Overcoming Critical Constraints to Sustaining Agricultural Productivity Growth in Asia and Pacific

I. Introduction

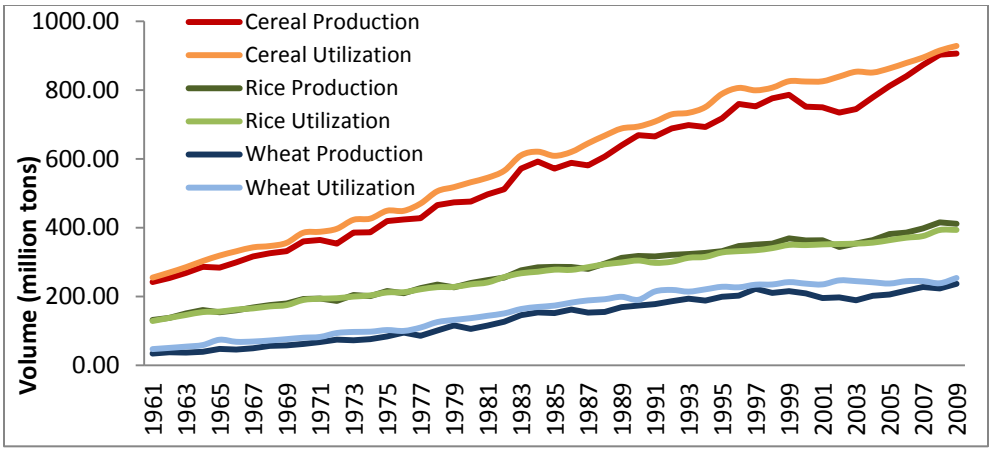
Despite the significant changes in their demand structure, cereals continue to be overwhelmingly the most important source of dietary energy of people in the Asia Pacific region[1]. Among the cereals, consumption of rice still utterly dominates accounting for about 24% of per capita calorie intake of the region. This share increases to an average 34% for East, Southeast and South Asian countries. Consumption of wheat, 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 food like maize and root crops with bread and pasta.

Figure 1 compares the production and utilization[2] of total cereals and of rice and wheat in the Asia Pacific from 1961 to the present. The graphs show two clear trends. One is on total cereal utilization outpacing production in the region as a whole primarily in East Asia and the Pacific Island countries (not shown because of the sub-region's small volumes of production and utilization, respectively) where production growth has significantly slowed down. By commodity, the significant gap between production and utilization has been on wheat. This is taking place primarily in Southeast Asia where the commodity is produced only in Myanmar. Second is the steady increase of cereals utilization while their production fluctuated. This is not surprising since agricultural production is greatly affected by factors beyond the control of the farmers such as inclement weather, plant pests and diseases and others. This would not matter so much if a production shortfall in one year was equally likely to be followed by a production recovery the following year. What is observed, however, is a pattern where periods of production shortfalls persist more than periods when this is above utilization resulting to cereals stocks dipping to low levels especially in the past decade (FAOSTAT, online).

Figure 1. Cereals production and utilization in Asia Pacific, 1961 to 2010.

[1] Asia and the Pacific region here includes the following sub-regions: (i) East Asia (China, Japan, and South Korea); (ii) Southeast Asia (Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Thailand, Timor-Leste, and Vietnam); (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.

[2] Utilization includes all uses of cereals, such as food, animal feed, seed and industrial use.



Source: FAOSTAT online, accessed June 2012

The importance of edible oils and fats in the region, on other hand, is due to their contribution to the dietary energy supply of the population especially among the poorer 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 (FAO) anticipates that consumption of oilcrop products will grow fast in the coming decades as incomes further rise (FAO Commodities and Trade Division, Basic Food Stuff, 2004). Recent projections by FAO indicate continued growth in demand by 2.2% per annum mostly for food use in developing primarily in Asia and notably in China and India (Thoenes, 2011). This is not to mention their growing prospects as feedstocks for biofuels development. Such growth in demand can put pressure on edible oil supply especially palm oil, soybean and rapeseed oil, the three edible oils that are well placed in terms of production and trade. While the region is key producer and exporter of palm oil (primarily because of Malaysia and Indonesia), it is a major importer of soybean and rapeseed oil (primarily because of China).

The emerging gap in food production and utilization described above prompted this study which has three key objectives:

(i) to identify the critical constraints towards a more sustained agricultural production and productivity growth, focusing on three key food commodities, namely, rice, wheat and edible oils, in the Asia Pacific region;
(ii) to identify broad policy options that may help overcome the identified constraints; and
(iii) to identify the respective roles of stakeholders in implementing the policy options.

The paper starts with a brief description of production and productivity growth. It documents as well the sources of such growth via the estimation of partial and total factor productivities (PFP and TFP). The PFP and TFP estimates are compared across countries hopefully to explain the differential production growth performances particularly for rice, wheat and edible oils. A diagnostic analysis was used to identify factors that would have influenced the observed trends and the estimates of PFPs and TFPs, highlighting these that have constrained increases in agricultural production. The last two sections of the paper present and discuss the broad policy measures to overcome the identified constraints and the role of key stakeholders in the realization of further production increases.

II. Production Growth: Contribution of Area and Yield

Agricultural production in the Asia Pacific region has been remarkable despite its limited arable land. The region's gross agricultural production index increased by more than fivefold from an index of 23% in 1961 to an index of 116% in 2010 representing an average growth rate of about 4% per annum. This growth rate was primarily contributed by cereals (which is mainly rice and wheat in the Asia Pacific region) that grew at an average rate of around 2.5% per annum.

