Jurnal Manajemen & Agribisnis, Vol. 16 No. 3, November 2019
Permalink/DOI: http://dx.doi.org/10.17358/jma.16.3.121
Available online at http://journal.ipb.ac.id/index.php/jmagr

Accredited SINTA 2
by Directorate General of Higher Education (DGHE),
Republic of Indonesia No 30/E/KPT/2018

DYNAMIC SYSTEM MODEL OF RICE SELF SUFFICIENCY TOWARDS FOOD SECURITY

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Abstract: Food security is the condition of fulfilling individual food that is sufficient, safe, equitable and affordable. The main target of fulfilling food sufficiency is dominated by rice self-sufficiency. Rice self-sufficiency is important because it has special reasons in terms of politics and social economy. The sustainability of rice self-sufficiency faces many challenges because domestic rice supply growth is not as fast as rice use. The purpose of this study is to simulate the scenario of achieving self-sufficiency in rice and formulating policy recommendations for developing management to achieve self-sufficiency in rice. Research data includes primary and secondary data. This research uses a dynamic system approach. Simulations carried out from 2018-2045. The simulated policy is intensification, extensification, suppression of postharvest losses and Indonesia a self-sufficiency country as well as an exporter of rice (scenario five), but the policy requires a very large budget. Scenario six, a combination of intensification, suppression of postharvest losses and land conversion becomes an alternative operational policy and is most likely to be applied. Land conversion is the biggest determinant in rice self-sufficiency. Recommendations address for the government include: (1) establish and protect longterm rice fields, (2) identify and map of areas that have the potential for the development of a periodic expansion of food crops; (3) guarantee the availability of agricultural facilities and infrastructure in accordance with the selected policy, both in the form of the application of scenario six and scenario five.

Keywords: dynamic system, food security, policy, rice, self-sufficiency

Abstrak: *Ketahanan pangan adalah kondisi pemenuhan makanan individu yang memadai, aman, merata dan terjangkau. Target utama pemenuhan kecukupan pangan didominasi oleh swasembada beras. Swasembada beras penting karena memiliki alasan khusus dalam hal politik dan ekonomi sosial. Keberlanjutan swasembada beras menghadapi banyak tantangan karena pertumbuhan pasokan beras domestik tidak secepat penggunaan beras. Tujuan dari penelitian ini adalah untuk mensimulasikan skenario pencapaian swasembada beras dan merumuskan rekomendasi kebijakan untuk mengembangkan manajemen untuk mencapai swasembada beras. Data penelitian mencakup data primer dan sekunder. Penelitian ini menggunakan pendekatan sistem dinamis. Simulasi dilakukan mulai 2018-2045. Kebijakan yang disimulasikan adalah intensifikasi, ekstensifikasi, penindasan kerugian pascapanen dan Indonesia negara swasembada serta pengekspor beras (skenario lima), tetapi kebijakan tersebut membutuhkan anggaran yang sangat besar. Skenario enam, kombinasi intensifikasi, penindasan kerugian pascapanen dan konversi lahan menjadi kebijakan operasional alternatif dan kemungkinan besar akan diterapkan. Konversi lahan adalah penentu kemandirian beras terbesar. Alamat rekomendasi untuk pemerintah meliputi: (1) membangun dan melindungi sawah jangka panjang, (2) identifikasi dan pemetaan daerah yang memiliki potensi untuk pengembangan ekspansi tanaman pangan secara berkala; (3) menjamin ketersediaan sarana dan prasarana pertanian sesuai dengan kebijakan yang dipilih, baik dalam bentuk penerapan skenario enam dan skenario lima.*

Kata kunci: *sistem dinamis, ketahanan pangan, kebijakan, beras, swasembada*

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INTRODUCTION

Food is an inseparable part of basic human rights guaranteed in the 1945 Constitution of the Republic of Indonesia. The government is mandated to accomplish national food security. The main concept of food security, as stated in the Law Number (No.) 18 of 2012 regarding Food, consisted of two aspects which are (1) easy access to food and (2) sufficient, safe and nutritious food. Food sufficiency in terms of staple food is preferably obtained from domestic production or self-sufficiency production. Thus, self-sufficiency is the pillar of food security (FAO, 2015). The main commodity target for self-sufficiency in Indonesia is rice (Kementan, 2015). Rice has been consumed as the staple food for more than 95% of Indonesia's population (Sudaryanto, 2013). Rice is easily obtained and served, and also gives an impact on national stability (Subejo, 2014).

For five decades, rice self-sufficiency has developed dynamically. During the Old Order era (1952–1964) until the transitional government (1965–1967), rice self-sufficiency was hardly achieved. Rice self-sufficiency was finally accomplished in several government periods which are during New Order era (1984), the First United Indonesia Cabinet (2007–2009), and the Working Cabinet (2016). Based on Indonesian history, realizing and maintaining rice self-sufficiency is quite challenging. Rice self-sufficiency is a dynamic condition and required careful provision. The dynamics of rice self-sufficiency occurs due to changes in the factors forming the system of rice self-sufficiency. These factors are the rice supply and demand (Suryana, 2014). From the supply side, over the past six years (2013–2018) domestic rice production has been fluctuated, while on the other hand the consumption of domestic rice keeps increasing. In 2013, rice production was 41.69 million tons. In 2014, it dropped to 41.42 million tons. Then in 2017, it rose again by 47.59 million tons (Pusdatin, 2019). Unfortunately in 2018, it fell sharply to 32.42 million tons (BPS, 2018).

