Sustainable development of crop production under the climate changes in Asia

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Abstract

For the future food security, the status of world crop production must be carefully monitored. At present, the negative impacts of climate changes are anticipated to give adverse influences on agricultural production. In this study, the present status of the crop production in the world and tropics was studied in comparison to the recent past and the tendencies were analyzed. The tropics have increased the importance in the world agricultural production and special attentions were given to the production in the tropics. Recently, world 3 major cereals production has been high and stable. Annual production in recent several years could feed more than 10 billion people if all the harvested crops were delivered fairly and equally and consumed for food only. This stably large production has been realized by the development of agricultural technologies, farm management improvement, cropping systems optimization, etc. General stability of the society in the world may have contributed too. Based on the agricultural statistics of recent several decades, the causes of the present high crop productivities and future prospect of world food production is discussed.

Keyword: Energy consumption, Major cereals, Positive impacts, Sugarcane, Tropics

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Introduction

The adaptation to the climate change, or global warming is one of the biggest challenges, now we are facing. Global surface temperature at present was 1.09 ºC higher than 1950-1900 period according to IPCC (2023) and this trend may continue unless appropriate measures are taken. Global warming has caused many weather and climatic extremes in every region across the world (IPCC, 2023), and may have given adverse effects on various aspects of our activities, including agriculture. Recently, the occurrences of the climatic events have been reported frequently in many areas in the world, such as drought and heat wave, torrential rain and resulting flood, etc. These climatic events may have negative impacts on agricultural production, and they are frequently reported recently (IPCC, 2023).

On the other hand, overall agricultural production has increased under such circumstances as shown by world agricultural statistics (e.g. FAOSTAT). There are various factors, which contribute to the present stable and high agricultural production of the world under the progress of global warming, such as the development of agricultural technologies and stabilization of the public order in many areas. One of them may be positive impacts of global warming on agricultural production. In this paper, these factors are discussed later in details.

The studies on the impacts of global warming on agricultural production have been tended to focus on the agricultural activities in the temperate areas, because the temperate areas are major crop production sites in the world, even though many crops including rice, maize and sugarcane are tropically originated. This is also because in the tropics air temperatures are originally high and the increase in air temperatures may not have caused direct large influences. Recently, however, the crop productivity in the tropics have been rapidly increased, as shown later in this paper and the importance of crop production in this area is increasing. In addition, the instability of rainfall, frequent occurrence of climatic events, such as drought and flood, has been reported recently in the tropics (IPCC, 2023). It is prerequisite for more studies on the impacts of climate changes on agricultural production in the tropics.

This paper aims to describe the present status of world major crop production, analyze the factors which contribute to the present stable and large crop production, and discuss the future prospect of world crop production and measures to mitigate negative impacts of climate changes. Major concerns are placed on those in the tropics.

Material and Methods

Statistical data on agricultural production and fertilizer use were collected from FAO websites (FAOSTAT). Production (t), cultivated area (ha) and yield (t/ha) of 4 major crops, i.e. bread wheat, rice, maize and sugarcane, in the world and tropics, were collected during these 30 years. Three major cereals were selected due to its importance as staple food crops in many parts of the world and it is very convenient for discussing world food security. Sugarcane was selected for its importance in tropical areas. Collected data were analyzed for the long-term changes, stability, comparison among areas. The contribution of the tropics to world crop production was analyzed, and especially ASEAN areas were mainly focused on for the analysis.

Results and Discussion

1. 3 major cereals

Recent trends of the production of major 3 cereals (rice, maize and bread wheat) in the world are shown in Fig. 1. In these 3 decades, world 3 major cereals production has increased from ca. 1.5 billion tons to ca. 2.7 tons, although the cultivating area did not show conspicuous changes. The present world cereal production is huge. If the annual consumption of 3 major cereals per capita is assumed to be ca. 200 kg, which is a rough estimate of the consumption of 3 major cereals of Japanese for these 10 years, this amount could have feed more than 12 billion people. In addition, the world 3 major cereals production in recent years has been very stable (Fig. 2), even though recent increase in climatic events, such as drought and flood, probably due partly to the adverse influences of global warming. During the period from 2014 to 2016, large scale El Nino phenomenon occurred and the agricultural damages caused by drought and flood, or other environmental stresses were frequently reported in many areas in the world (IPCC, 2023).

