THE DETERMINANTS OF PADDY FIELDS CONVERSION IN JAVA AND SUMATRA

(*Faktor-Faktor Penentu Konversi Luas Lahan Sawah di Jawa dan Sumatera*)

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Abstract

Recently, the paddy fields conversion rate is alarmingly high and without significant effort by the government on the existing paddy fields, national food security and food self-sufficiency in Indonesia will be at risk. Therefore, to address this issue, the government needs to identify the main drivers of paddy fields conversion in Indonesia, particularly in Java and Sumatra as national rice barn. Employing panel data of 256 in the regencies/cities level in Java and Sumatra from 2010-2017, this study investigates the determinants of paddy fields conversion in Java and Sumatra. This study identified that the factors which affected paddy fields conversion in Java are the gross regional domestic product (GRDP) in agriculture sector, the GRDP in service sector, and population density. In contrary, the GRDP in service sector doesn't significant with the changed of paddy fields in Sumatra, however GRDP in industry sector affect the paddy fields conversion in Sumatra. Other variables which affected paddy fields conversion in Sumatra are GRDP in agricultural sector and population density. Moreover, geospatial analysis also used in this study. It reveals that the changes of paddy fields in Java is dominated by settlement, and in Sumatra suspected turned dominated into palm oil plantation due to the growth of oil palm industry.

Keywords: paddy fields, land conversion, geospatial

Abstrak

Konversi lahan sawah di Indonesia yang selalu meningkat setiap tahun bisa mengancam ketahanan pangan nasional dan swasembada pangan. Pemerintah perlu melakukan tindakan yang nyata dan signifikan untuk menanggulangi isu tersebut. Salah satu langkah awal untuk mengatasi permasalahan tersebut adalah dengan mengidentifikasi faktor-faktor pendorong konversi lahan sawah yang terjadi di Indonesia, terutama di Pulau Jawa dan Sumatera sebagai lumbung padi nasional. Oleh karena itu, dengan menggunakan data panel dari 256 kabupaten/kota di Pulau Jawa dan Sumatera pada periode tahun 2010-2017, penelitian ini menganalisa faktor-faktor penentu konversi lahan sawah di Jawa dan Sumatera. Hasil penelitian ini membuktikan bahwa faktor-faktor utama yang memengaruhi konversi lahan sawah di Jawa adalah PDRB di sektor pertanian, PDRB di sektor jasa, dan kepadatan penduduk. Sebaliknya, PDRB di sektor jasa tidak berpengaruh terhadap perubahan luas lahan sawah di Sumatera, melainkan PDRB di sektor industri memberikan dampak terhadap konversi lahan sawah di Sumatera. Faktor-faktor lain yang memengaruhi konversi lahan sawah di Sumatera adalah PDRB di sektor pertanian dan kepadatan penduduk. Analisis geospasial juga digunakan di dalam penelitian ini. Berdasarkan analisis geospasial, perubahan lahan sawah di Pulau Jawa didominasi menjadi area pemukiman, sedangkan sebagian besar perubahan sawah di Sumatera berubah menjadi area tanaman yang diduga adalah kelapa sawit. Kelapa sawit berkembang diduga karena pertumbuhan industri minyak kelapa sawit di Sumatera.

Kata kunci: lahan sawah, konversi lahan, geospasial

INTRODUCTION

In the 21st century, due to the nature of the land as a limited natural resource, varieties of activities and purposes are compete to utilize the land (Harvey & Pilgrim, 2011; Palmer et al., 2009). This competition changes land quality and land use in many regions in the world over 20 years, which caused land conversion, specifically agricultural land conversion (Smith et al., 2010).

As an agrarian country, Indonesia cannot avoid the phenomenon of agriculture land conversion due to its economic development and growing population (Azadi et al., 2011). The most common type of agriculture conversion occurring in Indonesia is paddy field conversion (Ilham et al., 2005). This is primarily due to three factors (1) it is easier to develop non-agricultural activities such as housing and industry in paddy fields, which are flatter than dry land, (2) past development focused on increasing rice production so that more economic infrastructure is available in paddy fields area than in dry land area, and (3) paddy fields are closer to consumer areas or relatively populated urban areas as compared to dry land areas, which are mostly found in hilly and mountainous regions.

Table 1. Classification and Change in the Area of Paddy Fields in Indonesia, 1990-2009

(hectare)

Classification of Paddy Fields	1990	2000	2009
1. Irrigated paddy fields			
1.1 Technical irrigation	1,766,056	1,787,583	1,774,276
1.2 Semi technical irrigation	2,289,195	2,227,900	2,190,139
1.3 Simple irrigation	1,772,678	1,725,576	1,560,349
2. Non-irrigated paddy fields			
2.1 Rainfed	2,227,024	1,994,601	2,174,501
2.2 Tidal	426,802	421,865	407,594
Total of paddy fields	8,481,755	8,157,525	8,106,859

Source: Ministry of Agrarian Affairs and Spatial Planning/National Land Agency, 2010.

As shown in Table 1, paddy fields in Indonesia can be classified into two types—irrigated and non-irrigated. From 1990 to 2009, paddy fields in Indonesia have decreased and been converted for other uses (see Table 1). From the early 1990s to 1997, the technocratic policies of economic development in Indonesia led to massive footloose industrialization strategies. During the crisis period (1998-2000), the agriculture sector was the savior of the Indonesian economy, especially because of the surge in the exchange rate of USD that was enjoyed by export commodities in the agriculture sector, especially plantations and fisheries.