Several factors have been found to hinder the stability of rice production. One of the factors is (1) reduced land availability. Every year the rice field area is reduced due to rice field conversion to non-agriculture area. According to Government Regulation No. 1 of 2011 on the Determination and Conversion of Sustainable Food Agricultural Land, the conversion of rice fields in 1999–2002 had amounted to 110,000 ha/year. Moreover in 2018, the Minister of Agrarian Affairs and Spatial Planning stated that 150,000–200,000 ha of rice fields are converted every year to non-agriculture land (Kompas, 2018; Detik Finance, 2018). This condition is aggravated by the government's low ability to print new rice fields. The average rice fields printing ability of government from 2013-2018 is only 49,983 ha/year. Even in 2018, only 9,737 ha of new rice fields were planted in Indonesia (Kementan, 2019b). Another factor affecting sustainability of rice production is (2) irrigation canal damage (Damayanti, 2013). The absence of water throughout the year, especially during the dry season, reduces the Plant Index (PI), thus decreasing the rice production. Damage to irrigation network causes potential rice harvest loss around 4.5 million milled dry grains (MDG) per year (Kementan, 2017b). (3) The third factor influencing the stability of rice production is the decline in productivity (by 5.3 tons/ha in 2015 to 5.18 tons/ha in 2018) (Kementan, 2018a). Productivity is affected by seed and fertilizer. The application of seeds and fertilizers has not been appropriate with the recommendation of the six appropriate principles (Ditjen PSP, 2015) which are punctual, precise quality, quantity, type, price and place. Delay in the distribution of fertilizers to farmers results in the loss of 3 million MDG per year (Kementan, 2017b). Besides seeds and fertilizers, another factor determining productivity is the Climate Change Impact (CCI) and Plant Disturbing Organism (PDO). Crop failure due to ICC/PDO is 0.98% of the planting area (Ditlin TP, 2019). The fourth factor affecting production stability is (4) the high losses of post-harvest (around 10.43%) (Direktorat Pascapanen TP, 2015). Loss of rice yield during pre-harvest and harvest time is about 3.5 million tons of MDG per year (Kementan, 2017b).

Meanwhile, Indonesia's average rice consumption is quite high compared to other countries. Indonesia's average rice consumption is 38.24 million tons/year, whereas Thailand’s rice consumption is only 10.62 million tons/year and Vietnam's is 21.43 million tons/year (Pusdatin, 2016). The high consumption of rice is the result of Indonesia's population growth rate of 1.19% per year (BPS, 2013) and the increasing trend of rice consumption per capita. In 2013, rice consumption was 96.3 kg/cap/year and increased to 97.1 kg/cap/year in 2018.

Planning a policy system requires knowledge and thorough observation of the system. Perceived from the non-static nature of the system constituent factors, thus planning of rice self-sufficiency system policies with an approach that understands these conditions is needed. Therefore, this study used a dynamic system approach in policy formulation because this approach is able to describe the process of change that occurs in a system from time to time (Hartrisari, 2007). This dynamic system approach is also comprehensive. The problem of achieving rice self-sufficiency should not be seen partially, because rice self-sufficiency is determined by complex factors, not only one or two factors (e.g. land or fertilizer). Factors in rice self-sufficiency are also interrelated. The complexity of the rice self-sufficiency system in a dynamic system can be simplified with the help of a model. Besides understanding the processes in the system, this model can also predict changes over time. This approach is very advantageous due to unfeasibility to conduct a series of experiments in the real world as if laboratory experiment. Planning for rice self-sufficiency policy should be conscientious because the costs incurred in implementing rice self-sufficiency policy are not few and have long-term impacts. Ineffective decision making may result in large losses and give negative impact in the long term.

This study simulated a dynamic model that combines several scenarios to improve rice production as in the study of Irmadamayanti et al. (2015) and reduce rice consumption. This is contrast to previous studies, which used other than dynamic systems methods to determine rice self-sufficiency and only emphasize on increasing production for rice self-sufficiency partially. This study predicts the ability of rice self-sufficiency in Indonesia and the amount of agricultural costs needed to achieve rice self-sufficiency using a dynamic system approach. The ability of rice self-sufficiency is expressed in the level of SSR (Self Sufficiency Ratio, while the cost of agriculture is stated in Indonesian Rupiah (IDR). The production data and rice field area used the latest BPS method which is Area Sample Framework. This study simulated the policy scenario of increasing rice production to achieve holistic rice self-sufficiency in terms of demand and supply and combine rice production policies ranging from intensification, extensification, rice consumption reduction, postharvest losses suppression and focus on rice field conversion control. This study aimed to: (1) simulate the scenario of achieving rice self-sufficiency in a dynamic system model; and (2) formulate policy recommendations in the framework of developing management to achieve rice self-sufficiency towards food security.

