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FULL LENGTH ARTICLE

The dynamics of rice production in Indonesia 1961–2009

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Abstract Rice is one of the important agricultural products in Indonesia. The production has been fully supported by infrastructure including research and development as well as government regulations in pricing. Its vulnerability to climate change requires adaptation strategies on irrigation, biotechnology and selection of alternative crops. The primary goal of this paper was to evaluate the historical perspective of the dynamics of rice production, technologies particularly in seed inventions, labour in farming and consumption of rice from 1961 to 2009 in conjunction with land capability. The study of historical rice production could be a benefit for future agricultural planning in Indonesia.

1. Introduction

Recently, rice (*Oryza sativa*) has become the staple food for almost all Indonesians, although according to Boomgard (2003) maize provided a source of carbohydrate for people in the Eastern regions of Indonesia in the 17th century. Other carbohydrate sources such as roots and tubers had been introduced by Europeans from about 16th to 19th century, including Irish potato (*Solanum tuberosum*), cassava (*Manihot utilisima*), sweet potato (*Ipomoea batatas*) and taro (*Colocasia esculenta*). Those kinds of crops have been less popular than rice for most of Indonesians even during the worst Indonesian economic turmoil 1997–1999 (Hartini et al., 2005). Long-term government policies on rice subsidy might contribute on the attractiveness to consume rice more than the others.

Infrastructure including research and development (R&D) and regulations has been supporting the dynamics of rice production in Indonesia. During the Dutch colonization, irrigation networks were developed to support paddy cultivation, mainly concentrated in Java Island. Van Valkenberg (1925) reported that irrigation systems in Java were mainly related to existing stream channel such as (Bengawan) Solo River in Central Java and Cimanuk River in West Java. After independence, Indonesian government attempted to maintain and subsequently expand new irrigation networks. Recently, the Food and Agriculture Organization (FAO) noticed about 4.5 million hectares of paddy fields are supported by irrigation networks.

Several discussions about Indonesian paddy fields are found in the literature. Two papers by van Valkenberg (1925, 1936) on Javanese agriculture probably were the earliest records, although did not specifically mention about rice fields. Van der Kroef (1963) gave a thorough debate on predicaments and outlook on the economy of rice. In an attempt to provide spatial distribution of rice fields on higher resolution, optical

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remote sensing data have been employed to some extent using supervised classification (Panuju et al., 2007a) or autonomous technique (Panuju et al., 2007b). Both techniques could be used for routine monitoring at fairly reliable accuracy. Another paper used a radar sensor to minimize atmospheric effects such as cloud, hence produced a better rice field map (Raimadoya et al., 2007).

Despite its importance, tremendous land conversion has been occurring. For regions which have been the most productive areas such as the Northern Coastal Region (NCR), specific reports on land use changes were presented including a paper by Firman (1997) for West Java NCR and a thesis by Damayanti (2003) on East Java NCR. The modelling of land use change in Java was also presented (Verburg et al., 1999).

Reports of Firman (1997) and Damayanti (2003) specifically mentioned the importance of the anthropogenic factor on agricultural land conversion. This includes urbanization and economical imbalance between rural and urban or, in a wider scale, Java and other islands. On the other hand, natural causes might drive the alteration. Rice production in Indonesia has been found to be vulnerable of climate change and adaptation strategies on irrigation, biotechnology and selection of alternative crops are necessary (Naylor et al., 2007). Exclusively in Sidoarjo region (East Java NCR), an additional thread of expanding mud flow upon a failure of mining activity might affect the overall rice production in the region.

Nonetheless, contemporary discussion about the historically active rice production is lacking, especially on a broader scale. The primary goal of this study was to evaluate the historical perspective of the dynamics of rice production in Indonesia. This would lead to a better understanding of complexities in the production as required of improved policy analysis. Both physical and socio-economic aspects are discussed in following subsections.

2. Data and analysis

2.1. Spatial data

In this research, physical characteristics of rice production were explored through land capability map. The map was derived from a set of Indonesian land system map called RePPProT (Regional Physical Planning Program for Transmigration) dated 1985 accessible through BAKOSURTANAL (Indonesian National Coordinating Agency for Surveys and Mapping). The RePPPRoT map is a reconnaissance-scale (1:250,000) dataset derived from a combined field survey, aerial photographs and satellite imageries, primarily employed to support transmigration policies. Physical properties of land used to obtain land capability were soil (at the level of great soil group), terrain (slope) and average of annual rainfall.

2.2. Statistical data analysis

For time-series analysis, primary data were taken from common sources such as Food and Agriculture Organization (FAO), International Rice Research Institute (IRRI), Rice Research Institute of Indonesian Ministry of Agriculture (*Balai Penelitian Padi Departemen Pertanian*) and Indonesian Statistical Agency (*Badan Pusat Statistik*). The FAO databases which contain demographic data, production, yield, area, price, import, and export of paddy and also spatial distribution of irrigation networks were employed. All FAO data were accessed from FAO website (www.fao.org) on March 2012. Time frame of FAO was fairly different; some data were captured from 1961 to 2009, and the others were between 1980 and 2011. Moreover, seed varieties were obtained from the cooperative website of Indonesian research institutes and International Rice Research Institutes (IRRI) (www.knowledgebank.irri.org).