The problems caused by paddy field conversion in Indonesia are undoubtedly inseparable from the role of Java and Sumatra as the national rice barns in Indonesia. Java has the largest paddy fields in Indonesia, constituting 43 percent of the total paddy fields in Indonesia (Isa, 2014), followed by Sumatra. Based on the data from the Ministry of Agriculture, paddy fields in Java and Sumatra decreased by 2.4 percent between 2010-2017. Moreover, high-resolution spatial data analyses revealed that the national paddy fields conversion rate was estimated to be 96.512 ha per annum (Mulyani et al., 2016). This conversion rate is alarmingly high and, without significant effort by the government, the existing paddy fields and national food security in Indonesia are at risk.

Paddy fields and water resources are unequally distributed due to the varied Indonesian resource endowment across islands and population densities. Most irrigated paddy fields located in Java contribute to over 50 percent of the national rice production. Past agricultural development efforts primarily focused on increasing rice production. Poverty alleviation, crop diversification, and irrigation management were not taken into consideration in any development planning and implementation programs. The continuous conversion of irrigated paddy fields for non-agricultural uses, along with declined landholding and low diversification, were some major agricultural problems (Pasandaran & Zuliasri, 2001).

As shown in Table 2, irrigated and non-irrigated paddy fields in Sumatra and Java were on the decrease. From 2010-2017, majority of the share of non-irrigation paddy fields in Indonesia was dominated by Sumatra, where the farmers of non-irrigated paddy fields converted their paddy fields more than those of irrigated paddy fields. This was done due to inadequate water resulting from the lack of irrigation infrastructure in Sumatra (Hamzah et al., 2014).

The lack of irrigation management and infrastructure in Indonesia can spur the conversion of paddy fields in Indonesia, particularly in Java and Sumatra as the national rice barns in Indonesia. Therefore, paddy field conversion in Sumatra and Java can threat the national program targets related to national food security and food self-sufficiency.

However, the objective of this is to identified the determinant factor of paddy field conversion in Java and Sumatra. Even though this phenomenon in Indonesia and other countries has already been studied, no study has focused on Java and Sumatra. This gap in the existing body of research will be filled by this study. By understanding the determinants of paddy field conversion, the study will provide a direction to policymakers regarding the factors to be targeted through regulatory and policy action.

Paddy field conversion refers to the process of shifting the function of paddy fields to other purposes, and this phenomenon is almost unavoidable during periods of economic development and population growth (Farhanah & Prajanti, 2015; Stern, 1992; Tan et al., 2009; Taiwo, 2013). There has been a recent debate between the pro-urbanist and pro-ruralist perspectives on whether paddy fields should be converted for other uses or maintained as they are.

According to the pro-urbanists, paddy field conversion is a logical consequence of economic development and urbanization. Economic growth calls for more and more land for infrastructure, industries, and housing. Therefore, it was suggested that such growth would require the conversion of paddy fields for other uses and that the decline of rice production due to limited paddy fields could be solved through agricultural technology and intensification. Therefore, this conversion would not create a problem for the future from the pro-urbanist perspective (Azadi et al., 2011).

Table 2. The Distribution of Paddy Fields in Indonesia by Island, 2010-2017

(hectare)

Islands in Indonesia	2010	2011	2012	2013	2014	2015	2016	2017
Irrigated Paddy Fields								
Sumatra	1,078,747	1,108,650	1,114,400	1,071,717	1,063,431	1,059,492	1,064,302	1,056,967
Java	2,493,829	2,482,748	2,478,726	2,444,729	2,443,085	2,420,176	2,419,201	2,381,668
Bali	81,040	79,912	79,127	78,163	75,980	75,360	75,548	74,025
Nusa Tenggara	307,554	308,958	309,016	306,595	306,243	313,524	315,373	316,863
Kalimantan	234,078	232,711	208,179	171,422	158,358	165,365	166,266	168,467
Sulawesi	652,031	662,541	686,915	684,392	690,678	691,609	712,080	714,133
Maluku	19,569	21,493	23,337	21,489	20,266	21,571	22,265	24,538
Papua	31,367	31,334	32,190	42,689	8,767	11,988	12,358	12,401
Non-Irrigated Paddy Fields								
Sumatra	1,221,150	1,172,318	1,171,052	1,174,417	1,159,937	1,145,596	1,150,584	1,161,872
Java	759,393	772,968	786,687	790,977	807,576	807,356	807,178	819,129
Bali	358	252	272	262	675	562	548	539
Nusa Tenggara	73,544	75,796	86,363	115,676	121,009	128,380	141,896	143,790
Kalimantan	767,685	835,780	884,021	910,811	889,843	890,859	916,403	905,822
Sulawesi	281,486	277,293	287,137	309,901	325,638	318,537	337,182	333,166
Maluku	1,360	1,685	1,994	4,063	3,769	3,624	5,157	5,415
Papua	4,101	4,070	3,896	9,248	43,663	46,969	50,202	51,882

Source: Ministry of Agriculture, 2019.