These recent high and stable cereal production may have been realized by the development of agricultural science and technology, such as high yielding varieties, fertilizer application technologies, plant protection technologies, irrigation & drainage technologies, agricultural machineries, etc. Other factors, like economic development and general social stability in many countries and regions may also contribute to these high and stable crop production. In this regard, recent expansion of COVID-19 and its adverse impacts on economic activities may have caused serious influences on world cereal production, although at least the production in 2020 and 2021 was not much reduced. Russian invasion to Ukraine in early 2022 had very serious impacts on the world food supply chain, and it is considered that the production may also have been heavily influenced adversely, but at present, world agricultural statistics is not available and its impacts on the world production of major cereals is not known yet.

Fig. 3 shows the production of maize and rice of the world, tropics and Southeast Asia during these 3 decades. The world maize production increased by 2.4 times during this period, but that of the tropics increased by 4.2 time and that of Southeast Asia by 3.2 time. The world maize production increase was remarkable, but that of the tropics and Southeast Asia is even more remarkable. The increase in the rice production was also observed, but the extent of the increase was less than that in maize. The increase in the rice production in the tropics and Southeast Asia was a little bit more appreciable. Anyway, these data suggested that the tropical areas, including Southeast Asia, recently have increased the contribution to world cereal production.

In Southeast Asian countries, what kind of trends were seen in major cereals production? Table 1 shows the production of maize and rice in major producers in Southeast Asia during these 3 decades. In maize production, all countries except for Thailand showed large increase during these 3 decades. Thailand maintained already high maize production during this period.

Major countries in Southeast Asia also increased rice production, although the extent of the increase is smaller than that of maize. Thailand showed the increase, but the extent of the increase is smaller than that of Vietnam, Myanmar and the Philippines. It is generally accepted that Thailand has more producing potential of rice, and the production of rice in Thailand is seriously affected by price and government policy (Poramacom, 2014).

To these large increases, the improvement of the productivities has contributed in both crops (Table 2). In maize, all the countries showed large increases in the productivity. In rice, the same trend was observed, but the extent of the increase was smaller than that in maize. It is pointed out that rice productivity in Thailand is lower than that of the other countries. It may be due to low rice yield in Northeast Thailand. Because of the lack of irrigation facility and the prevailing sandy soils, which is characterized by their low water holding capacity and poor nutrition, the productivity of rice in that area is generally low and unstable (Kono et al., 2001). In addition, paddy fields in this area occupies 40% of total paddy fields of Thailand, causing the reduction in the rice productivity of Thailand.

Just like the trend of the world production of maize and rice, the production of both crops was stable during the period from 2015 to 2019, in which most countries show low C.V. (the coefficient of variance) (Table 3). Only one exception with a high value of C.V. is the maize production in Indonesia, but the large C.V. value was due to its increase with a large extent and not caused by the fluctuation of the production. It can be concluded that the production of 2 major cereals in Southeast Asia is stably high recently and have contributed to world food production in a relatively large extent. It can be also said that the presence of Southeast Asia in the world maize and rice production is steadily larger and this trend may continue, unless unexpected events occur.

2. Sugarcane

Fig. 4 shows the recent trends of the production of sugarcane in the world. In these 3 decades, world sugarcane production has increased from ca. 1 billion tons to ca. 2 billion tons, by twice with the increase in the harvested area. In addition, sugarcane production in recent years has been very stable (Fig. 5), just like 3 major cereals, even though recent increase in climatic events. As stated in the last section, during the period from 2014 to 2016, large scale El Nino phenomenon occurred and the agricultural damages caused by drought and flood, or other environmental stresses were frequently reported in many areas in the world.

These recent high and stable sugarcane production may have been realized by the development of agricultural science and technology, such as breeding high yielding varieties, fertilizer application technologies, plant protection technologies, irrigation & drainage technologies, agricultural machineries, etc., just like 3 major cereals. In addition, sugarcane is known to be very tolerant to various environmental stresses, such as drought, high temperature and waterlogging (Ferreira et al., 2017). These traits may contribute to the stable production of this crop during these several years. Of course, other factors, like economic development and general social stability in many countries and regions may also contribute to these high and stable production just like 3 major cereals shown in the previous section. Recent expansion of COVID-19 and its adverse impacts were also expected to occur, but at least in 2020 and 2021, the conspicuous changes of the production were not known. The influences of the Russian invasion to Ukraine are also anticipated, but most of sugarcane producing countries are located in tropical areas and the direct influences are considered to be limited, although the price increase of fertilizers and fuels (for agricultural machineries and transportations) may have given some adverse effects.

