Land Suitability and Dynamic System Model for Land Use Planning of Paddy Field in Indramayu Regency, Indonesia

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SUMMARY

Indonesia is fourth most populated country in the world after China, India and the USA with the population at more than 255 million in 2015. Rice is the staple food for more than 95% of Indonesian population. With the rice consumption rate at 113 $kg.capita^{-1}.year^{-1}$, the dependence of Indonesia on rice is very high, and so this explain the importance of maintaining paddy field land utilization. One of the problem for Indonesia is the fact that actual rice concentration production from paddy field was in Java Island. Even though, Java Island is the most populated Island in Indonesia, making a high pressing on paddy field to be converted to become other land utilization such as settlements and industry. This high paddy field conversion give an impact on declining the food security of the country. For this reason, maintaining the sustainable paddy field is very important. This study was done in Indramayu Regency, one of the center of rice production in Java Island as a case study. The objectives of this research were: (i) to identify the land suitability for paddy field, including its limiting factors, (ii) to model the rice production and consumption in the socio-economic context of the region, and (iii) to plan the spatial priority area of paddy field protection according to land suitability and model prediction. A land evaluation steps for paddy was done using the data of soil survey, while SPOT-6 imagery was used to delineate paddy fields. Dynamic system model of rice production and consumption is built using Powersim software. Based on the model built and land suitability, the land area of paddy field to be protected is delineated in order to maintaining rice self sufficiency of the region until next 2030. The research results showed that land suitability class for paddy fields in research area ranged from suitable (S2) to marginally suitable (S3). Several land characteristics were discovered as limiting factors, i.e. nutrient retention and nutrient availability. The model predicts that with the current situation, the ability of the region to export rice would decrease by 10-15% in the next 15 years. By combining model prediction with land suitability, priority areas of paddy field protection were delineated. Policy recommendation were also compiled in term of maintaining paddy field area as well as food self-sufficiency of the region.

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1. INTRODUCTION

Rice has high contribution to food sovereignty in Indonesia, because rice is the main food for most of Indonesian population. With the population of more than 255 million by 2015 (Indonesian Statistics, 2015; Widiatmaka *et al*., 2016) and per-capita consumption of 113 kg.capita^{-1}.year^{1} (Statistic of Indonesia, 2014; Widiatmaka *et al*., 2015), with 95% of the population use rice as staple food (Swastika *et al.*, 2007), Indonesia's rice needs reach at least 27 million tons of rice each year (Ministry of Agriculture, 2014). In Indonesia, rice is produced by the production centers which are generally located in the island of Java. The data of 2015 show that more than 50% of Indonesia's rice production comes from the island of Java (Indonesian Statistics, 2015; Widiatmaka *et al*., 2016), a small island with the extent of only 7% of the total Indonesian land area (Indonesian Statistics, 2015). West Java Province is one of the provinces in Java Island which is the production center. The region has a high soil fertility, generally suitable for paddy field. With an area of paddy field in the province of West Java which reached 2,029,891 ha, so far this province produce 12,083,162 tons in 2013 (Statistics of West Java Province, 2014), or 17% of Indonesian rice production (Statistics of Indonesia, 2014).

Indramayu is one of regencies in West Java Province that has extensive paddy fields, covering an area of 116,925 ha or 55% of regency's area in 2014 (Statistics of Indramayu Regency, 2014). This regency is the third largest rice production centers in West Java (Statistics of West Java Province, 2014). Similar with other regions in Java Island, Indramayu Regency is actually faced with the issue of paddy field conversion into other land utilizations. This relate with the increasing pressure from high population growth and its implication to the more and more need for residential and industrial buildings. Paddy fields which are generally located in the relatively flat area becomes the main target of land conversion. Land conversion in Indramayu it-self has not been calculated, but the high paddy field conversion in Java Island which is 3,600 ha.year^{-1} (Santosa *et al*., 2015) expect that paddy field conversion into another land utilization in this region was also high.

These high land conversion of paddy field will certainly affect the overall state of food sovereignty. If the entire rice production centers in Java Island experience the same events, the ability of the country to provide food for more than 255 million lives will be disrupted. Facing to this phenomena, protection of paddy field from land conversion is urgently needed. The Indonesian government itself has launched a protection through the application of Law No. 41/2009. In the concept of protection, one of the parameters used is the land suitability for paddy field. Paddy field with high land suitability level, which means having the high productivity, need to be given a priority to be protected, compared to land with lower land suitability level. In this case, the spatial analysis of land suitability becomes important. Many methods can be used to assess land suitability (Rossiter, 2001; FAO, 2007; De la Rosa & Van Diepen, 2002; Akinci, 2013), but the most commonly used in Indonesia is using the method of limiting factor (Ritung, 2007; Hardjowigeno & Widiatmaka, 2011; Widiatmaka *et al*., 2015).

Assessing the land to be protected only by its land suitability is of course not enough. Many other factors which affect also the adequacy of food supply and demand, among others production, consumption, population growth and others should also be considered. Theoretically, consideration of these factors in the calculation of the adequacy of food can be done using the model. The dynamic system modelling is one of the method which can be used. This approach was first developed by Forrester (1968). Since then, the methodology of dynamic system modeling was widely used in various fields, including in the field of environment (Guo *et al*., 2001), agriculture (Li *et al*., 2012; Turner *et al.*, 2013), biology (Russel *et al*., 2013), social (Karami *et al*., 2017), education (Vondel *et al*., 2017); land use planning (Widiatmaka *et al*., 2014; Xu *et al*., 2016), engineering (Pan *et al*., 2017; Salim *et al*., 2017) and many other fields.

