cover images [8]. In this study, land use/cover in 2000 and 2016 were overlaid. Post-classification comparison (PCC) method was employed to determine changed of paddy field and into settlements area and unchanged of paddy field during the time period studied. For accuracy assessment, points from Ground Control Points and visual classification based on Google map are utilized. Regarding further analysis, the research focused on paddy field, therefore other land use/land cover were not analyzed.

4. Results

4.1. Land use/cover in 2000

The land use/cover image in 2000 was produced through supervised classification method using Landsat TM datasets (Figure 2). In the land use/cover image, Karawang covered about 191416 ha. The land use/cover distribution consisted of paddy field (60.45%), aquaculture use (9.09%), upland agriculture (6.78%), forest cover (6.47%), urban settlements (5.23%), mixed garden (4.11%), shrub land (4.08%), fallow land (2.47%), and water body (1.31%). Accuracy assessment of the land use/cover map was found with an overall accuracy of 84% and Kappa coefficient of 0.83 (Table 3).

4.2. Land use/cover in 2016

The land use/cover image in 2016 was produced using Landsat OLI/TIRS datasets (Figure 2). The data revealed that in 2016, the land use/cover distribution consisted of paddy field (57.27%), urban settlements (9.68%), aquaculture use (8.29%), forest cover (6.95%), shrub land (6.4%), mixed garden (5.55%), upland agriculture (4.09%), water body (1.59%), and fallow land (0.15%). Accuracy assessment of the land use/cover map was observed with an overall accuracy of 89.89% and Kappa coefficient of 0.88 (Table 4). Higher accuracy assessment of land use/cover map of 2016 was obtained due to availability of recent ground truth information.