Fig. 6 shows the production of sugarcane of the world, tropics and Southeast Asia during these 3 decades. The world production increased by 1.9 times during this period, and that of the tropics by 2.2 times and that of Southeast Asia by 2.1 times. Considering the fact that most of the sugarcane production is done in the tropics, it is not surprising that the increase rate is not very different between that of world and tropics. Still, the increases in the sugarcane production in these 30 years are large, and the contribution of the development of agricultural technologies must be high.

Fig. 6 shows stable increase in sugarcane production in Southeast Asia, but in each country in this area what kind of trend was observed? Table 4 shows the production of sugarcane in major producers in Southeast Asia during these 3 decades. All countries in mainland Southeast Asia showed large increases in sugarcane production during these 3 decades. Thailand showed 3.6 times increase during this period and in 2019 the production exceeded 130 million t per year. Although Myanmar showed 5.1 times increase, the production was about 12 million t per year. Similarly, Vietnam showed 2.9 times increase, but the total production was rather limited. Table 4 showed that Thailand is the leading producer of sugarcane in this area and occupied more than 80% of the sugarcane production in mainland Southeast Asia. In insular Southeast Asia, Indonesia and Philippines are major producers of sugarcane. Indonesia showed a slight increase in these 30 years, and Philippines showed a decrease. As a result, the sugarcane production in this area, which was similar to that of mainland Southeast Asia 30 years ago, was much less than that in 2019. The causes of the lack of increase in Indonesia and Philippines are not clear, but both countries are rice importers and the demand of rice production is large. It is considered that the farmland allocation and/or farmers intension to sugarcane cultivation is rather restricted, in comparison to rice. On the contrary, Thailand is a large rice exporter and farmers may have options to select sugarcane instead of rice or upland crops. Sugarcane is tolerant to wetland conditions to some extent, and the conversion from paddy fields to sugarcane fields is not very difficult.

In Mainland Southeast Asia, to large increases of sugarcane production, the improvement of the productivities may have contributed (Table 5). The productivity of sugarcane was 1.3 to 1.6 times larger than those of 30 years ago in this area, although the increases in the production were much larger than that of the productivity, suggesting the production area increased in these 30 years in this area. On the contrary, in Insular Southeast Asia, the productivity was not improved or reduced. The reason is not clear, but agricultural investment to sugarcane production may have been restricted to some extent.

Just like the trend of the world production of sugarcane, the production of sugarcane was stable or stably increased during the period from 2015 to 2019, in which most countries showed low C.V. (the coefficient of variance) (Table 6), with the exceptions of Vietnam and Philippines in 2019. Although a high value of C.V. was shown in the production in Thailand, the large C.V. value was due to its increases of recent 2 years with a large extent and not caused by the big fluctuations of the production during these 5 years. The causes of the abrupt reductions in the production in 2019 in Vietnam and Philippines are not clear, and further investigations are necessary. Recent increase in the production in Thailand may be caused by the changes of the Government policy on sugarcane price, but the details are not known.

3. Future prospect

As shown in the former sections, the present world agricultural production is large and stable, even though the influence of global warming is becoming apparent in recent years. During this period, world population has increased by 1.45 times (from 5.24 billion in 1989 to 7.63 billion in 2019), whereas those of southeast Asia 1.52 times (0.432 billion to 0.656 billion). It seems that the improvement of world agricultural productivities satisfies the increase in the world food demand at present. As previously stated, the development of agricultural technologies may have largely contributed to the present high and stable agricultural production. For example, Fig. 7 shows the changes of the world N fertilizer use during these 30 years. The world N fertilizer use has been increased from ca. 79 million t in 1989 to 105 million t in 2019 by 1.33 times. In the tropics and Southeast Asia, the increment was larger than that, 2.49 and 2.34 times, respectively. Other fertilizers showed similar tendencies (data not shown). Recently, crop cultivation management has been developed, with the optimization of the cropping systems, adapting to local environment. The agricultural fields have been well managed with the efforts of farmers, researchers and public or private agricultural extension workers. The irrigation systems have been gradually developed, although in some areas, full irrigation system development is still difficult. The recent developments of agricultural machineries may have promoted the improvement of crop productivities in various areas in the world. Effective plant breeding could have produced many new varieties by not only conventional methods, but also molecular breeding (Lenaerts et al., 2019).

