Spatial and Temporal Patterns of the Decreasing Rice Field in Sidorejo Sub-district, Salatiga City, Central Java Province, Indonesia

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Abstract. The agricultural land conversion and all its utilization happens as time goes by. This conversion commonly happens in Indonesia, including in Sidorejo District, Salatiga City. Sidorejo is one of the potential areas of agriculture, especially for agriculture area in Central Java. The agriculture area in Sidorejo has decreased by 3.12 \text{km}^2 in the past 10 years (2007 - 2017). The purpose of this research is to map changes of rice field area in spatial and temporal manner. The research variables include topography, river network, farmer education level, farmers' income, and population. This study utilizes primary data obtained from interviews and questionnaires, while the secondary data is obtained from Centre of Statistical Bureau, Geospatial Information Bureau, and USGS DEM. The analytical method used in this study is overlay and transects in a systematically random sample. The results indicated that rice fields area changes in the western and eastern parts of Sidorejo for 10 years (2007-2017) which were generally triggered by population. Rice field area changing in west correlates with topography, river networks, education levels and low farmer incomes. Meanwhile, rice field area changing in east correlates with the level of education and high income of farmers.

Keywords: Agriculture, Land use, Salatiga.

1. Introduction

Land is the earth surface with physical characteristics such as: provision of water and cover plants which are found as a human activity space [1, 2]. Land use becomes an aspect of human mastery as a description of human behavior towards land to achieve the desired objectives of the land use [3, 4]. Conversion of the use of agricultural land and its type occurs all the time. Conversion of agricultural land to non-agricultural land becomes one of the central issues of agricultural development due to its significantly negative impact on food production and environmental problems [5, 6, 7].

Land use conversion commonly occurs in Indonesia, including the District of Sidorejo, in Salatiga City [5]. Every development program regarding infrastructure requires suitable land. On the other hand, the need for human habitation increases along with the increase in population. The conversion of agricultural land use in Sidorejo District generally occurs into paddy fields. Sidorejo is one of the agriculture areas, especially rice potentially. Although it has become a city, Sidorejo still has extensive
agricultural land. According to BPS data in 2017, the total agricultural land area in Sidorejo District is around 3.78 km². The decrease in agricultural land area in Sidorejo Subdistrict from 2007 to 2017 reached 3.12 km². The implication of conversion of agricultural land to farmers is the change of agrarian structure in the farming community [5]. These implications are obvious after land conversion happens for a long period of time. Conversion of agricultural land to non-agricultural land becomes one of the central issues of agricultural development due to significantly negative impact on food production in addition to other socio-economic aspects and environmental problems [6].

The purpose of this research is to spatially and temporally map agricultural land area changes in Sidorejo District. This research is very important to determine the condition of agricultural land use with the assumption of a comparison of multitemporal population number (2007 – 2017) [7]. This research is employed as a reference in developing appropriate policies for the future land use management.

2. Methodology

Sidorejo District is one of the Districts in Salatiga City. Geographically, Sidorejo is at 110° 29' 38.4" E and 7° 18' 36" S. Sidorejo District is located in the north of Salatiga City. Sidorejo has an area of approximately 15.84 km² divided into six sub-districts of: Salatiga, Sidorejo Lor, Blotongan, Pulutan, Bugel, and Kauman Kidul.

The variables used in this study are topography, river, farmer’s education level, farmer's income and population. Topography and river are obtained from the results of processing map data that has been verified in the field. Farmer’s income and farmer’s education level are obtained from interviews with farmers directly. The population is obtained from Statistical Centre Bureau data. All of these variables were correlated with changes in rice land use in Sidorejo District. Maps of multitemporal land use (2007 & 2017), river data in 2017, road data in 2017, and irrigation area data in 2017 were obtained from the Geospatial Information Agency. In addition, Digital Elevation Model data was obtained from USGS in 2017. The sampling technique used in this research is the stratified random sampling technique. The point of the sample was based on the distribution pattern of paddy fields in Sidorejo District. The pattern of the distribution of rice fields depicted in Sidorejo is rice fields in the west and east.