METHODS

This study was conducted at the Ministry of Agriculture from September 2018 until March 2019. The research data included primary and secondary data. Primary data were obtained from direct interviews with experts (researchers in Agricultural Research and Development and decision makers in Planning Bureau). Secondary data were obtained from various sources (Table 1). This research formulated policy recommendations to achieve rice self-sufficiency in Indonesia with a dynamic system approach. The stages of the dynamic system modeling process, according to Hartrisari (2007) are: (1) needs analysis, (2) problem formulation, (3) system identification, (4) system modeling, (5) validation and (6) implementation. The self-sufficiency level is calculated based on the ratio of production to consumption. Agricultural costs calculated in this study include: subsidized seeds costs, purchase of Combine Harvester (CH) and Dryer, revitalization of Agriculture, Fisheries and Forestry (AFF), PDO control, Farmer-level Irrigation Network (FIN, Jaringan Irigasi Tingkat Usaha Tani) rehabilitation, rice field printing, swamp optimization, extension, and fertilizer budget allocation. Rice production results from the paddy converted rice production detracted the need for feed, seeds, scattered and industry. Rice needs consist of non-food uses (feed, scattered, industry), direct consumption (household), indirect consumption (no household) and government rice reserves (Pusdatin, 2016). The Self Sufficiency Ratio (SSR) formula used to calculate the ability of self-sufficiency or level of rice self-sufficiency in Indonesia is as follows:

$$SSR = (\text{Rice production}/\text{Rice needs}) \times 100\%$$

Modeling and simulation in this study used the Powersim Program. The validation test was conduction using Absolute Mean Error (AME) test with a deviation limit of 5-10% (Muhammadi et al. 2001). The validation test was calculated in the Microsoft Excel program.

$$AME = [(Si - Ai)/Ai]$$

Note: Si (Si/N, where S = simulation value); Ai (Ai/N, where A = actual value); N (observation time interval).

Table 1. Input model data

Variables and Parameters	Value	Data Sources
Lowland rice area (2018)	7,105,145 ha	BPS, 2018
Upland rice area (2018)	1,274,000 ha	Kementan, 2018b
Swamp rice area (2018)	44,787 ha	Ditjen PSP, 2019; Kementan, 2019b
Rice area conversion rate	149,328.18 ha/year	BPS, 2018; Kementan, 2018a and 2019b; Ditjen PSP, 2018; Processed
Planting Index (PI)	1.54/year	BPS, 2018
Damaged tertiary irrigation	4,419,397 ha	Ditjen PSP, 2019
Lowland rice productivity (2018)	5.19 tons/ha	BPS, 2018
Upland rice productivity (2018)	3.281 tons/ha	Kementan, 2018b
Swamp rice productivity	3 tons/ha	Alwi, 2014
Certified superior seeds	20%	Kementan, 2017b
Balanced fertilizer	35%	Hartatik et al. 2015
Extension service (2018)	30%	Kementan, 2017b
PDO/CCI harvest failure fraction	0.98%	Ditlin TP, 2019
PDO/CCI control	50%	Balitbangtan, 2012
Postharvest losses	10.43%	Direktorat Pascapanen TP, 2015
Dryer availability	3,300 unit	Balitbangtan, 2019
CH availability	22,421 unit	Balitbangtan, 2019
Rice yield	64.02% /year	BPS, 2018
Total AFF	172,940 unit	Balitbangtan, 2019
Rice consumption (2018)	97.1 kg/capita/year	BKP, 2019
Total population (2018)	265 million people	BPS, 2013
Population growth	1.19%/year	BPS, 2013
Ministry of Agriculture budget (2018)	IDR 23.8 trillion	Kementan, 2018c
Fertilizer allocation budget	IDR 28 trillion	

The rice self-sufficiency system is divided into two subsystems, namely the rice supply subsystem and the domestic rice use subsystem. The system structure was illustrated by the Causal Loop Diagram (CLD) in Figure 1. The CLD consisted of the system building variables which were connected by arrows as relationship markers between variables (Hartrisari, 2007). In Figure 1, improvement in rice production started from the application of technology and Good Agricultural Practices (GAP)/Good Handling Practices (GHP). This application encourages: (1) improvement of irrigation and mechanization to increase PI; (2) the use of certified superior varied seeds, use of fertilizers according to recommendations and extension assistance to increase productivity; (3) mechanization to suppress losses; (4) AFF revitalization to increase yield. Increasing rice production results in increase in domestic rice supply and rice self-sufficiency. Land conversion causes reduction in the rice field area. Increasing the raw land area increases the planting and harvest area. Improved PDO/CCI control intensifies harvested area. The rise in the use of domestic rice is influenced by increases in household consumption, industry, feed, and Government Rice Reserve (GRR) variables. Increasing the supply of rice and decreasing the rice use will create self-sufficiency.