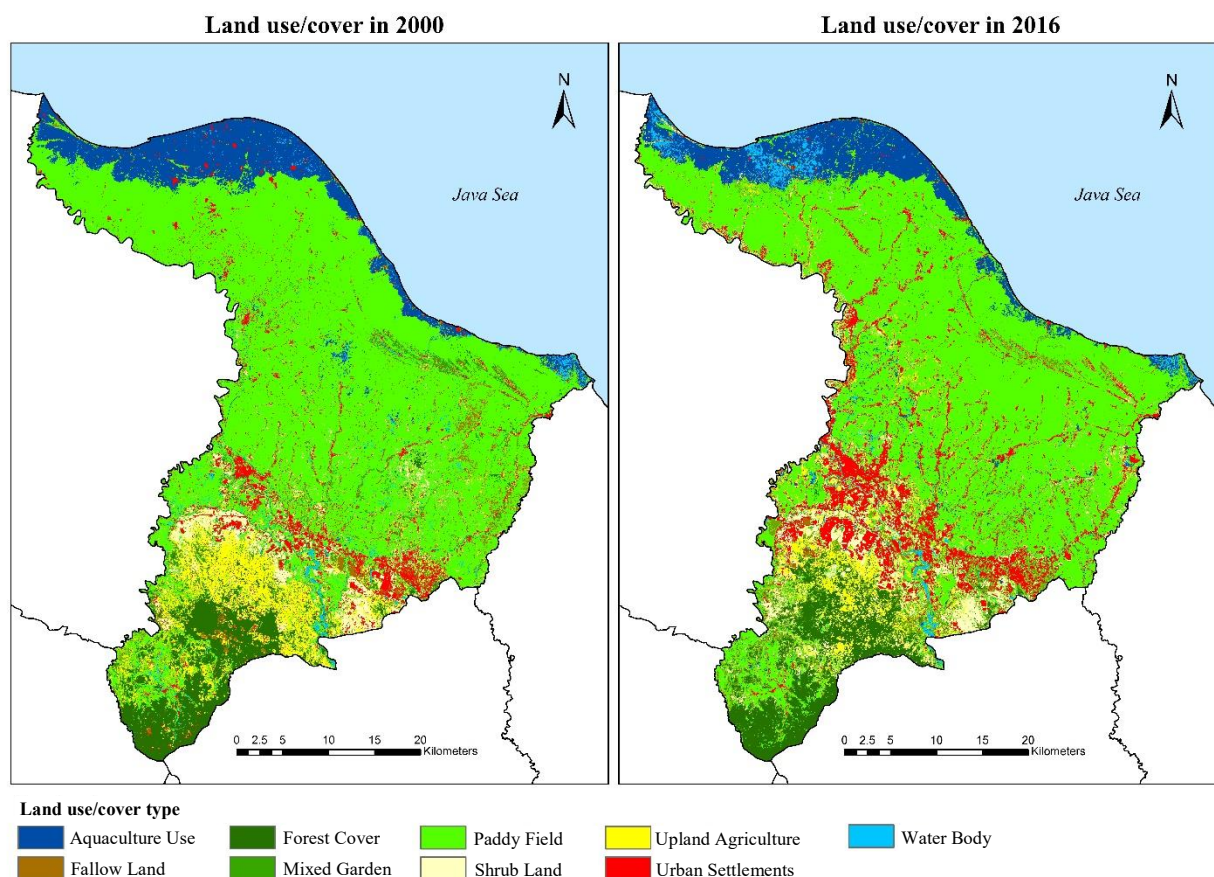


Figure 2. Land use/cover image in 2000 and 2016 for Karawang areas.

4.3. Accuracy assessment of land use/cover in 2000 and 2016

Multiple accuracy assessments of land use/cover in 2000 and 2016 were described in the form of confusion matrix. Total of 482 and 396 reference points based on random sampling of ground truth data

and visual interpretation were taken for accuracy assessments of land use/cover in 2000 and 2016, respectively. Diagonal line showed correctly classified pixels between land use/cover class and reference points. While off-diagonal line corresponded to misclassified class (commission and omission error). Sufficient accuracy of paddy field and urban area were therefore required to evaluate the paddy field land use/cover change. The accuracy assessment is listed in Table 3 and 4.

Low accuracy of land use/cover map in 2000 and 2016 were found in aquaculture use and water body. It happened due to similar surface characteristics. Misclassified pixel was known as salt and paper or pixel noise. Removing the pixel noise could improve the quality of classification.

Table 3. Accuracy assessment of land use/cover (LU) 2000.

| LU | Ground truth reference points | | | | | | | | | | UA (%) | PA (%) |
|-------|-------------------------------|----|----|----|----|----|----|----|----|-------|--------|--------|
| | FC | MG | PF | UA | SL | FL | AU | WB | US | Total | | |
| FC | 40 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 44 | 90.91 | 86.96 |
| MG | 1 | 46 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 50 | 92.00 | 92.00 |
| PF | 1 | 0 | 71 | 0 | 1 | 1 | 3 | 3 | 2 | 82 | 86.59 | 89.87 |
| UA | 1 | 0 | 0 | 42 | 0 | 0 | 0 | 0 | 0 | 45 | 93.33 | 84.00 |
| SL | 0 | 0 | 1 | 2 | 31 | 1 | 0 | 0 | 1 | 36 | 86.11 | 77.50 |
| FL | 2 | 0 | 0 | 2 | 1 | 18 | 0 | 0 | 3 | 26 | 69.23 | 81.82 |
| AU | 0 | 0 | 0 | 0 | 0 | 0 | 46 | 13 | 0 | 59 | 77.97 | 79.31 |
| WB | 0 | 0 | 1 | 0 | 0 | 0 | 6 | 39 | 0 | 46 | 84.78 | 70.91 |
| US | 1 | 0 | 6 | 0 | 0 | 2 | 3 | 0 | 76 | 94 | 80.85 | 92.68 |
| Total | 46 | 48 | 79 | 50 | 34 | 22 | 58 | 55 | 82 | 482 | | |

Overall Accuracy: 84.85%; Kappa Coefficient: 0.83

FC: Forest Cover; MG: Mixed Garden; PF: Paddy Field; UA: Upland Agriculture; SL: Shrub Land; FL: Fallow Land; AU: Aquaculture Use; WB: Water Body; U: Urban Settlements; UA: User's Accuracy; PA: Producer's Accuracy