As another factor, the stability of the world society and good public order in general may have contributed to the present status of crop production. To apply the outcomes of the improvement of agricultural research to actual production, the stability of the society are indispensable. During recent 3 decades, the world is generally stable and peaceful, and this is one of the important factors for the world high and stable agricultural production. In this meaning, we need to carefully observe the effects of what happens in Ukraine at present.

In addition to the above factors, we need to consider the positive impacts of climate changes. Although negative impacts of climate changes on agricultural production have been emphasized, we should recognize that there are several positive influences of climate changes. Within a certain range of the temperature, global warming accelerates photosynthetic activities of crops in line with a rise of atmospheric CO_2. As the respiration activities of crops also increase, the net productivities reach the maximum at a certain threshold temperature, depending on crop species. When the temperature is lower than this threshold, the higher the temperature, the higher the net photosynthetic activity. Another positive impact is the expansion of cultivated area to higher latitude or altitude. Recent increase in the cultivated area of each crop is partly due to the expansion of cultivated area to higher latitude or altitude areas. Global warming may have induced the extension of cropping season. Air and soil temperature rise enables early planting and late harvest. The extension of cropping period may allow farmers to use more productive late varieties and more flexible cropping systems.

Another important positive impact of global warming is the expansion of cultivation of highly productive tropical crops (C_4 plants) to higher latitude and altitude areas. Many domesticated plants originated in tropical areas, such as maize and sugarcane, have C_4 photosynthetic pathway and are known to be highly productive, although their advantages are decreasing due to the rise of atmospheric CO_2 concentration. Recent increases in the production of maize and sugarcane may be partly due to this factor.

Although we understand that recent crop production is high and stable, does this trend continue? Are there no worries about future food security? Unfortunately, answers to these questions are "No". There are many problems to threaten the present agricultural productivities and production systems.

The first problem is direct negative impact of climate changes. At present, it seems positive impacts exceed negative ones, but soon the negative impacts may overtake the positive ones. Climatic events like drought, extreme heat and flooding are more frequent than the recent past (IPCC, 2023) and this trend will continue. Rainfall is more instable, and the crop season is more unstable together with more frequent climatic events and natural disasters. If the temperature rise cannot be suppressed, the air temperature exceeds the threshold for maximum net photosynthesis for many crops. The temperature rise causes not only the reduction in quantitative productivities, but also adverse influences on crop growth, such as the failure in flower bud initiations in some crops (Craufurd & Wheeler, 2009, Krishna Jagadish, 2020). It is rather difficult to predict when the negative impacts exceed the positive ones, but it is not distant future unless further development of agricultural technologies and appropriate measures to suppress the global warming are taken.

Another big issue is energy consumptions for the agricultural production. The present high and stable productivities are highly dependent on the energy consumption. At actual cultivation in the modern agriculture, it is prerequisite to use agricultural machines, which consume much energy and the use of the machine is quickly extended including the tropics. The production of agricultural chemicals, i.e. chemical fertilizers, pesticides and herbicides, consume a lot of energy. Postharvest treatments essential for commercialized agriculture need large amounts of energy. In some of horticultural production, tremendous energy is consumed for the environmental control. Even, new variety development needs a large amount of energy. Table 7 shows the ratio of input energy to the energy outputs in Japanese agriculture (Yoshimoto & Ogimoto, 1994). This table shows that modern agriculture must consume energy with concrete examples. But energy is not infinite.

Although the above issues are difficult challenges to be solved, we need to make efforts to deal with them and many researchers, farmers and related stakeholders are actually accumulating efforts to do so. In order to adapt the agricultural technologies to the climate changes, new cultivation systems are necessary, which include new variety development, new cultivation management, and new cropping system development. As repeatedly stated, recently the frequency of the climatic events like drought, extreme heat and flooding are increasing. New varieties tolerant to these environmental stresses are necessary. In addition, cultivation management to avoid damages from these stresses must be developed, such as technologies to avoid sensitive stages of crop growth from high frequency period of climatic events. This can be enabled by introducing new cropping systems and/or the adaptive genotypes together with the weather simulation technologies. Smart agriculture can optimize the cultivation of crops under new environment caused by the climate changes (Lipper et al., 2014). Smart agriculture is also effective for the energy saving cultivation (Bandur et al., 2019). The development of energy saving new varieties are also necessary.