RESULTS

Dynamic System Model of Rice Self-Sufficiency

The dynamic models in Figures 2 and 3 represent the rice self-sufficiency system in Indonesia. The variables used in the model were adopted from previous studies and documented history of successful rice self-sufficiency during the New Order era (1984), the First United Indonesia Cabinet (2007–2009) and the Working Cabinet (2016). The actual attempts of the New Order era to obtain rice self-sufficiency were the development of Bimas (Bimbingan massal, massal guidance), direct command by the President to implement five farms attempts (good land management, use of superior seeds, proper fertilization, pest/disease control, and irrigation), agricultural extensification and also rehabilitation of agricultural production facilities. The success of rice self-sufficiency during the Working Cabinet was obtained through the seven revitalization program in terms of: (1) land; (2) seedlings and cultivation; (3) infrastructure and facilities; (4) human resources; (5) agricultural financing; (6) farmer organization; (7) downstream technology and industry. The success of rice self-sufficiency in the Working Cabinet is also supported by UPSUS (Upaya Khusus, special efforts) to increase rice production which involved improvement of irrigation networks, land optimization, farming assistance, provision of agricultural equipment and machinery assistance both pre-harvest and post-harvest, seeds and fertilizers, pest/PDO control and expansion of planting area (DG PSP, 2015). Besides, the food diversification was also being socialized. During this period, the budget allocation was doubled in 2015 and mostly used for agricultural infrastructure. Furthermore, by combining these, the researchers categorized the rice supply subsystem variables consisted of productivity (seeds, fertilizer, extension services), PI (irrigation), pest/PDO control, postharvest handling (AFF revitalization, CH, dryer), land area (upland, swamps, lowland rice fields), feed, and Bulog stock.