With such background, the objective of the research conducted in Indramayu Regency, West Java are: (i) to assess the level of land suitability for paddy, (ii) to model the adequacy of food in the region, and (iii) to plan land utilization based on land suitability for paddy field and dynamic system models.

2. MATERIAL AND METHODS

Research Area. The research was conducted in Indramayu Regency, West Java Province, Indonesia. The regency has a strategic location because the region lies in the north coast of Java Island, on the main road connecting the western part of Java Island (with cities such as Jakarta and Bandung) with the central and east part of Java Island (with cities such as Yogyakarta and Surabaya). Geographically, the regency is located at position of 107º52'- 108º36'E and 06º15'- 06º40' S **(Figure 1)**. Administratively, the region consists of 31 districts and 309 villages. The region covers an area of approximately 209,942 ha, with a long coastline of approximately 147 km that stretches along the north coast of Java Island.

Figure 1. Situation map of the research area of Indramayu Regency, West Java Province

Since the region lies on the north coast of Java Island, its physiographic is lowland, the area is relatively flat: the area with a slope of less than 8% reach 56% of the area. Indramayu regency has 14 streams flowing towards the north to the Sea of Java and a relatively large rivers which are Cimanuk River, Cipanas River, Cipunegara River, Cilalanang River, Kumpulkuista River, and Cimanis Rivers. Due to its soil fertility, Indramayu regency is one of the areas which become agricultural center and a buffer zone provision of food stocks.

Indramayu Regency has a tropical climate. Daily air temperature ranges between 27º to 34ºC. The humidity range from 70 to 80%. The average rainfall per month is 200.08 mm with an average rainy day of 3.25 days per month. Average annual rainfall was 1,428.45 mm with the number of rainy days 75 days. The minimum rainfall of 47 mm occurred in December, while the maximum rainfall of 602.4 mm occurred in February.

The population of Indramayu Regency in 2014 was 1,708,551 inhabitants (Statistics of Indramayu Regency, 2014), so the population density was 813.8 people.km^{-2}. Karangampel Districts has the highest population density which is 2,125.5 inhabitants.km^{-2}, while and the lowest one is Cikedung districts, with a density of 267.1 inhabitants.km^{-2}. When compared to the average population of Java Island which was 3,408 inhabitants.km^{-2}, thus the population of Indramayu Regency was relatively low.

Mapping of Soil and Land Unit. Soil map with its land units were made at scale of 1 : 25,000 for this research. The soil map at this scale was derived from soil map at scale of 1 : 250,000 which was available before, detailed by using Indonesian Topographic Map at scale of 1 : 25,000 (GIA, 1992). In each land unit, soil samples were collected from soil depth of 0-25 cm for laboratory analysis.

Laboratory analysis was conducted on soil chemical properties including soil pH, P_2O_5, K_2O, exchangeable K, Na, Ca and Mg, Cation Exchange Capacity (CEC) and base saturation (BS). This laboratory analysis was conducted in the Laboratory of the Department of Soil Science and Land Resources at Bogor Agricultural University.

Analysis of Land Use and Land Cover. Analysis of land use and land cover was performed using SPOT 6 imagery of 2014 acquisition date. Analysis was performed by supervised classification by using ERDAS Imagine software. The classification system used was classification system of the Indonesian National Standard (SNI, 2010). Field checking was conducted on September 2016. The results of field checks were used for correction of classification.

Land Suitability Evaluation. Land suitability evaluation for paddy field was done by using minimum limiting factor (De la Rosa & Van Diepen, 2002; Hardjowigeno & Widiatmaka, 2011). The criteria used are the land suitability criteria for paddy field, established according to reference (Djaenudin *et al.,* 2003; Ritung, *et al*., 2007; Hardjowigeno & Widiatmaka 2011). Result of land evaluation was land classification into classes of S1 (highly suitable), S2 (suitable), S3 (marginally suitable), N1 (currently not suitable) and N2 (permanently not suitable). The sub-class was indicated by abbreviation of limiting factors (Hardjowigeno & Widiatmaka, 2011; Djaenudin *et al*., 2003). Interpretation of land suitability was carried on: (a) existing paddy field, obtained from the land use and land cover interpretation; this analysis is intended to obtain level of land suitability of existing paddy field, and (b) outside the existing paddy field, but land has the potencies to be used as paddy field according to existing land use/land cover; this analysis is intended to have the area potential for extension of paddy field.

System Dynamic Modeling. In this step, the production and consumption of rice can be seen as a system that can be modeled. The model is implemented in a causal loop and stock flow diagram **(Figure 2)**. In the model, it is stated that the amount of rice (from paddy) produced is determined by the area of paddy field and paddy productivity. Paddy field area itself would strongly associated with an area of settlement. The more extensive the settlements, meaning the extent of paddy field will decrease. Rice consumption is determined by the number of population and the level of the average rice consumption of the population. The equilibrium between rice production and rice consumption will determine the amount of surplus and deficit of rice in Indramayu Regency. The data used for this modeling were derived from many sources, both statistical, tabular and spatial data from the soil and land suitability mapping as described previously. Tabular data concerning the number of population, consumption levels and cropping index were derived from Statistics of Indramayu Regency during last 5 years (2010-2014). The model was used to predict the performance of food sufficiency of Indramayu Regency in the next 15 years, until 2030.

The result of the model needs certainly to be validated. In this study, validation was performed using Average Mean Error (AME). The AME is a comparison of the difference between the value of the model with the actual value, divided by the actual value. The parameters which were validated in this research is the parameter, in which the actual data is available, i.e. number of population, area of paddy field and production of paddy. Actual value used is the value of the statistical data from Statistics Indramayu in 5 years (2010 to 2014). In the validation, the model is considered to be valid when the value of AME were between 1-10% (Hartrisari, 2007).

