Sustainable agriculture in Indonesia: Facts and challenges to keep growing in harmony with environment

M. Faiz Syuaib

(Department of Mechanical and Biosystem Engineering Faculty of Agricultural Engineering & Technology, Bogor Agricultural University (IPB))

Abstract: The nature of agricultural production system in Indonesia is very diverse from shifting cultivation to intensive crop farming, from rain-fed to intensive-irrigated paddy field, from vegetables mix farming to monoculture industrial plantations, from subsistence small-scale farming to large-scale commercial plantation. As the fourth most populous country in the world that is inhabited by 250 million people, agriculture plays a substantial role in Indonesian economy which generates close to half of total employment and accounts for about a fifth of GDP, as well as the very important contributor of export. Notwithstanding the great potential resources and market demand, the sustainability of agriculture in the country remains challenging. The challenge is how to continue the agricultural development and economic growth that is needed to improve the quality of life and the basic needs of the growing population while at the same time to protect the environment by reducing the pressure on the carrying capacity. Rapid pace of agricultural development in the last four decades –as well as the commercialization, industrialization and urbanization– has led to significant changes in agricultural production systems. In some regions, modernization of agricultural technologies has increased production to keep pace with the population growth, but other problems in supply chain and distribution still plague many communities and regions. Concerning the current conditions of agricultural practices in dealing with the needs to improve productivity and at the same time to conserve the environment and natural resources, we need to adjust our understanding and formulate action strategies for developing agricultural practices better and more sustainable future. This paper discussed the present status of agricultural condition and practices in Indonesia as well as some challenges and strategies to overcome.

Keywords: Indonesia, agriculture, sustainable, facts, challenges

Citation: Syuaib, M.F. 2016 Sustainable agriculture in Indonesia: Facts and challenges to keep growing in harmony with environment. Agricultural Engineering International: CIGR Journal, 18 (2):170-184.

1 Introduction

Indonesia is the world's largest archipelagic country which is stretched between two continents, Asia and Australia and between two oceans, Pacific and Indian. The Archipelago is extended over 5,500 km distance from east to west and 1,900 km from north to south, and consists of more than 17,000 islands, 81.000 km coastline, 1.9 million km^2 land territory and 3.2 million km^2 of sea territory. Indonesia has reservoirs with rich bio diversity in tropical agro and marine ecosystem, which contain various indigenous variety of flora and fauna, many of them are typical indigenous that never found in other places in the world.

Indonesia is considered as an agricultural country where agriculture has long been serving as the backbone of its economy. Not with standing the declining contribution of agricultural sector to the country's GDP, agriculture has never lost its role as the nation's leading employer. Nearly half of the Indonesian people are employed – directly or indirectly – in agricultural sector, either as small-holder grass-root farmers or labor farmers of industrial plantations. Predominant characteristics of Indonesian grass-root farming systems are family based, small farm holdings, small capital, subsistence crops and traditional (non-mechanized) management. However, rapid industrialization and urbanization, rather than

Received date: 2016-03-20 **Accepted date:** 2016-05-04

***Corresponding author: M. Faiz Syuaib.** Bogor Agricultural University (IPB) Faculty of Agricultural Engineering and Technology (FATETA) Kampus IPB Darmaga, Bogor 16680. INDONESIA. Email: mfsyuaib@yahoo.com; faizs@ipb.ac.id Telephone/Fax: +62-251-8623026

stagnant pace of agricultural growth, have been attracting the rural people to leave their farms and to find other jobs in non-agricultural or urban sectors.

Farming systems in Indonesia are diverse on commodities and ecosystems as well, which can be categorized basically into four types, such as: (1) intensive wetland (lowland-irrigated) paddy field, (2) upland (rainfed-dryland) secondary crops field, (3) estate plantations (industrial crops), and (4) agro-forestry. Lowland and upland crops are predominantly practiced by grass-root or individual farmers, while estate plantation and agro-forestry are mainly industrial/companies based management.

Agricultural development in Indonesia has been in good pace during the last four decades, however, the total production has not met the entire domestic demand of food and the majority of farmers still remain among the lower-income citizens. Furthermore, increasing inputs of chemicals and fertilizers in some agricultural production systems may pose a threat to the natural areas surrounding farmlands. Therefore, as we look for the future, the real challenge of agriculture is to continue increasing the production while at the same time to minimize the environmental damage and to conserve the resources, as well as reduce poverty, hunger and malnutrition.

2 Land utilization and agro-ecology features

Precisely located at the equatorial belt region, Indonesia has tropical monsoon-type climate which was characterized by slight changes of seasons and temperatures, low wind, high degree of humidity and periodically heavy rainfall. Generally, there are two (almost undistinguishable in some areas) seasons are recognized: The Rainy or Wet Season, which is affected by Northwest Monsoon and influenced by wet air masses from Asia continent and Pacific ocean, usually comesfrom October to March with the highest precipitation in January-February, and The Dry Season, which is affected by Southeast Monsoon and influenced by dry air masses from Australia continent, usually starts from April to September with the lowest precipitation in July-August. Almost no extreme change on temperature, where is ranging between 23 ℃ to 33 ℃ in low plains and 15 ℃ to 27 ℃ in highland areas. Average rainfall in the country is about 2400 mm annually, but wide diverse among the area ranges in 1000 mm to 4500 mm annually. Based on soil types, rainfall and length of growing period, five pragmatic agro-ecological zones might be recognized in the country; (1) dry land – dry climate, (2) dry land – wet climate, (3) highland, (4) lowland irrigation and (5) tidal swamp, as it is illustrated in Figure 1.