In terms of its value added, the agriculture sector expanded from an average value of US$320.9 billion in the 1960s to US$989.6 billion in the 2000 to 2010 (Table 1). The combined contribution of rice and wheat to total value added also expanded from US$107.6 billion in the 1960s to US$209.5 billion in the recent past decade. This is mostly accounted for by rice although its share has been on a decline, from 29.8% in the 1960s to 16.3% in the 2000s. The share of wheat to total value added has been small but has been more stable, averaging close to 5% over the reference period from 1961 to 2010. The share of oil crops to total value of agriculture is very negligible at an average of 0.04%.

Table 1. Total gross value of agricultural production and the respective share of rice, wheat and oil crops (Value in constant 2004-2006 prices in US$ million and share in %)

	1961-69	**1970-79**	**1980-89**	**1990-99**	**2000-10**
Asia and Pacific (gross value)	320941	404041	539753	748671	989591
Share of Rice (paddy)	29.79	28.82	25.46	20.74	16.27
Share of Wheat	3.74	4.70	5.83	5.75	4.90
Share of oilcrops	0.04	0.04	0.04	0.03	0.03
East Asia (gross value)	203135	249064	325640	441906	582978
Share of rice (paddy)	35.38	34.51	29.33	22.67	16.13
Share of Wheat	2.76	3.16	4.52	4.32	3.18
Share of oilcrops	0.03	0.04	0.04	0.04	0.04
South Asia (gross value)	66204	84921	115932	163025	213214
Share of rice (paddy)	23.94	23.30	22.49	21.14	18.68
Share of Wheat	5.86	8.73	10.07	10.16	9.51
Share of oilcrops	0.06	0.07	0.05	0.04	0.05
Southeast Asia (gross value)	25794	35789	52366	74810	106298
Share of rice (paddy)	30.07	29.53	29.92	27.19	24.96
Share of Wheat	-	-	-	-	-
Share of oilcrops	0.03	0.01	0.01	0.00	0.00
Pacific Islands (gross value)	327	367	426	478	492
Share of rice (paddy)	1.80	1.52	1.71	1.28	0.87
Share of Wheat	-	-	-	-	-
Share of oilcrops	-	-	-	-	-

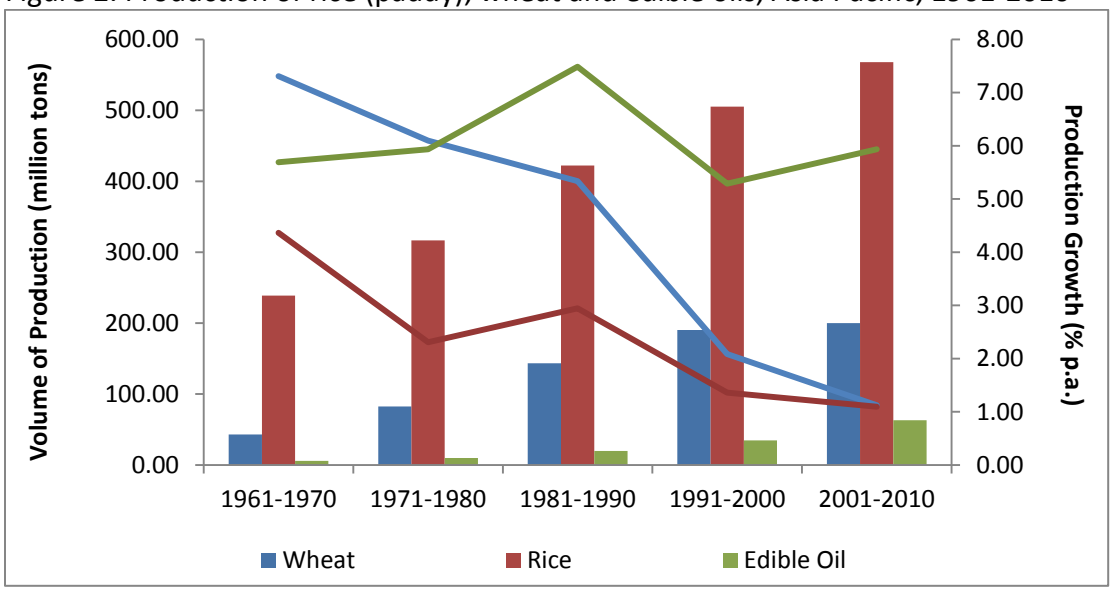
Note: '-' means either zero or negligible.
Source: FAOSTAT online, accessed June 2012

By sub-region, East Asia has accounted for about 60% of agriculture's total value added over the period, contributed primarily by China. South Asia accounted an average contribution of about 21%, also mostly from India. Southeast Asia's share has been averaging only a mere 9%.

Production Performance in Rice and Wheat

In the past 50 years, production of paddy rice and wheat in the Asia Pacific steadily expanded but at a decreasing rate (Figure 2). For paddy rice, the aggregate volume of production doubled from an average level of 239 million tons in 1961-70 to 568 million tons in 2001-10. Paddy rice production growth, however, slowed down from 4.3% to 1.1% during the same reference period. Wheat production in the region similarly increased almost fivefold from an average level of 43 million tons in 1961-70 to 200 million tons in 2001-10. The growth in production slowed down more drastically, however, from an average annual rate of 7.3% in 1961-70 to only 1.1% per annum in 2001-10.