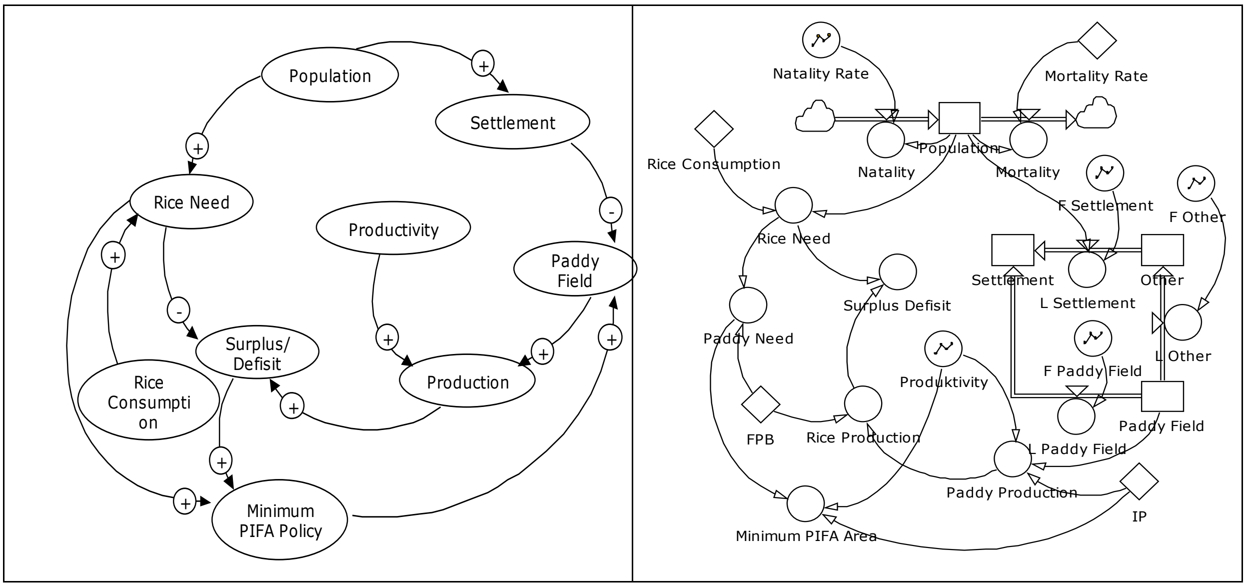


Figure 2. Causal loops and stock flow diagram of dynamic system model of production and consumption of paddy in Indramayu Regency

3. RESULTS AND DISCUSSION

Soil and Land Mapping Unit. Result of the analysis showed that the overall area of Indramayu Regency consists of 35 land mapping unit (LMU) on mapping scale of 1 : 25,000. LMU components used in this study include the soil class up to subgroup category (Soil Survey Staff, 2014), parent material, landform and slope. However, for simplification of the presentation in this paper, only map indicating soil class is presented (**Figure 3** and **Table 1**). The figure presents also sampling point of soil samples for laboratory analysis. In terms of soil class, classification using system of Soil Taxonomy (Soil Survey Staff, 2014) indicates that there are eight soil subgroups. Classification in the category of order show that there are only 3 (three) soil orders which are Entisols, Inceptisols and Alfisols.

Entisols occupies the smallest area, which is only 13,974 ha, or 6.7% of the area. Entisols in Indramayu consist of soil from the subgroup of Aquic Udorthents, Typic Hydraquents and Typic Udipsaments. Entisols is young soil with minimum development or at the very beginning of soil development. In the USDA classification (Soil Survey Staff, 2014), this soil has no other diagnostic horizon excepting Ochric epipedon, and Albic or Histic horizons. In Indramayu, this soil is distributed in the area of new sedimentation, either along the coast or along the river.

Soil with the most extensive deployment in Indramayu is Inceptisols order. This soil occupy an area of 167,742 ha, or 80.2% of the area. Inceptisols is also relatively young, but already more developed than Entisols. The diagnostic horizon in this soil is also relatively young, generally Cambic horizon (Soil Survey Staff, 2014). Because of its development which has not too advanced, then it is relatively fertile soil. Thus, the extent of Inceptisols in Indramayu reflect the fertility of the soil in this regency. In Indramayu Regency, Inceptisols consists of subgroups of Typic Dystrudepts, Typic Endoaquepts, and Typic Eutrudepts.

Third soil order in Indramayu is Alfisols. This soil occupies an area of 26,039 ha, or 12.5% of the area of Indramayu Regency. Alfisols is relatively the most developed soil in Indramayu, relatively more developed than Inceptisols. It is distributed in the highest altitude of the regency. Alfisols in this region is characterized by the accumulation of clay in the lower horizon, forming an Argillic horizon as diagnostic horizon (Soil Survey Staff, 2014). This soil usually has a relatively high base saturation (> 35%) at a depth of 180 cm from the soil surface (Soil Survey Staff, 2014) and therefore they have a relatively higher pH than the other two soil orders. Clay accumulation in the sub-horizon comes from the horizon above, washed away by rainwater (Widiatmaka *et al*., 2015).