On the other hand, pro-ruralists argued that paddy field conversion has serious and negative permanent impacts. The changes in the function of paddy fields are permanent when the areas are converted into housing areas or industries. However, the changes are temporary if the land is converted into other agriculture areas (for instance, a palm oil plantation), because over the next years, the land can be converted back into rice fields. However, the loss of paddy fields leads to a decline in rice production, creating serious problems due to wasted investment in irrigation infrastructure, and this could threaten food security (Azadi et al., 2011; Quasem, 2011).

Recognizing the determinants of paddy field conversion is a challenge, because there are multiple interactions among some factors, and this phenomenon is considerably different across regions as it has different determinant factors, spatial patterns, trends, and intensities (Azadi et al., 2015). Most of the literature related to paddy field conversion consists of case researches of local areas or specific countries and regions (Bieling et al., 2013; Primdahl, 2014 *in* Ustaglou & Williams, 2017).

Some studies identified that economic growth and population expansion, particularly in urban areas, have led to an intensive conversion of paddy fields into non-paddy fields of greater value, particularly within the urban fringe (Aprianto et al., 2018; Firman, 1999; Ho & Lin, 2004; Su & Xiao, 2013). However, some studies state that paddy field conversion occurs not in urban fringe area alone but also in rural areas (Parish et al., 1995; Chen & Davis, 1998).

Since 1980, the conversion of agricultural land to non-agricultural land has been widespread and intensely occurred in China. High population density, rapid economic growth, and urbanization are believed to be the main factors behind agricultural land conversion in China (Ho & Lin, 2004). In contrast, the study by Febrina (2017) identified that the paddy fields conversion in Indonesia is not affected by the growth of the population and the size of medium and large companies in the manufacturing industry as engines for economic growth.

Some studies attempted to identify the determinants of paddy field conversion to contribute to the analysis of the prime causes of land-use change. Smith et al. (2010) adapted his study from Contreras–Hermosilla (2000), who defined the underlying causes of land conversion as the development of infrastructure investment, population growth, urbanization, and economic growth. They also identified that the key drivers of paddy field degradation, both in developed countries and emerging economies, is a result of the industry sector, particularly the oil and mining industries (Lechner et al., 2016).

The intensity of paddy field conversion in developed nations is much lower than that in developing nations (Tan et al., 2009; Azadi et al., 2015). For instance, paddy field conversion in Germany was 114 ha per day in 2006 and 17 ha per day in the Netherlands between 1996-2000. In contrast, 514 ha of farmland was transformed per day in Indonesia between 2000-2002 and 802 ha of farmland per day in China in 2004 (Agus et al., 2006). However, this contrast may be because each country has different drivers, trends, and intensities of paddy fields conversion (Azadi et al., 2015).

As a developing country, Indonesia experienced paddy field conversion due to changes in the economic structure, increase in population density, urbanization, and consistency in the implementation of the spatial plan (Pakpahan & Anwar, 1989). According to Ilham et al. (2005), in terms of the micro level economy in Indonesia, the development of settlements affected paddy field conversion. However, at the macro level, the development of settlements, proxied by an increasing number of people, does not show a positive relationship, and paddy field conversion is positively correlated with the growth of Gross Domestic Product (GDP).

Economic growth, characterized by the development of industries, economic infrastructure, public facilities, and settlements, increases the demand for land. Therefore, using socio-economic indicators, such as the gross regional domestic product (GRDP), economic growth and population density could be identified as the determinants of paddy field conversion (Xie et al., 2005). The non-agriculture sector GRDP consists of GRDP in the industry and service sectors.

GRDP is one of the indicators that represents economic growth, which is one of the main factors behind paddy field conversion in Indonesia. Indonesia still relies on agriculture products, particularly rice, which is the staple food of the country. Therefore, the agriculture sector will always play an important role in the Indonesian economy.

Furthermore, GRDP in the industry and service sectors and the population density are indicated as main variables that influence paddy field conversion in Indonesia. This conversion occurs due to industrial development, which is an engine of economic growth, particularly the manufacturing and extractive industries. Oil and mining are direct causes for land use competition, or paddy field competition (Smith et al., 2010). The manufacturing and mining industries are important sectors that can develop Java and Sumatra (Ministry of Industry, 2013). Therefore, the variable GRDP in the industry sector, which consists of GRDP in manufacturing and mining industries, can be considered as the main driver of paddy field conversion in Java and Sumatra.

In the 1990s, paddy field conversion in Indonesia was largely uncontrolled and occurred at a very large scale. Rapid changes of land use in the urban center as well as the conversion of prime agricultural land to urban land use in fringe areas such as Surabaya and Bandung, wherein a sizeable portion of paddy fields was converted into residential and commercial areas (hotels, shopping malls, apartments, and condominiums). This demand for land is increasing tremendously because of the needs of the service sector, and this condition continues to exist (Febrina, 2017; Firman, 1997; 2000). Therefore, GRDP in the service sector is one of the determinants behind paddy field conversion.

Developing countries such as Indonesia are characterized by high population growth rates (Hayami & Godo, 2005). Meanwhile, the growing population gradually exhausts natural resources-paddy fields in this case. Therefore, these circumstances can be major determinants of paddy field conversion as they affect agricultural production (Boserup, 1966). As a proxy of population growth, this study employed the variable population density as an independent variable causing paddy field conversion in Indonesia. To study the impact of the development area with high GRDP, as in Java and Sumatra, population density becomes a good indicator, because the growth of the urban population continuously stimulates this conversion (Sudirman & Irham 2017; Susilo, 2017).