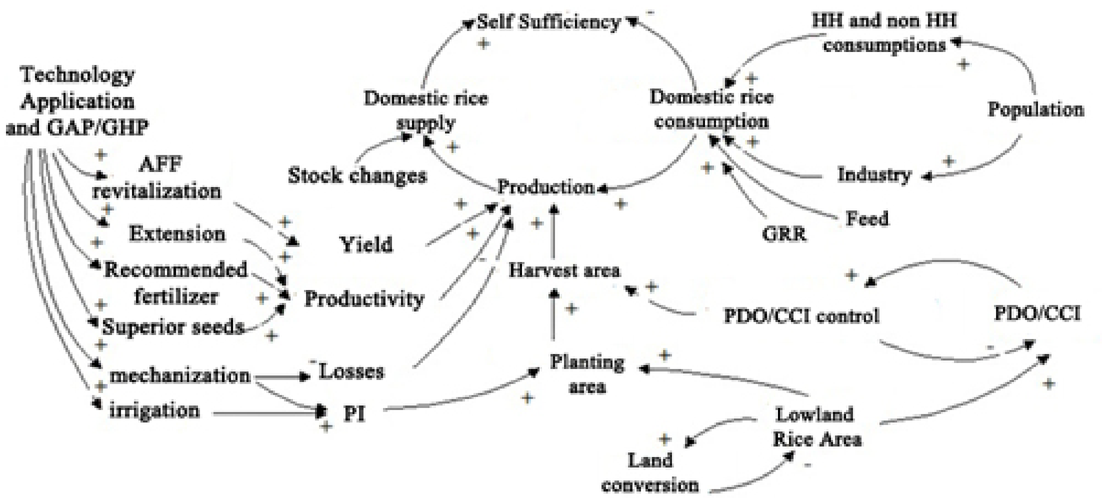

Figure 1. Rice self-sufficiency causal loop diagram

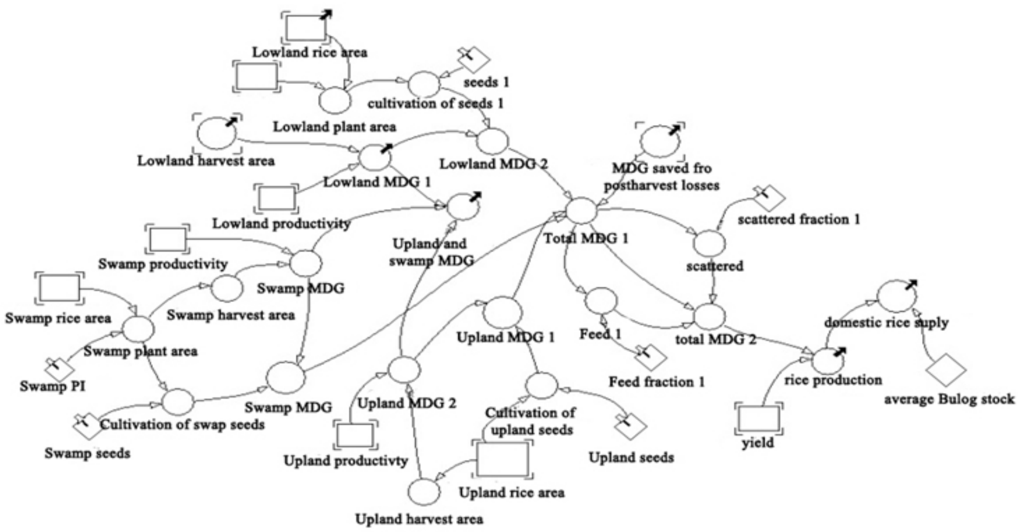

Figure 2. Stock Flow diagram of domestic rice supply subsystem

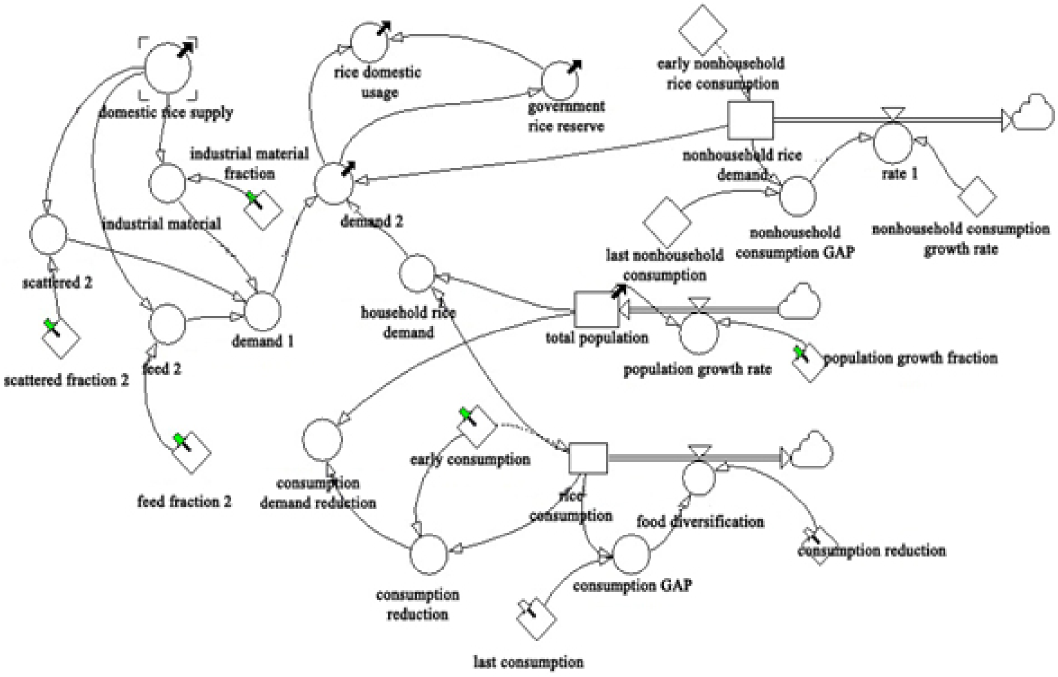

Figure 3. Dynamic model of domestic rice usage

The domestic rice usage subsystem in Figure 3 is limited by the variable of household rice needs, industry, scattered, feed and government rice reserves (GRR). All these variables were adopted from previous studies by Soemantri et al. (2016), Riansyah (2013) and BPS (2018). Ideal GRR should be around 8% of the total national rice needs and controlled by the government, including food and other uses (Kementan, 2018d). The level of self-sufficiency is calculated based on the ratio of production to consumption (SSR) (Pusdatin, 2016; Bala et al. 2014). In this study model, SSR is the ratio of domestic supply to rice usage. The agricultural cost of this study is derived from the Ministry of Agriculture's State Budget (APBN) to improve rice production and allocated for fertilizer subsidy budget. The output of agricultural study costs is the budget that the Ministry of Agriculture will use to increase rice production.

Model Validation

The AME test was conducted on the development of rice production variables, harvested area and total population in 2012–2018. Changes measurement method of rice production with the Area Sample Framework (ASF) method by BPS in 2018 required updated backcasting because the data series were used as actual data for the AME test. The backcasting lowland rice area index is 0.95, lowland rice production is 0.72 and lowland rice harvest area is 0.74 (Table 2).

The AME validation test value for these three variables was less than 5%, where lowland rice production was 2.56%, lowland rice harvest area was 2.90%, and the total population was 0.13% (Table 3). Thus, the difference between the simulation output and the actual output was not significant. The model is considered to have successfully described the real conditions.

Model Simulation

Figure 4 illustrates a comparison between self-sufficiency in the status quo and five scenarios for achieving self-sufficiency in the next 27 years. In the status quo scenario, agricultural development ran in accordance with the policies applied from the previous year, no policy changes were made to improve the level of rice self-sufficiency. The status quo assumptions are as follows: (1) tertiary irrigation network rehabilitation fraction is 19% per year or the average tertiary irrigation network rehabilitation per year is 601,406 ha; (2) the application of certified superior seeds is only 20% of the total planting area; (3) fertilizer application according to recommendations is only 35% of the lowland rice area; (4) extension services is 30% from the total villages in Indonesia; (5) PDO/CCI countermeasures by 50% of the planting area; (5) losses suppression is conducted by adding dryer by 1.39% per year and CH by 5.60% per year from the existing number; (6) AFF revitalization of 0.25% annually; (7) the rate of land conversion continues (149,328 ha/year); (8) land extensification with swamp optimization (14,781 ha/year) and rice field printing (41,074 ha/year); and (9) a decrease in rice consumption of 0.78% per year.