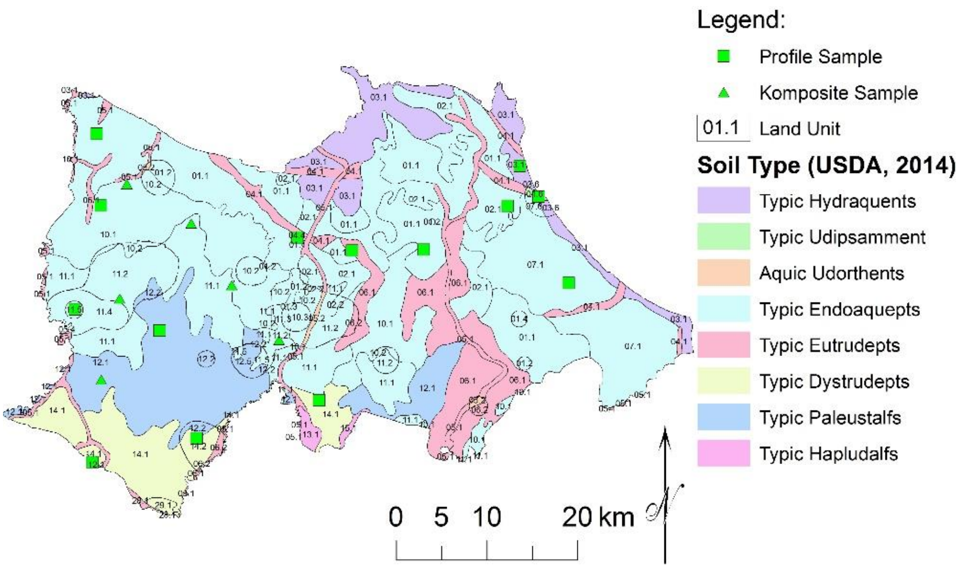


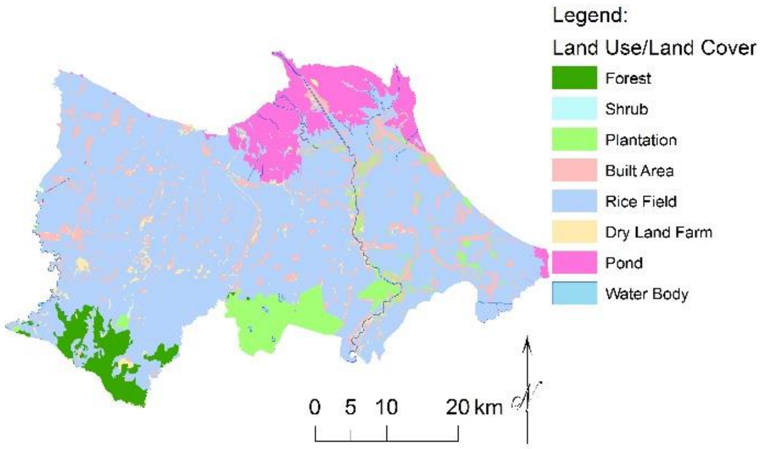
Figure 3. Soil map of Indramayu Regency

Table 1. Soil on different land mapping unit in Indramayu Regency

No	Soil subgroup (Soil Survey Staff, 2014)	Land Mapping Units	Area	
			ha	%
1	Aquic Udorthents	05.2	463.8	0.2
2	Typic Dystrudepts	14.1, 14.2, 29.1	14,495.3	7.0
3	Typic Endoaquepts	01.1, 01.2, 01.3, 01.4, 02.1, 02.2, 07.1, 07.6,	127,205.8	61.2

No	Soil subgroup (Soil Survey Staff, 2014)	Land Mapping Units	Area	
			ha	%
		10.1, 10.2, 10.3, 11.1, 11.2, 11.3, 11.4, 11.5		
4	Typic Eutrudepts	04.1, 04.4, 05.1, 05.4, 06.1, 06.2, 28.1	26,041.6	12.5
5	Typic Hapludalfs	13.1, 15.1	1,002.6	0.5
6	Typic Hydraquents	03.1, 03.6	13,340.9	6.4
7	Typic Paleustalfs	12.1, 12.2, 12.5	25,036.9	12.1
8	Typic Udipsamment	04.6	169.4	0.1
	Total		**207,756.3**	**100.0**

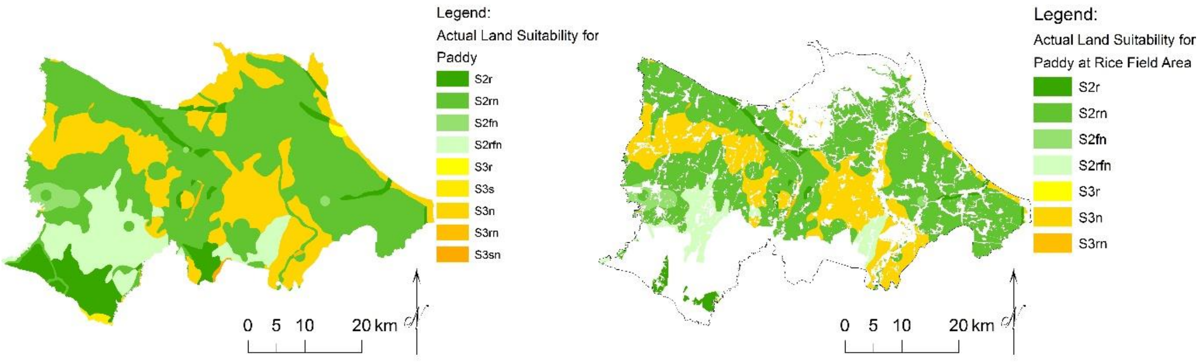
Land Use and Land Cover (LULC). Result of LULC analysis is displayed on **Figure 4**. The Indramayu Regency is dominated by paddy field (144,429 ha or 69.4%), this condition indicates that this regency as the one of center production of rice in Indonesia. The second LULC dominated in this regency is fishpond (19,334 ha or 19%). They are mostly found in the northern part of the regency in the coastal area. The forest area is found in the southern part of regency in the highland.