The purpose of this study is to find the determinants of paddy field conversion in Java and Sumatra. Panel data was utilized to develop the model. Some studies have identified the determinants of agricultural land conversion using socio-economic indicators such as population density and GRDP as driving factors of paddy field conversion in Indonesia (Xie et al., 2005). However, the literature on the determinants of paddy field conversion in Java and Sumatra is scarce. Furthermore, there are no studies identifying the factors of paddy field conversion that compare the islands using socio-economic factors. This study used geospatial analysis to support its findings and provided a comprehensive explanation of the determinants of paddy field conversion in each island.

METHOD

Paddy field conversion in Indonesia differs from one island to another, and each island has its own characteristics and problems. The source of the problem regarding paddy field conversion in Java is encouraged by the need for housing, which is stimulated by population growth. On other islands, paddy field conversion is mainly caused by the development of infrastructure and other public facilities with the purpose of increasing economic growth (Irawan, 2005).

Data Specification

Panel data method is considered to be more efficient as it combines information from cross sections and time components (Nazlioglu & Soytas, 2012). This study also employed geospatial analysis to detect the change of paddy fields in Java for the period 2015-2016 and in Sumatra for the period 2016-2017.

a. Dependent variables
   The Statistics Indonesia provided most of the data, which is publicly available, to estimate the model used in this study. It allows the comparison between regions. The dependent variables are total irrigated, and non-irrigated paddy fields (in ha). The data was collected from the Ministry of Agriculture, and the data for different years was used to analyze the changes in agricultural use, because it declares the size of the area by the end of the measurement year. It comprises of irrigated and non-irrigated paddy fields (in ha).
b. Independent variables
   The independent variables are the GRDP in the agriculture, industry, and service sectors and population density. The GRDP in the three sectors was acquired by sector (in million IDR/ km^2). The GRDP in agriculture (in million IDR) included agriculture, forestry, and fishery. The GRDP in the industry consisted of GRDP in the manufacture and mining industries (in million IDR), and GRDP in service consisted of GRDP in real estate and accommodation. The ratio of the population number to the total area represented the population density (in population/km^2).
c. Geospatial Data
   The land cover map for the years 2015, 2016, and 2017 issued by Ministry of Environment and Forestry (MEF) was used to detect the change in paddy fields in Java and Sumatra. The maps were derived from Landsat Imagery and the scale is 30x30 meters. The maps divided the land cover into 24 classes and are described in the table description of land cover code in Appendix A.1.

Empirical Methodology

This study employed quantitative and geospatial analyses to address the research questions. This study proved that the quantitative result and geospatial analysis have the similar results, and the comparation between these methods will sthrengtened the result.

The quantitative analysis employed used multiple linear regression methods to test the significance of the variables through F test and partial correlation, which uses a model from the research conducted by Febrina (2017) and Aprianto et al., (2018).

To test the factors influencing paddy fields conversion, a logarithmic regression equation model was created. Then, due to the data availability, the equation was constructed as follows:

$$lnY_{it} = B_0 + B_1 lnX1_{it} + B_2 lnX2_{it} + B_3 lnX3_{it} + B_4 lnX4_{it} + \mu_{it} \quad (1)$$

Where i refers to the province and t refers to the quarterly time period from 2010-2017; Y is the natural logarithm of the dependent variable, $X1$ is the natural logarithm of GRDP in the agriculture sector, $X2$ is the natural logarithm of GRDP in the industry sector, $X3$ is natural logarithm of the GRDP in the service sector, $X4$ is natural logarithm of population density, and μ_{it} is the disturbance term.

Geospatial analysis used tools such as the ArcMap software version 10.3 to identify land cover class for three consecutive years from 2015-2017. Then, we detected the change of paddy fields for the periods of 2015-2016 and 2016-2017 in each class. To analyze the changes, we re-classify the land cover class from the MEF into 10 major classes. Land cover with a similarity of physical appearances on the field or similar functions were reclassified into single classes, while the others remained. This can be seen in Table A.2 in the Appendix, which shows the result of the reclassification of the land cover class.

After the reclassification, we detected the change of paddy fields on each reclassified class. We calculated the overall area of change of the paddy fields and identified a new class for each major island for consecutive years. Some small islands on the perimeter of the main islands were also included in the analysis, considering that the surrounded islands were located on the same administrative boundaries with the province in the main islands. Then, we identified the new land cover on the change area and calculated the total of the new classes to identify major changes in one island.

Descriptive analyses are used to explain or describe event factually and to demonstrate how the concepts are interconnected. Combining works provides insight into phenomena that might not be fully understood if using only a qualitative or quantitative approach (Venkatesh et al., 2013). Several secondary data will be analyzed using descriptive statistics and explained narratively to support the discussion. Lastly, these patterns will be used as a logical basis for establishing the policy implications and the conclusion.

The secondary data used in this model are the size of agricultural land, specifically paddy fields, GRDP in industry that consist of the GRDP in manufacturing and mining industries, the GRDP in the service sector, the GRDP in the agriculture sector, and the population in district or city level in Java and Sumatra in the time period 2010-2017.

RESULTS AND DISCUSSION

This study examined the determinants of paddy fields conversion in Java and Sumatra in Indonesia from the socio-economic perspective. The determinant factors influencing paddy fields conversion in Java and Sumatra in this study were analyzed based on the effect of GRDP in the agriculture, industry, and service sectors and population density on total, irrigated, and non-irrigated paddy fields at the district/city level in Java and Sumatra.

