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**Working Paper**

## Overcoming Critical Constraints to Sustaining Productivity Growth in Key Commodities of Asia and the Pacific

ADB Economics Working Paper Series, No. 376

**Provided in Cooperation with:**

Asian Development Bank (ADB), Manila

*Suggested Citation:* Sombilla, Mercedita; Mapa, Dennis; Piza, Sharon (2013) : Overcoming Critical Constraints to Sustaining Productivity Growth in Key Commodities of Asia and the Pacific, ADB Economics Working Paper Series, No. 376, Asian Development Bank (ADB), Manila, <https://hdl.handle.net/11540/2074>

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## ADB Economics Working Paper Series



### Overcoming Critical Constraints to Sustaining Productivity Growth in Key Commodities of Asia and the Pacific

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Mercedita A. Sombilla, Dennis Mapa, and Sharon Piza

No. 376 | September 2013

Asian Development Bank



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No. 376    September 2013

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Asian Development Bank

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© 2013 by Asian Development Bank  
September 2013  
ISSN 1655-5252  
Publication Stock No. WPS136001

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## **ABSTRACT**

Two trends on yields have been observed for rice, wheat, and even edible oils in Asia. The deceleration of yield growth is one of these trends. The other relates to the differential yield increases across countries in the region. This study provides explanations for both trends and relates these to the exhaustion of the yield potential of current technology, emerging threats posed by climate change and other disturbances, varying levels of development across countries and hence the development of infrastructure, among others. Total factor productivity (TFP) estimates for these commodities indicate the potential to overcome these constraints, however. Key determinants of TFP growth were identified and discussed. While the influence of these determinants on the TFP estimates was not tested empirically in this study because of data limitations, evidence of the relationship was clear and strong in numerous TFP studies done for the agriculture sector as a whole, and for rice and wheat in various countries including Asian countries. Long-term growth will have to come from great advances in interventions being undertaken, three of which include (i) major breakthroughs in new varieties and farming systems in both fertile and unfertile lands; (ii) the restructuring of small farms into more efficient, mechanized large-scale operations, especially in production areas with good infrastructure for market access and irrigation; and (iii) the development of market mechanisms to enhance the comparative advantage of domestic production and explore the value-adding potential of commodities, particularly edible oil. Three policy recommendations are also forwarded to achieve these great advances: (i) sustained investment in agriculture; (ii) getting the mix of institutions right; and (iii) gearing up for globalization. The role of development partners as well as the private sector in effecting sustainable growth is briefly discussed as a concluding section.

**Keywords:** TFP, constraints, Asia Pacific, rice, wheat, edible oil, investment, institutions, globalization, private sector, development partners

**JEL Classification:** D24, D57, O13, Q11, Q18



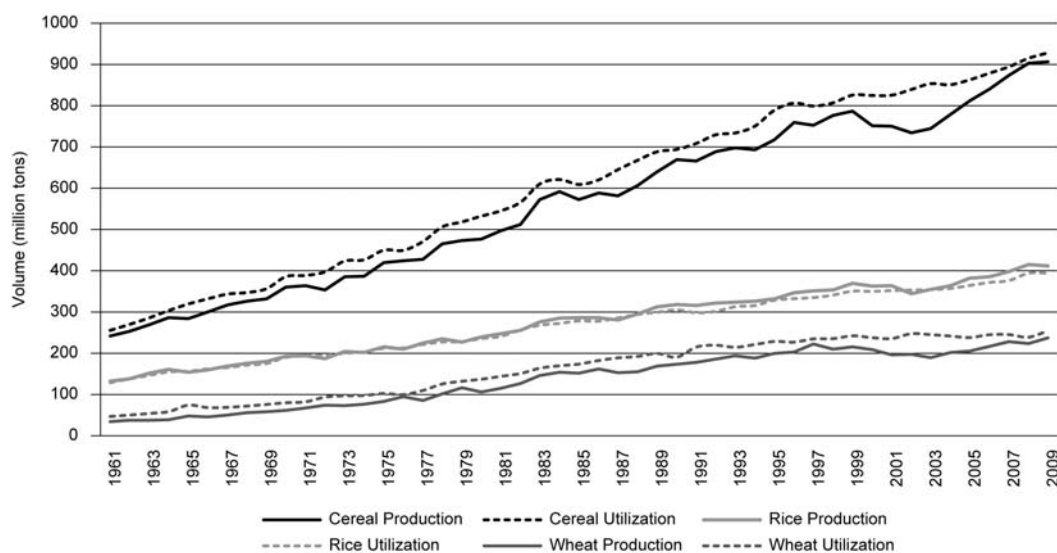


## I. INTRODUCTION

Despite significant changes in their demand structure, cereals continue to be overwhelmingly the most important source of dietary energy for people in the Asia and Pacific region.<sup>1</sup> Among the cereals, the consumption of rice still utterly dominates, accounting for about 24% of per capita calorie intake of the region. This share increases to an average of 34% for East, Southeast, and South Asian countries. Wheat consumption, which accounts for about 16% of per capita calorie intake, continues to be on the rise with the increasing substitution of rice and other staple foods like maize and root crops with bread and pasta.

Figure 1 compares the production and utilization<sup>2</sup> of total cereals and of rice and wheat in Asia and the Pacific from 1961 to the present. The graphs show two clear trends. One trend is that total cereal utilization outpaces production in the region as a whole, primarily in East Asia and the Pacific island countries, where production growth has significantly slowed down. By commodity, the significant gap between production and utilization has been in wheat. This is true primarily in Southeast Asia, where the commodity is produced in Myanmar and in Thailand, but in very limited quantities. The other trend relates to production fluctuations that indicate periods of shortfall occurring more than those when production exceeds utilization. This leads to apprehension that the emerging pattern has caused cereal stocks dipping to low levels especially in the past decade, thereby further endangering the attainment of food security (Food and Agriculture Organization of the United Nations Statistical Database [FAOSTAT]).

**Figure 1: Cereal Production and Utilization in Asia and the Pacific, 1961–2010**



Source: Food and Agriculture Organization of the United Nations Statistical Database (FAOSTAT). <http://faostat.fao.org/DesktopModules/Admin/Logon.aspx?tabID=0> (accessed June 2012).

<sup>1</sup> The Asia and Pacific region here includes the following subregions: (i) East Asia (the People's Republic of China, Japan, and the Republic of Korea); (ii) Southeast Asia (Cambodia, Indonesia, the Lao People's Democratic Republic, Malaysia, Myanmar, the Philippines, Thailand, Timor-Leste, and Viet Nam); (iii) South Asia (Bangladesh, India, Nepal, Pakistan, and Sri Lanka); and (iv) the Pacific Islands in Melanesia, Micronesia, and Polynesia, excluding Australia and New Zealand.

<sup>2</sup> Utilization includes all uses of cereals, such as food, animal feed, seed, and industrial use.

On the other hand, importance is given to edible oils and fats in the region due to their contribution to the dietary energy supply of the population, especially among the lower-income group. While this food group currently accounts for about a fifth of dietary energy supply in the developing world, the Food and Agriculture Organization of the United Nations (FAO) anticipates that the consumption of oil crop products will grow fast in the coming decades as incomes continue to rise. Recent projections by the FAO indicate continued growth in demand by 2.2% per annum mostly for food use in developing countries, primarily in Asia, notably in the People's Republic of China (PRC) and India (Thoenes 2011). This is not to mention their increasing use as feedstock for biofuels development. Such growth in demand can put pressure on the supply of edible oil, especially palm oil, soybean, and rapeseed oil—the three edible oils that are well-placed in terms of production and trade. Asia is a key producer and exporter of palm oil, primarily because of Indonesia and Malaysia. At the same time, it is also a major importer—in particular, the PRC—of soybean and rapeseed oils.

The emerging gap in food production and utilization described above prompted this study, which has the following objectives:

1. to describe production trends, particularly of rice, wheat, and edible oil; and to determine the contributions of area and yield to production growth;
2. to estimate total factor productivity (TFP), identify factors contributing to TFP estimates, and describe sources of future production increases;
3. to identify broad policy options to ensure that the sources of growth will work to sustain and increase growth; and
4. to identify the roles of stakeholders in implementing policy options

The paper has three major sections. Section II describes the production trends of rice, wheat, and edible oil crops, and the contributions of area and yield. To be noted, in particular, in the analysis of the trends is the plateauing of yield growth rates as well as the differential yield increases across countries in the region. Section III, presents the TFP estimates particularly for the three commodities in 1980–2010.<sup>3</sup> Subregional TFPs by commodity were estimated by decade over the said period. Country TFPs by commodity were estimated only for 1980–2010. This same section identifies the factors that contribute to the TFP estimates based on strong evidence from past studies. Also discussed are the possible sources of future productivity growth. The last section of the paper presents and discusses broad policy recommendations to help achieve further productivity growth.

## II. PRODUCTION GROWTH: CONTRIBUTION OF AREA AND YIELD

Agricultural production in Asia and the Pacific has been remarkable despite its limited arable land. The region's gross agricultural production index increased by more than fivefold, from 23% in 1961 to 116% in 2010, representing an average growth rate of about 4% per annum (FAOSTAT). This growth rate was contributed by cereals, mainly rice and wheat in Asia and the Pacific, at an average rate of around 2.5% per annum. However, in the past 2 decades from the 1990s, challenges have emerged that are affecting this remarkable performance.

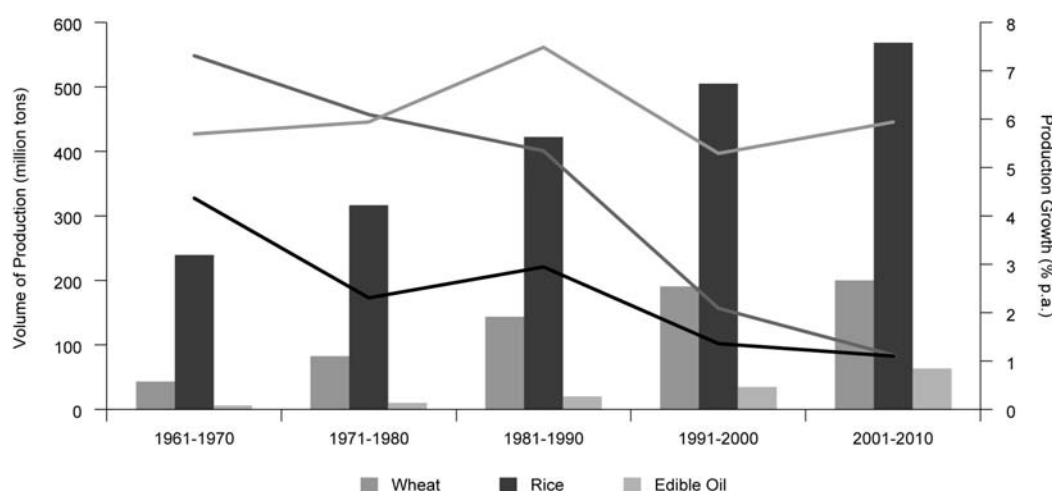
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<sup>3</sup> The discussion on production trends goes as far back as the 1960s. The TFP discussion, however, begins only with 1980 because of data limitations.

## A. Production Performance of Rice and Wheat

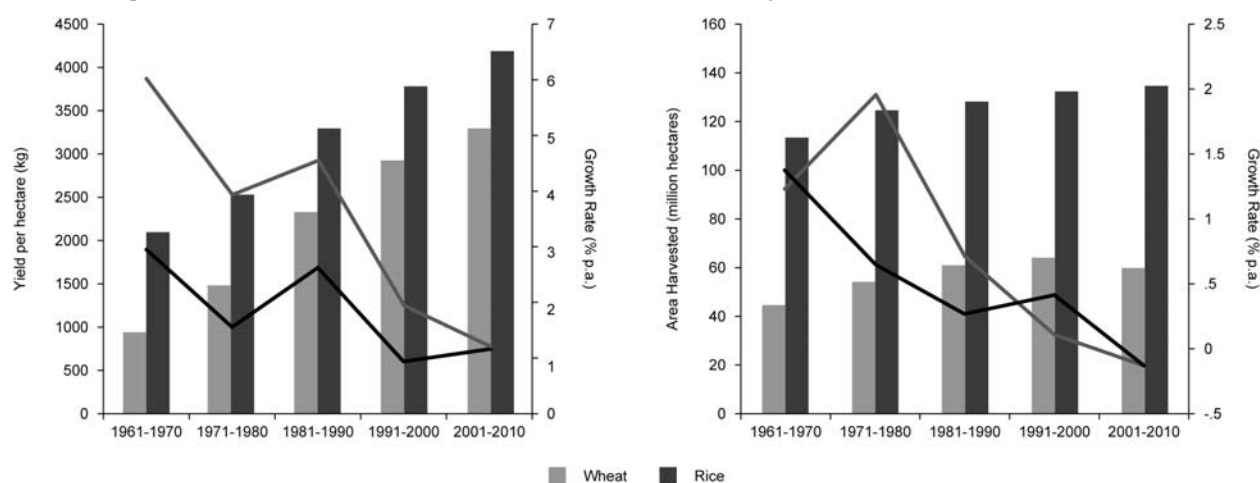
In the past 50 years, the production of paddy rice and wheat in Asia and the Pacific steadily expanded, but at a decreasing rate (Figure 2). The aggregate volume of paddy rice production doubled from an average level of 239 million tons in 1961–1970 to 568 million tons in 2001–2010, but at an annual growth rate that slowed down from 4.3% to 1.1% during the same period. Similarly, wheat production in the region increased almost fivefold from a relatively low average level of 43 million tons in 1961–1970 to a stunning 200 million tons in 2001–2010. Wheat production growth nonetheless slowed down more drastically, from an average annual rate of 7.3% in 1961–1970 to only 1.1% per annum in 2001–2010.

**Figure 2: Production of Paddy Rice, Wheat, and Edible Oils in Asia and the Pacific, 1961–2010**

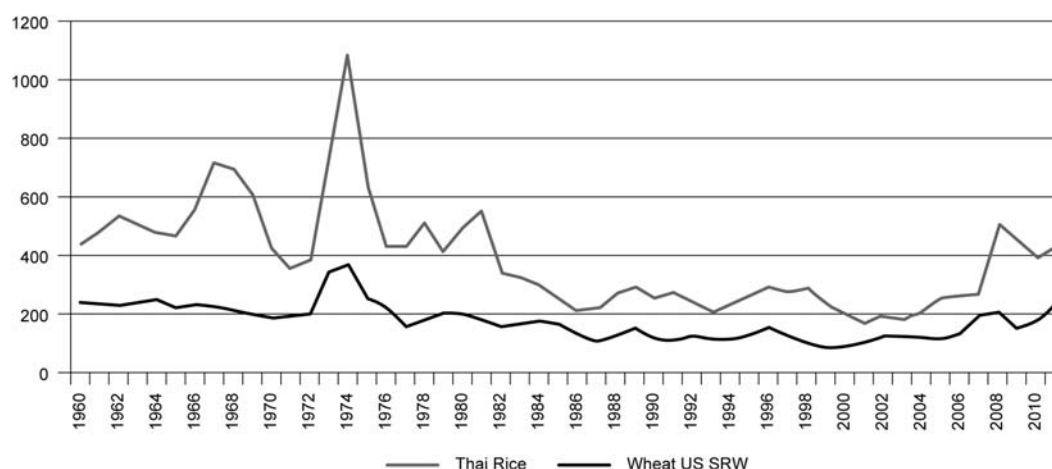


Source: Food and Agriculture Organization of the United Nations Statistical Database (FAOSTAT). <http://faostat.fao.org/DesktopModules/Admin/Logon.aspx?tabID=0> (accessed June 2012).