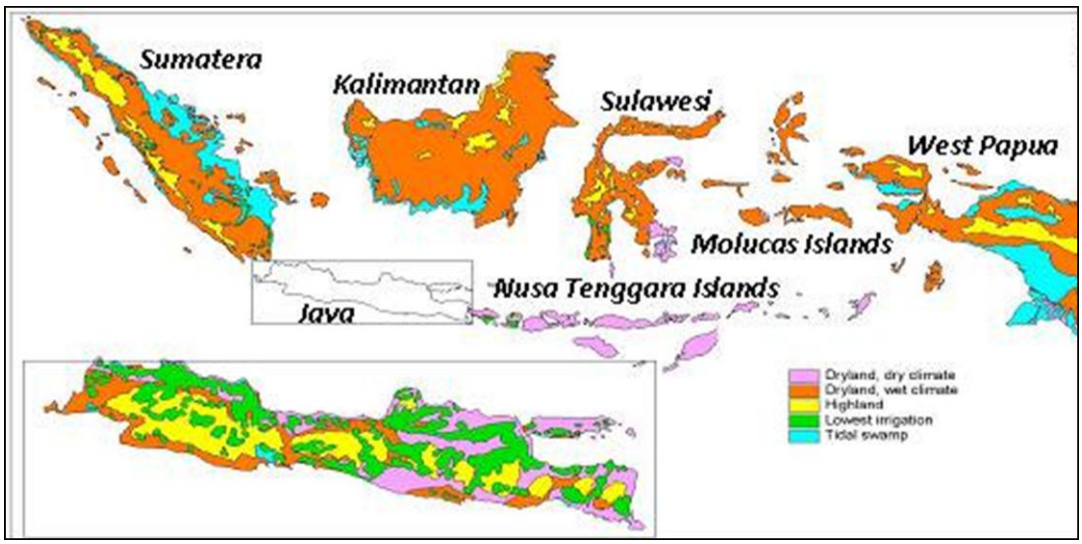


Figure 1 Agro-ecological zones of Indonesia (adapted from Central Agency of Soil and Agro-climate)

Indonesia is an archipelagic country consisting 5 main islands (Sumatera, Jawa, Kalimantan, Sulawesi and West Papua) and 2 smaller islands groups (Nusa Tenggara and Maluku). The total land area is about 191 million ha. More than 85% of the land surface of Indonesia is covered by vegetation tropical rain forest, woodland, mangrove, agricultural crops and grassland. Based on the land utilization features of Indonesia, nearly 30% (56.5 million ha) is recognized as agricultural land (wetland, upland, estate plantation, meadows), nearly 54% (102.3 million ha) is forest and wood land (permanent and industrial forests), and about 5% is housing and settlement area. Within 56.5 million ha of agricultural land, 22.4 million ha is estate plantation field, 17.2 million ha is dry-land (upland and garden) field, and 8 million ha is wetland (paddy) field in which 4.4 million ha (55%) of the paddy field is irrigated. A rough estimation of land utilization in Indonesia is shown in Table1., Figure 2 shows a comparative distribution of total land and agricultural land-use areas among the islands in the country.

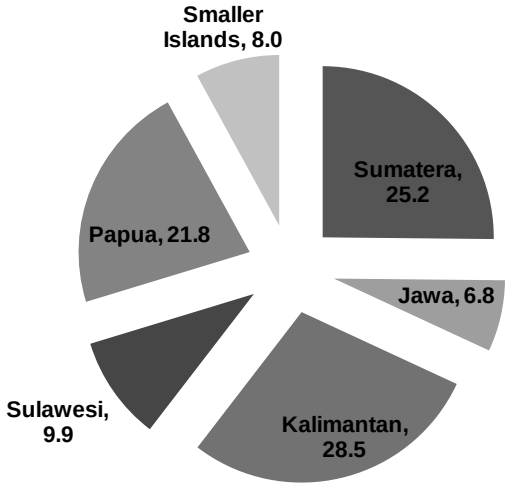
Among the islands, Java is the most important island for farming activities, since it is the most fertile and suitable land in the country for crops production. Paddy, other secondary food crops (grains and tubers), vegetables and fruits as well as sugarcane, tea and coffee are the main agricultural products in Java. Low coastal terrain at the northern part of Java Island is well known as the largest central of rice production area in the country. The middle part of the island is mountainous with very fertile highland that is mainly suitable for vegetable, tubers, seasonal crops and highland plantations such as tea and coffee. As it is graphically summarized in Figure 2, even though it only covers 6.8% of the country's total land area, Java contributes more than 29% of total arable land area which contributes more than half of national food crops harvested area. Moreover, Java contributes 40.7% of wetland (paddy) field, 17.8% upland (dry) field, 8.9% of industrial plantation of the country, and therefore, almost no fallow land remaining in Java.

Table 1Rough estimation of land utilization in Indonesia

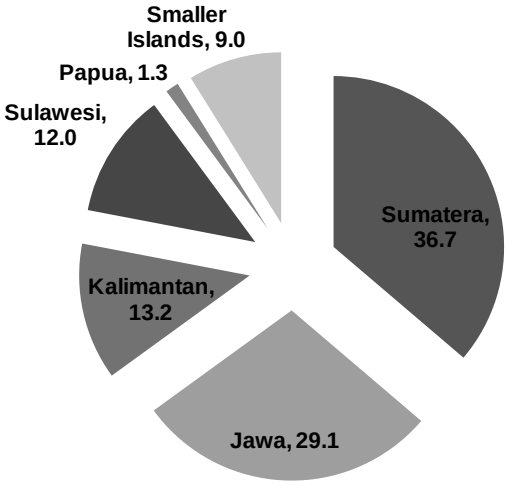
No	Type of Land Utilization	Area (x 1000 ha.)	% of total land area
1	Permanent Forest, & Wooded Land	93,062	48.7
2	Industrial forest/Agro-forestry	9,304	4.9
3	Estate plantation	22,380	11.7
4	Dry-land (upland & garden)	17,210	9.0
5	Temporary fallow land	14,785	7.7
6	Wetland (paddy field)	8,003	4.2
7	Housing/building/settlement/other	9,256	4.8
8	Swamp/marsh-land	4,755	2.5
9	Grassland/meadows	2,432	1.3
10	Inland water	9,936	5.2
	TOTAL LAND AREA	191,093	100.0