Java and Sumatra are the largest rice barns in Indonesia, which are also the most densely populated islands in Indonesia. Interestingly, although these islands have similar characteristics, each island has varying socio-economic characteristics in each city and regency, ranging from sparsely populated to densely populated areas, agricultural and non-agricultural, and regions with high or relatively low GRDP.

The multiple linear regression method was run to find out the determinant of paddy fields conversion on each island. Regarding the result from the Hausman test, the model equations are obtained based on the results of the estimation using the fixed effects model (FEM). The Hausman test was used to find the appropriate method between the FEM and random effects model (REM). The test delineates that the probability value for the cross-section F is under 0.05, which indicates that the condition rejects the H_0. In this case, this means that the FEM is better than the REM in 95 percent confidence level. Moreover, the FEM regression was selected because the variation of regencies' characteristics and times are accommodated in the intercepts/constants.

The Determinants of Paddy Field Conversion in Java

Table 3 presents the regression results of the determinants of paddy field conversion in Java. The regression results using the FEM method in Java above imply that the slope for the growth of GRDP in the agriculture, GRDP industry, and GRDP service sectors and the growth of population density are applicable to all regions *i.* When the individual effect and time effect are considered fixed, then the effect can be captured in the intercept. This result indicates that there is no correlation between the error and the independent variables.

Table 3. The Regression Result of Paddy Fields Conversion in Java

Variables	Total Paddy Fields	Irrigated Paddy Fields	Non-Irrigated Paddy Fields
R^2	0.818	0.812	0.391
Prob F	0.001	0.026	0.016
GRDP in Agriculture (ln)	0.692***	0.963**	2.076***
	0.240	0.433	0.748
GRDP in Industry (ln)	-0.018	-0.0003	0.353
	0,066	0.154	0.226
GRDP in Service (ln)	-0.234**	-0.435*	-1.119*
	0.097	0.242	0.648
Population Density (ln)	-1.901**	-2.094*	-0.96
	0.869	1.078	1.329
Constant	19.479***	20.381***	4.196
	6.070	7.260	9.340

Notes: Significant at * α = 5 percent, ** α = 1 percent, and *** α = 0.1 percent.
Robust standard errors are in parentheses.
Source: BPS, 2019 (Author's calculation).

Based on the estimation through the Stata program version 14.2, the coefficient of determination in Java can be seen from the adjusted R^2 value. The result for the adjusted R^2 value for total, irrigated, and non-irrigated paddy fields are 0.818, 0.812, and 0.391, respectively. This means that the independent variables within the model jointly affect the changing of total, irrigated, and non-irrigated paddy fields from 2010 to 2017, accounting for 81.8 percent, 81.2 percent, and 39.1 percent, respectively. Meanwhile, the remainder may come from factors that were not included in the model due to multiple interaction drivers and behavior factors, as mentioned previously.

As indicated in Table 3, the results exhibit the expected signs on the variable GRDP in agriculture and GRDP in service sectors and population density. The growth of GRDP in the service sector and the growth of population density for the result in each island are expected to have a negative sign, whereas the growth of GRDP in the agriculture sector is predicted to have a positive sign. The sign (-) indicates a negative correlation between the inverse or opposites of the independent variable and paddy fields, i.e., if the growth of the GRDP in the service sector and the growth of population density is high, then the growth of paddy fields will be low. On the other hand, the sign (+) points out the same direction relationship between the independent variable and paddy fields, i.e., if the growth of GRDP in the agriculture sector is high, then the growth of paddy fields will also be high.

The estimation results of panel data show that the growth of GRDP in agriculture and GRDP in industry significantly affect the growth of total, irrigated, and non-irrigated paddy fields in Java. Moreover, the growth of population density is significantly associated with the growth of total and irrigated paddy fields. However, the growth of the GRDP in the industry sector does not significantly affect the growth of the total paddy fields in Java.

According to the model equation above, 1 percent growth of GRDP in the agriculture sector is associated with 0.692 percent growth of total paddy fields in Java; specifically, 1 percent growth of GRDP in agriculture needs 0.963 percent of irrigated paddy fields and 2.076 percent of non-irrigated paddy fields. Sign (+) indicates the same direction of the relationship between the growth of GRDP in agriculture sector and the growth of paddy fields in Java. this implies that if the growth of GRDP in agriculture sector is high, then the growth of the paddy fields will also be high, which means that the contribution of the agriculture sector is still an important flagship sector for the development of Java (Aprianto et al., 2018).

However, the growth of GRDP in the service sector has a negative relationship with the growth of paddy fields, as 1 percent growth of GRDP in this sector is linked to a 0.234 percent decrease of total paddy fields; moreover, 1 percent growth of GRDP in the service sector is associated with a decrease of 0.435 percent of irrigated paddy fields and 1.119 percent of non-irrigated paddy fields in Java. The negative sign implies that if the growth of the GRDP in the service sector is high, the growth of the paddy fields will be low. This result is in accordance with the study by Francis et al. (2012), which states that the expansion of the service sector is driving out farming land.

Besides the variable growth of GRDP in the service sector, the relationship between the variable growth of population density and the growth of paddy fields in Java has the negative sign as well. This means that the size of total paddy fields will drop by 1.901 percent if the population density increased by 1 percent, and irrigated paddy fields will decrease by 2.094 percent if the population density in Java increased by 1 percent. This is in line with a statement by Sudirman & Irham (2017) and Susilo (2017) that paddy field conversion is intensively stimulated by the growth of the population in nearby or surrounding urban areas, which can be described by the growth of population density.