The sluggish growth in paddy rice and wheat production from the late 1980s was primarily attributed to the drastic decline in yield growth as the impact of Green Revolution technology began to wane. This trend is clear in Figure 3, which shows the drastic reduction in the average yearly yield growth rates: paddy rice from 3.34% in 1961–1970 to 1.27% in 2001–2010, and wheat from 6.01% in 1961–1970 to 1.21% in 2001–2010 (see also Appendix Tables 1 and 2). The Green Revolution—which involved the development and diffusion of high-yielding varieties (HYVs) of rice and wheat, and was accompanied by the increased use of inputs, particularly irrigation, fertilizers, and machineries—triggered agricultural growth in most of Asia and the Pacific from the mid-1960s, with the shift in the source of growth from area expansion to yield increases. In fact, area expansion never became a big source of production growth henceforth, with its annual growth rate diminishing over time. In the past decade, area was shown to have even contracted, with the annual growth rate estimate at -0.10% for paddy rice and -0.12% for wheat (see also Appendix Tables 1 and 2).

**Figure 3: Yield and Area Growth Trends of Paddy Rice and Wheat, 1961–2010**

Source: Food and Agriculture Organization of the United Nations Statistical Database (FAOSTAT). <http://faostat.fao.org/DesktopModules/Admin/Logon.aspx?tabID=0> (accessed June 2012).

**Figure 4: World Price Trends of Milled Rice and Wheat, 1960–2011**  
(\$ per ton, constant 2000 prices)

SRW = soft red winter, US = United States.

Source: World Bank Commodity Price Data ([http://econ.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTDEC\\_PROSPECTS/0,,contentMDK:21574907~menuPK:7859231~pagePK:64165401~piPK:64165026~theSitePK:476883,00.html](http://econ.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTDEC_PROSPECTS/0,,contentMDK:21574907~menuPK:7859231~pagePK:64165401~piPK:64165026~theSitePK:476883,00.html))

It should be pointed out that the expansion of cereal production—in particular, paddy rice for the region—was accompanied by a long-term decline in prices especially from 1973, when rice production recovered from the impact of severe drought that affected most of Asia (Figure 4). The decline in the world price of rice was as much as 83%, while that for wheat, as much as 64%, between 1974 and 2003.

The uptrend starting 2004 was due to the tightening of the rice and wheat supply as stocks were increasingly drawn to uses other than food, such as animal feed and feedstock for biofuel production. The policy-driven price increase that peaked in 2008 was due to major

producers and exporters holding on to their domestic production as speculation of a food crisis mounted. This was the combined effect of several abnormal events, including the financial crisis in the United States (US) and other developed countries, the rise of oil prices that affected the use of fertilizer and farm machineries, Thailand's pledging policy (Sombilla et al. 2011), and the production shortfalls in key grain-producing countries, which were alleged to be severe.

## 1. Subregional Production Trends in Rice

Table 1 shows the subregional trends in rice production, which clearly indicates the dominance of East Asia with its volume of production almost doubling from 110 million tons in the 1960s to about 209 million tons in 2001–2010. The subregion's average share over the period was 46%, decreasing from 50.7% in the 1960s to 36.5% in 2001–2010. Its production trend mimics that of the PRC, which accounts for the bulk of production, as can be gleaned from Appendix Table 1. Rice production in the PRC increased from 110 million tons in 1961–1970 to 201.2 million tons in 2001–2010, but with growth rates that declined to almost nil in the latter period. The expansion of the area harvested to rice in the 1960s and 1970s accounted for the production increases during those periods (Appendix Table 2). Yield growth subsequently took over as the key source of growth with the advent of Green Revolution technology in the mid-1960s. As yield levels increased more than twofold from 2.9 tons per hectare (t/ha) in the 1960s to 6.3 t/ha in 2001–2010 (Appendix Table 3), the area harvested to rice continued to contract to its 2001–2010 level of 29 million hectares (ha).

**Table 1: Subregional Rice Production Trends, 1961–1970 to 2001–2010**

Area Harvested (million hectares), Share to Asia Pacific									
	1961–1970	% Share	1971–1980	% Share	1981–1990	% Share	1991–2000	% Share	2001–2010
East Asia	34.6	30.4	39.6	31.7	36.7	28.7	34.6	26.1	31.7
Southeast Asia	30.4	26.7	32.6	26.1	35.8	28.0	40.0	30.1	45.3
South Asia	48.6	42.8	52.5	42.1	55.4	43.3	58.1	43.8	58.2
Pacific Islands	0.0	0.010	0.0	0.009	0.0	0.010	0.0	0.007	0.0
Asia Pacific	113.6	100.0	124.7	100.0	128.0	100.0	132.8	100.0	135.2

Paddy Yield (tons per hectare)					
	1961–1970	1971–1980	1981–1990	1991–2000	2001–2010
East Asia	3.2	3.9	5.3	6.1	6.4
Southeast Asia	1.7	2.1	2.8	3.3	3.9
South Asia	1.6	1.8	2.3	2.8	3.3
Pacific Islands	1.9	2.2	2.3	2.4	2.6
Asia Pacific	1.9	2.4	3.1	3.7	4.1

Paddy Production (thousand tons), Share to Asia Pacific									
	1961–1970	% Share	1971–1980	% Share	1981–1990	% Share	1991–2000	% Share	2001–2010
East Asia	109,998.9	50.7	152,626.3	51.8	194,485.4	48.5	210,284.9	43.3	201,208.8
Southeast Asia	52,477.5	24.2	69,117.8	23.5	101,752.6	25.4	131,900.8	27.1	176,782.4
South Asia	76,366.3	35.2	94,948.1	32.2	126,074.0	31.4	62,985.5	33.5	190,050.6
Pacific Islands	20.7	0.010	24.6	0.008	30.2	0.008	21.4	0.004	16.9
Asia Pacific	216,749.2	100.0	294,668.0	100.0	401,161.8	100.0	485,869.4	100.0	550,687.9

Source: Food and Agriculture Organization of the United Nations Statistical Database (FAOSTAT). <http://faostat.fao.org/site/339/default.aspx> (accessed June 2012).

The PRC was among the first countries to adopt the Green Revolution technology, which spread quickly to its rice farms. The technology improved crop management and enabled farmers to cultivate three rice crop cycles, especially in the more favorable farm areas. Yield growth rate reached 5.8% per annum in the 1960s, and continued to grow in the 1970s at the rate of 2.0% per annum and in the 1980s at 3.4% per annum, with the development and use of

hybrid rice from 1976 (Yuan 2002). The yield growth slowdown from the 1990s, which is also noted in other countries, was due to a number of reasons, foremost of which is the gradual exhaustion of the potential of HYVs. Other reasons include the degradation of soil and the depletion of water resources, especially in the irrigated areas where Green Revolution technology has been most effective (Lal 2002). On the economic side, changes in rice farming systems where cropping intensities were reduced from 300% to 200% contributed to the production slowdown. The relatively low price of rice resulted in farm returns that have become increasingly insufficient to cover the cost of inputs as well as the effort and time consumed in rice farming.

Southeast Asia's share in the region's total rice production over the period 1961–2010 was around 26%, increasing from slightly less than a quarter in the 1960s to almost a third in 2001–2010. The subregion's production growth also slowed down, but not as drastically as in the case of East Asia. This was because most Southeast Asian countries continued to hold rice in high regard and to aim for self-sufficiency in the commodity. However, they did not adopt and use Green Revolution technology simultaneously. The early adopters included Indonesia, Malaysia, and the Philippines. The rest of the Southeast Asian countries including Cambodia, the Lao People's Democratic Republic (Lao PDR), Viet Nam, and most recently Myanmar, intensified the adoption of the technology some years later with the resolution of their respective domestic and border conflicts, and through greater political stability.

Indonesia, the biggest rice producer in Southeast Asia, accounted for about 14.3 million tons (27%) of the subregion's production in the 1960s and 56.5 million tons (close to a third) in 2001–2010. Like other countries that adopted Green Revolution technology, Indonesia's phenomenal production growth started in 1968, when its yield levels gradually rose and accelerated in the 1970s to reach almost 4 t/ha in the late 1980s, more than double the yield of 1.9 t/ha in the 1960s. Yield levels continued to rise, but at rates that were much slower than those experienced during the early years of the Green Revolution. The higher yield growth in 2001–2010 was triggered by the food crisis in 2008–2009, which revived government support to strengthen the sector. The same production trends took place in Malaysia and the Philippines, although production levels were much lower because of much smaller rice-harvested areas.

Thailand has not only been a major producer but also an exporter of rice. It ranks second to Indonesia in terms of its share to the subregion's total rice production. Thailand's production increased almost threefold, from 12.1 million tons in the 1960s to 30.1 million tons in 2001–2010, primarily as a result of area expansion. Yield increases were not as dramatic as in other countries because Green Revolution technology was not very applicable in rainfed areas that constitute a large portion of the country's rice-growing areas. In these areas, low-yielding but high-quality traditional varieties of rice are cultivated, most of which are exported.

Rice production in the other countries of the Greater Mekong Subregion—namely, Cambodia, the Lao PDR, Myanmar, and Viet Nam—has similarly been on the rise, from area expansion in the 1960s and 1970s, and from huge yield increases that began in the 1980s (Appendix Tables 1 to 3). Among these countries, the most phenomenal performance has been by Viet Nam, with its yield growth averaging around 3% over 3 decades from the 1980s. This enabled the country to regain its position as a major net exporter of rice from the 1990s. Cambodia's sustained high production growth throughout the study period resulted from both area expansion and yield improvement. The development and expansion of irrigated rice areas, which began in the 1980s, enabled the country to cultivate two rice crop varieties per year, thereby raising yield growth rates to average more than 4% per year from the 1990s. Myanmar's rice production potential is still to be fully tapped. The country has performed well, with

production growth mainly from area expansion, with land resources that are still very much available. Yield growth has also been remarkable at slightly more than 2% in 2001–2010.

South Asia ranks second to East Asia in terms of its share to the region's production. As can be noted from Table 1, South Asia's share has been almost stable, declining only slightly from its 35% share in the 1960s to a 34% share in 2001–2010. Bangladesh, India, and Sri Lanka are the major rice producers, accounting for about 95% of the subregion's production (Appendix Table 1). Yield growth has accounted for most of the increase in production especially from the early 1980s, when Green Revolution technology started to be more widely adopted. The relatively slow uptake of the technology in South Asia as compared to East and Southeast Asia was partly due to the poor state of infrastructure, particularly their transport system. The area harvested is shown to have gradually declined, except in Sri Lanka, where area expansion posted a 3.6% annual growth rate in 2001–2010.

Rice production is very negligible in the Pacific Islands. Rice is cultivated mostly in Fiji, Papua New Guinea, and the Solomon Islands, where areas harvested to the commodity have been rapidly declining. Moreover, yields in these islands have been low, reaching only 2.6 t/ha in 2001–2010.

## **2. Subregional Production Trends of Wheat**

Table 2 shows the subregional production performance of wheat from 1961 to 2010. The country level performances are also shown in Appendix Tables 1 to 3. Unlike rice, wheat is not grown in all countries of Asia. It is grown extensively only in East Asia and South Asia, except in Sri Lanka. In Southeast Asia, Myanmar is the only country where the commodity is grown, but on a limited scale. However, in the countries where wheat is more extensively grown, production increased fourfold in East Asia and fivefold in South Asia. Yield levels in these subregions reached an average of 3.3 t/ha in 2001–2010, but are still lower in comparison to those achieved in other regions that averaged more than 5 t/ha. As with rice, wheat production growth in the region significantly slowed down in the past 2 decades, while demand for the commodity strengthened because of rising incomes and changing diets.

East Asia accounts for about 55% of wheat production in the region. This percentage share has declined from about 57% in the 1960s to about 51% in 2001–2010, primarily due to dwindling production in Japan and the Republic of Korea. The PRC has made up the decline in these countries, with its wheat production expanding from a mere 23.3 million tons in 1961–1970 to 102.1 million tons in 2001–2010. The remaining 45% of the region's total wheat production was accounted for by South Asia, mainly India, averaging 75% of the subregion's production. Pakistan accounted for 22% of the subregion's production.

It can be noted from Appendix Tables 1 to 3 that yield growth immediately became the major source of production increases in the 1960s with the rapid adoption and use of Green Revolution technology, especially in the rice–wheat areas across Northern Pakistan and India, from the Indus irrigation area in Sindh and Punjab, across the Indo-Gangetic Plain to the northeast of Bangladesh. Yield growth rates averaged about 4.9% per annum from 1960–1970 to 1981–1990, but then slowed down to 1.6% per annum in the 1990s and 2001–2010. The intensification of cropping in the wheat–rice areas has also resulted in the apparent degradation of the resource base in the form of salinization, over-exploitation of ground water, deterioration in soil physical and chemical properties, and pest and disease problems (Fujisaka, Harrington, and Hobbs 1994; Siddiq 1994).

**Table 2: Subregional Wheat Production Trends, 1961–1970 to 2001–2010**

	Area Harvested (million hectares), Share to Asia Pacific									
	1961-1970	% Share	1971-1980	% Share	1981-1990	% Share	1991-2000	% Share	2001-2010	% Share
East Asia	25.3	56.3	27.9	50.9	29.4	48.0	29.6	45.7	23.7	39.2
Southeast Asia	0.1	0.2	0.1	0.1	0.1	0.2	0.1	0.2	0.1	0.2
South Asia	19.6	43.5	26.8	49.0	31.8	51.8	35.1	54.1	36.6	60.6
Pacific Islands	0.0	0.00009	0.0	0.0009	0.0	0.00040	0.0	0.00012	0.0	0.00002
Asia Pacific	45.0	100.0	54.7	100.0	61.4	100.0	64.8	100.0	60.3	100.0

	Yield (tons per hectare)				
	1961-1970	1971-1980	1981-1990	1991-2000	2001-2010
East Asia	1.0	1.6	2.9	3.6	4.3
Southeast Asia	5.3	7.1	13.8	9.6	15.4
South Asia	0.9	1.4	1.9	2.4	2.6
Pacific Islands	2.6	2.2	1.3	1.9	1.5
Asia Pacific	1.0	1.5	2.3	2.9	3.3

	Production (thousand tons), Share to Asia Pacific									
	1961-1970	% Share	1971-1980	% Share	1981-1990	% Share	1991-2000	% Share	2001-2010	% Share
East Asia	24,618.1	57.1	45,748.0	55.5	84,216.5	58.7	106,865.6	56.2	102,867.9	51.4
Southeast Asia	45.4	0.1	54.1	0.1	158.5	0.1	107.9	0.1	146.3	0.1
South Asia	18,458.5	42.8	36,699.3	44.5	59,021.2	41.2	83,242.6	43.8	96,959.5	48.5
Pacific Islands	0.1	0.0	0.1	0.0	0.3	0.0	0.1	0.0	0.0	0.0
Asia Pacific	43,122.1	100.0	82,501.5	100.0	143,396.6	100.0	190,216.3	100.0	199,973.8	100.0

Source: Food and Agriculture Organization of the United Nations Statistical Database (FAOSTAT). <http://faostat.fao.org/site/339/default.aspx> (accessed June 2012).