Data source: summarized from CBS and the Ministry of Agriculture (2014)

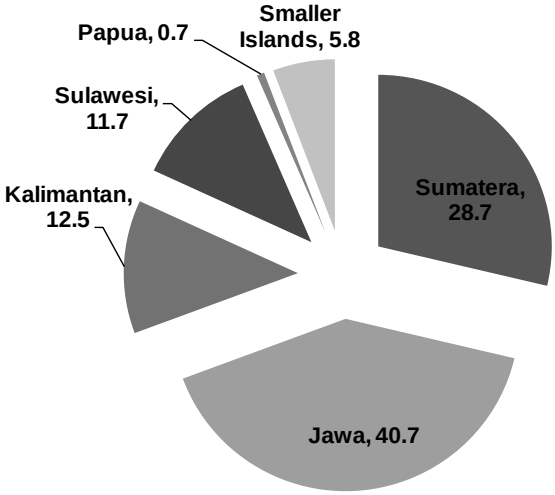
Compared to Java, other islands are typically less fertile. Most lowlands in Kalimantan, West Papua and the eastern part of Sumatra are swampy, difficult to drain and mostly covered by thick organic and peat soil. Mangrove or swamps forests are common along the shores of alluvial lowlands of those areas. Therefore, most of lowlands in those areas are virtually uninhabited and un-cultivated.



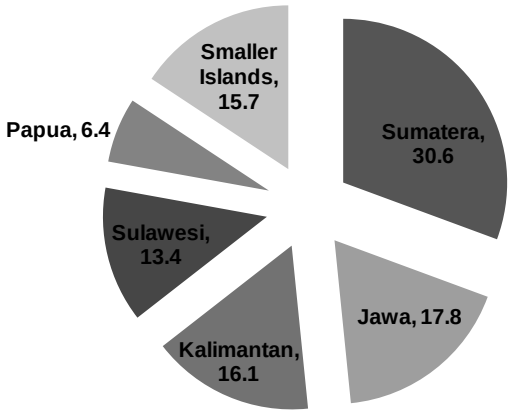
(a) total land area (%)



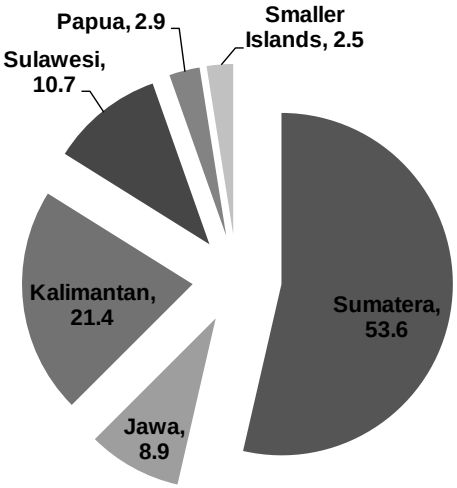
(b). arable land area (%)



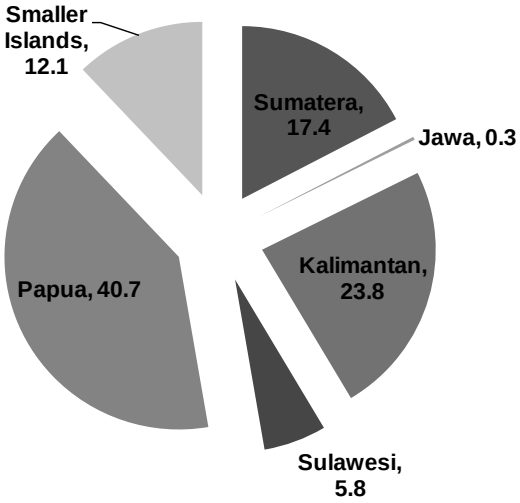
(c)wet-land paddy field area (%)



(d) upland (dry-land) field area (%)



(e) industrial plantation field area (%)



(f) fallow land area (%)

Figure2 Distribution of total land area and agricultural land-use among the islands in Indonesia (data source CBS, 2014, total of Indonesia = 100%)

On the other hand, upland soils such as those in most of Borneo and Papua are infertile, although they mostly

have a cover of thick tropical rain forest vegetation. However, Sumatera and Sulawesi contribute relatively significant arable land area compared to Kalimantan and Papua. Estate (commercial) plantations such as oil palm, rubber, coconut and coffee are main agricultural products in these areas, in Sumatra especially. Except some parts of Bali, Lombok and Sumbawa Islands, the areas of smaller islands which are called as the islands of Nusa Tenggara and Maluku are less humid but rather barren, dry, and the landscape is predominated by savanna and steppes. The natural conditions of these areas have affected the way of people's living, which cattle grazing and marine fisheries are predominant activity there.

2.1 Farmwork systems and operations

Farming system in Indonesia is diverse on commodities and ecosystems as well, which basically can be categorized into four types: (1) wetland (lowland) paddy field, (2) upland crops field (secondary food crops and horticultures), (3) estate plantations (industrial crops), and (4) agro-forestry. Lowland and upland cropping systems are predominant fields of common (grass-root) farm households, while estate plantation and agro-forestry are mostly managed by related private or state owned industrial companies. Some illustrations of the typical Indonesian farming and farm works systems are shown in Figures 3-8.

As most Asian countries, rice is the main staple food, so it is the most important and strategic commodity in Indonesia. Rice is staple food for more than 80% of the people and also major source of income for majority of the grass-root farmers; therefore paddy is the most important food crop grown in Indonesia. With diversification programs, however, other commodities are included in the farming systems and supplement to the income from rice.