Moreover, the geospatial analysis by ArcMap software version 10.3 identified and detected the changes in paddy fields in Java for the period 2015-2016 and 2016-2017 as follows.

Table 4. The Changes of Paddy Fields to Other Use in Java

(hectare)

The Changed of Paddy Fields in Java	2015-2016	2016-2017
Forest	32,529	30,315
Bush	856	162
Dry agriculture	115,154	212,622
Ponds	20,388	10,644
Plantation	2,324	3,779
Settlement	46,395	133,798
Airport/port	210	8
Open land	1,259	716
Mining	216	355
Lake and swamp	1,612	1,542
Savana	-	2
Total	220,944	393,945

Source: Processing by author, 2019.

Table 4 depicted that the change in paddy fields was dominated by dry agriculture and settlement or housing areas. Around 46,395 ha of paddy fields were converted into housing areas between 2015 and 2016 and 133,798 ha between 2016 and 2017. For more detailed information about the conversion of paddy fields data, refer to Appendix A, Table A3.

It can be concluded that rapid population growth and urbanization leads to pressure on paddy fields due to the expansion of residential facilities (Fazal, 2001). Moreover, this is in line with the research by Buchori & Sukamto (2019) that used cellular automata on a 1 : 10,000 scale in Central Java and Yogyakarta. They found that, from 2007 to 2017, the rice fields in central Java and Yogyakarta mostly experienced changes for the purpose of creating housing areas.

The population explosion in Java was not a new phenomenon, and it has been putting pressure on paddy field resources for a long time. The increase in the population of Java had shifted paddy field expansion to outer Java, while Java changes into a more urbanized society (Bottema, 1995; Firman, 1997; Verburg et al., 1999). This condition spurs the change of agricultural land use to expand and intensify service area (Verburg et al., 1999). It is predicted that the largest decline of paddy fields in Java in the period from 1994-2010 were found in the most fertile areas, which implies that the impact of rice production will decrease on the large scale (Verburg et al., 1999). This study proves the statement that the growth of GRDP in the service sector significantly affects paddy field conversion in Java.

This result is in accordance with the international experience, where rapid economic growth is always accompanied by a shift of land from agriculture to industry and service use such as infrastructure and residential use (Ramankutty, 2002). Some local researchers also found similar findings that paddy fields in Java area are mostly converted into service areas such as housing complexes, infrastructure, and accommodation (Irawan, 2005; Mulyani et.al., 2016).

The biggest change in paddy fields is to become dry agriculture land. This shows the degradation of the quality of paddy fields in Java. It indicates the poor condition of the irrigation network due to poor management of irrigation, such as low efficiency of the use of water by farmers in Java. Another reason could be the damage of irrigation infrastructure caused by natural disasters that occurred during 2010-2012 (Ministry of Agriculture, 2013).

The Determinants of Paddy Field Conversion in Sumatra

The estimated result of the determinant paddy fields in Sumatra differs from that of Java. The estimation result of the panel data is based on the results of the estimation, using the FEM for Sumatra.

Based on the estimation, the signs of all the variables are consistent with the expectations. Following this, the coefficients of determination in Sumatra can be seen from the adjusted R^2 value. The results for the adjusted R^2 values for total paddy fields, irrigated paddy fields, and non-irrigated paddy fields are 0.204, 0.604, and 0.146, respectively. This implies that the independent variables within the model jointly affect the conversions of total paddy fields, irrigated paddy fields, and non-irrigated paddy fields from 2010 to 2017, accounting for 20.4 percent, 60.4 percent, and 14.6 percent, respectively. The remainder may come from the factors not included in the model due to multiple interaction drivers and behavior factors, as mentioned previously.

Table 5. The Regression Result of Paddy Fields Conversion in Sumatra

Variables	Total Paddy Fields	Irrigated Paddy Fields	Non-Irrigated Paddy Fields
R^2	0.204	0.604	0.146
Prob F	0.012	0.000	0.036
GRDP in Agriculture (ln)	2.388*	0.773***	2.599**
	1.362	0.166	1.112
GRDP in Industry (ln)	-0.616*	-0.137	-0.407**
	0.365	0.131	0.189
GRDP in Service (ln)	-0.060	0.317	-0.090
	0.578	0.334	0.451
Population Density (ln)	-3.984***	-0.274*	-4.799***
	1.252	0.147	1.553
Constant	15.972***	2.469*	15.395***
	3.854	1.192	5.046

Notes: Significant at * α = 5 percent, ** α = 1 percent, and *** α = 0.1 percent.
Robust standard errors are in parentheses.
Source: BPS, 2019 (Author's calculation).

Regarding Table 5, the panel data model in Sumatra shows that the growth of GRDP in the agriculture sector significantly increased the growth of paddy fields, both irrigated and non-irrigated fields. Based on the estimation, 1 percent growth of the GRDP in the agriculture sector is associated with 2.388 percent growth of total paddy fields in Sumatra; specifically, 1 percent growth of GRDP in agriculture requires 0.773 percent of total irrigated paddy fields in Java. The size of non-irrigated paddy fields will increase by 2.599 percent if the GRDP in the agriculture sector increases by 1 percent. This indicates that the agriculture sector still plays a central role in Sumatra's economic growth. The shift in the economic structure of Sumatra toward industry must continue to support the development of the primary sector, especially for agriculture commodities that have a competitive advantage for the welfare of the community in general and farmers in particular (Iyan, 2014).