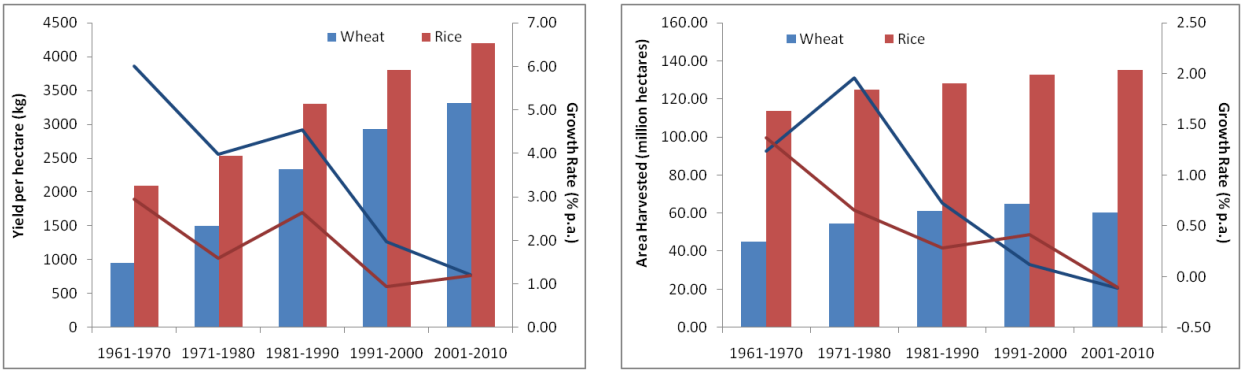
Figure 2. Production of rice (paddy), wheat and edible oils, Asia Pacific, 1961-2010



Source: FAOSTAT online, accessed June 2012

The sluggish growth in paddy rice and wheat production in Asia and the Pacific from the late 1980s was primarily attributed to the drastic decline in yield growth as the impact of the green revolution technology began to wane. This trend is clear in Figure 3 which shows the drastic reduction in the average yearly yield growth rate of paddy rice from 3.34% in 1961-70 to 1.27% in 2001-10 and of wheat from 6.01% in 1961-70 to 1.21% in 2001-10 (see also Annex Tables 1 and 2). The Green Revolution that involved the development and diffusion of high-yielding varieties (HYVs) of rice and wheat and accompanied by the use of increased levels of inputs, particularly irrigation, fertilizers and machineries, triggered agricultural growth in most of Asia Pacific from the mid-1960s and the shift of the source of growth from area expansion to yield. The latter, in fact, never became a big source of production growth henceforth and its annual growth rate continued to diminish over the period. In the past decade, area growth was shown to have even contracted with the respective annual growth rates averaging -0.10% for paddy rice and -0.12% for wheat (see also Annex Tables 1 and 2).

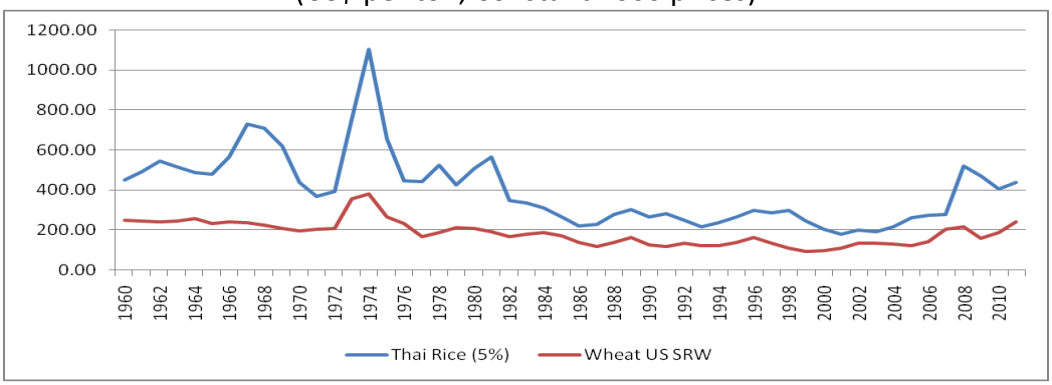
Figure 3. Yield and Area Growth Trends of Paddy Rice and Wheat, 1961 to 2010.



Source: FAOSTAT, online

It should be pointed out that the expansion of cereal production, paddy rice in particular for the region, was accompanied by a long-term decline in prices especially from mid-1973 after rice production recovered from the impact of severe drought that affected most of Asia (Figure 4). World rice and wheat price reduction was as much as 83% and 64% between 1974 and 2003. The uptrend starting 2004 was due to tightening of the rice and wheat supply in the global market as major producers and exporters held on to their grain produced to ensure sufficient availability domestically as news spread about a food crisis.