The PRC's yield levels increased from 0.94 t/ha in the 1960s to 4.3 t/ha in 2001–2010. Yield growth rates in the country averaged close to 7% per annum from the 1960s to 1980s and drastically decreased to about 2% in the 2 decades that followed. India's yield was almost the same as that of the PRC in the 1960s at 0.93 t/ha, but improvements were much slower with its highest yield level averaging only 2.7 t/ha in 2001–2010. India's yield growth averaged 3.7% per annum from the 1960s to the 1980s, and declined to 1.5% in the following decades. In Myanmar, wheat is grown mostly in the Sagaing Division and Shan State. The recorded growth performance of Myanmar should be taken with caution, however. A rectification of the county's statistics is underway.

## **B. Production Performance of Edible Oil**

Edible oil production in Asia and the Pacific increased more than elevenfold from an average level of 5.77 million tons in the 1960s to an average level of 63.4 million tons in 2001–2010 (Table 3). South Asia initially accounted for about 50% of the Asia and Pacific region's edible oil production in the 1960s, but its production increased only threefold over 50 years. It was gradually taken over by Southeast Asia from the 1970s to 2001–2010, when the subregion's production expanded from 1.4 million tons in the 1960s to 38.3 million tons in 2001–2010. In East Asia, edible oil production went up from 1.9 million tons in the 1960s to about 17.0 million tons in 2001–2010. Key edible oils produced in this subregion are palm oil, rape seed oil, and soybean oil. Produced in much smaller volumes are coconut oil, cottonseed oil, and groundnut oil.



**Table 3: Edible Oil Production (million tons) and Yield Growth (%), 1971–1980 to 2001–2010**

	East Asia	Southeast Asia	South Asia	Pacific Islands	TOTAL Asia and the Pacific
1961–1970	1.87	1.35	2.50	0.05	5.77
1971–1980	2.95	3.79	2.97	0.10	9.82
<i>Yield growth</i>	<i>1.14</i>	<i>2.08</i>	<i>0.26</i>	<i>3.85</i>	<i>1.83</i>
1981–1990	6.10	9.15	4.31	0.22	19.78
<i>Yield growth</i>	<i>3.44</i>	<i>2.73</i>	<i>3.98</i>	<i>−0.09</i>	<i>2.51</i>
1991–2000	9.74	18.01	6.45	0.37	34.57
<i>Yield growth</i>	<i>2.26</i>	<i>1.90</i>	<i>1.33</i>	<i>0.35</i>	<i>1.46</i>
2001–2010	16.99	38.27	7.56	0.55	63.37
<i>Yield growth</i>	<i>1.42</i>	<i>3.56</i>	<i>2.32</i>	<i>1.33</i>	<i>2.16</i>

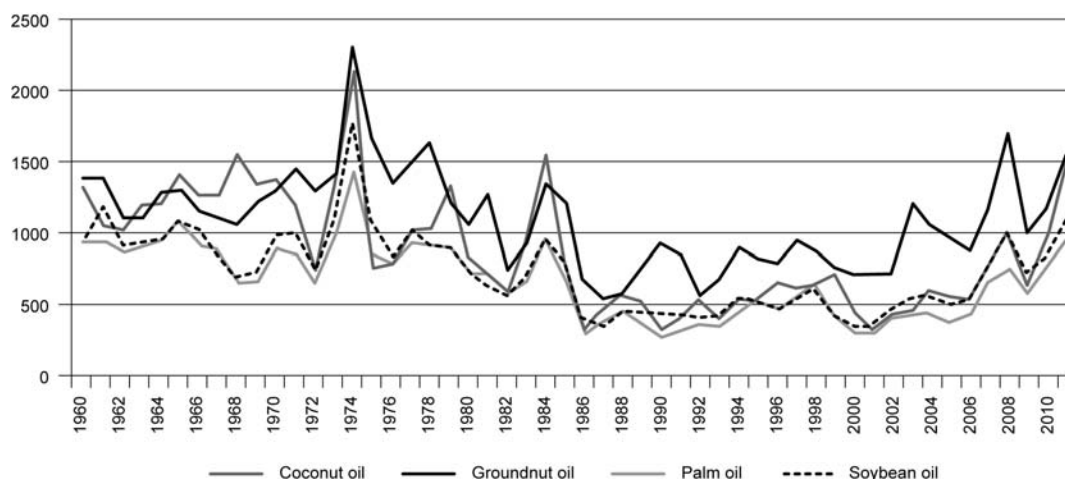
Note: Edible oils include coconut (copra), cottonseed, groundnut, linseed, olive (virgin), palm kernel, palm, rapeseed, safflower, sesame, soybean, and sunflower oils.

Source: Food and Agriculture Organization of the United Nations Statistical Database (FAOSTAT). <http://faostat.fao.org/site/339/default.aspx> (accessed June 2012).

The surge in the production of edible oil was driven primarily by the surge in the demand for food use—still more than 80% of edible oil use—and industrial uses that catapulted in the last 2 decades with the emergence of new applications, such as biofuels. This expansion was contributed primarily by yield growth, which expanded at 1.97% per annum over 1971–2010 in South Asia, from 0.26% per annum in 1971–1980 to 2.32% per annum in 2001–2010; and 2.57% per annum over 1971–2010 in Southeast Asia, from 2.08% per annum in 1971–1980 to 3.56% per annum in 2001–2010. Strong yield growth was also exhibited by the countries in both subregions (Appendix Table 4). It is only in East Asia where annual yield growth slowed down; hence, the huge edible oil imports in the subregion. This yield growth as well as the huge oil imports are primarily the PRC's. The reinvigorated demand also explains the edible oil price trend shown in Figure 5.

Table 4 indicates the importance of Asia and the Pacific in the world edible oil market. The region accounted for about 53% of the world's total edible oil production in 2010 (FAOSTAT). In fact, four countries in the region—the PRC, India, Indonesia, and Malaysia—already account for 47% of the world's production. India's rapeseed oil production in 2010 was 10% of the world's production, an increase from about 0.4 million tons in the 1960s to about 2.0 million tons in 2001–2010 (Table 4). On the other hand, Indonesia and Malaysia produce about 85% of the world's palm oil, most of which is exported. The PRC produces 24% of the world's total production of rapeseed oil, and 23% of soybean oil. The PRC is a major importer of palm, soybean, and rapeseed oils; India, of palm and soybean oils; and Pakistan, of palm oil.

**Figure 5: World Price Trends of Edible Oil, 1960–2011**  
(\$ per ton, constant 2000 prices)



Source: Food and Agriculture Organization of the United Nations (FAO) Food Price Index. <http://www.fao.org/worldfoodsituation/wfs-home/foodpricesindex/en/> (accessed June 2012).

**Table 4: Share of Major Edible Oil Producers in Asia and the Pacific to World Edible Oil Production**  
(tons)

	Total Oil	Palm Oil	Rapeseed Oil	Soybean Oil	Others
<b>World</b>	<b>146,196,016</b>	<b>45,097,422</b>	<b>22,527,177</b>	<b>39,761,852</b>	<b>38,809,565</b>
People's Republic of China	19,213,251	245,400	5,320,500	9,069,800	4,577,551
Share to total (%)	13.1	0.5	23.6	22.8	11.8
India	5,800,600	—	2,284,000	1,349,300	2,167,300
Share to total (%)	4.0	—	10.1	3.4	5.6
Indonesia	25,158,066	21,534,000	—	365,539	3,258,527
Share to total (%)	17.2	47.7	—	0.9	8.4
Malaysia	19,167,931	16,993,000	110,731	—	2,064,200
Share to total (%)	13.1	37.7	0.5	—	5.3

— = no data.

Source: Food and Agriculture Organization of the United Nations Statistical Database (FAOSTAT). <http://faostat.fao.org/site/339/default.aspx> (accessed June 2012).

### III. TOTAL FACTOR PRODUCTIVITY AND SOURCES OF FUTURE PRODUCTION GROWTH

As land and other resources become scarcer, production growth increasingly has to depend on yield improvements. Two things have been observed, however, in relation to yield trends especially after the Green Revolution. One is the slowdown in yield growth rates, which creates apprehension about where future production growth would be generated. The other observation is the widening of yield gaps across countries, which could not be explained by mere geophysical or climatic differences. For example, yields of wheat in India during the post-Green Revolution period were nearly double those in Pakistan, although they started at the same level

in the 1960s (Murgai, Ali, and Byerlee 2001). Similarly, Indonesia's rice yield increases have outstripped those of Malaysia and the Philippines despite their having almost the same geographic and climatic features. Identifying the sources of these differential productivity gains could help identify the appropriate interventions towards more sustainable growth.

Productivity gains from sources other than conventional inputs like land, water, and labor are measured through TFP. TFP analysis involves the comparison of an index of output changes with an index of input changes, so that the residual growth of productivity is attributed to technological progress. Technological progress, on the other hand, is made possible by various other inputs including agricultural research and development; extension service; human capital development such as training and education; changes in the quality of inputs; and changes in the physical, economic, and policy environment (Evenson and Pray 1991; Alston, Norton, and Pardey 1995; Ahearn et al. 1998; and Sombilla 2011).

In this section, TFP is estimated and compared across subregions and a number of countries in Asia and the Pacific, particularly for the three commodities in focus.

#### **A. Analytical Approach and Data Use**

An econometric model of the aggregate production function is used to estimate TFP. The econometric model assumes that the production function takes the form of the Cobb–Douglas production function, a commonly used model for estimating TFP (Felipe 1997). The model takes the form of an exponential time trend,

$$Q_t = e^{rt} K_t^\beta L_t^\alpha \varepsilon_t$$

Taking the natural logarithm we have,

$$\log(Q_t) = c + r * t + \alpha \log(L_t) + \beta \log(K_t) + \log(\varepsilon_t)$$

where  $Q_t$  is the total output at time  $t$ .  $L_t$  is the total labor force in the agriculture sector, and  $K_t$  is the total land area used for agriculture. The time shift factor ( $t$ ) proxies the effects of productivity and technical progress.

Due to data limitations, as mentioned earlier, TFP was estimated and analyzed over 3 decades, from 1980 to 2010. This period covers the peak of the second wave of the Green Revolution in the 1980s, when the adoption of the high-yielding rice and wheat varieties further spread to the so-called “late adopting countries,” and the use of modern inputs like fertilizer was intensified not only in the irrigated areas but also in rainfed areas (Byerlee 1992).<sup>4</sup> The decade of the 1990s covers the post-Green Revolution period when investment in agriculture started to slow down, input use primarily on rice and wheat was leveling off, and the degradation of soil and water from intensified cropping was increasingly manifesting in declining or stagnant yield levels (Flinn and De Datta 1984, Greenland 1997, Dawe et al. 2000; Kumar and Yadav 2001). The final decade of the study period can be considered a period of regeneration when governments once again enhanced efforts to reverse productivity trends by augmenting investment in the sector, including investments in research and development, irrigation, and other productivity-enhancing infrastructure facilities and support services.

<sup>4</sup> The 1960s marked the start of the Green Revolution, which peaked in the 1970s. Early adopters of what was known as the first wave of the technology included the PRC, Indonesia, Malaysia, and the Philippines.

The data set is a yearly panel data consisting of 20 countries in the Asia and Pacific region, and is taken from the FAO database from 1971 to 2010. The countries covered are classified according to the subregional groupings, defined as:

- East Asia: the PRC and Mongolia;
- South Asia: Bangladesh, India, Nepal, Pakistan, and Sri Lanka;
- Southeast Asia: Cambodia, Indonesia, the Lao PDR, Malaysia, Myanmar, the Philippines, Thailand, and Viet Nam; and
- Pacific: Fiji, Papua New Guinea, Solomon Islands, Timor-Leste, Vanuatu.

There is a limitation on the data, particularly on input use, which cut the length of the time series covered and used in this study. The decadal TFP estimates by commodity, which reflect the periods of the development of the Green Revolution technology described above, were done only for each subregion and not for each country. The TFP by commodity for the selected countries was therefore estimated only for the whole period of 1980–2010. Second, data on input use is very scanty, and if available, is not allocated by commodity in the FAO Statistical Database (FAOSTAT),<sup>5</sup> the key source of data for this study. Commodity disaggregated input data are available for some countries, but these were not used because of possible problems with their comparability. Third, because the data on many of the production inputs were not readily and easily available, proxy variables were used in the TFP estimation. All these limitations may have resulted in under- or over-estimated TFP values. They nonetheless indicate the innovations that countries can take advantage of—from a better understanding and application of modern science primarily—to effect productivity gains.

## B. TFP Estimation Results

The decadal TFP estimates for rice, wheat, and edible oils shown in Tables 5 to 7 indicate that the slowdown in the growth of crop yields, as reflected in published databases such as the FAOSTAT, does not seem to translate to a general decline in productivity. This is evident at least for rice, where TFP indices have, in fact, even increased over time (Table 5). The observed decline in yield growth after the Green Revolution seemed to be more than offset by TFP improvements except in some countries like the PRC, India, and Viet Nam (Appendix Table 5). TFP estimates for 1980–2010 in India and Viet Nam are negative, while those for the PRC are almost negligible. The other rice-producing countries, particularly Cambodia, the Lao PDR, and Myanmar, exhibited strong TFP growth for the same period. Similarly, Indonesia, the Philippines, and Thailand also exhibited positive TFP improvements.

The picture is different for wheat in the region's key producing areas. Productivity seems to be declining, as seen from the negative TFP estimates in South Asia and East Asia over 1981–2010 (Table 6). The rice–wheat systems in the Punjabs of India and Bangladesh are the largest wheat producers in South Asia. Their negative TFP estimates for the period in focus, as indicated in Appendix Table 5, must have come from the degradation of resources that follow intensification (Murgai, Ali, and Byerlee 2001). The relatively decent wheat production performances of Nepal and Pakistan during the same period have not been strong enough to overcome the general deterioration of wheat productivity.

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<sup>5</sup> FAOSTAT was used as the key source of data to ensure uniformity in definition, particularly of input and output variables across countries, as well as in their units of measurement.

**Table 5: Average TFP (%) in Rice Net Value (\$ '000, constant price)**

Region	1981–2010	1981–1990	1991–2000	2001–2010
Asia–Pacific	1.40	1.27	0.15	2.70
East Asia	0.20	0.84	0.96	2.22
South Asia	2.02	0.08	2.42	3.52
Southeast Asia	1.49	–1.48	1.75	3.10

TFP = total factor productivity.

Source: Authors' estimates based on FAO data.

**Table 6. Average TFP (%) in Wheat Net Value (\$'000, constant price)**

Region	1981–2010	1981–1990	1991–2000	2001–2010
Asia–Pacific	–0.67	4.94	1.39	3.15
East Asia	–2.90	4.69	–5.44	4.44
South Asia	–0.03	5.95	6.12	–7.25
Southeast Asia	5.35	–18.35	3.71	7.56

TFP = total factor productivity.

Source: Authors' estimates based on FAO data.