No	Land use/ Land cover	Area	
		ha	%
1	Forest	7,919.5	3.8
2	Built area	18,213.8	8.8
3	Dry land	4,099.2	2.0
4	Water body	1,452.8	0.7
5	Estate/plantation	12,485.4	6.0
6	Paddy field	144,429.0	69.4
7	Shrubs	75.0	0.0
8	Fishpond	19,333,9	9.3
	Total	**208,008.6**	**100.0**

Figure 4. Results of land use and land cover analysis of Indramayu Regency using SPOT 6, 2014

Land Suitability for Paddy Field. The results of soil analysis is presented in the form of a summary table as shown in **Table 2**. Land suitability for each land mapping unit by applying the soil analysis on each LMU are presented in **Figure 5**. The result showed that the land suitability for paddy field in Indramayu Regency range from S2 (suitable) to the S3 (marginally suitable). The limiting factor appears includes n (nutrient availability), f (nutrient retention), and r (rooting media) (**Figure 5** and **Table 3**).



a b

Figure 5. Land Suitability for paddy field in Indramayu Regency: a. whole Indramayu Regency, b. in the existing paddy field area

Table 2. The results of soil analysis (average for each land mapping unit)

LMU	n	pH	Org-C	Tot-N	P-Bray	Ca	Mg	K	Na	CEC	BS
			-------%------		ppm	--------------cmol(+).kg^{-1}--------------					%
01.1	6	6.94	1.22	0.13	3.80	22.18	15.71	0.93	5.22	36.11	95.67
01.2	4	6.56	0.90	0.14	6.82	28.81	12.94	0.50	2.38	28.90	100.00
01.4	1	6.71	1.32	0.10	5.92	19.44	13.97	0.39	1.54	9.65	100.00
02.1	6	6.63	1.14	0.13	5.89	22.95	16.41	0.71	4.15	39.05	93.33
03.1	3	7.21	1.03	0.11	3.55	16.29	16.29	1.93	21.02	39.39	100.00
04.4	1	7.10	1.24	0.11	0.00	19.39	13.18	1.28	1.21	31.10	100.00
04.6	1	6.60	0.54	0.05	0.00	6.26	4.93	0.38	0.10	18.00	65.00
05.1	1	6.61	1.20	0.18	5.39	17.01	16.83	0.84	8.22	20.10	100.00
06.1	3	5.98	1.28	0.11	3.52	23.73	11.84	0.63	1.24	33.54	86.33
06.2	1	6.71	1.10	0.12	7.49	28.24	14.55	0.44	0.82	36.18	100.00
07.1	5	6.59	1.17	0.11	5.35	25.66	12.75	0.52	2.54	27.76	99.40
10.1	9	6.35	1.20	0.10	4.48	21.57	11.45	0.50	1.35	26.97	95.44
10.2	1	6.61	1.05	0.12	5.09	22.97	14.58	0.84	1.93	30.35	100.00
10.3	1	7.01	1.32	0.07	3.07	11.59	6.15	0.28	0.89	8.84	100.00
11.1	6	5.55	1.17	0.12	3.33	18.31	10.04	0.43	1.05	28.89	95.38
11.2	6	5.86	0.87	0.10	3.67	15.66	6.95	0.35	0.83	20.66	91.88
11.4	1	5.18	1.25	0.10	3.37	10.48	3.05	0.37	0.52	10.65	100.00
11.5	1	6.20	0.85	0.11	0.00	4.90	2.00	0.20	0.10	23.70	30.00
12.1	9	5.77	1.02	0.10	4.94	17.16	10.82	0.39	0.63	26.16	93.55
12.2	1	6.02	1.18	0.11	4.42	29.21	15.68	0.63	0.91	38.99	100.00
12.5	1	4.51	0.66	0.08	3.15	3.26	2.05	0.27	0.16	10.45	54.93
14.1	5	5.70	2.25	0.15	3.93	18.97	11.76	0.59	0.50	30.13	88.60
14.2	5	4.84	1.41	0.14	3.76	6.59	5.40	1.72	0.69	16.85	82.00

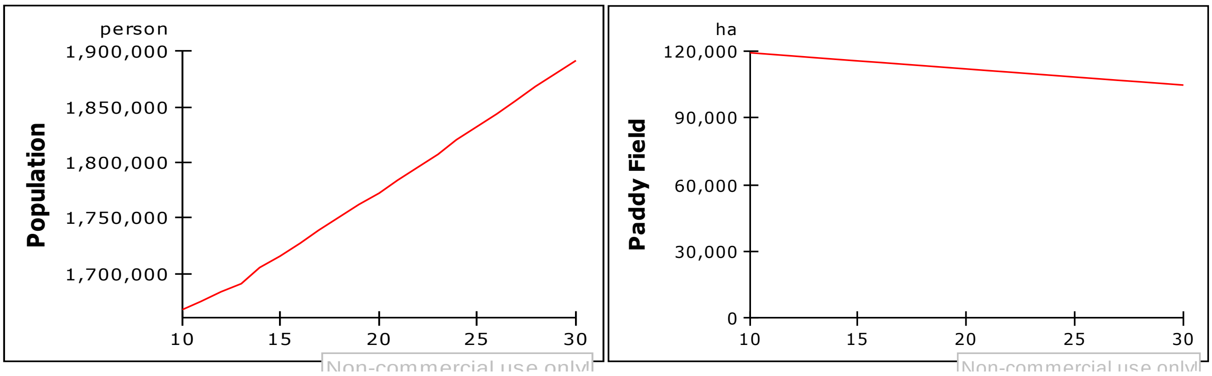
Table 3. The actual land suitability of paddy field in the paddy