Table 4. Accuracy assessment of land use/cover (LU) 2016.

| LU | Ground truth reference points | | | | | | | | | | UA (%) | PA (%) |
|-------|-------------------------------|----|----|----|----|----|----|----|----|-------|--------|--------|
| | FC | MG | PF | UA | SL | FL | AU | WB | US | Total | | |
| FC | 45 | 2 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 50 | 90.00 | 100.00 |
| MG | 0 | 25 | 1 | 2 | 0 | 0 | 1 | 0 | 0 | 29 | 86.21 | 80.65 |
| PF | 0 | 0 | 69 | 0 | 0 | 1 | 1 | 3 | 0 | 74 | 93.24 | 97.18 |
| UA | 0 | 2 | 0 | 34 | 3 | 0 | 0 | 0 | 0 | 39 | 87.18 | 79.07 |
| SL | 0 | 2 | 0 | 4 | 27 | 1 | 0 | 1 | 0 | 35 | 77.14 | 90.00 |
| FL | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 0 | 13 | 100.00 | 76.47 |
| AU | 0 | 0 | 1 | 0 | 0 | 0 | 49 | 7 | 0 | 57 | 85.96 | 90.74 |
| WB | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 34 | 0 | 37 | 91.89 | 75.56 |
| US | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 60 | 62 | 96.77 | 100.00 |
| Total | 45 | 31 | 71 | 43 | 30 | 17 | 54 | 45 | 60 | 396 | | |

Overall Accuracy: 89.89%; Kappa Coefficient: 0.88

FC: Forest Cover; MG: Mixed Garden; PF: Paddy Field; UA: Upland Agriculture; SL: Shrub Land; FL: Fallow Land; AU: Aquaculture Use; WB: Water Body; U: Urban Settlements; UA: User's Accuracy; PA: Producer's Accuracy

4.4. Land use/cover changes in 2000-2016

Summary of land use/cover changes from 2000 until 2016 is described in Table 5. Within 17 years, considerable land use/cover changes occurred in paddy field and urban settlements in Karawang. Increased of urban settlements were followed by decreased of paddy field areas. In 2016, urban settlements increased 4.46% (8530.3 ha) from initial area of 10,004 ha in 2000 (Table 5). Meanwhile paddy field in 2016 reduced 3.18% (6091.02) from initial area of 115,720 ha in 2000 (Table 5). Loss of paddy field was occurred dominantly in marginal area of urban settlement. According to the [9], extensive road network, industrial decentralization, and affordable house price were the main factor that contributed the most to the rapid population growth in suburban area. In spite of the economic benefit

that came from industrial decentralization, adverse effect of industrial growth has therefore threaten Karawang as the second largest rice-producing region in West Java [10].

Table 5. Land use/cover change of Karawang from 2000 until 2016.

| No. | Land use/cover Type | Year | | | | Change | |
|-------|---------------------|-----------|-------|---------|-------|----------|------|
| | | 2000 | | 2016 | | | |
| | | (ha) | (%) | (ha) | (%) | (ha) | (%) |
| 1 | Forest Cover | 12397.05 | 6.48 | 13305.3 | 6.95 | 908.25 | 0.47 |
| 2 | Mixed Garden | 7865.91 | 4.11 | 10639.8 | 5.56 | 2773.89 | 1.45 |
| 3 | Paddy Field | 115720.02 | 60.45 | 109629 | 57.27 | -6091.02 | 3.18 |
| 4 | Upland Agriculture | 12981.96 | 6.78 | 7839.18 | 4.10 | -5142.78 | 2.69 |
| 5 | Shrub Land | 7801.83 | 4.08 | 12259.3 | 6.40 | 4457.47 | 2.33 |
| 6 | Fallow Land | 4726.12 | 2.47 | 298.94 | 0.16 | -4427.18 | 2.31 |
| 7 | Aquaculture Use | 17402.85 | 9.09 | 15864 | 8.29 | -1538.85 | 0.8 |
| 8 | Water Body | 2515.86 | 1.31 | 3045.78 | 1.59 | 529.92 | 0.28 |
| 9 | Urban Settlements | 10004.4 | 5.23 | 18534.7 | 9.68 | 8530.3 | 4.46 |
| Total | | 191416 | 100 | 191416 | 100 | | |