The TFP estimate of wheat for East Asia for the whole period was also negative following primarily that of the PRC, the major wheat producer in the subregion. The positive TFP estimate for the subregion in 2001–2010, however, could have been contributed by the PRC's rebound in wheat production. Increased rainfall during the autumn and winter months in the northern part of the country provided better conditions for wheat growth, such that the growth rate went up to 1.59% per annum during the period as compared to the 0.45% per annum growth rate in 1991–2000.

Likewise, the TFP estimates for edible oil are not encouraging (Table 7). Those of Malaysia and India are negative, while Indonesia's is positive but small (Appendix Table 5). The PRC's TFP estimate for 1981–2000 was at 1.95%. These are the key edible oil producers in the region. The potential for edible oil production increases is shown by Nepal (rapeseed), Sri Lanka (coconut oil), Cambodia (coconut, groundnut, and soybean), Myanmar (groundnut, sesame, sunflower, and soybean), and the Philippines (coconut).

The differential embrace by governments of the components of Green Revolution technology through their investments in modern seed adoption, fertilizer use, irrigation (including shallow tube wells), and other infrastructure facilities (e.g., roads and bridges), research and development (R&D) and extension, and training and other forms of human capacity development, are deemed to have accounted for the differential rise in yield levels and TFP improvements. Many of these investments were infused in the 1990s, enabling countries to accumulate significant capital that is being fully utilized now. Investments made by the early Green Revolution adopters like the PRC, Indonesia, India, Pakistan, and the Philippines may have reached their peak potential, while the late adopters are still benefiting from them. The differential development and use of the key production inputs by country are presented and analyzed in the subsequent sections, especially in relation to the TFP estimates. While the influence of these sources of growth on the TFP estimates was not tested empirically in this study because of data limitations, evidence of their relationship was clear and strong in

numerous TFP studies done for the agriculture sector as a whole, and for rice and wheat in various countries, including Asian countries (Fuglie 2010; Murgai, Ali, and Byerlee 2001; Llanto 2012; Fan et al. 2011).

**Table 7: Average TFP (%) in Edible Oil Net Value (\$'000, constant price)**

Region	1981–2010	1981–1990	1991–2000	2001–2010
Asia and the Pacific	–0.67	4.94	–0.39	3.15
East Asia	–2.90	4.69	–5.44	4.44
South Asia	–0.03	5.95	6.12	–7.25
Southeast Asia	5.35	–18.35	3.71	7.56
Pacific	–0.65	–3.69	0.48	2.08

TFP = total factor productivity.

Source: Authors' estimates based on data from the Food and Agriculture Organization of the United Nations (FAO).

### C. Sources of TFP Improvements and Differential Productivity Gains

**Irrigation Development and Consequences.** The development of irrigation facilities made water more available and accessible for production. These facilities were initially large-scale surface irrigation facilities developed prior to 1980, and subsequently, tube wells and ground water irrigation systems. The latest figures from the FAO indicate that an average of 37% of land under cultivation in Asia is irrigated (FAO 2012). By country, the percentage of cultivated land with irrigation is as follows: Malaysia, 70%; the PRC, 67%; India, 56%; Bangladesh, 47%; Viet Nam, 46%; Thailand, 33%; Cambodia, 20%; and the Lao PDR, 19% (FAO AQUASTAT). Cultivated land under irrigation in other tropical countries of South Asia and the Pacific islands average between 20% and 25%. The figures indicate that many countries are still dependent on rainfall for water. For example, despite the huge river deltas in Cambodia, Myanmar, Thailand, and Viet Nam, rice cultivation in these countries remains extensive with large areas under rainfed lowland or deep water cultivation. Viet Nam has moved into the second stage of developing its delta areas with an increased share of irrigation and better control of water, which has resulted in a higher yield level. In Myanmar, irrigation development, mostly in the form of pumps, expanded rapidly only in the late 1990s. This resulted in the expansion of sown area in the Ayeyarwady Delta.

The extent and type of irrigation systems have influenced cropping intensities that vary across countries, as shown in Table 8. Countries with relatively high cropping intensities are those with high percentages of cultivated area under irrigation. These include the PRC, India, Indonesia, and Viet Nam. Crop intensification has accounted for the differential rate of productivity growth especially among countries from an almost homogenous environment, e.g., India and Pakistan; Cambodia, the Lao PDR, Myanmar, and Viet Nam; and Indonesia and the Philippines.

**Table 8: Cropping Intensity: Total Area of Irrigated Crops as Percentage of Area Equipped for Irrigation**

Country	Cropping Intensity	Year
Bangladesh	118.4	2008
Cambodia	108.7	2006
People's Republic of China (PRC)*	212.2	2006
India	131.5	2008
Indonesia	199.2	2005
Lao People's Democratic Republic (Lao PDR)	119.9	2005
Myanmar	77.4	2000
Nepal	104.5	2002
Pakistan	111.3	2008
Philippines	143.5	2006
Sri Lanka	130.5	2006
Thailand	115.2	2007
Viet Nam	190.4	2005

\* For the PRC, cropping intensity is estimated as percentage of harvested area to cereals and coarse grains to total irrigated area.

Source: Food and Agriculture Organization of the United Nations (FAO) AQUASTAT. <http://www.fao.org/nr/water/aquastat/data/query/index.html> (accessed August 2012).

It should be noted, however, that countries with high cropping intensities have experienced severe degradation of their irrigation areas in the form of salinization, over-exploitation of groundwater, deterioration in soil physical and chemical properties, and pest and disease problems. The degradation of soil has been the result of poor farm management practices, including the excessive and imbalanced use of fertilizer and other chemical inputs (Fujisaka, Harrington, and Hobbs 1994). As will be shown in the subsequent section, countries that have a high cropping intensity—the PRC, India, Indonesia, and Viet Nam—are the same countries that have exhibited not only high rates of fertilizer application but also imbalanced use of the input. The degradation of these resources has affected yield performance and has contributed to the negative (in most countries for wheat; in India and Viet Nam for rice) or low (the PRC, Indonesia, and Pakistan for rice) TFP estimates (Lal 2002).

**Fertilizer Application.** Table 9 shows the rates of fertilizer application across different regions, with Asia at a relatively high level compared to other developing regions and even the world average. The rates of fertilizer application per hectare across Asia in 2007–2008 are varied (Table 10). Many countries like the PRC, India (especially in the Punjab), Pakistan (for wheat), and Viet Nam (for rice), far exceeded the world average. Countries like Cambodia, Myanmar, and the South Asian countries have rates of fertilizer use that are still below the recommended level. The intensity of fertilizer consumption also varies within a country itself. In India, different states have exhibited fertilizer use ranging from 40 kilograms per hectare (kg/ha) of total nutrients in Rajasthan to 184 kg/ha in Punjab (FAO 2006). Despite the higher levels of fertilizer use in the rice–wheat systems of the Indo-Gangetic Plains, the recommended levels of use have never been followed.

**Table 9: Regional Fertilizer Rates for Wheat and Rice by Region**

Regions	Wheat	Rice
North America	84	184
Latin America	76	90
West Europe	213	279
Eastern Europe	95	—
Former Soviet Union	25	107
Africa	63	19
Asia	144	140
Oceania*	—	—
World	116	112

— = no data.

\* Australia's figures are grouped for cereals.

Note: Fertilizer rate here is nitrogen, phosphorus oxide, and potassium oxide in kilograms per hectare.

Source: Table 14 in *Fertilizer Use by Crop*, FAO 2006.

Studies have shown that the continued use of fertilizers in countries that have exhibited high rates of fertilizer application would only result in low returns at the margin, especially when this has affected soil fertility (Byerlee 1992). This explains the possible small contribution of fertilizer to productivity levels in the PRC, India, Pakistan, and Viet Nam, which have been heavy users of the input. Increasing the rate of fertilizer application in countries with low rates of fertilizer use, on the other hand, like Cambodia, the Lao PDR, and Myanmar in Southeast Asia, and Nepal and Sri Lanka in South Asia, could result in productivity gains.

Rice accounts for more than 50.8% of total fertilizer use in Southeast Asia. In South Asia, it is about 32% of the total, while wheat is around 22%. The share of fertilizer use in both rice and wheat in East Asia is more than 50% of total fertilizer use.

**Labor Use.** Labor is also a critical factor to crop production, especially in high-intensity rice farms. In India, wet paddy rice requires approximately 125 days per ha, while dry wheat production takes somewhere between 33 and 47 days per ha. In the PRC, farmers take roughly 12–25 days of work per *mu*<sup>6</sup> planted with rice (i.e., 180–375 days per ha), while they take only 4–10 days of work per *mu* of wheat (i.e., 60–150 days per ha). In the Philippines and Thailand, labor use in rice production has ranged from 80 to 90 person-days per ha, depending on whether the area is rainfed or irrigated. In north Viet Nam, however, labor use in rice production can go as high as 321 person-days per ha.

<sup>6</sup> 1 hectare=15 mu; 1 mu=0.667 hectare.



Table 10: Rates of Fertilizer Use per Hectare of Nutrients, 2007–2008

Countries	Nitrogen						Phosphorus						Potassium						Nitrogen + Phosphorus + Potassium									
	Oil Crops			Oil Crops			Oil Crops			Oil Crops			Oil Crops			Oil Crops			Oil Crops									
	Wheat	Rice	Palm Oil	Soy-bean	Peanut	Rape-seed	Wheat	Rice	Palm Oil	Soy-bean	Peanut	Rape-seed	S'flower	Wheat	Rice	Palm Oil	Soy-bean	Peanut	Rape-seed	S'flower	Wheat	Rice	Palm Oil	Soy-bean	Peanut	Rape-seed	S'flower	
Bangladesh	—	104	—	—	—	—	—	15	—	—	—	—	—	—	12	—	—	—	—	—	—	0	131	0	0	0	0	0
Cambodia	—	7	—	—	—	—	—	5	—	—	—	—	—	—	—	—	—	—	—	—	—	0	12	0	0	0	0	0
PRC	182	195	—	51	101	169	108	62	—	41	59	55	27	10	60	—	7	11	14	14	273	317	0	99	171	238	149	
India	110	100	—	17	29	82	—	41	33	—	16	40	25	—	8	21	—	3	17	4	—	159	154	0	36	86	111	0
Indonesia	—	98	80	—	—	—	—	—	9	30	—	—	—	—	—	10	97	—	—	—	—	0	117	207	0	0	0	0
Malaysia	—	138	98	—	—	—	—	73	34	—	—	—	—	—	81	223	—	—	—	—	—	0	292	355	0	0	0	0
Myanmar	—	7	—	—	—	—	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	0	10	0	0	0	0	0
Pakistan	129	104	—	—	—	—	—	25	21	—	—	—	—	—	1	1	—	—	—	—	155	126	0	0	0	0	0	0
Philippines	—	49	—	—	—	—	—	8	—	—	—	—	—	—	3	—	—	—	—	—	—	0	60	0	0	0	0	0
Rep. of Korea	59	127	—	—	—	—	—	17	53	—	52	—	—	22	52	—	34	—	—	—	98	232	0	86	0	0	0	0
Thailand	—	25	—	—	—	—	—	7	—	—	—	—	—	—	1	—	—	—	—	—	—	0	33	0	0	0	0	0
Viet Nam	—	104	—	—	—	—	—	61	—	—	—	—	—	—	—	—	—	—	—	—	—	0	199	0	0	0	0	0
Other Asia	34	88	32	5	42	70	45	13	23	19	17	13	12	6	3	18	43	2	5	6	50	129	94	24	60	88	57	
WORLD	80	101	78	11	37	112	28	29	31	31	33	29	34	14	8	25	137	26	12	22	6	117	157	246	70	78	168	48

— = no data, PRC = People's Republic of China.

Source: Rosas, F. 2011. *World Fertilizer Model—The WorldNPK Model*.

Having sufficient labor for production, however, is becoming more difficult because of the declining availability of labor, as indicated by the economically active agricultural population in Table 11. Two trends are clear from the table: the declining rates of increase of this group; and the shrinking proportion of male agricultural labor to total agricultural labor, in relation to the expanding proportion of their female counterparts particularly in most countries of South Asia, the PRC in East Asia, and Indonesia in Southeast Asia. A key reason for these patterns is the relatively high labor out migration of the more skilled farmers in the rural areas, leaving behind the elderly, the uneducated, and the female members of the household to continue farming (Paris et al. 2009). This emerging trend is affecting the quality of labor that greatly matters if new and more precise agricultural technologies are to be used properly and efficiently. The availability of this type of labor is still scarce in many Asian countries because of the incidence of low literacy rates, with the mean number of years of schooling at just about 50% of the expected length of time. Subsequently, many countries are reported with low human development indices (HDIs) (Table 12). Bangladesh, Cambodia, the Lao PDR, Nepal, and Pakistan are the countries with literacy rates below 70%; with the addition of Myanmar, these countries also exhibited HDIs in the low to bottom medium range. Nonetheless, it can be noted that these countries experienced an average rise in literacy rate of 9 percentage points between 2000 and 2010. They also experienced a rapid improvement in their HDIs over the period 1990–2010. For example, in 2000–2010, HDI growth rates ranged from 1.3% per annum in Nepal to 3.2% per annum in Myanmar.

Countries that reported high literacy rates and which are grouped in the upper medium to high range in HDI include the PRC, Indonesia, the Republic of Korea, Malaysia, the Philippines, Thailand, and Viet Nam. As can be further noted, however, these countries exhibited small improvements in both their literacy rates and HDIs: literacy rates rose an average of slightly over 2 percentage points between 2000 and 2010, while HDI growth rates slowed down to less than 1% per annum in 2000–2010.

Better educated and better skilled labor is likewise going to be needed, as farm mechanization is increasingly being considered given the growing scarcity of labor. Farm mechanization is still in its infancy in many countries, however.

**Mechanization.** Notwithstanding the importance of agricultural mechanization and the acceleration of the use of machinery in the region as a whole in the last few years, vast differences still exist in the levels of machine use among Asian countries. The level of mechanization is low in Bangladesh, Cambodia, Indonesia, Nepal, and Sri Lanka, where the majority of farmers continue to use traditional tools in their production system (Table 13). In contrast, it is high in the PRC, India, and the Republic of Korea, where significant development in agricultural mechanization has been taking place. The gaps in the level of mechanization are indeed huge when you compare the intensity of machine use in Bangladesh, which increased from 0.32 kilowatt per ha (kW/ha) in 1984 to 1.17 kW/ha in 2007 (Islam 2008), with that of the PRC, where the intensity level in 2000 was already 3.36 kW/ha and rose further to 5.26 kW/ha in 2008 (China Statistics Press 2009). On the other hand, the number of agricultural tractors in India increased from 1.1 million in the early 1960s to 13.36 million in 2007 (Kulkarni 2009). It is also evident from Table 13 that not all farm activities are mechanized. Land preparation is highly mechanized, followed by threshing and harvesting. Rice milling is also highly mechanized in most countries in the region.