Of course, population growth is a big problem for world future food security. Although the world population growth is less worried than the past, due to the economic development of some populated countries and resulting reduction in the rate of population growth, this is still a big issue, especially in rapidly developing countries in the tropics. As described previously, social stability and overall peaceful world is a necessary condition for the stable agricultural production. At present, large-scale conflicts produces an instable world status and the food systems are deeply and seriously damaged. Although the present crop production is stably high, there are always some famines somewhere in the world, indicating the lack of the appropriate distribution systems of food. These issues are also big challenges for future food security, but they are multidisciplinary issues and cannot be solved by efforts of only agricultural researchers and farmers. Dialogues among various stakeholders including policy makers are indispensable.

Conclusion

In this study, based on the world agricultural statistics, the present status of world important crop production was analyzed, and it was shown that the world crop production at present is high and stable. Various factors may have contributed to the high and stable productivity of crop production including agricultural technology development. There is a possibility that the positive impacts of climate changes may have appeared at this stage of global warming. Although the present 3 major cereal crop production can feed more than 10 billion people, present world food systems failed to feed all the people in the world. In the near future, negative impacts of climate changes may overtake positive ones and we need to prepare for that. The consumption of huge amount of energy for agricultural production is another big issue for the future agricultural production. These issues are so-called grand challenges for all of us, and multidisciplinary and multilateral collaborations are necessary for the future stable agricultural production.

References

Bandur, D., Jaksic, B., Bandur, M., Jovic, S. 2019. An analysis of energy efficiency in wireless sensor networks (WSNs) applied in smart agriculture. Comput. Elec. Agric. 156:500-507.

Craufurd, P. Q. and Wheeler, T. R. 2009. Climate change and the flowering time of annual crops. J. Exp. Bot. 60:2529-2539. doi: 10.1093/jxb/erp196.

Ferreira, T. H. S., Tsunada, M. S., Bassi, D., Araujo, P., Mattiello, L., Guidelli, G. V., Righetto, G. L., Goncalves, V. R., Lakshmanan, P., Menossi, M. 2017. Sugarcane water stress tolerance mechanisms and its implications on developing biotechnology solutions. Front. Plant Sci. 8. doi: 10.3389/fpls.2017.01077.

IPCC 2023. Climate Change 2023 Synthesis report Summary for policymakers. https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf.

Kono, Y., Tomita, S., Ngata, Y., Iwama, K., Nawata, E., Junthotai, K., Katawatin, R., Kyuma, K., Miyagawa, S., Niren, T., Noinchana, C., Sakuratani, T., Sributta, A., Watanabe, K. 2001. A GIS-based crop-modeling approach to evaluating the productivity of rainfed lowland paddy in North-east Thailand. ACIAR Proceedings 101:301-318.

Krishna Jagadish, S. V. 2020. Heat stress during flowering in cereals – effects and adaptation strategies. New Phytol. doi: 10.1111/nph.16429.

Lenaerts B., Collard, B. C. Y., Demont, M. 2019. Review: Improving global food security through accelerated plant breeding. Plant Sci. doi: 10.10 1016/j plantsci.2019.110207.

Lipper, L., Thornton, P., Campbell, B. M., Baedeker, T., Braimoh, A., Bwalya, M., Caron, P., Cattaneo, A., Garrity, D., Henry, K., Hottle, R., Jackson, L., Jarvis, A., Kossam, F., Mann, W., McCarthy, N., Meybeck, A., Neufeldt, H., Remington, T., Sen, P. T., Sessa, R., Shula, R., Tibu, A., Torquebiau, E. F. 2014. Climate-smart agriculture for food security. Nat. Clim. Chang. 4:1068-1072.

Poramacom, N. 2014. Rice production, prices and related policy in Thailand. Inter. J. Busi. Soc. Sci. 5:201-210.

Yoshimoto, H and Ogimoto, K. 1994. Life-cycle energy at home. J. IEE. Jap. 114:723-728. doi: 10.1541/ieejjournal.114.723.