Figure 4. World price trends of Rice (milled) and Wheat, 1960-2011
(US$ per ton, Constant 2000 prices)



Source:

<u>Sub-regional production trend in rice</u>

Table 1 shows the sub-regional rice production trend which 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 to 2010. The sub-region'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 China's which account for the bulk of production as can be gleaned from Annex Table 1. China's rice production increased from 110 million tons in 1961-70 to 201.2 million tons in 2001-2020 but with growth rates that decline to almost a nil in 2001-10. Expansion of area

Table 1. Sub-regional Rice Production Trends, 1961/70 to 2001/10

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	34.6	30.4	39.6	31.7	36.7	28.7	34.6	26.1	31.7	23.4
Southeast Asia	30.4	26.7	32.6	26.1	35.8	28.0	40.0	30.1	45.3	33.5
South Asia	48.6	42.8	52.5	42.1	55.4	43.3	58.1	43.8	58.2	43.1
Pacific Islands	0.0	0.010	0.0	0.009	0.0	0.010	0.0	0.007	0.0	0.005
Asia Pacific	113.6	100.0	124.7	100.0	128.0	100.0	132.8	100.0	135.2	100.0

	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*	*% Share*
East Asia	109998.9	50.7	152626.3	51.8	194485.4	48.5	210284.9	43.3	201208.8	36.5
Southeast Asia	52477.5	24.2	69117.8	23.5	101752.6	25.4	131900.8	27.1	176782.4	32.1
South Asia	76366.3	35.2	94948.1	32.2	126074.0	31.4	162985.5	33.5	190050.6	34.5
Pacific Islands	20.7	0.010	24.6	0.008	30.2	0.008	21.4	0.004	16.9	0.003
Asia Pacific	216749.2	100.0	294668.0	100.0	401161.8	100.0	485869.4	100.0	550687.9	100.0

Source: FAOSTAT, online

harvested to rice in the 1960's and 1970's accounted for the production increases during those periods (Annex Table 2). Yield growth subsequently took over as the key source of growth with the advent of the Green Revolution technology from the mid -1960s. As yield levels increased more than twofold from 2.9 tons per hectare in the 1960s to 6.3 tons per hectare in 2001 to 2010 (Annex Table 3), area harvested to rice continued to contract to its 2001-2010 level of 29 million hectares. China was among the first adopter of the Green Revolution technology that spread quickly to its rice farms. The technology improved crop management and enabled farmers to cultivate three rice crops especially in the more favourable rice farms. Yield growth rate reached 5.8% per annum in the 1960s. It continued to grow in the 1970s and 1980s at respectable rates of 2.0% and 3.4% per annum, respectively, with the development and use of hybrid rice from 1976 (Yuan, 1996). The yield growth slowdown from the 1990s, which will also be noted in other countries, was due to a number of reasons foremost of which has been the gradual exhaustion of the potentials of the high yielding varieties. Other reasons include the degradation of soil and depletion of water resources, especially in the irrigated areas where the Green Revolution technology has been most effective. On the economic side, was the changes in rice farming systems where cropping intensities were reduced from three to two primarily due to farm returns that have become increasingly insufficient to justify the cost of inputs as well as the efforts and time consumed in rice farming.

Southeast Asia's share to the region's total rice production over the period 1961 to 2102 was around 26%, increasing from slightly less than a quarter in the 1960s to almost a third in 2001 to 2010. The sub-region's production growth also slowed down but not as drastic as in the case of East Asia and also of South Asia as will be subsequently discussed). This is due to the continued high regard of rice by most country governments in achieving their of food security goal. Moreover, the adoption and use of the Green Revolution technology did not start at the same time among the countries in the region. The early adopters included Indonesia, Malaysia

and the Philippines. The rest of Southeast Asian countries including Cambodia, Lao PDR, Vietnam and now Myanmar adopted the technology some years later with their resolution of domestic and border conflicts and achievement of greater political stability.

Indonesia, the biggest rice producer in the sub-region, accounted for about 14.3 million tons (or 27%) of the sub-region's production in the 1960s to 56.5 million tons (or close to a third) of the sub-region's production in 2001-10. Like those that adopted the Green Revolution technology, the country's phenomenal production growth started from 1968 when yield levels gradually rose and accelerated in the 1970s to reach almost 4 tons per hectare in the late 1980s, more than double the 1.9 tons per hectare yield level in the 1960s. Yield levels continued to rise but at rates which were much slower than those experienced during the early years of the Green Revolution technology. The stronger yield growth in 2001-2010 was triggered by the food crisis in 2008-2009 that pushed the prices of grains to go up. The same production trends took place in the Philippines and Malaysia, although their production levels were much lower because of much smaller rice harvested areas. Philippine rice area has been only about a third of Indonesia's while Malaysia's rice area has been slightly more than a half of Indonesia's.

Thailand has not only been a major producer but also an exporter of rice. It ranks next to Indonesia in terms of its share to the sub-region's total rice production. Thailand's production increased almost threefold from 12.1 million tons in the 1960s to 30.1 million tons in the 2001-10 that came primarily from area expansion. Yield increases were not as dramatic as in other countries because the Green Revolution technology was not very applicable to rainfed areas that constituted a large portion of the country's rice growing areas. Low yielding but high quality traditional varieties of rice are cultivated in these areas, a large portion of which are exported.

Rice production in the other countries of the Greater Mekong Sub-region, namely, Cambodia, Lao PDR, Myanmar and Vietnam have similarly been on the rise, from area expansion in the 1960s and 1970's and from huge yield increases from the mid-1980s (Annex Tables 1 to 3). Among these countries, the most phenomenal performance was staged by Vietnam enabling it to regain its position as net exporter of the commodity from the 1990s. Cambodia's sustained high production growth throughout the study period has come from the expansion of irrigated rice areas that commenced in the 1980s and which enabled the cultivation of two rice crops. This cropping intensity was not impossible in earlier decades because of the country's rice areas which are generally rainfed.