**Table 11: Economically Active Population in Agriculture, 1980–1989 to 2001–2010 and 2011–2012**

Countries	Economically Active in Agriculture, Total				Economically Active in Agriculture, Male				Economically Active in Agriculture, Female			
	1980–89	1990–99	2000–10	2011–12	1980–89	1990–99	2000–10	2011–12	1980–89	1990–99	2000–10	2011–12
<b>East Asia</b>												
	441,092	506,355	511,847	503,100	236,445	265,696	266,592	262,282	204,647	240,659	245,255	240,818
					54	52	52	52	46	48	48	48
PRC	427,442	495,950	504,682	497,426	229,152	259,938	262,603	259,124	198,291	236,012	242,079	238,301
					54	52	52	52	46	48	48	48
Japan	5,490	3,739	2,011	1,282	2,891	2,057	1,174	769	2,599	1,682	837	513
					53	55	58	60	47	45	42	40
Republic of Korea	4,569	2,903	1,713	1,167	2,450	1,633	959	662	2,119	1,271	754	505
					54	56	56	57	46	44	44	43
<b>South Asia</b>												
	251,376	292,183	334,746	361,183	169,479	194,483	220,496	234,845	81,897	97,700	114,250	126,338
					67	67	66	65	33	33	34	35
Bangladesh	27,392	31,173	32,329	31,911	15,406	17,313	16,840	15,438	11,986	13,861	15,488	16,474
					56	56	52	48	44	44	48	52
India	192,591	224,451	254,885	274,170	130,306	151,142	172,403	185,066	62,285	73,309	82,482	89,104
					68	67	68	68	32	33	32	32
Nepal	5,970	7,462	10,342	12,583	3,759	4,333	5,532	6,489	2,211	3,129	4,810	6,094
					63	58	53	52	37	42	47	48
Pakistan	14,506	16,423	21,552	25,260	12,271	13,106	15,841	17,417	2,234	3,317	5,711	7,844
					85	80	74	69	15	20	26	31
Sri Lanka	3,216	3,518	3,843	4,042	2,109	2,286	2,454	2,532	1,107	1,232	1,389	1,510
					66	65	64	63	34	35	36	37
<b>Southeast Asia</b>												
	105,346	124,594	136,549	140,538	60,530	71,463	78,666	80,959	44,817	53,131	57,863	59,538
					57	57	58	58	43	43	42	42
Cambodia	2,668	3,476	4,547	5,061	1,154	1,570	2,167	2,474	1,515	1,907	2,380	2,587
					43	45	48	49	57	55	52	51
Indonesia	37,135	45,102	49,031	49,466	23,554	27,477	29,874	29,908	13,581	17,626	19,157	19,558
					63	61	61	60	37	39	39	40
Lao PDR	1,292	1,658	2,102	2,452	629	802	1,000	1,174	663	857	1,102	1,278
					49	48	48	48	51	52	52	52
Malaysia	1,983	1,886	1,741	1,571	1,227	1,339	1,331	1,251	756	547	409	320
					62	71	76	80	38	29	24	20
Myanmar	13,032	15,645	17,962	19,054	6,867	8,244	9,414	9,935	6,165	7,401	8,548	9,120
					53	53	52	52	47	47	48	48
Philippines	9,872	11,679	13,019	13,507	7,308	8,849	9,856	10,237	2,565	2,831	3,163	3,271
					74	76	76	76	26	24	24	24
Thailand	19,097	20,386	19,941	18,987	9,815	10,932	10,818	10,473	9,282	9,454	9,122	8,514
					51	54	54	55	49	46	46	45
Timor-Leste	221	257	299	368	124	147	166	203	98	111	133	166
					56	57	55	55	44	43	45	45
Viet Nam	20,029	24,499	27,905	30,071	9,841	12,100	14,036	15,345	10,188	12,398	13,869	14,726
					49	49	50	51	51	51	50	49

PRC = People's Republic of China, Lao PDR = Lao People's Democratic Republic.

Note: Figures in italics are percentages to total.

Source: ADB 2012.

Table 12: Literacy Rates and Human Development Index

	Literacy Rates		Human Development Index (HDI)										
			Human Development Index (level)								HDI Category		
	2000	2010	1980	1990	2000	2005	2009	2010	2011	1980–2011	1990–2011	2000–2011	
Countries													
Republic of Korea	–	–	0.634	0.742	0.830	0.866	0.889	0.894	0.897	Very high	1.13	0.91	0.72
Malaysia	88.7	93.1	0.559	0.631	0.705	0.738	0.752	0.758	0.761	High	1.00	0.90	0.69
Sri Lanka	90.7	91.2	0.539	0.583	0.633	0.662	0.680	0.686	0.691	Medium	0.80	0.81	0.80
People's Rep. of China	90.9	94.3	0.404	0.49	0.588	0.633	0.674	0.682	0.687	Medium	1.73	1.62	1.43
Thailand	92.6	93.5	0.486	0.566	0.626	0.622	0.636	0.641	0.644	Medium	0.51	0.58	0.62
Philippines	92.6	95.4	0.55	0.571	0.602	0.622	0.636	0.641	0.644	Medium	0.51	0.58	0.62
Indonesia	90.4	90.4	0.423	0.481	0.543	0.572	0.607	0.613	0.617	Medium	1.23	1.19	1.17
Viet Nam	90.2	93.2	–	0.435	0.528	0.561	0.584	0.590	0.593	Medium	–	1.50	1.60
India	61.0	62.8	0.344	0.410	0.461	0.504	0.535	0.542	0.547	Medium	1.51	1.38	1.56
Lao People's Democratic Republic	69.6	72.7	–	0.376	0.448	0.484	0.514	0.520	0.524	Medium	–	1.59	1.44
Cambodia	67.3	73.9	–	–	0.438	0.491	0.513	0.518	0.523	Medium	–	–	1.62
Pakistan	42.7	54.9	0.359	0.399	0.436	0.480	0.499	0.503	0.504	Low	1.10	1.12	1.33
Bangladesh	47.5	56.8	0.303	0.352	0.422	0.462	0.491	0.496	0.500	Low	1.63	1.69	1.55
Timor-Leste	37.6	58.3	–	–	0.404	0.448	0.487	0.491	0.495	Low	–	–	1.86
Myanmar	89.9	92.3	0.279	0.298	0.380	0.436	0.474	0.479	0.483	Low	1.78	2.32	3.21
Nepal	48.6	60.3	0.242	0.340	0.398	0.424	0.449	0.455	0.458	Low	2.08	1.43	1.30
Regional													
East Asia and Pacific			0.428	0.498	0.581	0.622	0.658	0.666	0.671		1.46	1.43	1.31
South Asia			0.356	0.418	0.468	0.510	0.538	0.545	0.548		1.40	1.31	1.45
World			0.558	0.594	0.634	0.660	0.676	0.679	0.682		0.65	0.66	0.66

– = no data.

Sources: United Nations Educational, Scientific, and Cultural Organization (UNESCO), Institute for Statistics, <http://www.uis.unesco.org/literacy/Pages/default.aspx>; UN Economic and Social Commission for Asia and the Pacific (UNESCAP), Statistical Yearbook for Asia and the Pacific 2011, <http://www.unescap.org/stat/data/syb2011/>; Human Development Reports, [http://hdr.undp.org/en/media/HDR\\_2011\\_EN\\_Table2.pdf](http://hdr.undp.org/en/media/HDR_2011_EN_Table2.pdf)

**Table 13: Level of Mechanization in Some Asian Countries**

Countries	Farm Activities/Level of Mechanization				Overall	Overall Level of Mechanization
	Land preparation	Planting	Threshing	Harvesting		
Bangladesh	80%	Low	>80%	Low	Low	Low
Cambodia	Low	Low	Low	Low	<10%	Low
People's Republic of China	60%	35%	—	30%	42%	High
India	30%	10%	60%	20%	25%–30%	High
Indonesia	Low	Low	Low	Low	—	Low
Republic of Korea	High	High	High	High	>70%	High
Nepal	—	Low	Low	9 units of combined harvesters	Low	Medium
Philippines	13.20%	0.20%	69%	Low	—	Low
Sri Lanka	Low	Low	Low	Low	Low	Low
Thailand	High	Medium	—	—	Medium	Medium
Viet Nam	72%	20%	100%	—	—	Medium

— = no data.

Source: P. Soni and Y. Ou 2011.

The varying levels of mechanization and the use of different types of equipment in these countries contribute to the differences in productivity and production performance. Moreover, the varying skills of the labor force and their capacity to operate the machines effectively limits the efficient use of such modern input.

**Infrastructure Development.** Several studies have shown that rural infrastructure plays a significant role in improving agricultural productivity especially in developing countries, including those in Asia. The lack or unreliability of such infrastructure could constrain investments of productive capital and lead to a restriction or reduction of output (Llanto 2012). Antle's study (1983) of 47 less developed countries and 19 developed countries confirms the hypothesis that transportation and communication infrastructure contributes to aggregate agricultural productivity in those countries. In a more recent study by Pinstrip-Andersen and Shimokawa (2007), deficiencies in transportation, energy, telecommunications, and related infrastructure were shown to translate into poorly functioning domestic markets that can undermine growth in agricultural output.

Based on the results of past studies, the differential development of infrastructure facilities and services across Asia could have contributed to the differential productivity and production growth. Tables 14 and 15 show the development of transport and communication infrastructures in some Asian countries. In Table 14, we see that while there was marked road construction in some countries such as India, the quality of these roads, in terms of their being paved, deteriorated.

Table 15 clearly shows the rapid development of communication facilities in all countries. Almost all countries had internet services in 2000, albeit at low levels; since then, the expansion of this facility has been so rapid. The development of fixed-wired broadband was much slower. In some countries, subscription to this service was made available only in the latter part of 2000–2010. The data shows that Bangladesh still does not enjoy these services.

**Table 14: Transport Infrastructure Development, Asia**

Area/Country	Road Density (km per 1,000 km <sup>2</sup> land area)				Paved Roads (% of total road length)			
	Year		Year		Year		Year	
Bangladesh	1,509	1996	1,838	2003	8.4	1996	9.5	2003
Cambodia	203	1996	217	2004	7.5	1996	6.3	2004
PRC	359	2005	414	2009	40.8	2005	53.5	2008
India	796	1996	1382	2008	54.7	1996	49.5	2008
Indonesia	186	1996	263	2009	46.3	1996	56.9	2009
Republic of Korea	834	1996	1,083	2009	72.7	1996	79.2	2009
Lao PDR	141	2002	171	2009	14.1	2002	13.7	2009
Malaysia	281	2003	300	2004	74.0	1996	82.8	2006
Myanmar	43	1996	41	2005	12.2	1996	11.9	2005
Nepal	92	1999	139	2008	41.5	1996	53.9	2008
Pakistan	292	1996	335	2009	44.0	1996	65.4	2006
Philippines	541	1996	671	2003	17.4	1996	9.9	2003
Sri Lanka	1582	1996	1,551	2003	85.8	2002	81.0	2003
Thailand	126	1996	352	2006	97.5	1996	98.5	2000
Viet Nam	287	1996	516	2007	25.1	1996	47.6	2007

PRC = People's Republic of China, Lao PDR = Lao People's Democratic Republic, km = kilometer, km<sup>2</sup> = square kilometer.

Source: United Nations Economic and Social Commission for Asia and the Pacific 2012.

**Table 15: Communications Infrastructure Development, Asia**

Area/Country	Internet users (per 100 population)		Fixed-wired broadband subscribers (per 100 Area/Country population)			
	2000	2011	2002	2006	2010	2011
Bangladesh	0.1	5.0	0.0	0.0	0.0	0.0
Cambodia	0.0	3.1	0.0	0.0	0.3	0.2
PRC	1.8	38.3	0.3	3.9	9.4	11.6
India	0.5	10.1	0.0	0.2	0.9	1.0
Indonesia	0.9	18.0	0.0	0.1	1.0	1.1
Lao PDR	0.1	9.0	0.0	0.0	0.2	10.7
Malaysia	21.4	61.0	0.1	2.8	6.5	7.4
Myanmar	0.1	1.0	0.0	0.0	0.0	0.1
Nepal	0.2	9.0	0.0	0.0	0.2	0.3
Pakistan	1.3	9.0	0.0	0.0	0.3	0.4
Philippines	2.0	29.0	0.0	0.3	1.8	1.9
Sri Lanka	0.6	15.0	0.0	0.1	1.1	1.7
Thailand	3.7	23.7	0.0	0.0	4.6	5.4
Viet Nam	0.3	35.1	0.0	0.6	4.2	4.3

PRC = People's Republic of China, Lao PDR = Lao People's Democratic Republic.

Notes: Data for internet use in Myanmar was first recorded in 2005, and in Pakistan, in 2001.

Source: United Nations Economic and Social Commission for Asia and the Pacific 2012.

#### D. Sources of Future Productivity Growth

It is clear from the previous discussion that past studies have revealed availability, timing, and access to the relevant inputs to be the key to productivity and production growth. At the same time, the differential rates of access and use of these inputs explain why productivity growth in one country was more rapid than in its close neighbor despite their having similar or almost similar physical resources. Most of these inputs were brought about by the Green Revolution technology, which included HYVs, the increased use of fertilizer and pesticides, and the development of irrigation. Future increases in productivity and production growth will continue to come from the same sources, but will be dispensed and applied in a different manner to overcome a more difficult environment characterized by resource scarcity (e.g., land, water, energy, and nutrients) and environmental degradation (e.g., salinity, declining soil quality, and oxygen depletion of surface water), and in the recent decade, aggravated by climate change.

The most immediate source of further increases in productivity levels in rice, wheat, and even edible oil crops would be the continued use of existing technologies and management practices. Stress should be given to their appropriate application to close yield gaps—e.g., the use of healthy seeds, good land preparation with appropriate planting methods, good water management and correct fertilizer application, and proper harvesting practices (Lobell, Cassman, and Field 2009; Aggarwal et al. 2008; Piara Singh et al. 2001; Sebastian, Alviola, and Francisco 2000). Environment-friendly practices including the adoption of integrated crop protection technologies to control pests and weeds, diversified rotations to include legumes, and the use of conservation tillage, to name a few, can help maintain and increase yield levels, while matching crop phenology with water availability can reduce the effects of drought (Fukai, Sittisuang, and Chanphengsay 1998).

The long-term sources of higher productivity have to come from great advances in new discoveries that can rapidly stimulate production growth. Three of these advances are discussed here.

1. *Major breakthroughs in new varieties and farming systems in both favorable and unfavorable lands that will not only increase yield levels but also improve resource use efficiency and protect environmental quality.* R&D to discover more innovative and effective farm management practices to help reinvigorate soil health and the quality of degraded rice and wheat areas especially in the Indo-Gangetic Plain will be most helpful. New varieties that overcome the increasing scarcity of inputs, which are expected to be aggravated by the negative impacts of climate change, will have to be developed. This will involve the thorough selection of the desired genes as well as the use of modern science to provide the foundation to achieve the above-mentioned purposes. However, genomics and proteomics are still in their infancy in most of the Asian countries, such that the replacement of conventional breeding approaches by the so-called “Gene Revolution” seems to be farfetched (Evenson 2003, Pender 2008). Nevertheless, advances in new varieties are in the offing, like the GM C4 rice which has great photosynthetic efficiency and increased tolerance to drought or salt-stress, and can therefore significantly increase yield (Hareau et al. 2005, Datta 2002).
2. *The restructuring of small farms into more efficient, mechanized large-scale operations, especially in production areas with good infrastructure for market access and irrigation, such as the fertile plains, river valleys, and deltas in many Southeast Asian countries (e.g., the Greater Mekong Subregion), parts of the PRC,*

*and parts of India.* Large farms can take advantage of economies of scale in seed and other input supply. They can likewise easily exploit the productivity and cost-saving benefits from mechanization as well as the access to support services like credit and market information (Rosenzweig and Foster 2010). Moreover, large farms can reduce transaction costs because they can trade at scale and have great potential to be part of agribusiness enterprise where product standardization and certification are the norms. Despite the clear productivity and income advantages that can be gained from larger farms, restructuring poses a big challenge especially among rice and wheat farms, which continue to be subdivided because of rural population growth and the practice of bequeathing family assets to descendants. On the other hand, restructuring small edible oil farms into larger ones can be easier because their produce is meant for food processing, which requires huge volumes to achieve the desired economies of scale.