No	Land Suitability	Land Unit	Size	
			ha	%
1	S2r	01.3, 02.2, 04.1, 11.3, 14.1	4,016.6	3.1
2	S2rn	01.1, 01.2, 02.1, 05.1, 06.2, 07.1, 10.2, 11.1, 11.2, 11.5, 12.2	79,652.3	62.4
3	S2fn	01.4, 04.4, 11.4	2,234.4	1.8
4	S2rfn	12.1, 14.2	8,376.8	6.6
5	S3r	03.6, 07.6	115.5	0.1
6	S3n	03.1, 05.4, 06.1, 10.1, 10.3, 12.5	32,887.6	25.8
7	S3rn	04.6, 05.2	315.3	0.2
	Total		**127,598.4**	**100.0**

Limiting factor: f = nutrient retention; n = nutrient availability; r = rooting media

System Dynamic Model of Rice Availability. The results of the model validation for the total population, area of paddy field and rice production give the output value of AME, which were 0.1140%, 0.3425% and 0.3316% respectively. As example, with the total population in 2010 which was 1,668,153 people, in 2014 the total population was predicted by the model to become 1,705,263, while the actual population in 2014 according to statistical data was 1,708,551 people. The difference between the model and the actual data was so 3,288 people. The paddy field area in 2010 was amounted to 119,043 ha, it was predicted by the model to become 116,243 ha due to paddy field conversion into other land utilization; the actual value of 2014 was 116,925 ha. The production of paddy, which in 2010 was as much as 1,557,552 tons, was predicted by the model to become 1,622,221 tons in 2014, in fact, the actual paddy production in 2014 was as much as 1,625,179 tons. Since the value of AME is still below 1% as a whole, then the model is considered to be valid to be used to predict other parameters.

The results of simulations for parameters modeled were presented on **Figure 6**, respectively for the total population (Figure 6a), the area of paddy field (Figure 6b), production and consumption of rice (Figure 6c) and area to be protected (Figure 6d).



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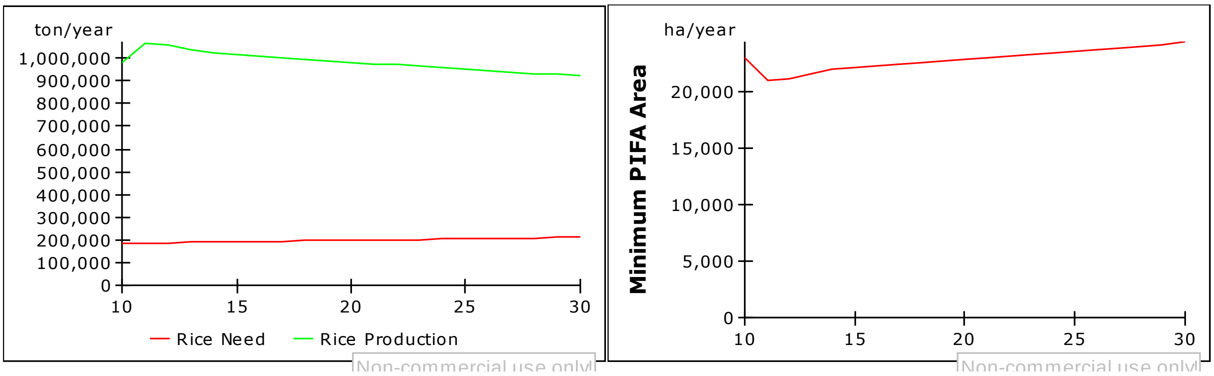

c d

Figure 6. Result of model simulations in Indramayu Regency for : a. populations, b. paddy field area, c. rice consumption and rice Production, and d. Minimal area of paddy field for internal regional food availability (Minimum PIFA)

Based on the model, the number of population in 2014 was 1,705,263 people, in 2030 will be 1,891,975 people. These increases of population is the resultant of births, deaths, in-migration and out-migration area which was calculated in the model. Paddy field area will decrease, from an area of 116,243 ha in 2014 to become 105,043 ha in 2030. In 2014, Indramayu Regency produces 1,017,781 tons of rice, with consumption needs in the region amounted to 192,694 tons. In 2014 so, Indramayu Regency experienced rice surplus which were amounted to 825,086 tons. This surplus was donated to out of Indramayu Regency's territory, or in other words, Indramayu contribute to national food sovereignty. Over the years, the production area is predicted to decrease, mainly due to paddy field conversion into other land utilization, while consumption is increasing due to population growth. In 2030, with a production of 919,718 tons and the level of consumption reached 213,793 tons, then the rice surplus of Indramayu Regency is 705,925 tons. It can be noted here so, that there has been a reduction in the ability of the Regency to contribute rice out of the territory, with a reduction of 14.4%. Reduction ranging from 10-15% have also been recorded in the study of Widiatmaka *et al.* (2013) and Rafiuddin (2015) in Karawang Regency, one of other centers of rice production in West Java. If all production centers in Java Island experiencing the same phenomena, then this will certainly dangerous for the sustainability of national food sovereignty. Figure 6d indicated the amount of paddy field area which should be minimal in Indramayu, when internal availability of rice would desired. In 2030, the minimum area of paddy fields which should be exist in Indramayu would be an area of 24,417 ha.

In order to anticipate a continued decline of this surplus, this study attempted prepared scenario (**Figure 7**). In reality, scenarios prepared can be both reduction of consumption and increasing of production. However, to simplify the calculations, in this paper only scenario of increasing of production were done. This scenario is the most likely scenario possible for Indramayu Regency in the near future. Increasing production can be achieved through increasing Cropping Index (CI). Cropping Index is the ratio between area used for paddy field with harvest area, or in other words how many times a piece of land is planted with paddy field. Actually, CI of Indramayu Regency is equal to 2.1. Effort for increasing CI can be done through improvement of irrigation facilities, so that several area where paddy fields are planted once in a year can be improved its water availability in order to be planted into 2 or even 3 times in a year. In the moderate scenario, the CI was considered to be increased from 2.1 to become 2.3, whereas in the optimistic scenario, the CI was considered to be increased to become 2.5.