Computation of differences, ratios, and growth was calculated on some variables based on FAO estimation. In this analysis, the difference in production and consumption was utilized as a measure of surplus-production, while ratio between production and consumption was employed as a measure of sufficiency. The growth was employed particularly to explore production increase due to the release of paddy varieties introduced at the corresponding time. The estimation of differences, ratios and growth was based on the following equations:

$$D_{xy} = X - Y \tag{1}$$

$$R_{x,y} = \frac{X}{Y} \tag{2}$$

$$\Delta X = \frac{X_{(t1)} - X_{(t0)}}{X_{(t0)}} * 100\% \tag{3}$$

where,

D_{xy} = difference of production (X) and consumption (Y)
$R_{x,y}$ = ratio between production and consumption
ΔX = growth of variable x on corresponding time lag (between t0 and t1)

Statistical data analysis was employed to understand the relationship among variables related to paddy production and its productivity, particularly to understand the role of irrigation and seed inventions to production. Using the Pearson correlation, relationships among of variables including land use, demographic, production, yield, irrigated area and number of inventions on rice varieties were investigated. It was assumed that those relationships were linear. Pearson correlation coefficient was computed using the following equation:

$$r_{xy} = \frac{\sum_{i=1}^{n}[x_i - \bar{x}][y_i - \bar{y}]}{\sqrt{\left\{\sum_{i=1}^{n}[x_i - \bar{x}]^2\right\}\left\{\sum_{i=1}^{n}[y_i - \bar{y}]^2\right\}}} \tag{4}$$

where

r_{xy} = correlation coefficient between variable x and y
x_i or y_i = value of variable x or y in sample i, where i = 1, 2, 3,…, n
$\bar{x}$ or $\bar{y}$ = average of variable x or y

To analyse the role of seed inventions on production, yield, and harvested area in Indonesia, three-year production was averaged and then correlated with the number of paddy varieties released in the period. Due to insufficient data, this research only concentrated on lowland (*sawah*) and rainfed (*gogo*) varieties, although tidal (*pasang surut*) varieties and hybrid varieties have also been released.

3. Results and discussion

3.1. Physical properties of land

In this research, land capability approach was employed to provide spatial and attribute information to support efficient and sustainable agricultural systems using some fundamental data such as soil types, slope and climate. The RePPProT dataset is the finest-scale maps available throughout Indonesia. Semi detailed datasets have been available. Nonetheless, the data are fairly limited and only available for specific locations at various scales (1:25,000 to 1:50,000). Fig. 1 shows the spatial distribution of capable regions to support paddy cultivation in Indonesia.

Distribution and acreage of capable area for paddy cultivation is presented in Table 1. Since input data are considerably coarse, five primary locations of rice suitability for each region are presented at *kabupaten* (regency) level. In general, the acreage and percentage of capable area were in line with the size of the respective island. The biggest island, Borneo has the biggest capable area. Then, it is followed by Papua, Sumatra, and Java-Bali. The difference is only found in Celebes that is supposed to follow Sumatra according to the size of the area. However the acreage is not the only factor affecting harvested area, production or yield. Additional factors of importance include cultivation preferences of local farmers, methods of cultivations, and inputs for rice farming. It is arguable that input and management including seed varieties, fertilizer, water from irrigation and other inputs and methods to manage pests and diseases also play a significant role. All those factors bring together to produce certain productivity. Apparently, micro climate might also contribute to productivity.

Majority of locations in Java-Bali, Sumatra and Celebes have been exploited for rice production, mostly strengthened by irrigation networks. Other regions are left unexploited for different reasons. Particular problem in Nusatenggara has been climate which is semi arid. Although the eastern part of Nusatenggara was found capable, only the western part (Lombok Island and west Sumbawa) has sufficient downpours. Many suitable areas in Borneo are located on the coastal zone. These areas are highly affected by tides, hence rice production on the sites are restricted due to limited seed invention and land allocation (particularly for conservation). A major attempt on rice field expansion in Borneo was the Million Hectare Peatland Project (*Proyek Lahan Gambut Sejuta Hektar*) on mid 1990s which was environmentally criticized. Both Mollucas and Papua have been unexploited probably because of low population and most of the land is covered by thick tropical rain forest. In addition, Papuan farmers prefer to cultivate potatoes or sweet potatoes. Development of paddy field on both regions may be linked with transmigration programme, most of which are Javanese.

3.2. Irrigation

Infrastructure development has been taking an important role to improve paddy yield in Indonesia. One of the most important infrastructures related to paddy cultivation is irrigation. Indonesian government has been continuing the development of irrigation networks which were developed before World War II by the Dutch (van der Kroef, 1963) during the colonization era. The network development costs about $70 millions. Table 2 shows the distribution of irrigated land in some major regions in Indonesia based on FAO data.

It is shown that Java was the highest producer at 55% and then followed by Sumatera at 22% and Celebes at about 10%. Specifically, West Java was the highest contributor of rice and had the largest area as well, similar to the report of van Valkenburg (1936) mentioning relative significance of West Java on *sawah* area. Nevertheless, the highest yield was found in Bali (5.59 tonnes per hectare) and followed by East Java (5.34 tonnes per hectare) and Central Java (5.23 tonnes per hectare). West Java even produced the smallest yield (5.20 tonnes per hectare) compared with other Java and Bali areas. It is interesting to see that the area having the highest production does not reflect the highest yield.

Apparently, irrigation networks had been developed mostly in Java. Although Java is only about 6% of Indonesia's land