3. *The development of market mechanisms to enhance the comparative advantage of domestic production and enable countries to specialize and explore their niche in a more globalized market.* Capturing value-added opportunities—to move beyond being a producer of raw commodities—is one way to enhance market potential and encourage productivity increases. Good value chain analyses will be helpful in defining the niche market for various commodities and their value-added potential. The jasmine rice of Thailand and the basmati rice of Pakistan are examples of products that have established niche markets. Some of the edible oils, like the palm oil of Malaysia and Indonesia, rapeseed oil of India and the PRC, and soybean oil of the PRC, can be further developed toward establishing more captured markets.

#### **IV. KEY POLICY RECOMMENDATIONS FOR SUSTAINING PRODUCTIVITY GROWTH AND THE ROLE OF DEVELOPMENT PARTNERS**

The policies advocated in this study to stimulate further productivity increases and to ensure more sustainable production growth and supply availability in rice, wheat, edible oils, and perhaps in other agricultural crops, are not new and are no different from what have been recommended before. Three key policies deemed most critical to achieve more sustained growth are presented and discussed here. The study additionally stresses two things that need to be seriously attended to. One is the critical role of good governance, which would ensure the genuine implementation of policies to create an environment that would maximize and sustain productivity gains especially from the immediate and long-term sources discussed in the previous section. The other is the need for these policies to have a marked impact in enhancing the production potential of small and marginal farmers, and in helping them take advantage of new technologies and new markets. Despite the encouragement toward consolidation, small farms, especially those for rice, wheat, and other staple crops, will continue to exist as major sources of food supply—and as such, they are deserving of the support that is to be extended to them.

1. *Sustained investment in agriculture sector.* Investments in agriculture include those in R&D, irrigation, transport and other infrastructure, and the development of human capital, especially in the rural areas. While governments must continue to allocate more funds for research, the increasing contribution of the private sector in this area must also be encouraged, especially in the field of biotechnology and other cutting-edge research.



Investment in human capital, as much as possible through education, will be most helpful to better understand the new and more complex technologies that will play a key role in providing the genetic foundation for higher yields. Several studies have shown that the returns on planting high-yield variety seeds are higher for educated than for uneducated farmers (Timmer 2005). As presented and discussed earlier, the level of education of farmers in most countries in Asia is in the bottom range compared with that of other countries in the developing world. Improving the education of farmers in many Asian countries is complicated and difficult, considering that many of the rice and wheat farmers are old.

Investment in rural roads and other infrastructure facilities to lower transport cost, facilitate the market of goods, and facilitate the flow of information is a development stab that can never go wrong. Areas with potential for agriculture production increases and those where such facilities are still underdeveloped or lacking should be clear priorities. The state of farming in the remote and upland areas of most Asian countries can grow from mere food subsistence to a market surplus economy when roads and other transport facilities are provided and put in place. Investments in new drainage systems or the rehabilitation of existing ones must be afforded priority since good drainage systems are central to resolving waterlogging and salinity problems. Unlike the irrigation systems that can be left to private markets to develop, the construction and maintenance of drainage structures are public goods and will remain so, at least beyond the farm-field where most of the drainage investments are needed.

2. *Getting fundamental institutions right.* More efficient extension services are urgently needed now to help farmers correct their use of existing technologies and farm management practices, teach them anew how to properly and profitably adopt these technologies and management practices, and deliver information about new and/or developing technologies. As it should have always been, an effective extension service is a two-way process—imparting information and knowledge to farmers and other beneficiaries, on the one hand; and on the other, learning about their farm experiences, which are valuable inputs to scientists and researchers.

The more modern way of providing extension services is through the introduction and use of information and communication technologies (ICTs). ICTs can be used for long-distance learning programs, and thereby help to strengthen human capital. They can provide information on weather, price, and profitable income diversification possibilities at lower costs. An example of an ICT that has become extensively used and extremely useful to farmers is the mobile phone.

Access to well-functioning credit as well as to credible insurance markets is becoming more and more indispensable, especially among small farmers. Access to credit enables farmers to adopt new technologies that require an initial investment. On the other hand, the availability of crop insurance allays the fears, especially of small farmers, of risks and the uncertainty of yields—which is usually high when a new technology is adopted, or when calamities take place, which has become more frequent and more violent because of climate change.

The proper implementation of the agrarian reform program in a number of countries in the region, such as the Philippines—particularly, the segregation of the

collective land titles—will not only help relax the credit constraints but also encourage private investment in land development.

3. *Gearing up for globalization.* Enhancing investment primarily in the areas identified above and making institutions work more forcefully but efficiently are the key steps to gearing up the agriculture sector as a whole for globalization. Once these support services are in place, pushing for global trade reforms will make agriculture more profitable, especially for developing countries (Timmer 2005). Many countries in Asia are in transition from being centrally planned or socialist economies to market-oriented economies. These countries have to complete this transition by creating the legal and institutional framework, including reforms in their monetary and fiscal systems to be compatible with the principles of a market economy. Additional trade reforms include the removal of input and other subsidies that hinder the competitive stance of farmers. The removal of subsidies would free resources for high-priority public investments in rural infrastructure, education, and research and extension that would encourage both higher productivity growth and more sustainable systems. Legal and regulatory frameworks, trade and taxation policies, and sector-specific policies all influence the incentives facing farmers. Overvalued exchange rates, for example, act as an implicit tax on agriculture and reduce farmers' incentives to produce.

Biosecurity regulations including sanitary and phytosanitary regulations, as well as those for biosafety, have to be put in place. Likewise, assistance in the development of national biosecurity policies and regulatory frameworks is needed. Border control laws and market access protocols have to be reviewed and strengthened if they exist, or be instituted if insufficient or totally absent.

Last, but not least, is the need to encourage greater private sector participation in the agricultural development process. This includes greater efforts to privatize state-owned enterprises that have not been operating efficiently. Private sector involvement has to be enhanced, not only in what has been their traditional involvement but also in activities that are until now still mainly public sector domain, such as R&D and extension, and the development of infrastructure facilities. While it can be noted that private sector research in agriculture is expanding, much of this research is copyrighted, hindering their access and use by developing countries and poor farmers. In cases where it is deemed more appropriate to use public sector funds for development projects, the private sector could come in to manage these endeavors once they are completed, to ensure efficiency. The development of staple food crops—their R&D, extension needs, as well as infrastructure needs—has continued to be the domain of the public sector. Innovative schemes that will get the private sector more involved, perhaps in the value-adding and marketing aspects, will better prepare small farmers to compete in the more open market.

## **A. The Role of Development Partners and the Private Sector**

Meeting the investment requirements for significant and more sustainable productivity and production growth is a formidable challenge for any developing country in Asia, despite the alleged rapid economic growth. As has been discussed, substantial investment will be needed on all fronts: (i) in infrastructure, to facilitate the mobility of people, goods, and inputs; (ii) in R&D and extension, to ensure that appropriate and tested technologies and farm practices are continuously disseminated and made available; (iii) in capacity-building activities to ensure that users, particularly the small and marginal farmers, understand and properly use the technologies and farming practices; and (iv) in strengthening institutions, particularly the setting up of more vigilant and effective governance mechanisms for farmers and other stakeholders to aid the subscription of new technologies and effectively follow and apply farm practices. Public funds will continue to be insufficient to cover all these investment needs. The fund support of development partners will be critical in harnessing agricultural science to modernize and invigorate the sector, including the small and marginal producers who are mostly rice and wheat growers, and who are foreseen to dominate agriculture in the next decade.

In addition, private sector financing has to increasingly come in. The new agriculture that is characterized by far-reaching technologies and innovations, and dynamic markets in extensive value chains clearly suggests the importance of private sector involvement, particularly in agricultural research and development (Sombilla 2011). Private sector financing will continue to be used in areas where they have the comparative advantage to strengthen agriculture—primarily, the agribusiness sector—and enhance the inclusion of smallholders and rural workers. Such areas include:

1. the acquisition, exchange, distribution, and improvement of genetic stocks of crops and other commodities using both conventional technology and biotechnology;
2. the production and distribution of improved seeds;
3. the production of fertilizers and the development of more efficient management practices to optimize crop production;
4. the development of diagnostics to detect diseases in crops;
5. the production of pesticides and pesticide application within the context of chemical control or integrated pest management;
6. the development of strategies to ensure the responsible deployment of resistance genes in crops that will optimize gene durability;
7. the processing, storage, and use of food and feed products, including the control of postharvest losses; and
8. global strategic planning and policy analysis aimed at developing commercial agriculture-based products to meet global needs.

# APPENDIX

## Appendix Table 1: Production of Paddy Rice and Wheat, 1961–1970 to 2001–2010

Countries	PADDY RICE									
	Average Production ('000 tons)					Average Growth Rate (%)				
	1961–1970	1971–1980	1981–1990	1991–2000	2001–2010	1961–1970	1971–1980	1981–1990	1991–2000	2001–2010
<b>East Asia</b>	<b>109,998.9</b>	<b>152,626.3</b>	<b>194,485.4</b>	<b>210,284.9</b>	<b>201,208.8</b>	<b>6.55</b>	<b>1.78</b>	<b>2.94</b>	<b>-0.11</b>	<b>0.35</b>
PRC	87,884.8	130,577.5	173,305.0	190,961.7	183,838.0	8.30	2.41	3.08	-0.03	0.50
Japan	17,103.7	15,360.5	13,436.6	12,341.8	10,823.2	0.40	-2.49	0.92	0.67	-0.93
Republic of Korea	5,010.5	6,688.3	7,743.9	6,981.4	6,547.6	2.77	0.63	4.31	-0.48	-1.68
<b>Southeast Asia</b>	<b>52,477.5</b>	<b>69,117.8</b>	<b>101,752.6</b>	<b>131,900.8</b>	<b>176,782.4</b>	<b>3.73</b>	<b>3.05</b>	<b>2.85</b>	<b>3.22</b>	<b>2.81</b>
Cambodia	2,670.5	1,277.9	2,013.0	3,107.1	5,878.7	7.79	9.29	6.82	6.08	8.35
Indonesia	14,335.0	23,424.0	39,021.6	48,987.5	56,500.2	5.83	4.50	4.35	1.46	2.53
Lao PDR	718.0	832.4	1,261.9	1,602.4	2,671.8	6.66	2.48	4.71	5.23	3.24
Malaysia	1,290.8	1,925.7	1,762.4	2,077.9	2,305.0	5.23	2.95	-0.59	1.38	1.83
Myanmar	7,742.0	9,500.0	14,009.2	17,382.2	28,032.4	2.46	5.48	0.53	4.61	4.61
Philippines	4,392.7	6,316.1	8,647.5	10,498.3	14,924.6	4.29	3.50	2.90	3.28	2.50
Thailand	12,070.3	14,932.7	19,072.4	22,235.1	30,143.4	4.07	3.05	0.33	4.32	2.12
Timor-Leste	14.2	23.0	38.9	47.1	69.7	0.06	10.38	4.85	3.79	12.89
Viet Nam	9,244.0	10,886.2	15,925.6	25,953.0	36,256.7	1.69	1.70	5.32	5.42	2.13
<b>South Asia</b>	<b>76,366.3</b>	<b>94,948.1</b>	<b>126,074.0</b>	<b>162,985.5</b>	<b>190,050.6</b>	<b>2.57</b>	<b>3.26</b>	<b>3.44</b>	<b>1.94</b>	<b>0.75</b>
Bangladesh	15,802.7	18,055.8	23,113.1	29,116.8	41,603.0	2.10	2.62	2.64	3.63	2.85
India	54,936.2	68,900.3	92,838.8	121,673.9	132,960.3	2.61	3.72	4.02	1.46	0.23
Nepal	2,158.4	2,336.0	2,819.2	3,489.0	4,191.2	1.08	1.28	5.46	3.08	-0.14
Pakistan	2,336.3	4,091.3	4,928.5	6,155.6	8,016.0	8.40	3.73	0.75	4.56	1.29
Sri Lanka	1,132.7	1,584.8	2,374.3	2,550.3	3,280.0	7.71	4.23	2.60	1.95	4.92
<b>Pacific Islands</b>	<b>20.7</b>	<b>24.6</b>	<b>30.2</b>	<b>21.4</b>	<b>16.9</b>	<b>2.44</b>	<b>3.89</b>	<b>-0.20</b>	<b>-3.29</b>	<b>-2.97</b>
<b>Asia and the Pacific</b>	<b>216,749.2</b>	<b>294,668.0</b>	<b>401,161.8</b>	<b>485,869.4</b>	<b>550,687.9</b>	<b>4.76</b>	<b>2.63</b>	<b>3.00</b>	<b>1.46</b>	<b>1.18</b>

Countries	WHEAT									
	Average Production ('000 tons)					Average Growth Rate (%)				
	1961–1970	1971–1980	1981–1990	1991–2000	2001–2010	1961–1970	1971–1980	1981–1990	1991–2000	2001–2010
<b>East Asia</b>	<b>24,618.1</b>	<b>45,748.0</b>	<b>84,216.5</b>	<b>106,865.6</b>	<b>102,867.9</b>	<b>7.29</b>	<b>7.39</b>	<b>6.12</b>	<b>0.42</b>	<b>1.57</b>
PRC	23,337.1	45,321.9	83,355.4	106,255.4	102,056.6	8.55	7.52	6.16	0.45	1.59
Japan	1,092.3	334.9	833.6	605.6	799.3	-7.94	5.62	5.54	-2.17	-1.20
Republic of Korea	188.7	91.2	27.5	4.6	12.0	3.53	-0.68	-26.04	45.02	41.80
<b>Southeast Asia</b>	<b>45.4</b>	<b>54.1</b>	<b>158.5</b>	<b>107.9</b>	<b>146.3</b>	<b>30.85</b>	<b>24.58</b>	<b>5.40</b>	<b>-1.58</b>	<b>7.26</b>
Myanmar	45.4	54.1	158.3	107.2	145.4	30.85	24.58	5.36	-1.62	7.29
Thailand	0.0	0.0	0.4	0.7	1.0				6.97	3.30
<b>South Asia</b>	<b>18,458.5</b>	<b>36,699.3</b>	<b>59,021.2</b>	<b>83,242.6</b>	<b>96,959.5</b>	<b>8.31</b>	<b>5.03</b>	<b>4.42</b>	<b>4.40</b>	<b>0.73</b>
Bangladesh	53.3	268.8	1,092.3	1,399.5	1,108.2	16.27	26.44	2.26	7.80	-6.13
India	13,302.7	27,780.3	44,760.7	63,909.1	73,412.3	8.33	5.30	4.91	4.52	0.76
Nepal	188.3	338.4	655.6	953.2	1,397.1	8.29	6.55	7.42	3.60	3.09
Pakistan	4,934.2	8,311.9	12,512.7	16,980.9	21,042.0	8.51	4.43	3.30	4.21	1.34
<b>Pacific Islands</b>	<b>0.1</b>	<b>0.1</b>	<b>0.3</b>	<b>0.1</b>	<b>0.0</b>	<b>4.14</b>	<b>37.41</b>	<b>24.13</b>	<b>-0.44</b>	<b>26.76</b>
<b>Asia and the Pacific</b>	<b>43,122.1</b>	<b>82,501.5</b>	<b>143,396.6</b>	<b>190,216.3</b>	<b>199,973.8</b>	<b>7.31</b>	<b>6.10</b>	<b>5.34</b>	<b>2.09</b>	<b>1.12</b>

PRC = People's Republic of China, Lao PDR = Lao People's Democratic Republic.