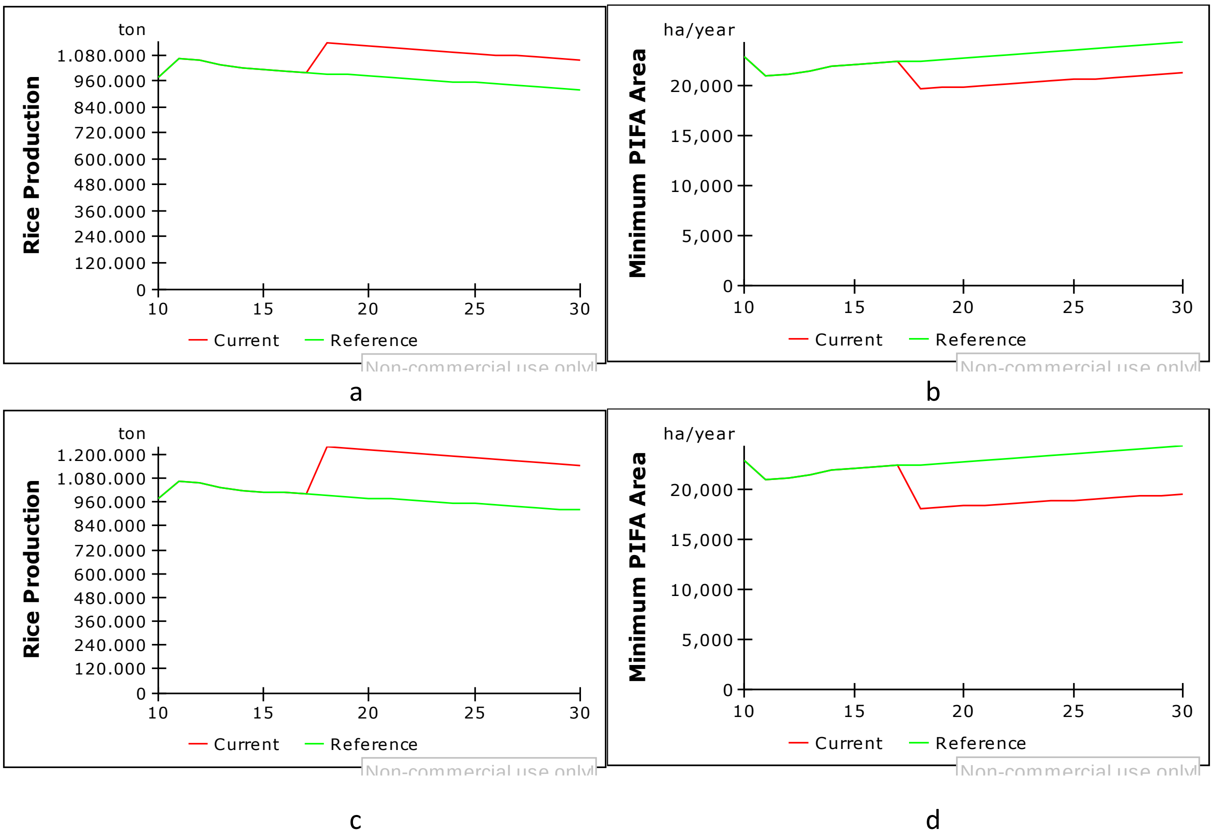

Figure 7. Result of the modeling of (a) paddy production, and (b) Minimum PIFA area, according to moderate scenario, (c) paddy production and (d) Minimum PIFA area according to optimist scenario.

With the scenario of increasing CI, it can be seen in the **Figure 7** and **Table 4** that the production can be increased. In the moderate scenario (increasing CI to become 2.3), production in 2030 will be 1,052,414.04 tons. With consumption levels remained as without scenario (at 213,793 tons in 2030), thus the rice surplus of Indramayu Regency in 2030 will become 838,620.91 tons (Table 4). In the scenario 2 (optimistic, increasing CI to become 2.5), the rice surplus will become 930,135.17 tons. It can be seen here that increasing CI will compensate the increasing consumption due to population growth. In the optimistic scenario, with higher CI enhanced, the surplus can be higher.

Table 4. Performance surplus of rice according to the scenario compared to actual condition (modeled)