Table 1 Crop production of Southeast Asia during these 30 years.

a) maize (million t, except "2019/1989" rows, whose values are unitless)

Year	Mainland				Insular		
	Myanmar	Thailand	Vietnam	Total	Indonesia	Philippines	Total
1889	0.19	4.39	0.84	5.52	6.19	4.52	10.81
1999	0.34	4.29	1.75	6.57	9.20	4.58	13.92
2009	1.23	4.62	4.37	12.27	17.63	7.03	24.83
2019	1.99	4.31	4.76	13.18	30.69	7.98	38.80
2019/1989	10.25	0.98	5.68	2.39	4.96	1.76	3.59

b) rice (million t, except "2019/1989" rows, whose values are unitless)

Year	Mainland				Insular		
	Myanmar	Thailand	Vietnam	Total	Indonesia	Philippines	Total
1889	13.81	20.60	19.00	57.48	44.73	9.46	55.97
1999	20.13	24.17	31.39	81.83	50.87	11.79	64.72
2009	32.17	32.40	38.95	114.24	59.01	16.27	77.91
2019	26.27	28.36	43.45	112.40	54.60	18.81	76.41
2019/1989	1.90	1.38	2.29	1.96	1.22	1.99	1.37

Table 2 Crop yield of Southeast Asia during these 30 years.

a) maize (t/ha, except "2019/1989" rows, whose values are unitless)

Year	Mainland				Insular		
	Myanmar	Thailand	Vietnam	Total	Indonesia	Philippines	Total
1889	1.58	2.57	1.64	1.67	2.10	1.23	1.60
1999		3.55	2.53	2.35	2.66	1.74	1.95
2009	3.38	4.18	4.01	4.24	4.24	2.62	3.45
2019	3.85	4.50	4.80	4.64	5.44	3.17	4.81
2019/1989	2.44	1.75	2.92	2.78	2.59	2.59	3.01

b) rice (t/ha, except "2019/1989" rows, whose values are unitless)

Year	Mainland				Insular		
	Myanmar	Thailand	Vietnam	Total	Indonesia	Philippines	Total
1889	2.92	2.09	3.21	2.40	4.25	2.70	2.88
1999	3.24	2.42	4.10	2.93	4.25	2.95	2.66
2009	3.99	2.91	5.24	3.76	5.01	3.59	3.19
2019	3.80	2.92	5.82	4.11	5.11	4.04	3.71
2019/1989	1.30	1.40	1.81	1.71	1.20	1.50	1.29

Table 3 Crop production of Southeast Asia during these 5 years.

a) maize (million t, except "C. V." rows)

Year	Mainland				Insular		
	Myanmar	Thailand	Vietnam	Total	Indonesia	Philippines	Total
2015	1.75	4.73	5.29	13.68	19.61	7.52	27.34
2016	1.83	4.39	5.24	13.68	23.58	7.22	30.96
2017	1.91	4.82	5.11	13.78	28.92	7.91	36.99
2018	1.98	5.07	4.87	14.14	30.25	7.77	38.18
2019	1.99	4.31	4.76	13.18	30.69	7.98	38.80
C.V.*	5.4%	6.7%	4.6%	2.5%	18.2%	4.1%	14.7%

b) rice (million t, except "C. V." rows)

Year	Mainland				Insular		
	Myanmar	Thailand	Vietnam	Total	Indonesia	Philippines	Total
2015	26.21	27.70	45.09	112.44	61.03	18.15	82.00
2016	25.67	31.86	43.11	114.74	59.39	17.63	79.82
2017	26.55	32.90	42.76	116.77	59.43	19.28	81.34
2018	27.57	32.35	44.05	118.44	59.20	19.07	80.96
2019	26.27	28.36	43.45	112.40	54.60	18.81	76.41
C.V. *	2.6%	7.9%	2.1%	2.3%	4.1%	3.7%	2.8%

* C. V. stands for coefficient of variance.

Table 4 Sugarcane production of Southeast Asia during these 30 years (million t, except "2019/1989" rows, whose values are unitless).

Year	Mainland				Insular		
	Myanmar	Thailand	Vietnam	Total	Indonesia	Philippines	Total
1989	2.35	36.67	5.34	44.36	26.81	25.26	52.08
1999	5.36	50.33	17.76	73.46	23.50	23.78	47.28
2009	9.56	66.82	15.61	91.99	26.40	22.93	49.33
2019	11.85	131.00	15.27	158.12	29.10	20.72	49.82
2019/1989	5.05	3.57	2.86	3.56	1.09	0.82	0.96

Table 5 Sugarcane yield of Southeast Asia during these 30 years (t/ha, except "2019/1989" rows, whose values are unitless).