The results of the status quo simulation showed that the SSR has been slowed down to below 90% starting in 2038. Rice self-sufficiency sustains for 20 years. The shortage of rice production is covered by imports and certainly continues to worsen every year. The condition occurs due to higher number of converted rice field every year that is sold by farmers for economic reason (Harini et al. 2013). Thus, the reduction in rice self-sufficiency needs to be anticipated by developing several scenarios. The scenario simulation runs from 2018 until 2045. The scenario is built on parameters that are easily controlled by the government with minimum SSR target of 90% considering the budget available, as in Table 4. The scenarios are grouped into: (1) scenario 1 (apply of policy A); (2) scenario 2 (use combination of policies A and C); (3) scenario 3 (implement the combination of policies A, C and E); (4) scenario 4 (employ the combination of policies A, C, E and F); (5) scenario 5 (apply a combination of policies A, C, E, F and G), (6) scenario 6 (use a combination of policies B, D, G, without land extensification and consumption reduction).

Table 2. Backcasting of lowland rice area, rice field production, and rice field harvest area in

Year	Lowland Rice Area (million Ha)		Lowland Rice Production (million Ton)		Lowland Rice Harvest Area (million Ha)	
	Kementan	BPS (ASF)	Kementan	BPS (ASF)	Kementan	BPS (ASF)
2018	7.45	7.10	78.81	56.53	14.72	10.90
2017	8.16	7.78	77.36	55.49	14.55	10.77
2016	8.18	7.80	75.48	54.14	13.98	10.35
2015	8.09	7.71	71.76	51.47	13.02	9.64
2014	8.11	7.73	67.10	48.13	12.66	9.37
2013	8.12	7.75	67.39	48.34	12.67	9.38
2012	8.13	7.75	65.18	46.76	12.28	9.09
Index	0.95		0.72		0.74	

Table 3. The AME validation test value for variables of rice field production, rice field harvest area, and total population

Year	Lowland Rice Area (million Ha)		Lowland Rice Production (million Ton)		Lowland Rice Harvest Area (million Ha)	
	Actual	Simulation	Actual	Simulation	Actual	Simulation
2018	46.76	46.17	9.09	8.98	244.69	245.43
2017	48.34	49.45	9.38	9.59	248.82	248.74
2016	48.13	51.98	9.38	10.07	252.16	252.09
2015	51.48	53.91	9.65	10.42	255.46	255.49
2014	54.14	55.33	10.35	10.67	258.71	258.94
2013	55.49	56.33	10.78	10.85	261.89	262.43
2012	56.54	56.99	10.90	10.95	265.02	265.97
Value	2.56		2.90		0.13	