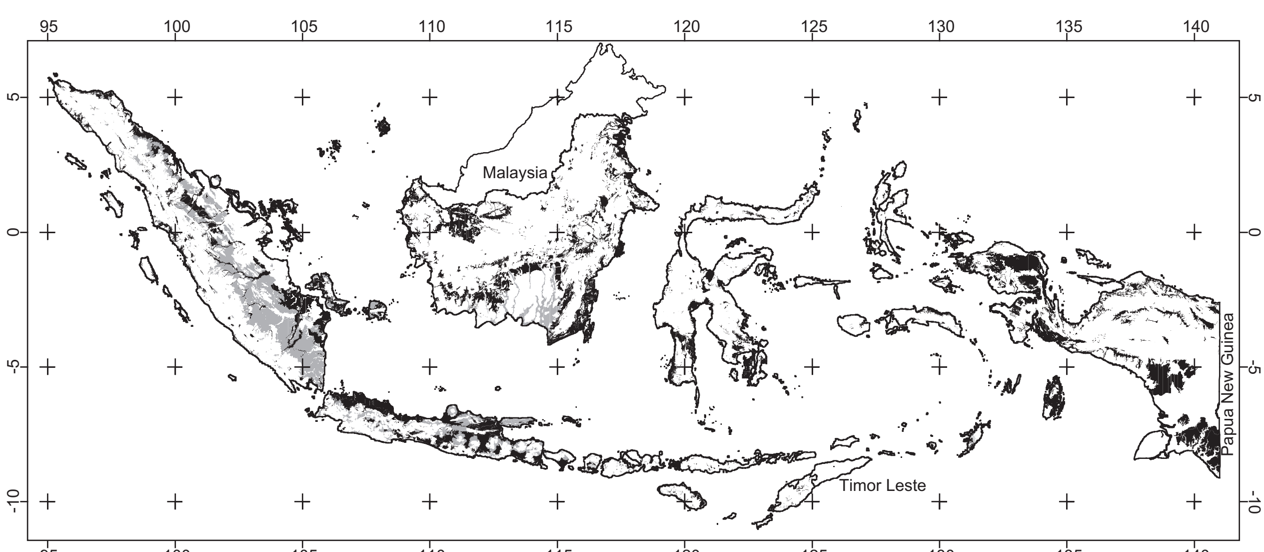

Figure 1 Capability map for paddy cultivation. Black and grey respectively denotes high and marginal resources.

Table 1 Distribution of suitable area for paddy cultivation.

Region	Suitable (000 ha)	Percentage	Primary locations
Sumatra	7852	21.29	Musi Banyuasin, Ogan Komering Ilir, Bangka, Kampar, Rokan Hulu
Java and Bali	4450	12.07	Indramayu, Bojonegoro, Lamongan, Karawang, Subang
Nusatenggara	579	1.57	Sumba Timur, Sumba Barat, Lombok Tengah, Sumbawa, Manggarai
Borneo	10,290	27.90	Kotawaringin Timur, Kotabaru, Sintang, Kutai Timur, Sanggau
Celebes	2958	8.02	Kendari, Poso, Muna, Luwu Utara, Wajo
Mollucas	1066	2.89	Maluku Tenggara, Maluku Tengah, Maluku Utara, Halmahera Tengah, Maluku Tenggara Barat
Papua	9683	26.26	Merauke, Manokwari, Jayapura, Sorong, Fak-Fak
Total	36,878	100.00	

Table 2 Distribution of irrigated area (ha) and its percentage (%) in major islands in Indonesia.

Island	Production (P) (tonnes)	Harvested area (H) (ha)	Yield (Y) (tonnes/ha)	Irrigated area (I) (ha)	% P	% I	P/I
Sumatera	121,78,529	25,23,393	4.83	802,000	22.39	17.99	15.185
West Java*	111,76,366	21,47,997	5.20	11,66,000	20.54	26.15	9.585
Central Java	94,37,454	18,04,689	5.23	948,000	17.35	21.26	9.955
East Java	93,46,947	17,50,903	5.34	793,000	17.18	17.78	11.787
Java	299,60,767	57,03,589	5.25	29,07,000	55.07	65.19	10.306
Bali	840,891	150,557	5.59	87,000	1.55	1.95	9.665
Nusa Tenggara	20,51,292	514,235	3.99	208,000	3.77	4.66	9.862
Borneo	32,87,062	717,971	4.58	59,000	6.04	1.32	55.713
Celebes	53,92,987	11,93,628	4.52	376,000	9.91	8.43	14.343
Moluccas	51,903	31,602	1.64	15,000	0.10	0.34	3.460
Papua	92,049	27,309	3.37	5000	0.17	0.11	18.410

Data production, harvested area and yield from www.bps.go.id and irrigation from www.fao.org.
* Including Jakarta province area.

Table 3 Coefficient correlation among production, harvested area, yield and irrigated area.

Variables	Irrigated area
Production	0.99
Harvested area (ha)	0.98
Yield/ha	0.46

area (MacAndrews, 1978), 65% of irrigation development had been located in that island. Support of the irrigation mostly was expected to improve rice production and productivity by ensuring water availability during cultivation period. The role of irrigation is studied using correlation analysis and presented in Table 3. Irrigated areas were obtained from FAO data, while production, harvested areas and yield are from Indonesian Ministry of Agriculture databases ranging from 1970 to 2009. The table indicates that irrigated area has a strong relationship with production and harvested area, but less correlated with yield. It implies that irrigation is not related to the improvement of productivity, however it significantly ensures production.

It has been a government's policy to maintain irrigated networks. Fig. 2 shows a time series data (1961–2009) on the irrigated areas and percentages of irrigation on all paddy areas (including upland) or *sawah* (a) and time series of percentage of irrigated land and yields (b). The figure indicates considerable increase of harvested land during 1961–2009 periods. In contrast, percentage of irrigated harvested area dropped significantly. The graph informs some possibilities related to the irrigated area including (a) an indication of partial abandonment or close down of the irrigation networks that previously developed as indicated by the report of Ravesteijn (2002), or (b) the expansion of paddy field was not followed by increasing development of irrigation network in terms of quality or spatial extent, or (c) lack of water forced conversion of *sawah* into *gogo* or other upland crops (*tegalan*), mostly to compete industrial water use, or (d) massive land use change located in the irrigated area.

Specifically in Java, the last has been strongly indicated. Research on land use change carried out by Winoto et al. (1996) mentioned efforts of some landowners (farmers) to dry up their irrigated area before converting to other land uses. The government regulation (KEPPRES 33/1990) prohibits land owners to convert irrigated (*sawah*) land directly. Firman (1997) also strengthened that the conversion trend in lowland areas particularly in Northern Region of West Java was due to industrial development.