The analytical method used in this study is overlay and extraction of transect lines. The GIS Overlay implemented in this research is the overlay of several thematic maps arranged in layers with the aim at identifying correlations between them [8, 9, 10, 11]. Thematic maps data that are stacked in layers include: river, irrigation area, land use, and administrative boundaries. The technique of extracting the transect is obtained by cross-sectioning on a map with a description in general on the appearance of the transect line and is interpreted through legend [12]. Transect line drawings were implemented on seven research samples focused on the use of rice fields.

3. Result and Discussion

3.1. Sidorejo Land use in 2007

Sidorejo land use in 2007 had a total area of 15.48 km² (Figure 1). The land use covers rice fields land and non-rice land. The use of rice fields includes irrigated and non-irrigated rice fields. The use of rice fields has a total area of 4.46 km² (28%) which is concentrated mostly in Blotongan, Pulutan and Kauman Kidul. The use of non-rice land is for settlement, office affairs, plantations, grassland, and yard with a total area of 11.02 km² (72%). The use of non-rice land is mostly concentrated in the Salatiga, Sidorejo Lor, Bugel and Blotongan.

3.2. Sidorejo Land use in 2017

Land use area in Sidorejo District in 2017 has the same total area as in 2007, which is 15.48 km² (Figure 2). The use of rice fields land has a total area of 3.20 km² (20%). The use of rice fields is still concentrated mostly in Blotongan, Pulutan, Salatiga and Kauman Kidul. Whereas, the non-rice land
use is developed into several categories, such as: trading, settlements, education, graveyard, yard, medical facility, industry, social facilities, plantation, and office affairs. The total area of non-rice land is 12.28 km² (80%). The use of non-rice land is still concentrated in the Salatiga, Sidorejo Lor, Bugel and Blotongan.

Figure 1. Sidorejo Land Use Map (2007)

Figure 2. Sidorejo Land Use Map (2017)

3.3. Multitemporal Rice Field Area Dynamic Sidorejo (2007 – 2017)
The land use of irrigated and non-irrigated rice fields in Sidorejo District has a total decrease of 1.26 km² (29%) (Figure 3). The biggest decrease in rice fields occurred in Blotongan with a total decrease of 0.42 km² (33%). In addition, the type of rice fields located in Blotongan is transformed into non-irrigated rice fields. On the other hand, rice fields from irrigation type to non-irrigated type occurred in Pulutan and Sidorejo Lor, although each of their total decrease was very small with 0.02 km² (1%) and 0.06 km² (4%). Rice fields with unchanged type are in the Kauman Kidul, Bugel, and Salatiga with
each of their total decrease in rice fields are 0.32 km$^2$ (25%), 0.20 km$^2$ (15%), and 0.24 km$^2$ (19%). Besides, the west Sidorejo has changed significantly its type of rice fields in 10 years (2007-2017).

3.4. Correlation Between Physical Aspect and Rice Fields
Altitude is the physical aspect related to the land use [1]. Land use for rice plants tends to be placed in lower places. Rice plants require warm temperature to grow optimally at low altitudes. Based on the theory of the land evolution scheme, the area of residential settlements is above the height of the wetlands [1].

The AB transect line presents land use condition in 2007 from Blotongan to Pulutan (Figure 4). The first sample point on the AB transect line (26m ASL) is irrigated rice land use. The second sample point on the AB transect line (27.9m ASL) is irrigated rice land use. Sample points 3 on the AB transect line (29.5m ASL) is non-irrigated land use. The second sample point on the A’B’ transect line (27.9m ASL) is non-irrigated rice land use. The sample point 3 on the A’B’ transect line (29.5m ASL) is the land use of the education area.