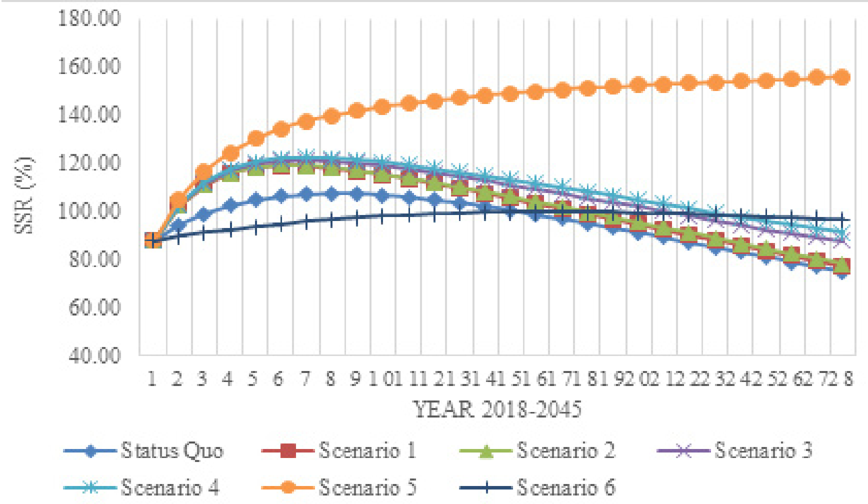

Figure 4. The Self Sufficiency Ratio (SSR) Comparison between each scenario

Table 4. Policies, variables, and self sufficiency model parameter

Policies	Variables	Parameter
Intensification	Lowland rice field PI (1.53→2.38)	Irrigation network rehabilitation by 47.50%/year
	Productivity (5.19→5.42 tons/ha)	Application of certified superior varieties in 40% lowland rice field area, 29% upland and swamp rice field area
		Application of balanced fertilizer in 36% lowland rice field area, 20% upland and swamp rice field area
		Extension service in 30% total villages
	PDO/CCI Control	PDO control in 20% of rice field area
		CCI control in 15% of rice field area
Intensification	Lowland rice field PI (1.53→1.98)	Irrigation network rehabilitation by 6%/year
	Productivity (5.19→5.35 ton/ha)	Application of certified superior varieties in 20% lowland rice field area, 10% upland and swamp rice field area
		Application of balanced fertilizer in 15% lowland rice field area, 10% upland and swamp rice field area
		Extension service in 20% total villages
	PDO/CCI Control	PDO control in 10% of rice field area
		CCI control in 5% of rice field area
Losses suppression	Losses suppression (10.43%→10.12%)	Adding dryer 2%/year and CH 7%/year from total existing number
	Yield (64.02%→64.85%)	AFF revitalization by 2%/year from total existing number
Losses suppression	Losses suppression (10.43%→10.36%)	Adding dryer 1%/year and CH 1%/year from total existing number
	Yield (64.02%→64.07%)	AFF revitalization by 0.1%/year from total existing number
Extensification	Add rice field printing	Rice field printing in 2018-2041: 41,074 ha/year, in 2042-2045: 60,000 ha/year
	Swamp utilization	Swamp optimalization 100,000 ha/year
Food diversification	Rice consumption reduction	Rice consumption reduction by 1.5%/year from 97.1→88.07 kg/cap/year
Zero conversion	Perpetual agricultural land	Agricultural land conversion 0%/year

The scenario simulation results in Figure 4 showed that scenario 5 by applying policies combination of intensification, postharvest losses suppression, extensification, household rice consumption reduction and zero agricultural land conversion produce the highest level of rice self-sufficiency compared to the status quo and the other scenarios. The SSR level in this scenario is more than 100 and tends to continuously increase. The SSR value above 100 indicates that Indonesia has potential to become a rice exporter. The zero land conversion variables gives the biggest contribution in increasing the level of rice self-sufficiency compared to the intensification, extensification, consumption reduction, and postharvest losses suppression variables. It is observed from distant gap between scenario 4 and 5 in Figure 4. This condition is in line with the study of Mahbubi (2013) that estimated food security may be achieved by stopping agricultural land conversion in the long term.

A gap that is not too distant but does not coincide between the status quo with scenario 1 and between scenario 2 and the scenario 3 in Figure 4 showed that increasing rice production by intensification and extensification is quite influential in raising the level of rice self-sufficiency (SSR). This condition supported another study which found that self-sufficiency is achieved through improvement of rice productivity (Cakra and Nazam, 2016) and expansion of rice field area (Oort et al. 2015). The SSR graphs among scenario 1, scenario 2, and 3 were in line and showed that the variable emphasis on losses and consumption reduction insignificantly increase rice self-sufficiency. Scenario 6 in Figure 4 showed that applying the policy of zero land conversion without extensification and consumption reduction is sufficient to produce a level of rice self-sufficiency above 90%.

Figure 5 showed a comparison of the agricultural costs needed to apply each scenario. Scenario 5 requires the greatest amount of agricultural cost and continuously rises each year. The huge amount of costs is to accommodate the policies which are the irrigation networks rehabilitation, supply of superior seeds and fertilizers, hold extension services, provide PDO/CCI control programs, purchasing CH and dryer, AFF revitalization, rice field printing, and swamp optimization. The high cost is proportional to the results obtained that Indonesia has great potential to be an exporter of rice in 2019-2045. Scenario 6 requires the lowest funding with satisfying result by achieving at least 90% of domestic rice needs within time span of 2019-2045. Financing scenario 6 involved expenses for: (1) irrigation network rehabilitation; (2) superior fertilizer and seed supply; (3) addition of extension services and PDO/CCI control; (4) and purchase CH and dryer, and also AFF revitalization.