Source: Food and Agriculture Organization of the United Nations Statistical Database (FAOSTAT), <http://faostat.fao.org/site/339/default.aspx>

Appendix Table 2: Average Harvested to Paddy Rice and Wheat, 1961–1970 to 2001–2010

Countries	PADDY RICE									
	Average Area Harvested (in million hectares)					Average Growth Rate (%)				
	1961–1970	1971–1980	1981–1990	1991–2000	2001–2010	1961–1970	1971–1980	1981–1990	1991–2000	2001–2010
<b>East Asia</b>	<b>34,593.0</b>	<b>39,600.0</b>	<b>36,701.4</b>	<b>34,615.7</b>	<b>31,653.4</b>	<b>1.90</b>	<b>0.26</b>	<b>-0.33</b>	<b>-1.03</b>	<b>-0.11</b>
PRC	30,162.5	35,746.5	33,245.1	31,529.0	29,003.7	2.30	0.44	-0.27	-0.98	-0.01
Japan	3,242.1	2,640.9	2,219.5	1,991.3	1,670.6	-1.30	-1.99	-1.32	-1.51	-0.82
Republic of Korea	1,188.5	1,212.6	1,236.7	1,095.4	979.1	0.77	0.25	0.10	-1.46	-1.81
<b>Southeast Asia</b>	<b>30,386.7</b>	<b>32,594.6</b>	<b>35,815.7</b>	<b>39,999.9</b>	<b>45,276.1</b>	<b>1.16</b>	<b>1.10</b>	<b>0.49</b>	<b>1.65</b>	<b>1.21</b>
Cambodia	2,229.1	1,075.9	1,540.3	1,839.9	2,388.7	1.70	1.59	5.27	0.91	3.99
Indonesia	7,455.4	8,509.5	9,828.1	11,276.7	12,063.2	2.02	1.08	1.59	1.24	1.19
Lao PDR	751.7	644.6	645.0	605.5	769.3	2.66	1.49	-0.88	1.38	1.98
Malaysia	597.1	723.6	686.4	686.3	670.2	3.56	0.72	-0.47	0.28	-0.33
Myanmar	4,707.6	4,811.4	4,646.1	5,604.2	7,345.3	1.47	0.14	-0.05	3.04	2.57
Philippines	3,186.0	3,526.0	3,331.5	3,635.6	4,209.4	0.10	0.88	-0.34	2.53	0.78
Thailand	6,654.6	8,101.5	9,403.2	9,385.3	10,381.0	1.61	3.21	-0.30	1.23	1.11
Timor-Leste	8.2	11.6	18.2	17.5	38.3	0.94	8.29	2.07	1.92	15.17
Viet Nam	4,796.9	5,190.4	5,737.0	6,948.8	7,410.7	0.09	1.77	0.78	2.42	-0.19
<b>South Asia</b>	<b>48,639.0</b>	<b>52,539.9</b>	<b>55,437.6</b>	<b>58,146.0</b>	<b>58,229.1</b>	<b>1.16</b>	<b>0.71</b>	<b>0.59</b>	<b>0.48</b>	<b>-1.09</b>
Bangladesh	9,370.9	9,940.8	10,347.6	10,229.7	10,851.7	1.82	0.45	0.18	0.37	0.93
India	36,205.7	38,893.6	40,907.3	43,412.1	42,429.5	0.91	0.70	0.71	0.47	-1.77
Nepal	1,125.2	1,238.2	1,375.9	1,463.2	1,528.3	0.94	0.80	1.38	0.92	-0.45
Pakistan	1,394.5	1,740.4	2,010.4	2,242.8	2,524.7	2.52	2.63	1.00	1.30	0.43
Sri Lanka	542.8	726.9	796.5	798.3	894.9	5.23	2.25	0.93	0.69	3.58
<b>Pacific Islands</b>	<b>11.1</b>	<b>11.2</b>	<b>13.2</b>	<b>9.1</b>	<b>6.7</b>	<b>-0.68</b>	<b>1.21</b>	<b>0.02</b>	<b>-5.90</b>	<b>-3.21</b>
<b>Asia and the Pacific</b>	<b>113,629.93</b>	<b>124,745.57</b>	<b>127,967.89</b>	<b>132,770.75</b>	<b>135,165.28</b>	<b>1.37</b>	<b>0.66</b>	<b>0.28</b>	<b>0.42</b>	<b>-0.10</b>

Countries	WHEAT									
	Average Area Harvested (in million hectares)					Average Growth Rate (%)				
	1961–1970	1971–1980	1981–1990	1991–2000	2001–2010	1961–1970	1971–1980	1981–1990	1991–2000	2001–2010
<b>East Asia</b>	<b>25,328.5</b>	<b>27,863.6</b>	<b>29,442.3</b>	<b>29,626.0</b>	<b>23,661.6</b>	<b>-0.15</b>	<b>1.35</b>	<b>0.56</b>	<b>-1.40</b>	<b>-0.83</b>
PRC	24,790.3	27,708.7	29,185.3	29,447.8	23,448.6	0.02	1.40	0.55	-1.38	-0.85
Japan	448.4	115.5	249.0	177.0	209.4	-10.78	1.30	3.34	-3.09	1.28
Republic of Korea	89.8	39.4	7.9	1.2	3.6	2.78	-5.47	-30.25	42.27	41.95
<b>Southeast Asia</b>	<b>80.0</b>	<b>73.1</b>	<b>114.8</b>	<b>112.9</b>	<b>94.6</b>	<b>16.61</b>	<b>4.79</b>	<b>5.66</b>	<b>-3.92</b>	<b>2.18</b>
Myanmar	80.0	73.1	114.6	111.8	93.6	16.61	4.79	5.60	-4.00	2.22
Thailand	0.0	0.0	0.5	1.1	1.0				5.53	-0.83
<b>South Asia</b>	<b>19,594.6</b>	<b>26,810.1</b>	<b>31,796.7</b>	<b>35,057.9</b>	<b>36,591.8</b>	<b>3.17</b>	<b>2.65</b>	<b>0.89</b>	<b>1.44</b>	<b>0.39</b>
Bangladesh	73.8	182.0	572.1	699.3	545.9	10.45	15.30	4.36	3.68	-7.47
India	14,000.0	20,108.0	23,303.0	25,546.9	26,903.5	3.01	3.06	0.64	1.62	0.44
Nepal	141.7	305.9	501.8	629.2	682.5	9.47	5.06	5.36	0.94	1.06
Pakistan	5,379.2	6,214.2	7,419.8	8,182.6	8,460.0	3.41	1.13	1.30	0.80	0.79
<b>Pacific Islands</b>	<b>0.0</b>	<b>0.0</b>	<b>0.2</b>	<b>0.1</b>	<b>0.0</b>	<b>-0.06</b>	<b>42.83</b>	<b>27.33</b>	<b>-12.10</b>	<b>34.78</b>
<b>Asia and the Pacific</b>	<b>45,003.2</b>	<b>54,746.8</b>	<b>61,354.1</b>	<b>64,796.9</b>	<b>60,348.1</b>	<b>1.24</b>	<b>1.96</b>	<b>0.73</b>	<b>0.12</b>	<b>-0.12</b>

PRC = People's Republic of China, Lao PDR = Lao People's Democratic Republic.

Source: Food and Agriculture Organization of the United Nations Statistical Database (FAOSTAT), <http://faostat.fao.org/site/339/default.aspx>

Appendix Table 3: Yield Levels for Paddy Rice and Wheat, 1961–1970 to 2001–2010

PADDY RICE												
Countries	Average Yield (kg/ha)						Average Growth (%)					
	1961–1970	1971–1980	1981–1990	1991–2000	2001–2010		1961–1970	1971–1980	1981–1990	1991–2000	2001–2010	
<b>East Asia</b>	<b>3,163.07</b>	<b>3,858.91</b>	<b>5,301.70</b>	<b>6,077.43</b>	<b>6,352.92</b>		<b>4.54</b>	<b>1.59</b>	<b>3.27</b>	<b>0.91</b>	<b>0.40</b>	
PRC	2,891.72	3,658.19	5,215.50	6,058.33	6,334.20		5.80	2.04	3.35	0.93	0.46	
Japan	5,279.53	5,811.30	6,055.03	6,211.81	6,478.86		1.72	-0.58	2.26	2.00	-0.14	
Republic of Korea	4,211.21	5,507.43	6,260.38	6,383.70	6,696.76		1.82	0.37	4.25	0.99	0.09	
<b>Southeast Asia</b>	<b>1,724.49</b>	<b>2,116.11</b>	<b>2,838.25</b>	<b>3,291.82</b>	<b>3,896.83</b>		<b>2.55</b>	<b>1.89</b>	<b>2.35</b>	<b>1.54</b>	<b>1.58</b>	
Cambodia	1,196.75	1,145.69	1,299.63	1,673.00	2,420.67		5.38	-0.29	1.37	4.88	3.80	
Indonesia	1,910.30	2,745.08	3,960.65	4,345.92	4,674.30		3.59	3.36	2.73	0.25	1.32	
Lao PDR	974.93	1,287.73	1,978.35	2,624.94	3,469.59		5.77	0.77	5.42	3.37	1.33	
Malaysia	2,152.26	2,660.60	2,641.85	3,027.47	3,439.93		1.53	1.95	-0.21	1.09	2.14	
Myanmar	1,643.15	1,976.17	3,016.03	3,091.84	3,794.48		0.81	5.22	0.62	1.48	2.03	
Philippines	1,377.95	1,787.27	2,594.01	2,882.99	3,540.32		4.30	2.61	3.26	0.41	1.71	
Thailand	1,811.21	1,844.80	2,025.73	2,365.68	2,903.15		2.32	-0.27	0.44	3.08	1.00	
Timor-Leste	1,725.37	1,962.92	2,151.70	2,690.48	1,825.49		-0.58	1.64	2.96	1.41	4.56	
Viet Nam	1,929.06	2,102.20	2,770.94	3,713.37	4,893.28		1.84	-0.09	4.47	2.94	2.32	
<b>South Asia</b>	<b>1,567.40</b>	<b>1,803.22</b>	<b>2,269.92</b>	<b>2,799.96</b>	<b>3,262.52</b>		<b>1.31</b>	<b>2.29</b>	<b>2.70</b>	<b>1.42</b>	<b>1.71</b>	
Bangladesh	1,684.52	1,812.69	2,233.92	2,839.18	3,825.36		0.16	2.03	2.54	3.21	1.88	
India	1,514.96	1,767.45	2,263.32	2,800.61	3,132.34		1.58	2.66	3.01	0.95	1.77	
Nepal	1,918.66	1,886.05	2,038.37	2,374.62	2,740.83		0.12	0.30	3.62	1.57	0.17	
Pakistan	1,648.85	2,348.09	2,452.75	2,728.56	3,153.31		5.51	1.12	-0.36	2.99	0.35	
Sri Lanka	2,071.01	2,134.80	2,986.16	3,195.96	3,655.68		2.52	1.60	1.98	1.25	1.76	
<b>Pacific Islands</b>	<b>1,853.49</b>	<b>2,190.67</b>	<b>2,294.14</b>	<b>2,373.90</b>	<b>2,555.76</b>		<b>1.28</b>	<b>2.49</b>	<b>-0.75</b>	<b>3.83</b>	<b>0.50</b>	
<b>Asia and the Pacific</b>	<b>2,096.68</b>	<b>2,536.13</b>	<b>3,298.36</b>	<b>3,802.38</b>	<b>4,199.43</b>		<b>2.96</b>	<b>1.60</b>	<b>2.65</b>	<b>0.94</b>	<b>1.18</b>	

WHEAT												
Countries	Average Yield (kg/ha)						Average Growth (%)					
	1961–1970	1971–1980	1981–1990	1991–2000	2001–2010		1961–1970	1971–1980	1981–1990	1991–2000	2001–2010	
<b>East Asia</b>	<b>972.38</b>	<b>1,630.59</b>	<b>2,853.96</b>	<b>3,611.43</b>	<b>4,344.38</b>		<b>7.57</b>	<b>5.81</b>	<b>5.51</b>	<b>1.77</b>	<b>2.43</b>	
PRC	940.93	1,624.25	2,849.65	3,612.42	4,349.19		8.70	5.88	5.55	1.78	2.47	
Japan	2,466.52	2,853.17	3,333.06	3,422.21	3,812.60		3.39	4.73	2.52	0.96	-2.45	
Republic of Korea	2,098.61	2,370.50	3,193.41	3,497.89	3,396.12		0.73	5.58	0.98	0.04	2.61	
<b>Southeast Asia</b>	<b>533.11</b>	<b>708.93</b>	<b>1,381.57</b>	<b>960.03</b>	<b>1,540.99</b>		<b>8.69</b>	<b>15.46</b>	<b>-0.36</b>	<b>2.20</b>	<b>5.51</b>	
Myanmar	533.11	708.94	1,382.52	963.46	1,547.57		8.69	15.46	-0.34	2.25	5.50	
Thailand			866.78	634.00	939.25					1.72	4.61	
<b>South Asia</b>	<b>928.76</b>	<b>1,361.87</b>	<b>1,853.38</b>	<b>2,368.75</b>	<b>2,647.13</b>		<b>4.53</b>	<b>2.25</b>	<b>3.47</b>	<b>2.95</b>	<b>0.28</b>	
Bangladesh	697.21	1,305.52	1,911.12	1,978.46	2,026.62		5.24	9.41	-1.88	4.05	1.37	
India	937.07	1,374.82	1,917.99	2,495.62	2,726.12		4.71	2.02	4.18	2.87	0.24	
Nepal	1,204.02	1,094.94	1,301.03	1,509.42	2,044.18		-0.32	1.25	1.87	2.65	1.92	
Pakistan	905.14	1,331.14	1,684.51	2,072.30	2,482.96		4.57	3.18	2.05	3.34	0.45	
<b>Pacific Islands</b>	<b>2,644.46</b>	<b>2,192.63</b>	<b>1,293.58</b>	<b>1,851.69</b>	<b>1,523.03</b>		<b>1.78</b>	<b>-2.23</b>	<b>5.78</b>	<b>13.97</b>	<b>-4.76</b>	
<b>Asia and the Pacific</b>	<b>953.13</b>	<b>1,497.49</b>	<b>2,332.36</b>	<b>2,933.96</b>	<b>3,309.19</b>		<b>6.01</b>	<b>3.99</b>	<b>4.54</b>	<b>1.97</b>	<b>1.21</b>	

PRC = People's Republic of China, Lao PDR = Lao People's Democratic Republic.