However, in contrast to Java, both total and non-irrigated paddy fields in Sumatra are significantly affected by the GRDP in the industry sector wherein, if GRDP in this sector increases by 1 percent, the total paddy fields will decrease by 0.616 percent and non-irrigated paddy fields by 0.407 percent. Among the other islands in Indonesia, GRDP Sumatra has the second highest share of GRDP in the industry sector after GRDP Java (Saragih, 2018). Saragih (2018) also stated that the manufacturing industry in Sumatra is growing because of the increase of the agroindustry, particularly the palm oil industry.

Regarding the regulation by the Ministry of Industry, No. 13/2010, Sumatra is designed to be the center of growth for the agroindustry, particularly the oil palm industry. The growth of the agroindustry in Sumatra encourages farmers to convert their paddy fields into palm oil plantations, as the income from estate crops is higher than that from paddy fields (Ishak et.al, 2017). For instance, the peasants in North Sumatra, who converted to palm oil plantations due to economic reasons, are what Indonesian policymakers call "germ peasants." They are the smallholders with rice fields areas of less 0.5 ha (Vel et al., 2016). In other words, they have insufficient land to maintain sustainable livelihoods

Table 6. The Changed Paddy Fields to Other Use in Sumatra

(hectare)

The Changed Paddy Fields in Sumatra	2016-2017
Forest	176
Bush	650
Dry agriculture	12,738
Ponds	13
Plantation	6,138
Settlement	4,086
Airport/port	39
Open land	6
Lake and swamp	11
Total	23,857

Source: Processing by Author, 2019.

from rice production alone. Local researchers have identified that paddy field conversion is also caused by economic reasons due to the growth of the palm oil industry in Sumatra (Alridiwirsah, 2013; Daulay et al., 2016; Fahri, 2014).

The geospatial analysis by ArcMap software version 10.3 identified and detected the conversion of paddy fields in Sumatra for the 2016-2017 period as depicted in Table 6, which describes the conversion of 6.138 ha of paddy fields into a plantation indicated as palm oil. Mulyani et.al. (2016) used a spatial analysis, using medium- and high-resolution images, and identified that the conversion of paddy fields in some areas in Sumatra has largely turned into palm oil plantations. This result supports the regression result, and it can be concluded that the growth of the agroindustry has significantly affected the growth of paddy fields in Sumatra.

The biggest change in paddy fields is the conversion to dry agriculture land. This condition shows the degradation of the quality of paddy fields in Java. The poor condition of irrigation network is due to poor management for irrigation, such as the low efficiency of the use of water by farmers in Java. Another reason is the damage of irrigation infrastructure, caused by the natural disasters that occurred in 2010-2012 (Ministry of Agriculture, 2013). For more detailed information about the change of paddy fields, refer to Appendix A on Table A4.

Lastly, the growth of total paddy fields will significantly drop by 3.984 percent and the irrigated paddy fields will decrease by 0.274 percent if the population density increases by 1 percent in Sumatra. Moreover, this 1 percent growth of population density will diminish non-irrigated paddy fields by 4.799 percent.

CONCLUSION

This study found evidence that the factors affecting paddy field conversion in Java are the GRDP in agricultural sector, the GRDP in service sector, and the population density. Moreover, the geospatial analysis defined that the conversions of paddy fields in Java from 2015-2016 and 2016-2017 were dominated by dry agriculture and settlement. It can be concluded that the growth of population density requirements and sustaining the needs, particularly those of the service sector such as residence space, are important determinants.

Other results showed that the factors affecting paddy field conversion in Sumatra differ from those affecting the conversion in Java. Paddy field conversion in Sumatra is affected by the GRDP in the agricultural sector, the GRDP and industry sector, and the population density. The geospatial analysis identified that the conversion of paddy fields in Sumatra from 2016-2017 was dominated by dry agriculture and plantation. According to the research by Mulyani et.al. (2016), palm oil plantations converted paddy fields in Sumatra due to the growth of the agro-industry in Sumatra. In conclusion, the conversion of paddy fields in Sumatra is due to the growth of the palm oil industry in Sumatra, which attracts farmers to convert their paddy fields into plantations for higher financial returns.

In addition, it can be concluded that the infrastructure of irrigation is an important factor to advance paddy field management and development in Indonesia. This is in line with Winoto (2008), who stated that the development of agricultural infrastructure, particularly irrigation, is an important condition for the advancement of agricultural productivity.

In order to realize food self-sufficiency and safeguard national food security, as mandated by Law No. 41 of 2009 concerning Sustainable Food Agricultural Land Protection (LP2B), it is necessary to accelerate the stipulation of regional regulations on Sustainable Food Agricultural Land/Food Agriculture Areas Sustainable (LP2B/KP2B), integrated in the Spatial Detail Plan/Regional Spatial Plan (Province and Regency/City). At present, most regions have established regional regulations; nevertheless, that only numerically limited, without including the spatial distribution of locations.