Year	Rice Need	Actual		Scenario 1		Scenario 2	
		Rice production	Surplus/ Defisit	Rice Production	Surplus/ Defisit	Rice Production	Surplus/ Defisit
2010	188,501.29	975,492.97	786,991.68	975,492.97	786,991.68	975,492.97	786,991.68
11	189,364.25	1,062,583.68	873,219.43	1,062,583.68	873,219.43	1,062,583.68	873,219.43
12	190,231.16	1,054,369.85	864,138.69	1,054,369.85	864,138.69	1,054,369.85	864,138.69
13	191,101.85	1,033,791.18	842,689.33	1,033,791.18	842,689.33	1,033,791.18	842,689.33
14	192,694.68	1,017,781.49	825,086.81	1,017,781.49	825,086.81	1,017,781.49	825,086.81
15	193,950.09	1,011,652.54	817,702.46	1,011,652.54	817,702.46	1,011,652.54	817,702.46
16	195,213.67	1,005,523.59	810,309.92	1,005,523.59	810,309.92	1,005,523.59	810,309.92
17	196,485.49	999,394.65	802,909.16	999,394.65	802,909.16	999,394.65	802,909.16
18	197,765.59	993,265.70	795,500.11	1,136,572.70	938,807.11	1,235,405.10	1,037,639.51
19	199,054.03	987,136.76	788,082.72	1,129,559.47	930,505.44	1,227,782.04	1,028,728.00
20	200,350.87	981,007.81	780,656.94	1,122,546.25	922,195.38	1,220,158.97	1,019,808.10
21	201,656.16	974,878.87	773,222.71	1,115,533.03	913,876.88	1,212,535.90	1,010,879.75
22	202,969.95	968,749.92	765,779.97	1,108,519.81	905,549.86	1,204,912.84	1,001,942.89
23	204,292.29	962,620.97	758,328.68	1,101,506.59	897,214.29	1,197,289.77	992,997.47
24	205,623.26	956,462.03	750,868.77	1,094,493.37	888,870.11	1,189,666.70	984,043.44
25	206,962.89	950,363.08	743,400.19	1,087,480.14	880,517.25	1,182,043.64	975,080.74
26	208,311.26	944,234.14	735,922.88	1,080,466.92	872,155.67	1,174,420.57	966,109.31
27	209,668.41	938,105.19	728,436.79	1,073,453.70	863,785.30	1,166,797.50	957,129.10
28	211,034.40	931,976.25	720,941.85	1,066,440.48	855,406.09	1,159,174.44	948,140.04
29	212,409.28	925,847.30	713,438.02	1,059,427.26	847,017.97	1,151,551.37	939,142.08
2030	213,793.13	919,718.35	705,925.22	1,052,414.04	838,620.91	1,143,928.30	930,135.17

The priority area of paddy field to be protected in 2030 can then be outlined. If we desired the availability of rice in the longer term, of course rice area required should also higher, in this case a minimum area of paddy field for internal regional food availability (minimum PIFA). This illustration can be used to set priorities for the region based on land suitability. Higher land suitability or land with less limiting factor should be given as higher priority. Results of prioritization by combining minimum PIFA with land suitability is presented in **Figure 8**.

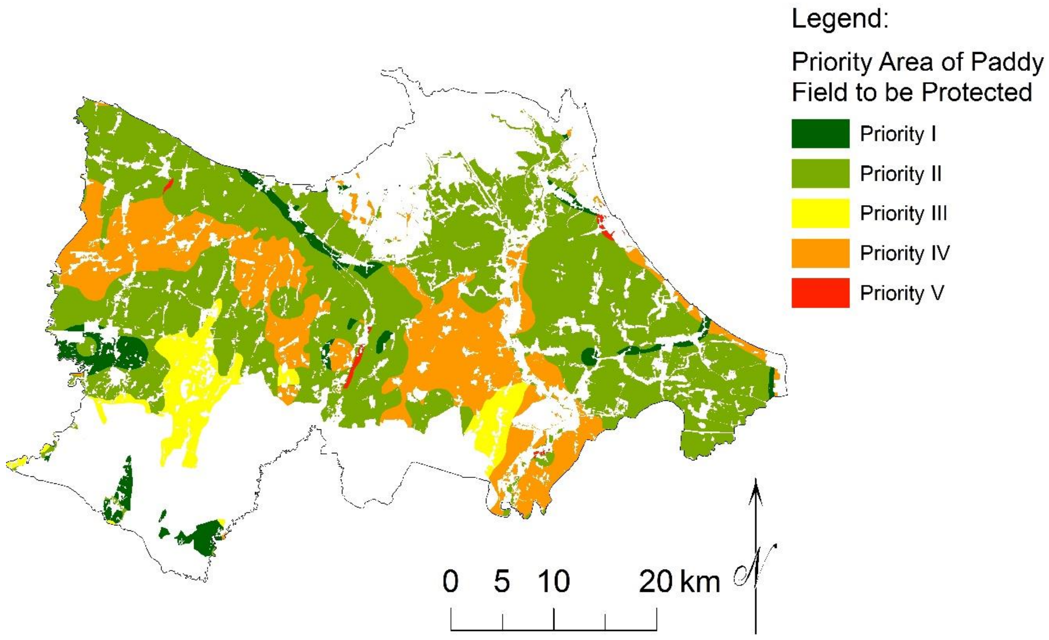

Figure 8. Priority area of paddy field to be protected in Indramayu Regency.

4. CONCLUSION

This study presents land use planning for paddy fields in Indramayu Regency, one of the rice production center in Java Island, in order to ensure the region to be able to provide food for the population in the internal regency, in addition to ensure its contribution to supply rice out of the regency. Based on existing land use and land cover, Indramayu Regency has main land use of paddy fields which covers >60% of the regency. The results of land suitability analysis showed that land suitability for paddy fields in the area which is actually used as paddy field, the majority (> 70%) of the area have land suitability level of S2 (suitable), the other have land suitability level of S3 (marginally suitable). The limiting factors consist of nutrient retention, butrient availability and rooting media. System dynamic modeling results show that in the current conditions, Indramayu regency still have sufficient food for its population, the regency can even contribute to national food sovereignty by exporting 81% of rice out of the territory. Along with the increasing food needs due to population growth and decreasing paddy field area due to land conversion, the ability to export out of the regency was reduced with 14% from in 2030 compared to the export of 2014. The moderate scenario compiled in the model show that such reduction capabilities to export can be pressed. With the moderate scenario by improvement of cropping index, Indramayu regency in 2030 will still able to export rice 79% out of the territory. In the optimistic scenario, the ability to export out of the territory is even higher, surpassing even export in the existing (2014) condition. Based on the analysis of land suitability and equilibrium of production and consumption according to the model, the priority of paddy field to be protected can be then arranged within five (5) priority levels, which can be presented spatially.

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