During the same period, other land use/cover types in Karawang were relatively stable with moderate changes. Decreased of land use/cover were occurred in upland agriculture (5142.78 ha), fallow land (4427.18 ha), and aquaculture use (1538.85 ha). While increased of land use/cover occurred in forest cover (908.25 ha), mixed garden (2773.89 ha), shrub land (4457.47 ha), and water body (529.92 ha) (Table 5).

Socio-economic factor had been considered as the reason of agricultural land abandonment in Karawang. According to Benayas [11], new economic opportunities offered to the rural people created rapid migration that lead to the agricultural land abandonment.

4.5. Change detection analysis

Change detection analysis of paddy field was described on the Figure 3. The figure showed changed and unchanged of paddy field during period of studies. In terms of urban expansion, paddy field was the highest land use/cover type that experienced changes to urban settlements. The data revealed that changed of paddy field into urban settlements from 2000 to 2016 (red area) was about 8273.37 ha (7.15%). Meanwhile, unchanged of paddy field from 2000 to 2016 (green area) covered about 95932.06 ha (82.9%).

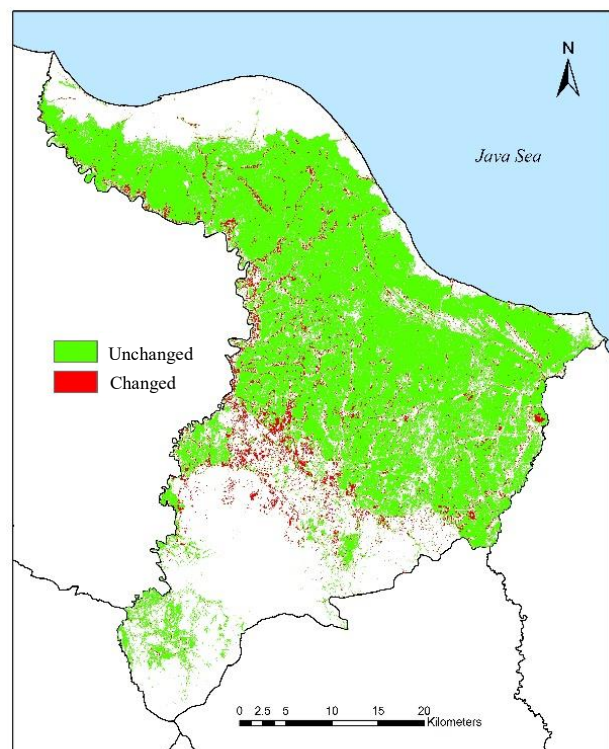


Figure 3. Change detection analysis of paddy field

5. Conclusion and recommendation

A geo-spatial model was developed to assess agricultural land use/cover changes for the suburban areas of Greater Jakarta, especially paddy field. Population pressure and industrial decentralization from greater Jakarta creates high demand on land resulted in conversion of paddy fields. Despite all the economic benefit that comes from industrial decentralization, high demand of land for industrial area, housing and infrastructure near the Greater Jakarta therefore threatened Karawang's potential as rice-

producing region. Appropriate uses of land under Sustainable Agricultural Land Regulation (LP2B) should be made and implemented to control urban expansion towards high productive paddy fields.

In the further research, the land use inventory for suburban areas of major cities in Indonesia will be included using time series form with collaboration of other research contributors to provide information for decision making of land use planning. Logistics regression will also be conducted to understand the influencing factors on agricultural land use/cover changes in Karawang. The developed model could help in planning of agricultural lands in the suburban areas to increase production of rice and urban growth with strong vision of sustainability.

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