The Indonesian government has had plans to develop a regulation on the establishment of sustainable paddy fields in Java and Bali since 2018. In the context of accelerating the stipulation of this regulation, the Ministry of Agrarian Affairs and Spatial Planning/National Land Agency collaborated with the regional government, which has the responsibility of arranging the determination of the regions targeted by the regulation.

Therefore, result of this study can be a valuable reference supporting the upcoming regulation on sustainable agricultural land, especially in terms of paddy fields, considering the socio-economic aspects of Java and Sumatra.

This study also identified that the irrigation system is an important factor to improve paddy field production in Java and Sumatra. Therefore, it is crucial for the government to establish a new irrigation system and improve the functioning of the irrigation network.

Lastly, the government has been regulating the incentive for sustainable agriculture land protection in the Government Regulation No. 12 of 2012. Nevertheless, farmers still convert their lands due to economic reasons. Therefore, schematic incentives are important and could benefit farmers. For example, output subsidies, such as the determination of the price of rice that produced in the LP2B zone by the government, could be more profitable for farmers.

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Regulation

Law Number No. 41 of 2009 concerning Sustainable Food Agricultural Land Protection (LP2B).

The Government Regulation No. 12 of 2012 concerning The Incentive for Sustainable Agriculture Land Protection.

Appendices

Table A.1. Description of Land Cover Code

Land Cover Code	Description
2001	Primary dryland forest
2002	Secondary dryland forest
2004	Primary mangrove forest
20041	Secondary mangrove forest
2005	Primary swamp forest
20051	Secondary swamp forest
2006	Plantation forest
2007	Shrubland
20071	Swamp bushes
20091	Dryland agriculture
20092	Dryland agriculture with bushes
20093	Rice field
20094	Pond
20122	Transmigration area/ kampong
2010	Plantation
2012	Settlement
20121	Airport/harbour
2014	Open land
20141	Mining
5003	Water body
5001	Lake
50011	Swamp
3000	Savanna
2500	Cloud cover

Table A.2. Reclassification Class of Land Cover

Land Cover Code	Description	Reclassified Class
2001	Primary dryland forest	Forest
2002	Secondary dryland forest	
2004	Primary mangrove forest	
20041	Secondary mangrove forest	
2005	Primary swamp forest	
20051	Secondary swamp forest	
2006	Plantation forest	
2007	Shrubland	Shrubland
20071	Swamp bushes	
2014	Open land	
3000	Savanna	
20091	Dryland agriculture	Agriculture area
20092	Dryland agriculture with bushes	
20093	Rice field	
20094	Pond	Pond
20122	Transmigration area/ kampong	Transmigration area

Land Cover Code	Description	Reclassified Class
2010	Plantation	Plantation
2012	Settlement	Settlement
20121	Airport/harbour	Airport/harbour
20141	Mining	Mining
5003	Water body	
5001	Lake	Water
50011	Swamp	
2500	Cloud cover	Cloud cover

Table A.3. The Changes of Paddy Fields in Java

Code	The Changes of Paddy Fields in Java Island	2015-2016		2016-2017	
		M²	Hectare	M²	Hectare
2001	Primary dryland forest	-	-	24,814.89	2.48
2002	Secondary dryland forest	2,652,595.12	265.26	3,160,652.36	316.07
20041	Secondacy mangrove forest	6,518,612.27	651.86	2,126.50	0.21
2006	Plantation forest	316,121,506.19	31,612.15	299,963,545.65	29,996.35
2007	Shrubland	141,903.80	14.19	1,624,829.27	162.48
20091	Dcyland agriculture	8,415,645.61	841.56	1,661,353,557.81	166,135.36
20092	Dcyland Agriculture with bushes	485,635,416.61	48,563.54	464,867,437.35	46,486.74
20094	Pond	665,905,628.97	66,590.56	106,441,758.63	10,644.18
2010	Plantation	203,883,487.83	20,388.35	37,788,556.79	3,778.86
2012	Settlement	23,237,577.95	2,323.76	1,337,980,410.07	133,798.04
20121	Airport/harbor	463,954,865.84	46,395.49	84,506.66	8.45
2014	Open land	2,103,752.13	210.38	7,158,259.20	715.83
20141	Mining	12,594,167.07	1,259.42	3,554,954.41	355.50
5001	Lake	2,157,988.12	215.80	15,421,486.09	1,542.15
3000	Savanna	15,088,268.58	1,508.83	22,847.78	2.28
50011	Swamp	1,031,305.34	103.13	-	-

Source: Ministry of Environment and Forestry, 2019 (Processing by Author).

Table A.4. The Changed of Paddy Fields in Sumatra

Code	The Changes of Paddy Fields in Sumatra Island	2016-2017	
		M²	Hectare
20041	Secondary mangrove forest	415,090.86	41.51
20051	Secondary swamp forest	11,102.31	1.11
2006	Plantation forest	1,331,438.96	133.14
2007	Shrubland	6,438,820.31	643.88
20071	Swamp bushes	61,355.54	6.14
20091	Dcyland agriculture	91,196,550.71	9,119.66
20092	Dcyland agriculture with bushes	36,183,316.55	3,618.33
20094	Pond	132,989.89	13.30
2010	Plantation	61,382,416.69	6,138.24
2012	Settlement	40,856,792.59	4,085.68
20121	Airport/harbor	390,378.04	39.04
2014	Open land	59,833.58	5.98
5001	Lake	114,590.65	11.46

Source: Ministry of Environment and Forestry, 2019 (Processing by Author).