Year	Mainland				Insular		
	Myanmar	Thailand	Vietnam	Average	Indonesia	Philippines	Average
1989	48.68	55.60	40.37	48.22	78.88	96.52	87.70
1999	42.75	54.86	51.60	49.73	60.09	58.85	59.47
2009	60.58	69.34	58.77	62.90	59.80	56.76	58.28
2019	65.03	71.39	65.43	67.28	70.97	54.63	62.80
2019/1989	1.34	1.28	1.62	1.40	0.90	0.57	0.72

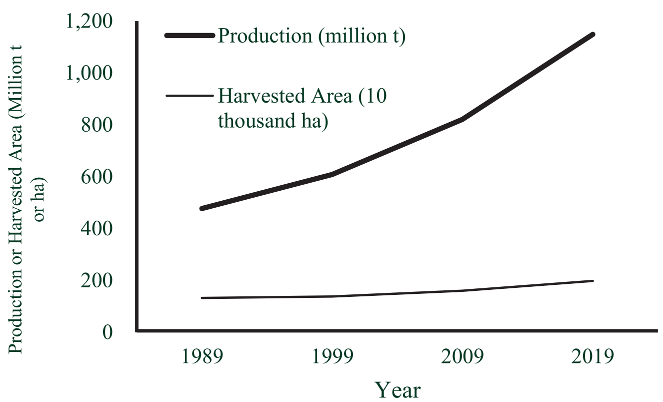
Table 6 Sugarcane production of Southeast Asia during these 30 years (million t, except "C. V." rows).

Year	Mainland				Insular		
	Myanmar	Thailand	Vietnam	Total	Indonesia	Philippines	Total
2015	10.14	94.14	18.34	122.62	27.00	22.93	49.93
2016	10.44	94.14	16.31	120.89	28.00	22.37	50.37
2017	10.37	93.09	18.36	121.81	28.00	29.29	57.29
2018	11.40	135.07	17.95	164.42	29.50	24.73	54.23
2019	11.85	131.00	15.27	158.12	29.10	20.72	49.82
C.V.	6.8%	19.7%	8.0%	15.8%	3.5%	13.7%	6.3%

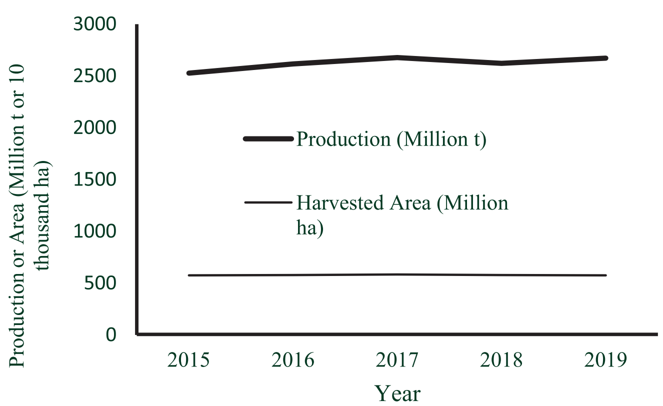
Table 7 The ratios of input energy against calorific value of food in Japan*

Ratio of input energy against calorific value											
Food											
Rice	Wheat	Potato	Legume	Fruit	Leafy Vegetable	Spirit	Fish	Meat	Egg	Milk	Fat
0.89	0.66	0.18	0.8	2.93	3.85	0.51	3.25	2.38	1.75	1.9	1.3

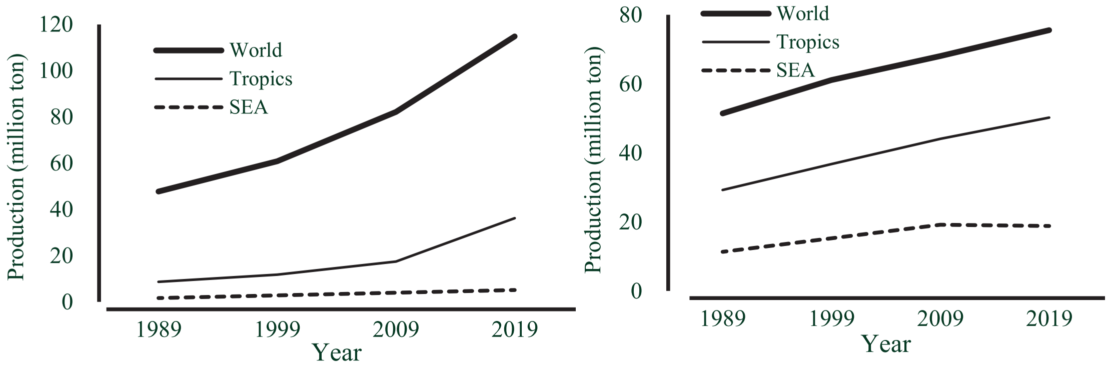
* Adopted from Yoshimoto & Ogimoto (1994)