3.3. Seed, fertilizer and rice production

Another important factor to elevate paddy production in Indonesia is seed technology. Since 1905 Indonesia has already established seed research located at Buitenzorg (now Bogor) (De Vries, 1949). According to Stads et al. (2007) Indonesia has one of the largest agricultural research systems in Asia. Along with government research institutes, some private

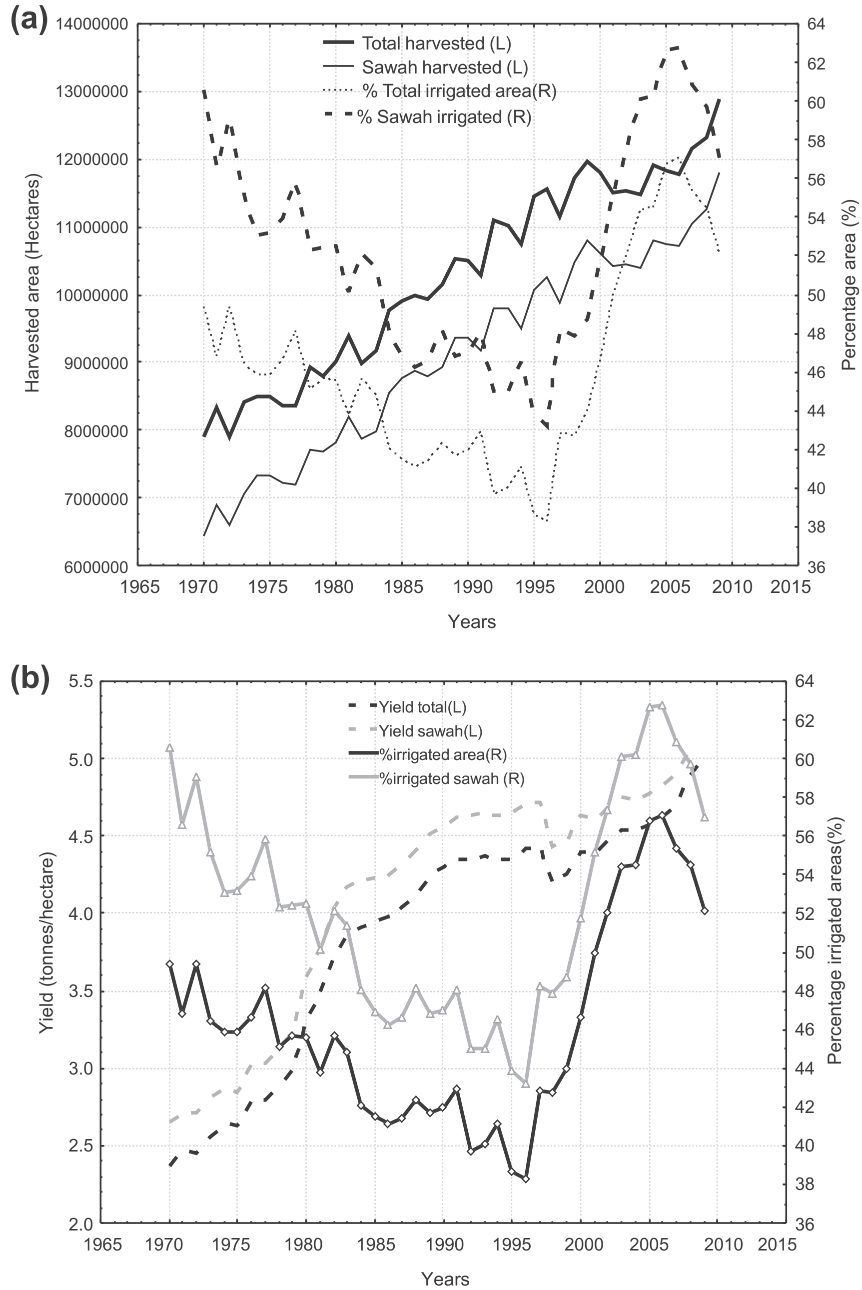

Figure 2 Irrigated lands and percentage of irrigated lands (a) and their yields (b) during 1961–2009 period.

companies have operated in seed development. Stads et al. (2007) also noted that private research institutes contributed almost 19% of R&D in agriculture including plantation and seed companies. Some have collaborated or independently invented new rice varieties, nonetheless according to IRRI (knowledgebank.irri.org) private companies mostly concentrated on developing hybrid varieties. Those private companies which have registered their inventions include PT BISI, PT KONDO, PT Bangun Pusaka, PT Bayer Crop Science, PT Karya Niaga Beras Mandiri, PT Triusaha Saritani, PT Dupont, PT Makmur Sejahtera Nusa Tenggara Barat, PT Sumber Alam Sutera, PT Primasid, and SL Agritech Corp. Most of the efforts have been contributed by the government especially the research institutes under the Ministry of Agriculture. We should note here that other government research agencies such as BATAN (National Agency for Nuclear Energy) have invented rice varieties as well. Detailed results on *sawah* and *gogo* (upland) varieties are presented in Table 4.

In addition to those two groups of rice varieties, Indonesian research institutes also have invented some for tidal (*pasang surut*) and hybrid varieties. Both have been rarely implemented and beyond the scope of the research. Tidal varieties are usually invented by the government institutes which have obligation to support any farming systems, including in least capable areas such as frequent waterlogged areas. Those areas are also subject to conservation therefore minor implementation of seed technology has been found. Hybrid varieties, on the other hand, are often introduced by the private companies

Table 4 Paddy varieties invented and released from 1943 to 2006 for *sawah* and *gogo*.