The CD transect line is a transect line of land use condition in 2007 from Sidorejo Lor to Salatiga (Figure 5). Sample point 4 on the CD transect line (26.7m ASL) is irrigated rice land use. Sample point 5 on the CD transect line (28.4m ASL) is irrigated rice land use. The C’D’ transect line is a transect line for 2017 land use conditions from Sidorejo Lor to Salatiga (Figure 5). Sample point 4 on the transect line C’D’ (26.7m ASL) is irrigated rice land use with reduced area than previously known (2007). Sample point 5 on the transect line C’D’ (28.4m ASL) is settlement land use.

Figure 3. Chart of Multitemporal Rice Field Area Changes (2007 – 2017)

Figure 4. Multitemporal AB & A’B’ Profile Graphs (2007 – 2017)
The EF transect line is a transect line of land use condition in 2007 from Bugel to Kauman Kidul (Figure 6). Sample point 6 on the EF transect line (30m ASL) is irrigated rice land use. Sample point 7 on the EF transect line (28m ASL) is irrigated rice land use. The E’F’ transect line is a transect of land use condition in 2017 from Bugel to Kauman Kidul (Figure 6). Sample point 6 on the E’F’ (28m ASL) transect line is settlement land use. The sample point 7 on the E’F’ transect line (28m ASL) is trading land use area.

The low topography in Sidorejo is utilized more by the residents as rice fields. The high topography is used by the population as an area of built up land such as settlements and other built-up land facilities [14]. The topography in the west of Sidorejo is lower when compared to east Sidorejo. This situation allows the river network in the lower to reach Sidorejo blockage due to sedimentation transported from the upstream of Sidorejo [6]. The type of river that is in the Blotongan is turned into a perennial river drying the irrigation area around the Blotongan paddy field. The change in the type of river and the irrigation area causes the type of irrigated rice fields in Blotongan turned into non-irrigated rice fields. Although the irrigation area in Pulutan is not dry, the irrigation area in Pulutan has been distributed to people's homes causing the dried up and changing their rice fields type into non-irrigated rice fields. The types of rice fields in the east of Sidorejo survive as irrigated rice fields because the river network and irrigation areas are not clogged and dried up.

3.5. Correlation Between Human Aspect and Rice Field

The population in Sidorejo has increased multi-temporally (2007 - 2017). The population in all Sidorejo in 2017 was 21738, which was more than the total population in 2007 (Figure 7). The increasing population of Sidorejo Sub-district resulted in increasing housing needs [7]. The use of vacant land in Sidorejo Sub-district is so limited that most residents of Sidorejo Sub-district use rice fields to be converted into settlement areas and other built facilities.
Based on table 1 column (b), the average level of education of farmers in west Sidorejo is completed only at the elementary level. While the education level of farmers in east Sidorejo is completed on average to high school level. This has an effect on the readiness of urbanization that occurs in Sidorejo Sub-District which has an impact on their rice fields [15]. Farmers in the eastern part of Sidorejo, especially the Kauman Kidul, tend to make their fields as part of catfish farms to earn more income. While some rice farmers in the Salatiga and Bugel use their paddy field compensation money which has been partially converted into infrastructure and local residents' settlements for business or work in fields other than their rice fields. Most farmers in the western part of Sidorejo only depend on their paddy fields which are reduced and changed their type without any innovation and creativity.

Based on table 1 column (c) and (d) shows the income of farmers is influenced by the number of harvests. Rice fields that have one to two harvest frequencies are non-irrigated rice fields. Rice fields that have a harvest frequency of two to three times are irrigated rice fields. The income of farmers in the west is less when compared to farmers in the east. Farmers in the east get the benefit from rice fields with a harvesting frequency of two to three times a year plus the efforts of farmers in other job or business. Farmers in the west can only harvest in one to two times a year because they are waiting for the rainy season to care for their rice having no business in other job.