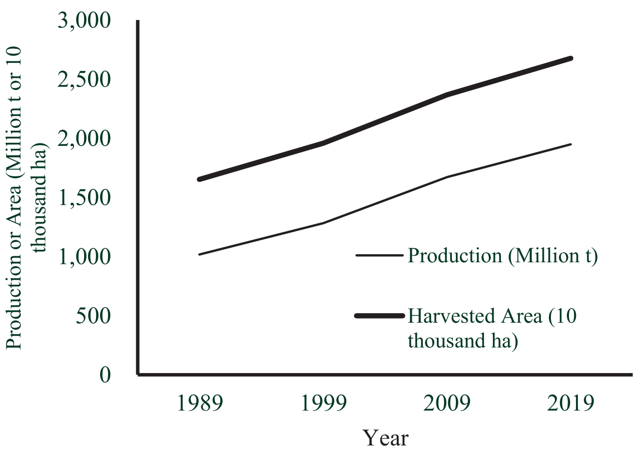
◄ Fig. 1 World major 3 cereals production during these 3 decades



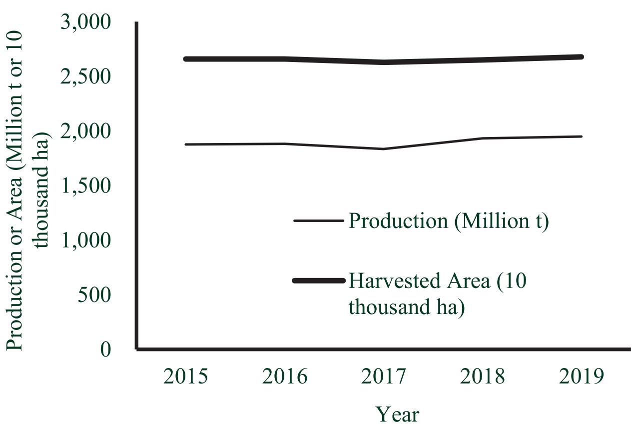
◄ Fig. 2 World 3 major cereals production during these 5 years.



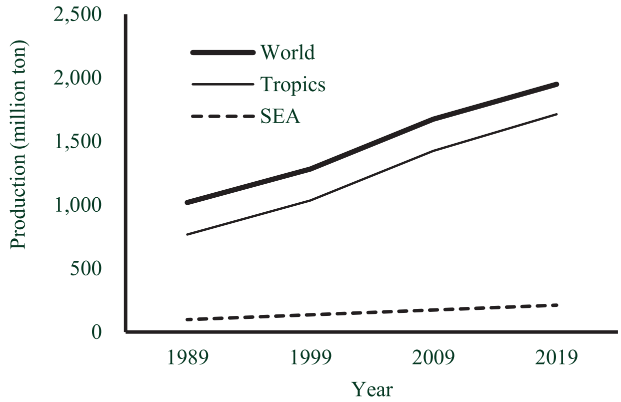
▲ Fig. 3　Production of maize (left) and rice (right) in the world, tropics and Southeast Asia during these 3 decades.



◄ Fig. 4　World production and harvested area of sugarcane during these 3 decades.



◄ Fig. 5　Production and harvested area of sugarcane in the world during these 30 years.



◄ Fig. 6 Production of sugarcane in the world, tropics and Southeast Asia during these 30 years.

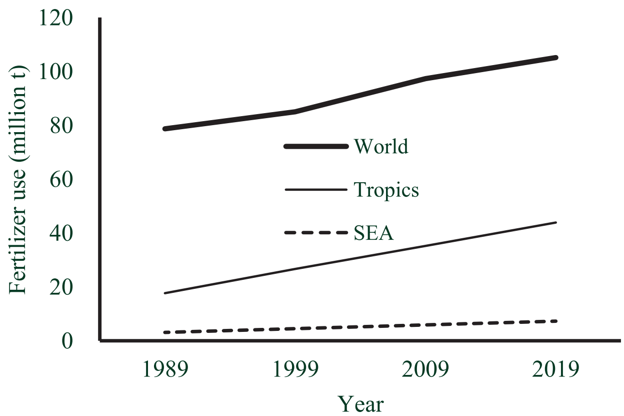


Fig. 7 Fertilizer use in the world, tropics and Southeast Asia during these 30 years.