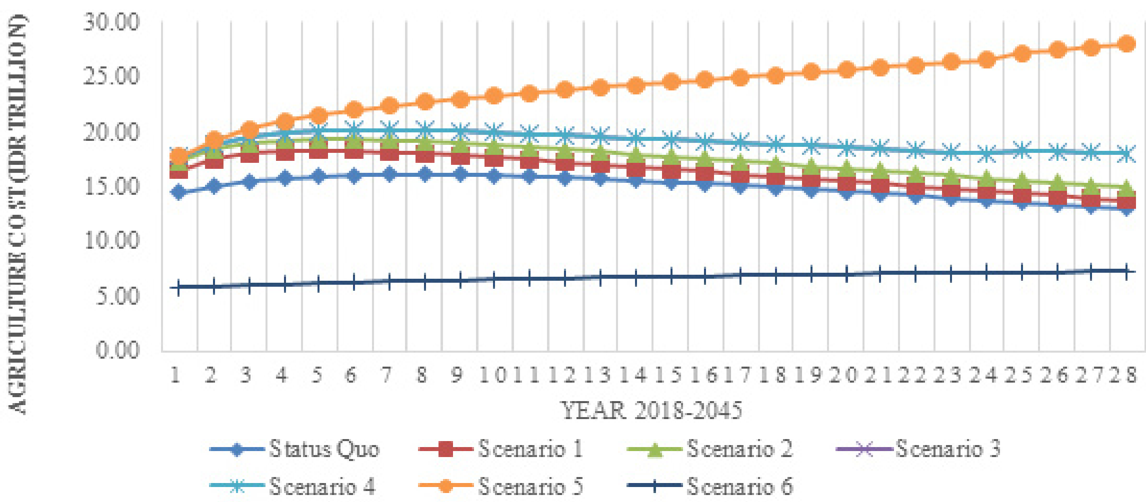

Figure 5. Agricultural cost comparisons among each scenario

Managerial Implications

Policies that are feasible to be implemented by government which able to achieve rice self-sufficiency target (SSR≥90%) are intensification, losses suppression, and zero rice field conversion (Scenario 6). However, Indonesia has potential to become a rice exporter and even become a world rice barn in 2045 by implementing policies combination of intensification, losses suppression, extensification, household rice consumption reduction and zero rice field conversion in 2018-2045. Managerial implications from this study are: (1) the government determines and protects perpetual rice fields by providing incentives for farmers, replace the converted rice fields, and strengthen the performance of the Rice Field Conversion Control Team stipulated in Presidential Regulation No. 59 of 2019, and also subsidize agricultural commodity with high price (Irawan and Friyatno, 2002); (2) renewal of identification and areas mapping to expand agricultural land for food crops, especially rice fields and subsequent planting of rice fields focused within the land; (3) cross-sectoral cooperation is needed and to revive local food processing technology research for food diversification; (4) the government needs to guarantee the availability of facilities and infrastructures to support rice self-sufficiency; (5) involvement of all stakeholders in financing rice self-sufficiency achievement.

More detailed alternative policies on achieving rice self-sufficiency to be implemented if it only targets rice self-sufficiency are as follows: (a) supporting and strengthening the implementation of Presidential Regulation of the Republic of Indonesia Number 59 of 2019 concerning Rice Field Conversion Control Team to protect perpetual rice field; (b) tertiary irrigation network rehabilitation by 6% per year from irrigation damage; (c) the use of certified superior seeds as much as 20% of lowland rice field, 10% of upland and swamp rice field; (d) the application of balanced fertilizer according to recommendations in 15% of the total lowland rice field area and 10% of upland and swamp rice field area; (e) PDO and CCI control covering 10% and 5% of the total planting area respectively; (f) addition of CH and dryer each as much as 1% of the existing number; and (g) AFF revitalization by 0.1% of the total AFF that has not been revitalized. However, if the government targets Indonesia to become a world rice barn by 2045, then the government should implement several policies combination such as intensification policies (tertiary irrigation networks rehabilitation of 47.50% per year from irrigation damage, use of certified superior seeds as much as 40% of lowland rice field area and 29% of upland and swamp rice field area, apply a balanced fertilizer according to recommendations as much as 36% of the total lowland rice field area and 20% of upland and swamp rice field, PDO and CCI control by 20% and 15% of the total planting area respectively), suppress postharvest losses (adding CH and dryer as much as 2% and 7% concomitantly, and AFF revitalization by 2% from the number of AFF), extensification (rice field printing starting in 2018-204: 41,074 ha/year, in 2042-204: 60,000 ha/year, swamp optimization of 100,000 ha/year), reduce household rice consumption by 1.5% per year and emphasize on the zero rice field conversion should be initiated in 2018-2045.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The results of dynamic system models simulation to achieve rice self-sufficiency showed that scenarios of intensification, suppression of postharvest losses, extensification, household rice consumption, and suppression on rice field conversion in scenario 5 are the ideal scenarios with highest SSR value, despite its biggest agricultural cost. Given the current budget availability, scenario 6 becomes the most feasible operational scenario to obtain rice self-sufficiency. The main policy of this scenario is prevention of rice field conversion. Therefore the recommendations for the government include: (1) determination and protection of perpetual rice fields, purchases of rice with high prices from farmers and strengthening the Rice Field Conversion Control Team stipulated in Presidential Regulation No. 59 of 2019; (2) identification and mapping of potential areas for the agricultural land expansion, especially rice fields, and periodically replace converted rice fields by the local government and private sector, as well as providing rewards for local governments that successfully conduct rice field printing; (3) cross-sectoral cooperation to encourage diverse, healthy and nutritious food consumption to reduce rice consumption; and (4) involving all stakeholders in financing rice self-sufficiency with percentage of 40% from the government, 30% from the farmers, and 30% from private sectors.

Recommendations

Further study on rice self-sufficiency needs to be conducted at the provincial and district level. The study model should be refined by completing the financial component of policy implementation in terms of rice consumption reduction, land conversion suppression, and incorporating pre-harvest mechanization technology in the rice self-sufficiency system model.

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