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 34% share in 2001-10. India, Bangladesh and Sri Lanka are the three major rice producers accounting for about 95% of the sub-region's production (Annex Table 1). Yield growth has accounted for most of the increase in production especially from the early 1908s when the Green Revolution technology started to be more widely adopted. The relatively slower uptake of the technology as compared to their neighbours in East and Southeast Asia was partly due to their poorer state of infrastructure development particularly

their transport system. Area harvested is shown to have gradually declined except in Sri Lanka where area expansion posted a 3.6% annual growth rate in 2001-10.

Rice production is very negligible in the Pacific Islands. It is mostly cultivated in Fiji, Papua New Guinea and the Solomon Island where area harvested has declined rapidly. Moreover, yields in these Islands have been low, reaching only 2.6 tons per hectare in 2001-10.

Sub-regional Production Trends of Wheat

Table 2 shows the sub-regional production performance of wheat. The country level performances are also shown in Annex Tables 1 to 3. Unlike rice, wheat is not grown in all countries in 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 on a subsistence level. However, in the countries where wheat is more extensively grown, production increased fourfold in East Asia and fivefold in South Asia. But yield levels in these sub-regions that reached 3.3 tons per hectare in 2001-10 still pales in comparison to those achieved in other regions that averaged more than 5 Tons per hectare. Like rice, wheat production growth significantly slowed down in the past two decades while demand for the commodity in the region 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% share in 2001-10 primarily due to the dwindling of production in Japan and the Republic of Korea (ROK). China has made up the decline in both Japan and ROK with its wheat production expanding from a mere 23.3 million tons in 1961-70 to 102.1 million tons in 2001-10. The remaining 45% of the region's total wheat production was accounted for by South Asia, mainly from India which shared an average of 75% of the sub-region's production. Pakistan accounted 22% of the sub-region's production.

It can be noted from the production Tables that yield growth immediately became the major source of production increases in the 1960s with the rapid adoption and use of the Green Revolution technology especially in rice-wheat areas that went 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 during the period from 1960-70 to 1981-90 but then slowed down to 1.6% per annum in 1990s and 2001-10.

China's yield levels increased form 0.94 ton per hectare in the 1960s to 4.3 tons per hectare in 2001-10. Yield growth rates in the country averaged close to 7% per annum from the 1960s to 1980s and was drastically reduced to about 2% in the two decades that followed. India's yield was almost the same as China in the 1960s at 0.93 ton per hectare but improvements were much slower. India's highest yield level only averaged 2.7 tons per hectare in 2001-10. 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 in Sagaing Division and Shan State.

Table 2. Sub-regional Wheat Production Trends, 1961/70 to 2001/10

	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	0.00009	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	24618.1	57.1	45748.0	55.5	84216.5	58.7	106865.6	56.2	102867.9	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	18458.5	42.8	36699.3	44.5	59021.2	41.2	83242.6	43.8	96959.5	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	43122.1	100.0	82501.5	100.0	143396.6	100.0	190216.3	100.0	199973.8	100.0

Source:

Recorded growth performance of Myanmar should be taken with caution, however. Rectification of the county's statistics is underway.

Production Performance of Edible Oil

Edible oil production in Asia-Pacific increased more than twelvefold from an average level of 5.77 million tons in the 1960s to an average level of 63.4 million tons in 2001-10 (Table 3). South Asia initially accounted for about 50% of Asia-Pacific's edible oil production in the 1960s but its production increased only threefold over 50 years. South Asia was gradually taken over by Southeast Asia from the 1970s to 2001-10 when the sub-region's production expanded from 1.4 million tons in the 1960s to 38.3 million tons in 2001-10. In East Asia, edible oil production increased from 1.9 million tons in the 1960s to about 17.0 million tons in 2001-10. Key edible oils produced in the region are palm oil, rape seed oil and soybean oil. Other edible oils produced in much lesser volume are coconut oil, cottonseed oil and groundnut oil.

The surge in the production of edible oil was primarily driven by the surge in demand for food use (still more than 80% of edible oil utilization) and industrial uses that catapulted in the last two decades with the emergence of new applications like the biofuels. Such expansion was contributed primarily by yield growth which expanded at 1.97% over the four decades from 1971 to 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 in Southeast Asia from 2.08% per annum in 1971-80 to 3.56% per annum in 2001-10. Strong growth in yield were also exhibited by the countries in both sub-regions (Annex Table 4).

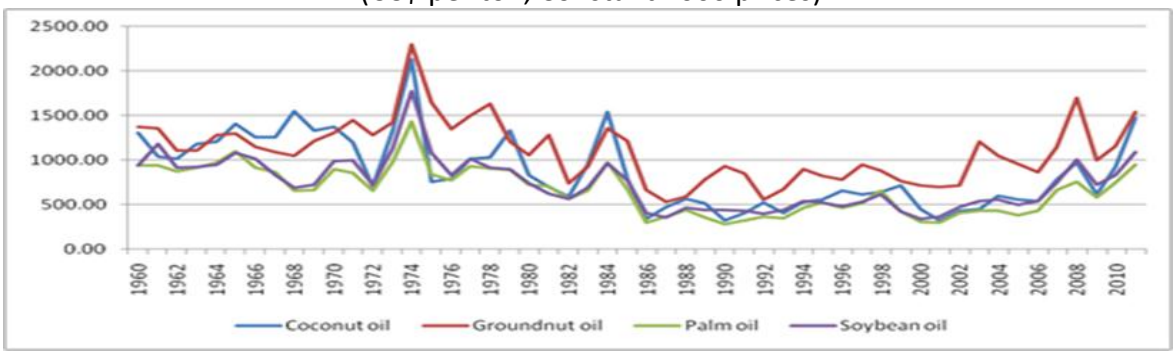
Table 3. Edible Oil Production (in million tons) and Yield growth (%), 1961-70 to 2001-10

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

Note: Edible oils include Coconut (copra) oil, Cottonseed oil, Groundnut oil, Linseed oil, Olive oil (virgin), Palm kernel oil, Palm oil, Rapeseed oil, Safflower oil, Sesame oil, Soybean oil, and Sunflower oil
Source: FAOStat, online (accessed in June 2012).