Year	Varieties for *sawah*	Varieties for *gogo*
1943–1960	Bengawan, Sigadis, Remaja, Jelita	Genjah Lampung, Seratus Malam
1961–1965	Dara, Sinta, Dewi Tara, Arimbi, Bathara	Kartuna
1966–1970	PB5, PB8, Siampat, C4–63, Dewi Ratih,	–
1971–1975	Pelita1, Pelita2, PB20, PB26, PB28, PB30	–
1976–1980	PB34, Gemar, Adil, Makmur, PB32, Serayu, Asahan, Brantas, Citarum, PB38, Semeru, Cisadane, Cimandiri, PB50	Gata, Gati, PB36
1981–1985	PB52, PB54, Cipunegara, Krueng Aceh, Batang Agam, Atomita1, Atomita2, Sadang, Bahbolon, Porong, Bogowonto, Kelara, Citanduy, PB56, IR46, Cikapundung, Batang Ombilin, Tuntang, Cisokan, Progo, Bahbutong, Batang Pane, Cimanuk, Cisanggarung, Tajum	Sentani, Tondano, Singkarak, Arias, Ranau, Maninjau
1986–1990	IR65, IR48, IR64, Dodokan, Jangkok, Ciliwung, Walanai, Lusi, Way Seputih, IR66, IR70, IR72, Batang Sumani, Atomita-3	Danau Bawah, Batur, Danau Atas, Poso, C22, Laut Tawar
1991–1995	Barumun, Atomita-4, Cenranae, Lanriang, IR-74, Bengawan Solo, IR68, Cibodas, Mamberamo	Danau Tempe, Situ Gintung, Gajah Mungkur, Kelimutu, Danau Rarem, Jati Luhur
1996–2000	Batang Anai, Cilosari, Digul, Cilamaya Muncul, Maros, Way Apo Buru, Widas, Ketonggo, Tukad Balian, Tukad Unda, Tukad Petanu, Cisantana, Ciherang, Kalimas, Bondoyudo, Celebes	Cirata, Limboto, Towuti
2001–2005	Singkil, Sintanur, Cimelati, Konawe, Batang Gadis, Ciujung, Conde, Angke, Wera, Woyla, Meraoke, Sunggal, Gilirang, Cigeulis, Setail, Luk Ulo, Cibogo, Batang Piaman, Batang Lembang, Ciapus, Fatmawati, Pepe, Logawa, Kahayan, Winongo, Rojolele, Diah Suci, Mekonggo, Pandanwangi, Mayang, Yuwono,	Danau Gaung, Batutegi, Silugonggo, Situ Patenggang, Situ Bagendit
2006	Sarinah, Aek Sibundong	No data

through their own research and development. Due to copyright protection, additional information is rarely obtainable for public purposes.

Apparently the most productive inventions occurred during 1981–1985 and 2001–2005 which were related to 5-yearly development framework (REPELITA). Between 1981 and 1985 the research institutes invented 25 strains of *sawah* varieties and six strains of *gogo* varieties. This was rather influential in Indonesian successfulness of self sufficiency in 1984. In the period of 2001–2005 the institutes invented 31 *sawah* varieties and five *gogo* varieties, primarily have characteristics to accommodate specific requirements such as pest resistance, micro climate adaptation, good taste, short ages and higher yield. The difference between *sawah* and *gogo* varieties is particularly in yield potential. *Sawah* varieties could produce between 5.5 and 8.0 tonnes per hectare, while *gogo* varieties are capable to obtain around 5 tonnes per hectare at maximum. According to Cassman (1999) yield potential is the yield obtained when cultivars are planted with the best management and have minimum stresses. Indonesian rice yield increased steadily; however the yield potential achieved was still less than 70%. The external factors influential in this problem are unavailability of irrigation network that could limit water balance, inappropriate pest management or insufficient fertilizer application. Detailed characteristics of each variety and its yield potential can be accessed from www. knowledgebank.irri.org.

Advanced technology in seed and fertilizer allows Indonesia to enter the Green Revolution which has been improving overall performance in agricultural systems. Although fertilizers have been monumental in Indonesian rice production, there has been limited data on the use of fertilizers throughout the nation, specifically in rice farming. FAO has been providing time series database of fertilizer application in Indonesia, however the database was in aggregate, hence we cannot determine a portion of the data belongs to rice farming. Time series consumption of phosphate-, potash-, N-fertilizers and urea as a specific form of N fertilizer which was popular in Indonesia during 1960–2009 is presented in Fig. 3. This figure shows that from 1995 N fertilizers appeared to be over-consumed. The increasing N fertilizers did not lift up yield, even slowed the rate down. Consumption of phosphate and potash was decreasing from 1992 to 2000 and slightly increasing after that.

The improvement of productivity is reflected by time series FAO data of average yield (tonnes per hectare) from 1961 to 2008. Fig. 4 shows the productivity superimposed with rice production in the same period. As shown, efforts to improve rice production and productivity have been significantly successful. Production significantly increased from about 10 million tonnes in 1961 to around 54 million tonnes in 2004. In addition, considerable increase was also noted in the same period from less than 2 tonnes per hectare in 1961 to about 4.5 tonnes per hectare in 2003. However, it can be seen that since 1990 the growth rate of production or yield tended to slow down. The highest growth rates occurred during 1970–1990. According to Pingali and Rosegrant (1993) the declining of rice production growth was affected by