Source: Food and Agriculture Organization of the United Nations Statistical Database (FAOSTAT), <http://faostat.fao.org/site/339/default.aspx>

**Appendix Table 4: Average Annual Growth Rate of Yield of Edible Oil**

<b>Country</b>	<b>1971–2010</b>	<b>1971–1980</b>	<b>1981–1990</b>	<b>1991–2000</b>	<b>2001–2010</b>
<b>South Asia</b>	<b>1.97</b>	<b>0.26</b>	<b>3.98</b>	<b>1.33</b>	<b>2.32</b>
Bangladesh	1.36	0.29	0.49	1.54	3.13
India	2.67	0.24	5.38	1.01	4.03
Nepal	1.03	0.03	1.98	0.53	1.59
Pakistan	2.99	1.55	7.09	1.67	1.67
Sri Lanka	1.81	–0.79	4.95	1.91	1.18
<b>Southeast Asia</b>	<b>2.57</b>	<b>2.08</b>	<b>2.73</b>	<b>1.90</b>	<b>3.56</b>
Cambodia	1.93	3.17	0.37	–1.00	5.16
Indonesia	3.30	1.88	3.30	3.47	4.56
Lao PDR	2.69	3.41	1.82	0.14	5.39
Malaysia	3.12	5.40	3.82	1.31	1.96
Myanmar	2.12	0.60	2.28	1.73	3.89
Philippines	2.56	1.68	4.68	3.06	0.81
Thailand	2.49	–0.74	4.28	3.09	3.32
Viet Nam	2.33	1.26	1.30	3.38	3.37
<b>East Asia</b>					
PRC	2.06	1.14	3.44	2.26	1.42
<b>Pacific</b>	<b>1.36</b>	<b>3.85</b>	<b>–0.09</b>	<b>0.35</b>	<b>1.33</b>
Fiji	0.52	12.74	–8.67	–1.54	–0.44
Papua New Guinea	3.89	5.48	1.24	6.38	2.46
Solomon Islands	1.83	2.39	0.87	2.95	1.11
Timor-Leste	–1.53	–5.22	1.76	–3.18	0.50
Vanuatu	2.09	3.88	4.34	–2.87	3.03

PRC = People's Republic of China, Lao PDR = Lao People's Democratic Republic.

Source: Food and Agriculture Organization of the United Nations Statistical Database (FAOSTAT), <http://faostat.fao.org/site/339/default.aspx>

**Appendix Table 5: Estimated Average TFP (in %) in Rice, Wheat,  
and Edible Oils in Asia, 1981–2010**  
(Net Value in 1,000 International \$; Constant Price)

Country	Rice	Wheat	Edible Oils
<b>South Asia</b>			
Bangladesh	4.37	–4.10	–2.10
India	–5.84	–3.57	–14.35
Nepal	5.76	7.67	17.35
Pakistan	0.63	3.55	–0.53
Sri Lanka	1.32	–	1.92
<b>Southeast Asia</b>			
Cambodia	14.28	–	11.71
Indonesia	0.91	–	0.18
Lao PDR	24.87	–	–0.76
Malaysia	2.32	–	–1.16
Myanmar	14.84	–10.18	7.74
Philippines	6.22	–	3.15
Thailand	1.96	6.34 <sup>a</sup>	0.09
Viet Nam	–3.28	–	–0.18
<b>East Asia</b>			
PRC	0.20	–0.18	1.95
Mongolia	–	–3.08	–

– = no data, PRC = People's Republic of China, Lao PDR = Lao People's Democratic Republic, TFP = total factor productivity.

<sup>a</sup> Thailand's TFP estimate for wheat should be taken with great caution as data is coming from a very small area.

Source: Authors' estimates using data from the Food and Agriculture Organization of the United Nations (FAO).



## REFERENCES

- Asian Development Bank (ADB). 2012. *Key Indicators for Asia and the Pacific 2012*. Manila: ADB.
- Aggarwal P. K., K. B. Hebbar, M. V. Venugopalan, S. Rani, A. Bala, A. Biswal, and S. P. Wani. 2008. Quantification of Yield Gaps in Rain-fed Rice, Wheat, Cotton and Mustard in India. *Global Theme on Agroecosystems Report No. 43*. International Crops Research Institute for the SemiArid Tropics (ICRISAT). India.
- Ahearn, M., J. Yee, E. Ball, and R. Nehring. 1998. Agricultural Productivity in the United States. USDA, ERS, *Agriculture Information Bulletin No. 740*.
- Alston, J. M., G.W. Norton, and P. G. Pardey. 1995. *Science Under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting*. Ithaca, NY: Cornell University Press.
- Antle, J. 1983. Infrastructure and Aggregate Agricultural Productivity: International Evidence. *Economic Development and Cultural Change* 31 (3). pp. 609–619.
- Byerlee, D. 1992. Technical Change, Productivity, and Sustainability in Irrigated Cropping Systems of South Asia: Emerging Issues in the Post-Green Revolution Era. *Journal of International Development* 4 (5). pp. 477–496.
- China Statistics Press. 2009. [People's Republic of] *China Statistical Yearbook*.
- Datta, S. K. 2002. Recent Developments in Transgenics for Abiotic Stress Tolerance in Rice. In M. Iwanaga, comp. Genetic Engineering of Crop Plants for Abiotic Stress. *JIRCAS Working Report 23*. Tsukuba, Ibaraki, Japan: Japan International Research Centre for Agricultural Sciences.
- Dawe, D., A. Dobermann, P. Moya, S. Abdulrachman, P. Lal, S. Y. Li, B. Lin, G. Panauallah, O. Sariam, Y. Singh, A. Swarup, P. S. Tan, and Q.X. Zhen. 2000. How Widespread are Yield Declines in Long-term Rice Experiments in Asia? *Field Crops Research* 66 (2). pp. 175–193.
- Evenson, R. E. 2003. GMOs: Prospects for Increased Crop Productivity in Developing Countries. *Yale University Economic Discussion Paper No. 878*. <http://ssrn.com/abstract=487503>
- Evenson, R. E., and C. E. Pray. 1991. *Research and Productivity in Asian Agriculture*. Ithaca, NY: Cornell University Press.
- Fan M., J. Shen, L. Yuan, R. Jiang, X. Chen, W. J. Davies, and F. Zhang. 2011. Improving Crop Productivity and Resource Use Efficiency to Ensure Food Security and Environmental Quality in [the People's Republic of] China. *Journal of Experimental Botany*. pp. 1–12. 2011 doi:10.1093/jxb/err248.
- Felipe, J. 1997. *Total Factor Productivity Growth in East Asia: A Critical Survey* (Mimeo). Manila: ADB.

- Flinn, J. C., and S. K. De Datta. 1984. Trends in Irrigated-Rice Yields under Intensive Cropping at Philippine Research Stations. *Field Crops Research* 9 (1). pp. 1–15.
- Food and Agriculture Organization of the United Nations (FAO). 2006. *Fertilizer Use by Crop*. FAO Fertilizer and Plant Nutrition Bulletin. Rome: FAO.
- . Statistical Database (FAOSTAT). <http://faostat.fao.org/DesktopModules/Admin/Logon.aspx?tabID=0> (accessed June 2012).
- Fuglie, K. O. 2010. Total Factor Productivity in the Global Agricultural Economy: Evidence from FAO Data. In J. M. Alston, B. A. Babcock, P. G. Pardey, eds. *The Shifting Patterns of Agricultural Production and Productivity Worldwide*. Ames, IA: The Midwest Agribusiness Trade Research and Information Center, Iowa State University.
- Fujisaka, S., L. Harrington, and P. Hobbs. 1994. Rice-Wheat in South Asia: Systems and Long-Term Priorities Established Through Diagnostic Research. *Agricultural Systems* 46 (2). pp. 169–187.
- Fukai, S., P. Sittisuang, and M. Chanphengsay. 1998. Increasing Production of Rainfed Lowland Rice in Drought Prone Environments—A Case Study in Thailand and [the Lao People’s Democratic Republic]. *Plant Production Science* 1 (1). pp. 75–82.
- Greenland, D. J. 1997. *The Sustainability of Rice Farming*. London and Manila: CAB International and International Rice Research Institute. p.115 and p.273.
- Hareau, G. G., G. Norton, B. F. Mills, and E. Peterson. 2005. Potential Benefits of Transgenic Rice in Asia: A General Equilibrium Analysis. *Quarterly Journal of International Agriculture* 44 (3). pp. 229–246.
- Human Development Reports, various issues. [http://hdr.undp.org/en/media/HDR\\_2011\\_EN\\_Table2.pdf](http://hdr.undp.org/en/media/HDR_2011_EN_Table2.pdf)
- Islam, Md. S. 2008. *Farm Mechanization for Sustainable Agriculture in Bangladesh: Problems and Prospects*. BARI, Joydebpur, Gazipur, Bangladesh. <http://un-csam.org/Activities%20Files/A09105thTC/PPT/bd-doc.pdf>
- Kulkarni. 2009. *Mechanization of Agriculture—Indian Scenario*. Central Institute of Agricultural Engineering (CIAE), Bhopal, India. <http://www.un-csam.org/Activities%20Files/A09105thTC/PPT/in-doc.pdf>
- Kumar, A., and D. S. Yadav. 2001. Long-Term Effects of Fertilizers on the Soil Fertility and Productivity of a Rice-Wheat System. *Journal of Agronomy and Crop Science* 186 (1). pp. 47–54.
- Kumar, P., S. Mittal, and M. Hossain. 2008. Agricultural Growth Accounting and Total Factor Productivity in South Asia: A Review and Policy Implications. *Agricultural Economics Research Review* 21 (2). pp. 145–172.
- Lal, R. 2002. Soil Carbon Sequestration in [the People’s Republic of] China through Agricultural Intensification, and Restoration of Degraded and Desertified Ecosystems. *Land Degradation and Development* 13 (6). pp. 469–478.

- Llanto, G. M. 2012. The Impact of Infrastructure on Agricultural Productivity. *Discussion Paper Series No. 2012-12*. Philippine Institute for Development Studies.
- Lobell, D. B., K. G. Cassman, and C. B. Field. 2009. Crop Yield Gaps: Their Importance, Magnitude, and Causes. *NCESR Publications and Research. Paper 3*.
- Murgai, R., M. Ali, and D. Byerlee. 2001. Productivity Growth and Sustainability in Post-Green Revolution Agriculture in the Indian and Pakistan Punjab. *World Bank Research Observer* 16 (2). pp. 199–218.
- Paris, T. R., J. Luis, D. Villanueva, M. F. Rola-Rubzen, T. N. C. Truong, and C. Wongsanum. 2009. Labour Out Migration on Rice Farming Households and Gender Roles: Synthesis of Findings in Thailand, the Philippines and Vietnam. Paper presented at the FAO-IFAD-ILO Workshop on Gaps, Trends and Current Research in Gender Dimensions of Agricultural and Rural Employment: Differentiated Pathways out of Poverty. Rome. 31 March–2 April.
- Pender, J. 2008. Agricultural Technology Choices for Poor Farmers in Less-Favored Areas of South and East Asia. *Occasional Paper No. 5*. International Fund for Agricultural Development.
- Piara Singh, D. Vijaya, N. T. Chinh, A. Pongkanjana, K. S. Prasad, K. Srinivas, and S. P. Wani. 2001. Potential Productivity and Yield Gap of Selected Crops in the Rainfed Regions of India, Thailand, and Viet Nam. *Natural Resource Management Program Report No. 5*. International Crops Research Institute for the SemiArid Tropics (ICRISAT). Patancheru 502 324, Andhra Pradesh, India.
- Pinstrup-Andersen, P., and S. Shimokawa. 2007. Rural Infrastructure and Agricultural Development. Paper presented at the Annual Bank Conference on Development Economic. Tokyo, Japan. 29–30 May.
- Rosas, F. 2011. *World Fertilizer Model—The World NPK Model*. Working Paper 11 WP-520. Center for Agricultural and Rural Development (CARD), Iowa State University.
- Rosenzweig, M. R., and A. D. Foster. 2010. Microeconomics of Technology Adoption. *Yale University Economic Growth Center Discussion Paper No. 984*. Yale Economics Department Working Paper No. 78. <http://ssrn.com/abstract=1540038>
- Sebastian, L., P. A. Alviola, and S. R. Francisco. 2000. Bridging the Rice Yield Gap in the Philippines. In M. K. Papademetriou, F. J. Dent, and E. M. Herath, eds. *Bridging the Rice Yield Gap in the Asia-Pacific Region*. Bangkok, Thailand: FAO Regional Office for Asia and Pacific.
- Siddiq, A. 1994. Sustainability of the Indus Basin: Impact of Tertiary Salinity/Sodicity on Wheat Productivity, Damage Assessment and Future Public Policy. PhD diss., Dept. of Agricultural Economics, University of Illinois, Urbana-Champaign.

- Sombilla, M. A. 2011. Toward a New Approach and Expanded Cooperation in Agricultural Research and Development in Developing East Asia Plus. In P.S. Intal, Jr., S. Oum, and M. J. O. Simorangkir, eds. *Agricultural Development, Trade and Regional Cooperation in Developing East Asia*. Jakarta: Economic Research Institute for ASEAN and East Asia (ERIA).
- Sombilla, M. A., A. M. Balisacan, D. B. Antiporta, and R. C. Dikitanan. 2011. *Policy Responses to the Food Price Crisis and Their Implications: The Case of Four Greater Mekong Subregion Countries*. International Fund for Agricultural Development Occasional Paper No. 12. <http://www.ifad.org/operations/projects/regions/pi/paper/12.pdf>
- Soni, P., and Y. Ou. 2011. *Agricultural Mechanization at a Glance in Selected Country Studies in Asia on Agricultural Machinery Development*. Beijing: United Nations Asian and Pacific Centre for Agricultural Engineering and Machinery (UNAPCAEM).
- Thoenes, P. 2011. Recent Trends and Medium-Term Prospects in Global Vegetable Oil Market. Slide presentation at the 10th International Conference on Fat and Oil Industry 2011. Ukraine, Kiev. 23–25 November.
- Timmer, C. P. 2005. Agriculture and Pro-Poor Growth: An Asian Perspective. Working Paper No. 63. Washington, DC: Center for Global Development.
- United Nations Educational, Scientific, and Cultural Organization (UNESCO). 2012. Institute for Statistics. <http://www.uis.unesco.org/literacy/Pages/default.aspx>
- United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP). 2012. Statistical Yearbook for Asia and the Pacific 2011. <http://www.unescap.org/stat/data/syb2011/>
- Yuan, L. P. 2002. The Second Generation of Hybrid Rice in [the People's Republic of] China. In *Sustainable Rice Production for Food Security*. Proceedings of the 20th Session of the International Rice Commission, Bangkok, Thailand, 23–26 July. Rome: FAO.

## **Overcoming Critical Constraints to Sustaining Productivity Growth in Key Commodities of Asia and the Pacific**

Rice, wheat, and edible oils make important contributions to Asian diets. But the emerging gap between the demand for these commodities and the slowing down of production are a cause for concern because of their implications to food security. This paper studies the trends in rice, wheat, and edible oil production, and relates them to technology, climate change, infrastructure, and development. A total factor productivity analysis shows that future production growth is possible. This can come from research and development, training and education, and improvements in physical and economic environment, as well as investments and partnerships with the private sector.

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