It is only in East Asia (which is equated to China's yield performance) where annual yield growth slowed down, thus explaining China's rapid increase in edible oil imports. The reinvigorated demand also explains the edible oil price trend as shown in Figure 4.

Figure 4. World price trends of Edible Oil, 1960-2011
(US$ per ton, Constant 2000 prices)



Source:

Table 4 indicates the importance of Asia-Pacific in the world edible oil market. In terms of its contribution to production, the region accounts for about 53% of the world's total edible oil production in 2010 (FAOStat, online). In fact, four countries in the region, namely, China, India, Indonesia, and Malaysia already account for 47% of the world's production. India's rapeseed oil production is 10% of the world's production in 2010, increasing from about 0.4 million tons in the 1960s to about 2.0 million tons in 2001-10 (Table 4). Indonesia and Malaysia account for

Table 4. Share of Major Edible Oil Producers in Asia-Pacific to World Edible Oil Production (in tons)

	Total Oil	Palm Oil	Rapeseed Oil	Soybean Oil	Others
World	**146196016**	**45097422**	**22527177**	**39761852**	**38809565**
China	19213251	245400	5320500	9069800	4577551
Share to total (%)	*13.1*	*0.5*	*23.6*	*22.8*	*11.8*
India	5800600	-	2284000	1349300	2167300
Share to total (%)	*4.0*	*-*	*10.1*	*3.4*	*5.6*
Indonesia	25158066	21534000	-	365539	3258527
Share to total (%)	*17.2*	*47.7*	*-*	*0.9*	*8.4*
Malaysia	19167931	16993000	110731	-	2064200
Share to total (%)	*13.1*	*37.7*	*0.5*	*-*	*5.3*

Source: FAOStat, online (accessed in June 2012)

about 85% of the world palm oil production, mostly for exports. China's rapeseed and soybean oil account for 24% and 23% of the world's total, respectively. China, India and Pakistan are major importers of palm oil, China and India of soybean oil and China of rapeseed oil.

III. Sources of Growth: Total Factor Productivity

Productivity growth in agriculture crops is commonly assessed through a change in crop yields. Crop yields are, however, only a measure of partial factor productivity and are incomplete measures of economic efficiency because they do not explicitly consider the growth in use of inputs other than land. Total factor productivity (TFP) growth has been widely used as a measure of the overall performance of the agricultural sector. TFP compares an index of output changes with an index of input changes, so that the residual growth of productivity is attributed to technological progress that can be attributed to 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). Change in TFP can also be due to unmeasured or imperfectly measured inputs.

Analytical Approach and Data

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

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

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 agricultural sector and K_t is the total land area in agriculture. The time shift factor (t) proxies the effects of productivity and technical progress.

The data set is a yearly panel data consisting of 20 countries in the Asia-Pacific Region. The data set are taken from the Food and Agriculture Organization (FAO) databank from 1971 to 2010.

The countries are classified according to the regional groupings defined as,

I. East Asia: China and Mongolia
II. South Asia: Bangladesh, India, Nepal, Pakistan and Sri Lanka
III. Southeast Asia: Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Thailand and Vietnam
IV. Pacific: Fiji, Papua New Guinea, Solomon Islands, Timor-Leste, Vanuatu

Growth in TFP was analyzed for 4 decades from 1971 to 2010. The decades from 1971 to 1990 reflect the peak of the first (1966-74) and second (1975-85) waves of the Green Revolution technology when the adoption of the high-yielding rice and wheat varieties became widespread and use of fertilizer and irrigation was intensified initially on irrigated areas and then on rainfed areas (Byerlee, 1992). The decade from 1991 to 2000 covers the post-Green Revolution period when investment in agriculture started to slow down, input use on rice and wheat levelled off and the degradation of soils and water from the intensified cropping are increasingly being manifested in declining or stagnant yield levels (Flinn and De Datta 1984; Greenlands, 1997; Dawe et el. 2000; Kumar and Yadav, 2001). The final decade of the reference study covers the impact of efforts to reverse yield growth slowdown which include enhanced level of investment in research and development, irrigation and other productivity enhancing infrastructure facilities and support services.

Input Use and Production Growth

As noted in the previous section, area expansion was no longer a source of production growth after the introduction of the Green Revolution technology. Area expansion happened only for rice in Southeast Asia when Cambodia, Lao PDR, Myanmar and Vietnam, the late adopters of the technology, became more emphatic on producing more of their staple food when they finally resolved domestic conflicts and gained more political stability (Annex Table 2). Yield gains became the engine of production growth, the overall trend of which has been almost similar across the countries, i.e. rapid growth from the mid-1960s to mid-1980s and slowing down thereafter. Huge variation of yield levels can be noted across countries even at the beginning of the Green Revolution technology which can be attributed to countries' geophysical characteristics (particularly the soil type and nutrients) as well as climatic conditions (Annex Table 3). China's yield level of 2.9 tons per hectare in the 1960s as compared to yield levels in Southeast and South Asian countries is due to its long summer days (countries closer to the

equator do not enjoy such long summer days), soil types and its available water resource for irrigation. But overtime, when the Green Revolution technology became more accessible and more adopted, yield gaps across countries widened. For example, yields for 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. Similarly, Indonesia's rice yield increases outstripped that of the Philippines and Malaysia. These differences in production performance relate to differences in input use that stimulated crop growth performance and influenced the extent of crop intensification.