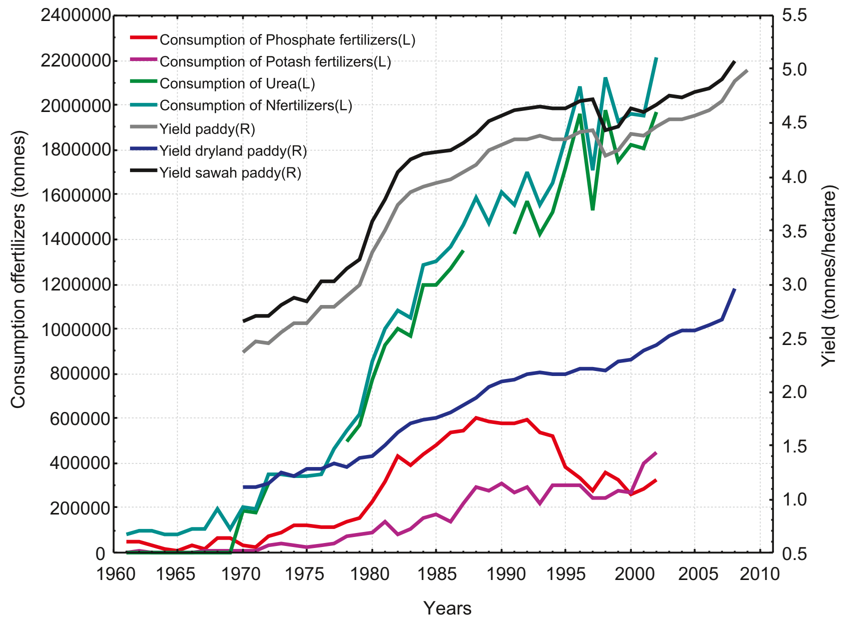

Figure 3 Consumption of fertilizers. Some data around 1990 were missing.

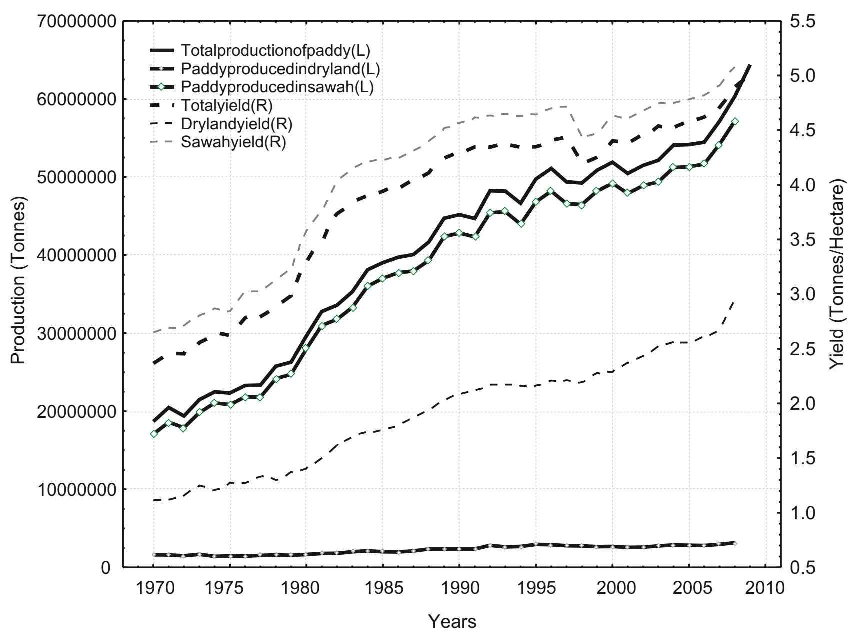

Figure 4 Production and yield per hectare of rice.

decreasing price worldwide and intensification. World price induced factors declined irrigation and research investments, while intensification increased input to sustain productivity. In fact, research expenditure had decreased from 7.4% before 1980 to 4.6% during 1980s, while irrigation investment had decreased significantly (72%) in Asia including Indonesia. Apparently the decreasing trends in research expenditure and irrigation investments tend to be continuing since then.

The role of seed inventions in Indonesia to improve paddy production and productivity is explored using coefficient correlation, presented in Table 5. The table shows the number of released varieties significantly related to production, yield and harvested area. Although it is not statistically significant, the trend of percentage growth in yield is positively correlated to the number of *sawah* varieties, but negatively correlated with the number of released *gogo* varieties. There is also substantial relationship between average of harvested area and the number of released varieties. These correlations have two possible reasons: (1) high responsiveness of farmers to introduction of new varieties, or (2) government or local people

Table 5 Correlation coefficient among number of released varieties (*sawah* and *gogo*), production and yield.

Variables	Released *sawah* varieties	Released *gogo* varieties	Combined
Average production	**0.63**	**0.56**	**0.69**
Average yield	**0.64**	**0.60**	**0.72**
Average harvested area	**0.61**	0.51	**0.66**
ΔProduction	−0.15	−0.24	−0.20
ΔYield	0.03	−0.16	−0.02
ΔHarvested area	−0.36	−0.23	−0.37

Note: bold typeface denotes significance at 5% level.

tried to open new areas for paddy cultivation. However, it seems that the efforts were only substantially correlated with *sawah* but not with *gogo*.

3.4. Population in agriculture

Due to small-scale farming system, especially in Java, agricultural mechanization has never been fully deployed. In most cases, personal or animal-assisted works are involved. Labour forces then take an important role in almost all farming activities. However, Suparmoko (2002) indicated that the number of agricultural population in Indonesia has been declining, causing a big threat to food security. Using FAO time series data, agricultural-related populations and economically-active people in agriculture are discussed in this section.

Fig. 5 shows that Indonesia experienced a very high population growth at a relatively constant rate. The percentage of agricultural population declined by almost 30% between 1980 and 2009. The figure indicates that agricultural sector has become unattractive for Indonesians; more inhabitants now prefer working in non-agricultural sectors such as industries or services. While economically-active population has been increased in time, the percentage of those populations in agriculture tended to decrease below 15%. This graph informs that Indonesian farming is facing a serious problem which needs to be resolved in near future.

To understand the role of economically active population in agriculture on paddy production, time series trend of ratio of production and area per capita from 1980 to 2009 is presented in Fig. 6. Production per capita is a ratio between production and economically active population in agriculture, while area per capita is a ratio between harvested area and economically active population in agriculture. Even though economically active population in agriculture is not always related to paddy cultivation, this measure could estimate production per capita or area per capita better than total population in agriculture or even total population.