Figure3 Typical rice (paddy) fields operations of grass-root farms in most area of Indonesia

Figure4 Specific rice (paddy) field operations in swamp/marshland field in Kalimantan

Paddy is grown on flat lowland up to terraced middle-range altitude (Figure 3-4). Java Island is the main area for growing rice which comprises 41% of paddy-field areas and contributes near to 60% of total harvested areas in the country. Other major areas of paddy fields are Bali, Lombok, west and southern part of Sumatra, and South Sulawesi. Blessed by the advantageous of tropical climate condition, a common feature of Indonesian farming activities is the fact that crops can be grown any time within a year. By using short growth period varieties, it is theoretically possible to make three crops a year in Indonesia. However, average cropping indexes of the country so far are approximately 1.6 and 1.2for irrigated and non-irrigated fields, respectively. As for upland/dryland fields, lowland areas are commonly cultivated by legumes or tubers, whereas highland areas are commonly cultivated by horticultures (Figure 5).

Human and animal remain predominant power sources of farm work in Indonesian. Mechanization is a 'luxurious' matter for most Indonesian farmers, especially for the grass-root farmers. However, in some 'well-developed' area (i.e. parts of Java, Sumatera and Sulawesi) farm mechanization has been applied; but it still has a narrow meaning and limited on such as utilization of hand tractor for land preparation, or utilization of thresher and rice milling unit (RMU) for post-harvest handling. Utilization of 4-wheel tractor, power sprayer, cultivator, and other machinery are merely found in bigger commercial estate plantations, such as oil palm, sugarcane or some industrial crops plantations. Table 2 shows the official data of amounts of major agricultural machinery used in Indonesian paddy fields and their working capacities (estimated calculation). The facts clearly reveal that approximately 50% of farm mechanization is applied for land preparation and postharvest operations, but less than 10% for other farm work operation activities in Indonesia. However, the use of farm machinery in food crop fields has been intensively increasing in the last few years by government support scheme due to boost up the nation rice production program presently.

Figure 5 Typical upland fields operations of grass-root farms in most area of Indonesia

Figure 6 Oil palm fields operations of industrialized commercial plantation

Figure 7 Sugarcane fields operations of industrialized commercial plantation

Figure 8 Pineapple and tea fields operations of industrialized commercial plantation

3 Fertilization situation

Since the so called “Green Revolution” program launched in late 60’s, application of chemical fertilizers was dramatically increased due to governmental encouragement to succeed growing agricultural productivity and the food self-sufficiency goal. For decades farmers have been using straight fertilizers (N, P, K) in accordance with recommended composition. Fertilizers consumption in agricultural sector reached 5 times level of 1975 in 1990 and increased slightly afterwards. Since the economic crisis, in 1998 the government reduced the subsidy of fertilizers and therefore the cost of agriculture input has increased; thus the farmers reduced the use of chemical fertilizers and started to improve the application methods and organic fertilizer became more favorable at present. While the economic crisis in industrial sector has not fully

recovered yet, agricultural estates have been intensified due to lift up the national income; fertilizers consumption for estate plantation therefore has been increasing since 2002. Figure 9 shows the trend of total domestic consumption of agricultural fertilizers (as the total consumption for crops farming and estate plantation)*(Komatsuzakiand Syuaib, 2011)*. And Figure 10 shows the domestic retail prices of four common fertilizers consumed in Indonesia (subsidized by government for grass-root farmer's retail price). The figures show that the trend of retail prices of fertilizers doubled since the 1998's economic crisis; and when the prices of fuel and most of industrial input materials were increasing, the consumption decreased at the time but then increased again after year 2002. The increasing consumption of chemical fertilizers after year 2002 is mainly caused by increasing planted areas of estate plantation. Meanwhile the consumption for crops farming conducting by common farmers actually decreased due to decreasing purchasing ability of the farmers because of very high prices of the fertilizers at the time. However, compared to the other regions in the world, the average fertilizer used (in term of nutrient per ha) in Indonesia is relatively less (Figure 11).

Table 2Agricultural machinery in use for rice cropping in Indonesia

Machine/ Equipment	Total unit	Unit capacity	Potentially working time (hours/crop)	Total servicing area (million ha/ crop)	Ratio of service to total field area,%
Hand Tractor (2W)	189,760	0.03-0.05 ha/hr	500	2.8 – 4.7	35 - 55
4W Tractor	2,992	0.06-0.12 ha/hr	500	0.09 – 0.18	< 2
Rice Transplanter	85	0.1 – 0.2 ha/hr	200	0.002 – 0.003	< 0.1
Hand Sprayer	1,546,765	0.10 - 0.12 ha/hr	100	– 17	>100
Power Sprayer	35,890	0.20 - 0.25 ha/hr	100	0.7 – 0.9	<10
Paddy Mower	3,416	0.03 – 0.05 ha/hr	200	0.02 – 0.03	<0.5
Power Reaper	644	0.03 – 0.05 ha/hr	200	0.004 -0.006	< 0.1
Combine Harvester	403	0.05 – 0.1 ha/hr	200	0.004 – 0.008	< 0.1
Pedal Thresher	135,456	0.07 - 0.1 ton/hr	200	0.9 – 1.2	< 2
Power Thresher	48,064	0.6 - 0.8 ton/hr	200	1 – 1.3	< 2
Rice Dryer	3,975	0.2 – 0.3 ton/hr	500	0.4 – 0.6	<5
RMU (Small)	24,987	0.3 – 0.5 ton/hr	500	0.6 – 1.0	<15
RMU (Medium)	8,177	1.0 – 2.0 ton/hr	500	0.6 – 1.2	< 15
RMU (Large)	10,263	2.0 – 5.0 ton/hr	500	1.6 – 4.0	20 - 50

Data are summarized from the Agric. Statistic (2013), and calculated based on Author's estimation (Syuaib, 2006)