Table 1. Farmer’s Income, Education, and Rice Harvest Frequency

| Farmer (a) | Education (b) | Rice Harvest Frequency (c) | Income per harvest (d) |
|-----------|---------------|----------------------------|------------------------|
| 1         | Elementary    | twice                      | IDR 1.500.000          |
| 2         | Elementary    | once                       | IDR 1.000.000          |
| 3         | Elementary    | twice                      | IDR 2.000.000          |
| 4         | Elementary    | twice                      | IDR 3.000.000          |
| 5         | Senior High School | twice              | IDR 3.000.000          |
| 6         | Senior High School | three times           | IDR 4.000.000          |
| 7         | Senior High School | three times           | IDR 4.000.000          |

4. Conclusion
Changes in irrigated and non-irrigated rice fields from 2007 to 2017 decreased by 1.26 Km². The change in non-rice land from 2007 to 2017 increased by 1.26 Km². The most reduced rice fields occurred in Blotongan with a decrease of 0.42 Km². On the other hand, the type of rice fields in the
Blotongan has changed significantly from irrigated rice fields to non-irrigated rice fields. The least reduced paddy fields occurred in the Pulutan with a decrease of 0.02 Km$^2$. Even though the paddy fields decreased the least, the types of rice fields in the Pulutan Village changed significantly also from irrigated rice fields to non-irrigated rice fields. Changes in area and type of paddy fields are influenced by altitude, river network, population, farmer education level, and farmer's income.

Acknowledgments
The authors would like to thank the Department of Geography, Faculty of Mathematics and Natural Science, Indonesia University, which has facilitated the second field study class for the research activities of undergraduate students and the lecturers in Salatiga City.

References
[1] Sandy M I 1999 Tanah Muka Bumi vol 1 (Jakarta: Geography Department, Universitas Indonesia) p 1
[2] Koji T, Mattulada, and Narifumi M 1986 Environment, Landuse, and Society InWallacea vol 5 (Japan: Kyoto University) p 105
[3] Frederick S 1999 The Living Landscape vol 2 (United States: Arizona State University) p 28
[4] Benjamin C and Peter K 2010 Global Environmental Forest Policies (London & Washington: Earthscan) p 159
[5] Marko K, Zulkarnain F, and Kusratmoko E 2016 Coupling of Markov Chains and Cellular Automata Spatial Models to Predict Land Cover Changes (Jakarta: Geography Department, Universitas Indonesia) 47 012032
[6] Alistair F P 1985 Geomorphology and Trends vol 1 (London) p 56
[7] Horstmann K and W Rutz 1971 The Population Distribution on Java (Tokyo: Institute of Developing Economies) p 29
[8] Gautam N C and Chennaiah G C 2007 Landuse and Landcover Mapping and Change Detection in Tripura Using Satellite LANDSAT Data6 p 517-528
[9] Tunrayo A, Xiangming X, Kai S, ad Chandresahekar B 2008 Mapping and Monitoring Agricultural Landuse in West Africa (Africa: Association of Remote Sensing of the Environment) PMB 5320
[10] Supriatna 2001 Dasar-Dasar Sistem Informasi Geografis vol 1 (Jakarta: Geography Department, Universitas Indonesia) p 1
[11] Nicholas C 1997 Exploring Geographic Information Systems vol 1 (Washington DC: University of Washington) p 105
[12] Kang T C 2006 Introduction to Geographic Information Systems vol 5 (New York: McGraw-Hill Education) p 281
[13] Dwyer D J 1964 Irrigation and Land Problems in the Central Plain of Luzon vol XXTH International Geographical Congress pp 236 – 246
[14] Sandy M I 1996 Republik Indonesia Geografi Regional vol 3 (Jakarta: Geography Department, Universitas Indonesia) p 24
[15] Sayogyo 1985 Pertanian dan Kemiskinan di Jawa vol 1 (Jakarta: Gramedia Indonesia) p 16