Fig. 6 shows contrasting trends between production per capita and area per capita. Production per capita tended to increase from about 0.4 tonnes per person per year in 1980 to more than 1.0 tonnes per person per year in 2009. It seems that the data can be fitted using quadratic model estimation resulting in $R^2 = 0.66$ and standard error equals to 0.05. The selected model shows the peak was achieved in the end of observations. Following Verburg et al. (1999), production per capita derived from economically active population can be utilized as a measure of labour productivity which shows expanding agricultural surplus by the time.

Moreover, trend of area per capita can be fitted in the quadratic form, with R^2 equals to 0.66 and standard error equals to 0.007. Apparently, the maximum of area per capita was reached in around 1980 at level 0.275 hectares per person per year. In the following years, the measures declined to less than 0.23 per hectares per person per year until 2005 and it lifted up to some extent to 0.265 in 2009. Slight decrease in number was due to a balanced condition between extending farming area and growth of farmers. This land holding estimation was significantly dropped from previous period, similar to the report

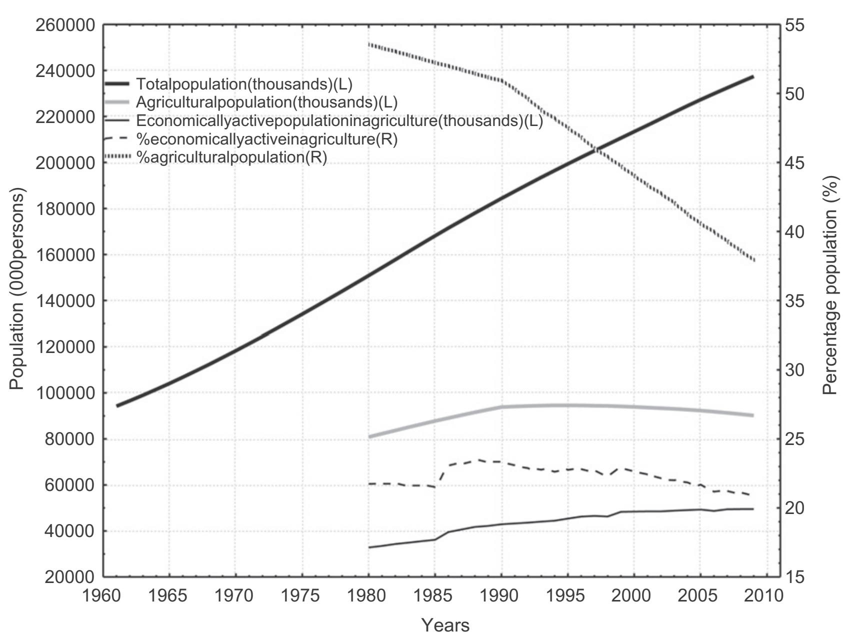

Figure 5 Dynamic of population in agriculture.

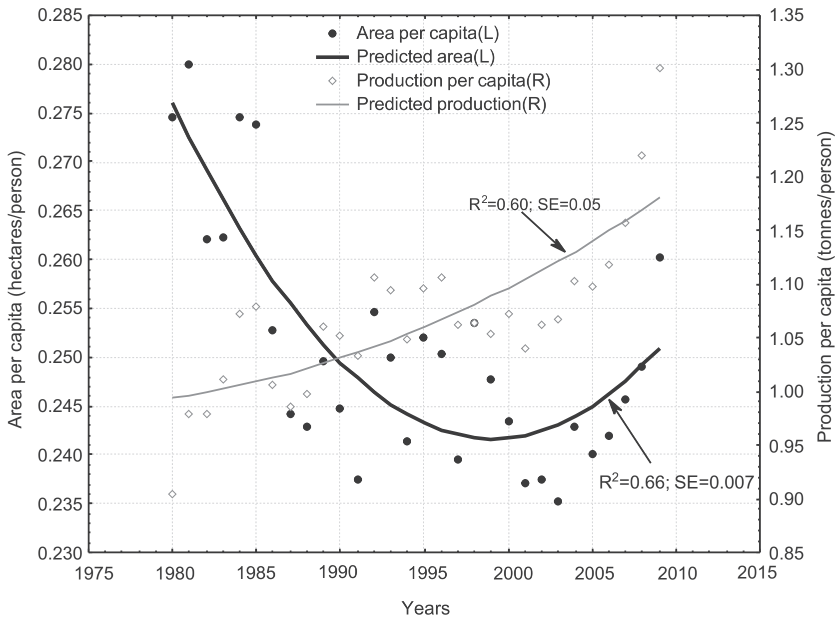

Figure 6 Production and area per capita.

of van der Kroef (1963). It was estimated that just after the World War I, irrigated land in Java was about 0.47 ha per capita or 0.6 ha per capita for non-irrigated land.

3.5. Rice consumption and distribution

If production of rice is expected to fulfil domestic demands or consumption, then the difference in between production and consumption could be regarded as surplus or shortage of production. Using FAO data, Fig. 7 shows time series rice production and consumption between 1961 and 2009. The consumption was calculated from rice for food, seed, feeding livestock, and waste. Apparently, data for processing were not significant or even not available, therefore it was not counted on consumption.

The figure indicates that in the period of observations, initially (1961–1980) production was always less than consumption, but in the next period surplus production was reached until 2009. It also illustrates that a rising trend of surplus was always less than 10 million tonnes per year. Before 1980, ratio of production and consumption fluctuated and less than 1 in average, and afterwards (1980–1990) the fluctuated pattern was still in existence. Since 1990 apparently the ratio showing sufficiency was achieved continually until 2009.

Apparently the main problem is not as simple as production and consumption itself. Production centres are fairly localized, while consumers are distributed in almost all areas. Distribution has been becoming another problem in Indonesian rice economy considering geographical properties of Indonesian archipelago. To tackle problems of distribution and to stabilize price and supply of rice in all areas, the government established an agency, now called BULOG (*Badan Urusan Logistik*, Agency for Logistical Affairs). This is particularly important to ensure supplies during unsuccessful harvesting (*paceklik*) due to natural disasters including pests and diseases or improper management.