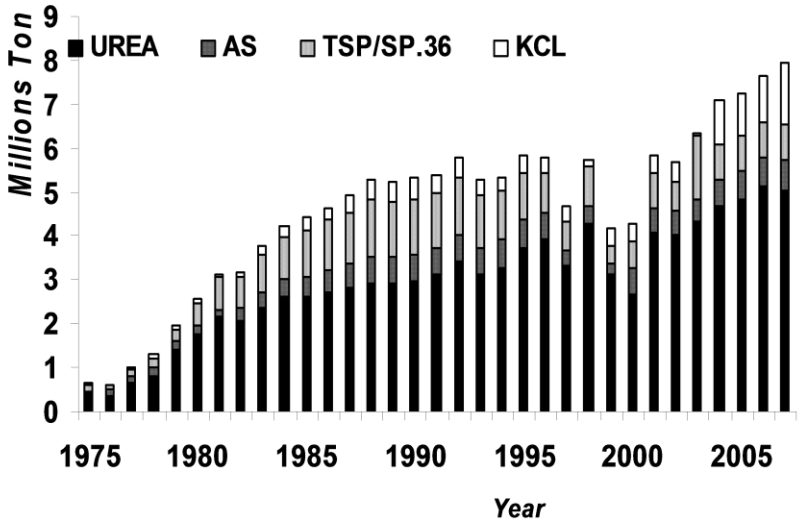


Figure 9 Domestic consumption of fertilizers (Komatsuzaki and Syuaib, 2011)

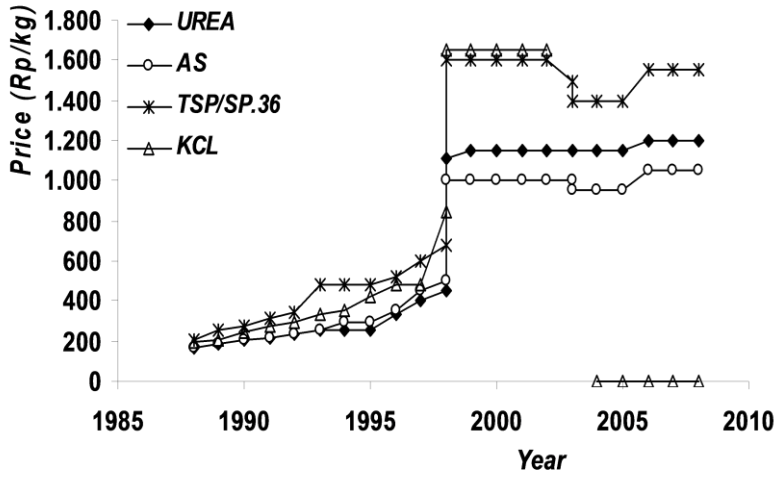
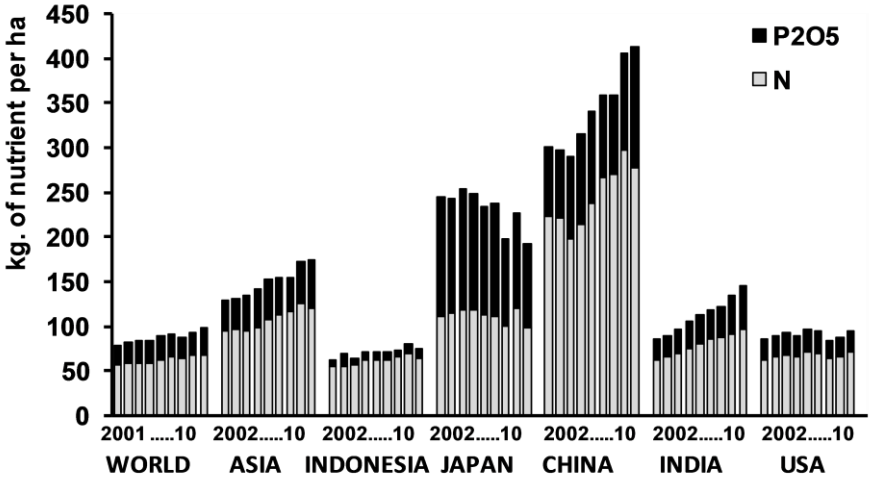


Figure 10Domestic retail prices of fertilizers (Komatsuzaki and Syuaib, 2011)



Data source: FAOSTAT (2015)

Figure11 Average fertilizer used in Indonesia compared to other countries or regions

4 Population and demographic related issues

Indonesia is the fourth most populous nation in the world following after China, India, and United States. The population is about 250 million presently (BPS, 2015) and it is projected to grow about 1.45% per annum. However, higher population growth sometimes undermines the efforts to promote sustainable development. Fortunately, declining trend of population growth recently allows the country to increase its ability to invest in human development, combat poverty and environmental protect and build the base for future sustainable development. On the other hand, rapid urbanization and a growing number of mega-cities have been creating new demographic and urban environmental problems.

Indonesia experiences a rapid urbanization due to rapid growth of industrial sector instead of agricultural sector. Indonesian urban population was only 12% in 1950's; it increased slowly to 16% in 1960's and became 20% in 1980. But thereafter, it was growing rapidly and now the urban population is about half of the total population (**Figure**12). Generally, rural population is strongly correlated to agricultural sector, and consequently rural population is strongly correlated to farmer population. Meanwhile, in term of employment, trend of the agricultural-engaged employment is decreasing within increasing in the ratios of women employment accordingly (see **Figure**13).In 1960's, agricultural-engage employment contributed about 70% of the total employment of Indonesia. Thereafter, it was

steeply decreasing to around 60% in 1970's, around 50% in 1980's and 1990's, and then it was rapidly decreasing and became 35% presently, along with rapid growth of urban sectors. Another concern related to the agricultural-engage employment is the gender ratio. In 1960's, 75% of the agricultural-engage employment were males; it was decreasing to 65% in 1980's and then continually decreasing to about 55% now.

Instead of the total number, uneven distribution of population between Java (also Bali) and other islands is perceived as major and challenging problem in country. Compared to other islands and areas, Java is very dense. Java Island – which accounts only 6.8% of the country's total land area – is inhabited by more than 57% of national population. Whereas in contrary, Kalimantan (28% of country's area) is inhabited only by about 6% and Papua (22% of country's area) is inhabited only by 1.5% of population. Therefore, the population density on Java is very high (1130 people/km^2); and it is almost nine-times compared to the national average (130 people/km^2), ten-times of Sumatera Island (115 people/km^2), eleven-times of Sulawesi Island (100 people/km^2), forty-times of Kalimantan (about 28 people/km^2), and 126-times of Papua (9 people/km^2). The figure of the distribution of farm household is comparatively similar (**Figure** 14).