A key input that influenced cropping intensities is the development of irrigation, initially large-scale surface irrigation and subsequently from the 1980s, tube wells and similar ground water irrigation systems. Latest figures from FAO indicate that an average of 37% of land under cultivation in the Asia is irrigated (FAO, 2012, online). China's percentage of cultivated land with irrigation is 55% while Bangladesh, Nepal, Republic of Korea and Viet Nam have more than 40% of cultivated land under irrigation. Other tropical countries of South Asia and the Pacific Islands have an average between 20% and 25% of their cultivated land under irrigation. But the type and quality of irrigation systems varied across countries and they mattered in the attainment of the cropping intensities as shown in Table 5.

Table 5. 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
India	131.5	2008
Indonesia	199.2	2005
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
Vietnam	190.4	2005

Source: FAO Aquastat, online accessed August 2012.

Another key input is fertilizer. As shown in Table 6, fertilizer consumption increased rapidly in in the 1960s and 1970s. The total consumption of chemical fertilizers in China rose from 2.4 million tons in the 1960s to about 46 million tons in 2001-10 or around 39 kg per hectare. It exceeded 64 million tons in 2009 (National Bureau of Statistics of China, 1950–2010). Fertilizer

Table 6: Fertilizer Consumption (%, based on nutrient equivalent)

Countries	1961-70	1971-80	1981-90	1991-2000	2000-10	1961-70	1971-80	1981-90	1991-2000	2000-10
	In 000 tons					in %				
China	2415.9	7302.8	19348.3	31818.0	45526.8	21.2	14.2	7.2	3.3	4.1
Bangladesh	73.5	231.2	595.5	1097.9	1479.9	21.4	12.3	8.4	4.0	2.6
India	1123.7	3469.8	8097.1	14142.0	20146.6	24.1	10.4	8.0	4.2	4.4
Nepal	2.1	13.3	42.6	91.3	29.1	42.9	17.5	12.3	4.2	0.5
Pakistan	139.0	573.8	1447.7	2329.6	3415.9	28.2	13.5	6.5	4.3	3.6
Sri Lanka	99.3	109.2	181.7	208.7	283.3	2.8	3.7	2.9	2.4	2.7
Cambodia	2.7	1.6	4.4	9.2	21.7	14.1	-40.4	42.5	21.3	9.7
Indonesia	150.9	520.2	1864.4	2492.6	3265.1	9.1	15.8	10.3	0.6	5.2
Lao PDR	0.5	0.3	1.1	4.3	-	108.0	116.9	24.7	30.3	6.9
Malaysia	106.9	273.4	624.4	1115.8	1427.6	10.7	10.5	8.0	3.9	3.4
Myanmar	15.8	55.5	140.6	134.0	109.8	24.8	13.5	0.1	9.0	-6.9
Philippines	119.1	255.5	384.5	620.2	755.7	12.0	6.1	5.5	2.8	-0.1
Thailand	60.3	199.0	514.6	1370.4	1871.9	22.7	11.7	12.1	6.6	2.6
Viet Nam	116.4	290.0	395.4	1221.3	2121.6	17.4	0.4	10.8	13.9	0.4

Source: FAOSTAT, online, accessed August 2012.

consumption in Southeast Asia is relatively small compared to East and South Asia, increasing from slightly more than half a million tons to 9.5 million tons in 2001-10. Per hectare use, however, has been slightly bigger than that of India. While quantity of fertilizer consumption continued to rise, their rate of increases have drastically gone down especially in the past two decades except in Cambodia, Lao PDR and Vietnam.

Labor use is also a critical factor to crop production especially in high intensity rice production. Wet paddy rice requires approximately 125 days per hectare in India, while dry wheat production in the same country takes somewhere between 33-47 days per hectare. In China, farmers employed roughly 12–25 days of work per *mu* planted with rice (i.e. 180 to 375 days per hectare), while only 4–10 days of work per *mu* of wheat (i.e. 60 to 150 days per hectare). Labor availability differs across the countries in the region as indicated by the number of economically active agricultural population in Table 7. Two trends are clear from the Table: (i) the declining rates of increase of this group of people and (ii) the shrinking proportion of male agricultural labor to total agricultural labor, while the proportion of their female counterpart has been expanding in most countries in South and Southeast Asia. The quality of labor also matters in agricultural production and this differs across countries. Many countries still show relatively high illiteracy rates and having access to poor sources drinking water nd sanitation facilities (Table 7). Most of the countries are reported with medium human development index (i.e. with indices between 0.523 to 0.901) except Bangladesh, Myanmar, Nepal, Pakistan and Timor Leste which are reported with low human development index (i.e. indices from 0.458 to 0.504).