Regulating rice distribution is not a new approach in Indonesia. Earliest record indicated that it was begun on 1933 under Dutch Administration, mainly designed to overcome fluctuating price. However, official institution was not formalized until 1939 when the Dutch government established Voeding Middelen Fonds (VMF) which was then changed into Sangyobu Nanyo Kohatsu Kaisha under Japanese Administration. After Indonesian Independence, this agency changed its name as well as the role for several times. A detailed summary of the changes can be found in BULOG website (www.bulog.org).

Some regulations were released in the past to define the function of BULOG, such as settling floor price, ceiling price and buffer-stock starting on 1970. Subsequently, the role of BULOG had been expanded to control some other commodities like sugar, flour, meat, maize, soy, peanut, mungbean, and also eggs and chicken particularly during Ied Mubarak (an Islamic festival) and Christmas. However, since the Indonesian crisis in 1998, the role has been totally changed due to international pressure to liberalize Indonesian economy. Since then, BULOG returned to control rice only.

4. Conclusion

Problems in Indonesian rice economy are complex and require appropriate approaches to ensure food sufficiency. Rice production has been very dynamic and supported by capable land resources, although relatively localized particularly in Java-Bali region. In addition, farming management is also an important aspect for increasing production and productivity. Irrigation networks were built extensively; nonetheless the rice production was not significantly improved mainly due to strong influence of external factors such as inability to finance and global market. In contrast, application of modern varieties and fertilizers has been lifting production per capita as well as the yield significantly. Population growth pressure has become a big threat to assure rice self sufficiency. Apparently, farming was not an interesting economic activity for present generation reflected by the decreasing trend of economically active population in agriculture.

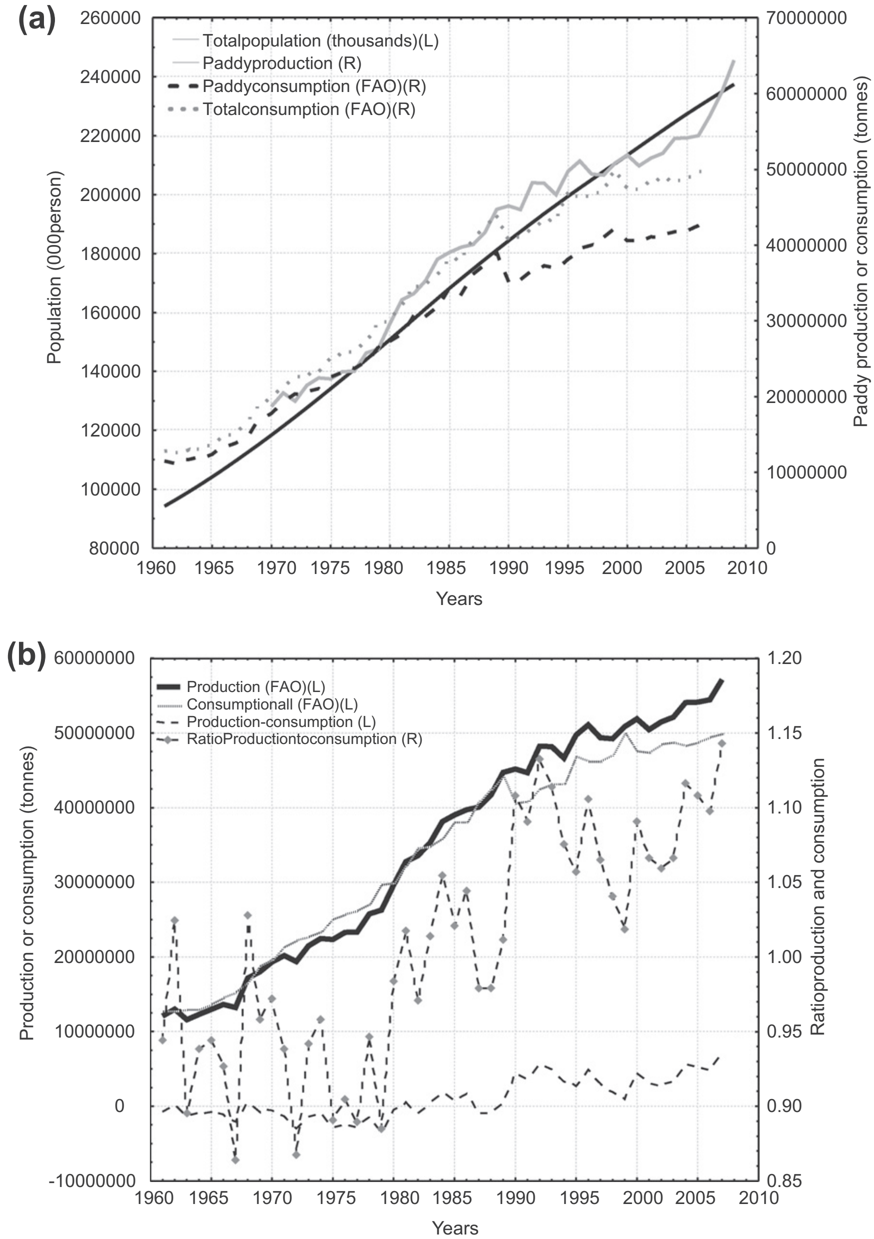

Figure 7 Total production and consumption of rice (a) and their ratio (b).

Due to archipelagic geo-location, distribution of goods has been a complicated problem in Indonesia. BULOG as a governmental entity needs to be strengthened to tackle difficult rice problems including ensuring distribution, buffer stock and stabilizing price. However, it seems that changing rules of BULOG might not be a single solution to deal with delivering and guaranteeing rice supply. Expanding producers' area particularly out of Java-Bali supported with irrigation network would be a good alternative coupling with the role of the agency.

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