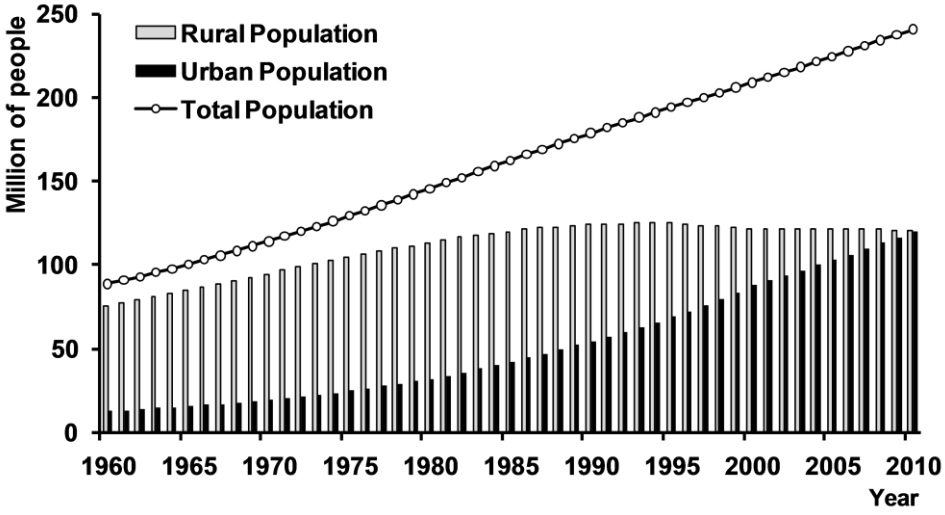


Figure 12 Trend of rural and urban population in Indonesia

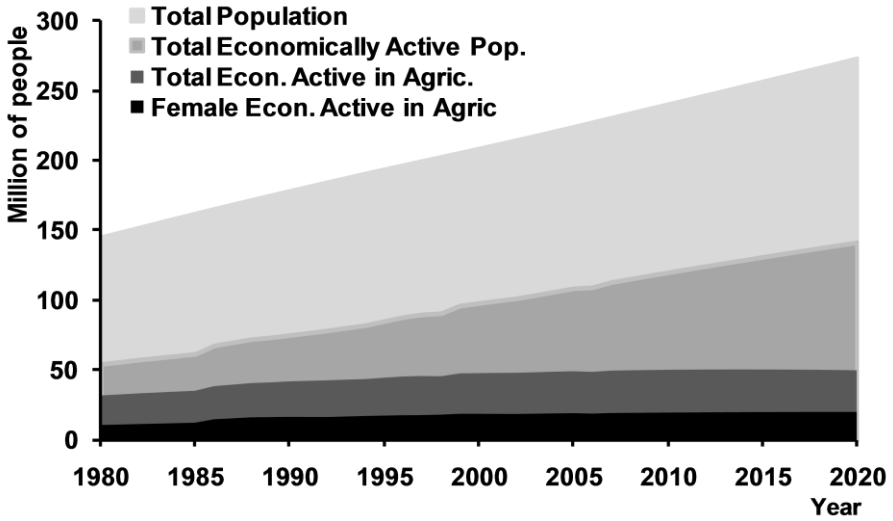
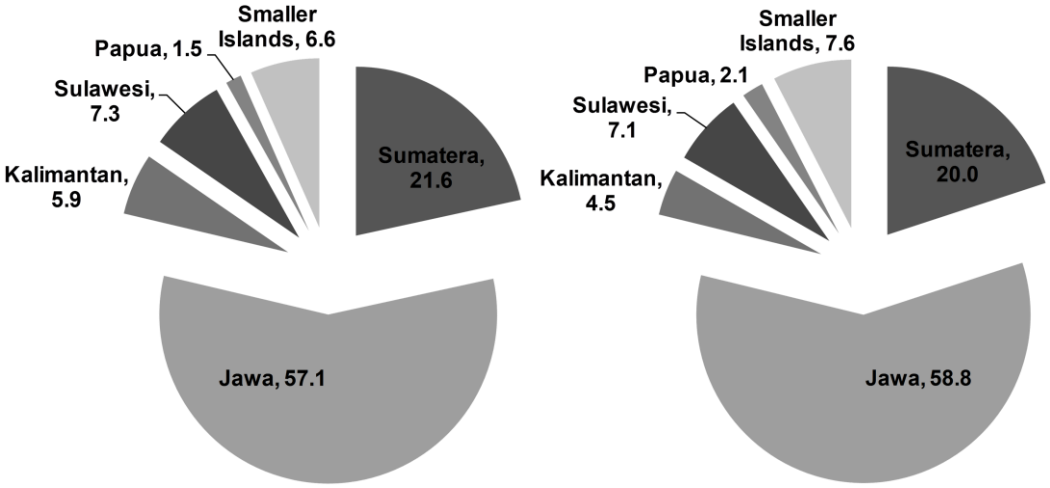


Figure 13 Trend of employment features in Indonesia



(a) total population (%) *(b) farm-household (%)*

Figure 14 Distribution of population and farm household among the islands in Indonesia (data source CBS, 2014, the total of Indonesia = 100%)

5 Agricultural production and productivity

Indonesia is one of the world's top ranks countries producing agricultural commodities, especially commodities of tropical in nature. The country is the first rank producer of palm-oil (CPO), coconut and rubber, the world's top three producers of rice, cacao, coffee beans and spices producers. On the other hand, the country is also one of the world's main importers of some agricultural products, such as: wheat, sugar, soybean, maize, rice, dairy products and some processed food. Therefore, the issues of balance of production and self-sufficiency are still challenging.

As an emerging and economic growing country, the population has been growing since decades. Economic and population growth stimulant, however, have come at a significant consequence in environmental and resource use; especially land use change to fulfill more arable land for food and permanent crops, as well as housing and industrial settlements. As it is illustrated in **Figure** 15, the areas of agricultural and arable land are slightly increasing, but the areas per capita are decreasing. The increment of agricultural land is mostly accentuated by the increment of agro-industrial plantation area – especially oil-palm plantation – rather than food crops area. As it is shown in **Figure** 16, the oil-palm plantation area has been increasing significantly in the last decade due to boost up economic advantage from the agricultural sector.

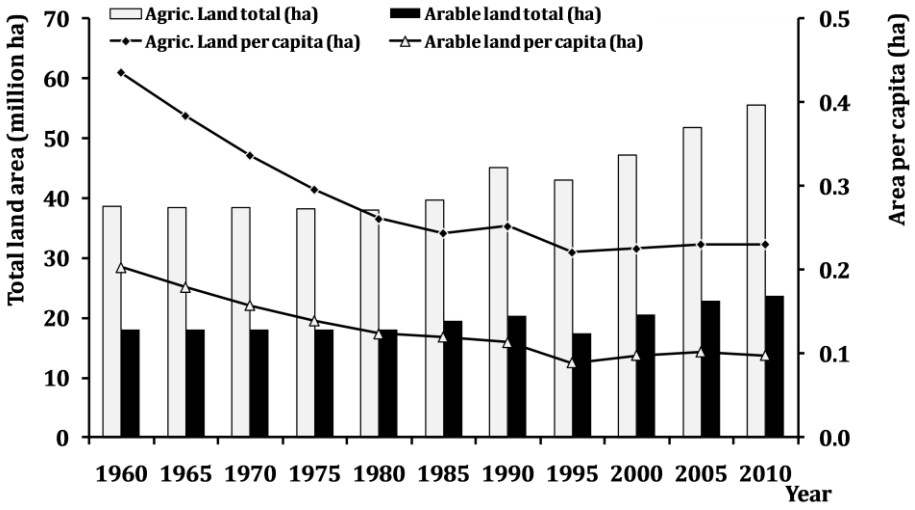


Figure 15 Trend of agricultural and arable land area in Indonesia

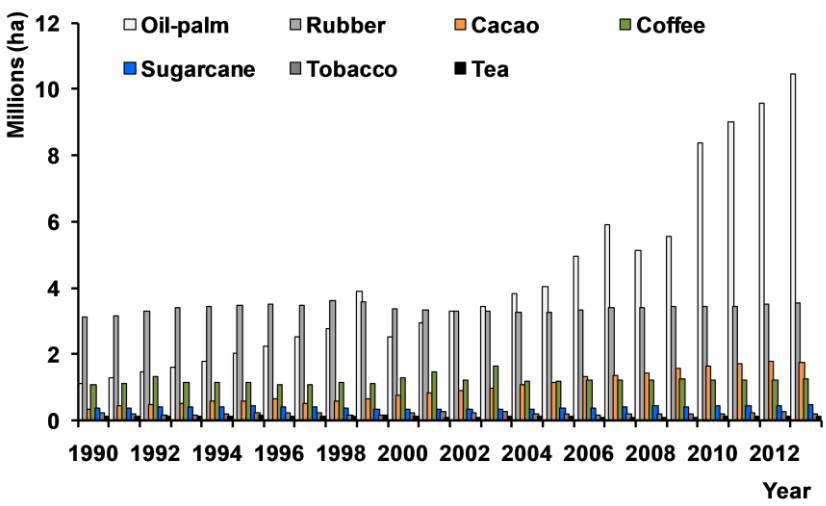


Figure 16 Trend of plantation areas of some major industrial commodities

In case of food crops agriculture, government has been putting a lot of efforts to increase productivity, especially on rice production even with less expansion of arable land. Almost no change in term of arable land area within 40 years, but it is slightly growing in term of harvested area. Hence, it means that the cropping index (CI) has been increasing within the time accordingly. The production of rice has been increasing as well, so it means that the productivity is increasing, even though the growth rate has been slowing down recently. As it is shown in Figure 17, in the 1980's, the national food production was growing in the best pace ever in the country history and the peak was in 1984-1986 where Indonesia reached self-sufficiency in rice. In this so called "green revolution"era, massive utilization of land and growing use of chemical fertilizer and pesticide has been practiced by most of the farmers due to increase in the yield. However, inthe same period, the population was increasing in higher rate. Therefore, the cultivated and harvested land per capita of population has been decreasing and the production per capita of population was stagnating within 1980's to 2000, but thenincreasing again recently due to the better technological input on the cultivation system (Figure 18). At present, an average of 500 m^2 of harvested area and about 150 kg rice (milled equivalent) production is domestically available per capita of population. Based on this data, the rice production in Indonesia is considered as "self-sufficient", since the average rice consumption of Indonesia is about 130 kg/capita. However, the divers of productivity, distribution and consumption among areas are sometimes gaining locally un-sufficiency. As for other crops productivities, the country is still partly depending on import to fulfill domestic demand, such as soybeans and maize.

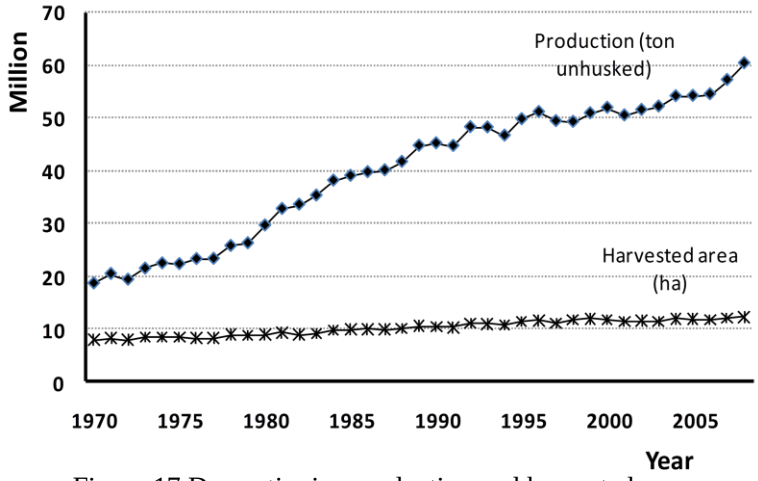


Figure 17 Domestic rice production and harvested area

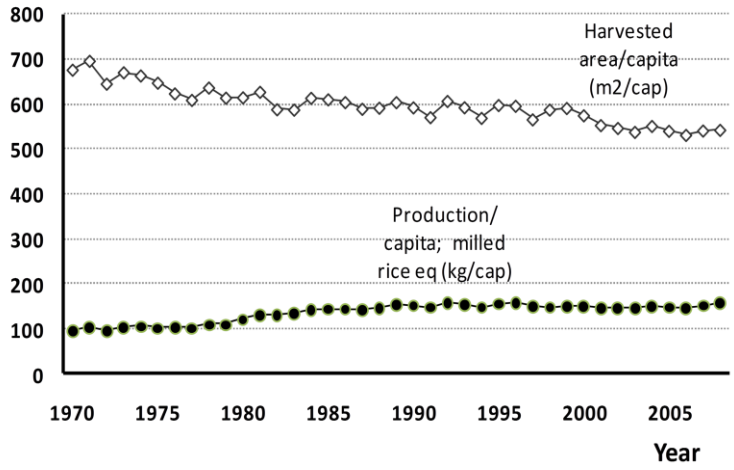


Figure 18 Per capita rice production and harvested area

6 Concluding remarks

Agricultural development in Indonesia has been in good pace during the last four decades to chase the need of the growing population. However, the total production has not met the entire domestic demand of food, and the majority of farmers still remain among the poorest citizens. In the country, modern farming technologies have kept production apace with population growth, but major problems with food distribution still plague many communities and regions. Furthermore, high dependency on chemicals in many intensive production systems may pose a threat to the nature surrounding farmlands. Therefore, as we look for the future, the real challenge of agriculture is to continue increasing the production while at the same time to minimize the environmental damage and conserve the resources, as well as reducing poverty, hunger and malnutrition.

Agricultural activities basically can contribute both positive and negative effects to the environment. It is diverse significantly as a function of the type of production and management system. When it is carried out in a sustainable manner, agriculture surely can be expected to: (1) conserve the natural resource and prevent the degradation of soil, water, and air quality; (2) contribute to the economic and social well-being; (3) ensure a safe and high-quality supply food and other agricultural products; (4) safeguard the livelihood and well-being of farmers, agricultural workers and their families.

Concerning to the present condition of agricultural practices in dealing with the needs to increase the productivity and at the same time to conserve the environment and natural resources, we need to adjust our understanding and formulate the action strategy to develop better and sustainable agricultural practices in the future. A sustainable approach of agriculture in Indonesia is necessary to keep growing the productivity (to fulfill human need) whereas at the same time it has to be in harmony with environment (to maintain environmental balance). The approach strategy may consist some aspects, such as: (1) production and management practices (precision input, appropriate technologies and mechanization, mix cropping system, diversify output, waste recycle etc.); (2) socio-economic (scale of production, capital and purchasing ability, efficiency & productivity, food safety & security, infrastructures); (3) policy and institutional drivers (fair trade, investment, competition, eco-labeling, incentives, R&D); (4) socio-cultural (local wisdom & indigenous knowledge, formal education, community education, consumer awareness, etc.); (5) regional and international networking and cooperation. Furthermore, a sustainable agricultural system has to always take into account three dimensions of sustainability: economy (technology), social (human) and agro-ecology (environment).

Bio-cycle farming or integrated farming system (IFS) might be one of the best approaches to be implemented in practice of sustainable agricultural production and management system. As an agricultural good practices system, IFS can give multiplying effects – economically, socially and environmentally – to the farmers, rural community as well as to the rural environment. Economically, the benefits of IFS may reduce the cost of farm production as well as increasing the value of farm products. Therefore, economically IFS will increase net income for the farmers. In social point of view, IFS can produce wider employment opportunity. In wider scale, IFS contributes to the promotion of agricultural sustainability and decreases agricultural vulnerability. The using of local matters as agricultural inputs will decrease dependency to external inputs. Environmental deterioration will be decreased by recycling and reusing waste. By decreasing agricultural vulnerability, agricultural system will be more sustainable and thus will be more ability to support the need of the growing population.

References

Syuaib, M.F. 2005. Farming system in Indonesia and its carbon balance feature. Workshop of Ecological Analysis and Control of Greenhouse Gas Emissions from Agriculture in Asia, College of Agriculture, Ibaraki University, Japan.

Syuaib, M.F. 2007. Challenges of environmental education for sustainable development in Indonesia. International Symposium & Workshop on Ecological Service Functions for Sustainable Agriculture in Asia, Ibaraki University, Japan.

Syuaib, M.F. 2009. Perspective of sustainable agriculture in Indonesia: Keep Growing in Harmony with Environment. Symposium & Workshop on "From Environmental to Sustainable Science: Thinking the Sift and the Role of Asian Agricultural Science". College of Agriculture, Ibaraki University, Japan.

Komatsuzaki, M and M. F. Syuaib, 2010. Comparison of the farming system and carbon sequestration between conventional and organic rice production in West Java, Indonesia. *Sustainability (Open Access International Journal)*. Bazel, Switzerland. 2(3):833-843

Komatsuzaki, M and M. F. Syuaib, 2011. New farm management strategy to enhance sustainable rice production in Japan and Indonesia. Book Chap. 14: Sustainable Agriculture and New Biotechnologies. CRC Press: Taylor & Francis Group, USA..

Ministry of Agriculture. Agriculture Statistics. 2014FAOSTAT. faostat.fao.org

Central Beureu of Statistics of the Republic of Indonesia (BPS: Biro Pusat Statistik). www.bps.go.id