It is also clear in the Asia-Pacific region how the promotion of agricultural mechanization has brought about a rapid change in the agricultural sector. Notwithstanding its importance, vast difference in the level of agricultural mechanization among the Asia-Pacific countries still exists. The use of machineries accelerated in the region as a whole in the last few years but the level

greatly differs from country to country. The level is low in Bangladesh, Cambodia, Indonesia, Nepal, and Sri Lanka where majority of farmers continue to use traditional tools in their production system (Table 8). In contrast, the level is high in China, India and South Korea where significant development in agricultural mechanization has been taking place. The gaps in the level of mechanization is indeed huge when you compare the intensity of machine use in Bangladesh which increased from 0.32 kW/hectare in 1984 to 1.17 kW/hectare in 2007 (Islam, 2008) with China's where the intensity level in 2000 is already 3.36 kW/hectare and rose further to 5.26 kW/hectare in 2008 (China Agricultural Yearbook, 2009). India's number of agricultural tractors increased from 1.1 million in the early 1960s to 13.36 million in 2007 (Kulkarni, 2009). It is also noted from Table 8 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. The varying level of mechanization and the use of different types of equipment account for the differences in production performance across countries. This is not to mention the varying skills and capacity of the countries' labor force to operate the machines effectively and efficiently.

Table 7: Economically Active Population in Agriculture, by Male and Female, 1980-89 to 2001-10 and 2011-2012 (estimates)

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
East Asia	441092.0	506355.3	511846.8	503100.0	236444.8	265696.2	266592.1	262282.0	204646.9	240658.9	245254.9	240818
					53.6	*52.5*	*52.1*	*52.1*	*46.4*	*47.5*	*47.9*	*47.9*
China	427442.1	495949.9	504681.5	497425.5	229151.6	259937.5	262602.5	259124.0	198290.5	236012.3	242079.0	238301
					53.6	*52.4*	*52.0*	*52.1*	*46.4*	*47.6*	*48.0*	*47.9*
Japan	5490.3	3738.8	2011.3	1281.5	2891.2	2056.8	1173.9	769.0	2598.9	1681.8	837.4	513
					52.7	*55.0*	*58.4*	*60.0*	*47.3*	*45.0*	*41.6*	*40.0*
Republic of Korea	4568.5	2903.2	1713.3	1166.5	2449.9	1632.7	959.3	662.0	2118.6	1270.6	754.0	504.5
					53.6	*56.2*	*56.0*	*56.8*	*46.4*	*43.8*	*44.0*	*43.2*
South Asia	251375.6	292183.4	334746.2	361182.5	169479.1	194482.7	220495.7	234845.0	81896.9	97699.9	114250.1	126338
					67.4	*66.6*	*65.9*	*65.0*	*32.6*	*33.4*	*34.1*	*35.0*
Bangladesh	27391.7	31173.2	32328.7	31910.5	15406.3	17312.6	16840.4	15437.5	11985.6	13860.7	15488.2	16473.5
					56.2	*55.5*	*52.1*	*48.4*	*43.8*	*44.5*	*47.9*	*51.6*
India	192591.3	224450.5	254885.2	274169.5	130306.3	151141.6	172403.5	185065.5	62285.2	73308.8	82481.5	89104
					67.7	*67.3*	*67.6*	*67.5*	*32.3*	*32.7*	*32.4*	*32.5*
Nepal	5970.3	7461.8	10341.7	12583.0	3758.7	4332.6	5532.1	6489.0	2211.4	3129.1	4809.7	6094
					63.0	*58.1*	*53.5*	*51.6*	*37.0*	*41.9*	*46.5*	*48.4*
Pakistan	14505.5	16422.9	21551.8	25260.0	12271.1	13105.7	15841.0	17417.0	2234.4	3317.1	5710.8	7843.5
					84.6	*79.8*	*73.5*	*69.0*	*15.4*	*20.2*	*26.5*	*31.1*
Sri Lanka	3216.0	3518.0	3843.2	4041.5	2109.2	2286.0	2454.1	2531.5	1106.8	1232.2	1389.2	1509.5
					65.6	*65.0*	*63.9*	*62.6*	*34.4*	*35.0*	*36.1*	*37.3*
Southeast Asia	105346.1	124594.4	136549.5	140538.0	60529.7	71463.4	78666.3	80998.5	44816.9	53131.2	57883.0	59537.5
					57.5	*57.4*	*57.6*	*57.6*	*42.5*	*42.6*	*42.4*	*42.4*
Cambodia	2668.0	3476.2	4547.4	5061.0	1153.5	1569.5	2166.9	2474.0	1514.5	1906.9	2380.3	2586.5
					43.2	*45.1*	*47.7*	*48.9*	*56.8*	*54.9*	*52.3*	*51.1*
Indonesia	37135.3	45102.3	49030.9	49465.5	23554.2	27476.5	29874.5	29907.5	13581.3	17625.9	19156.5	19558
					63.4	*60.9*	*60.9*	*60.5*	*36.6*	*39.1*	*39.1*	*39.5*
Lao PDR	1292.1	1658.2	2101.8	2452.0	628.8	801.5	1000.2	1173.5	663.4	856.5	1101.8	1278
					48.7	*48.3*	*47.6*	*47.9*	*51.3*	*51.7*	*52.4*	*52.1*
Malaysia	1983.3	1885.5	1740.5	1571.0	1227.4	1338.7	1331.3	1250.5	755.8	546.8	409.2	320
					61.9	*71.0*	*76.5*	*79.6*	*38.1*	*29.0*	*23.5*	*20.4*
Myanmar	13032.3	15645.2	17962.0	19054.0	6867.4	8244.0	9414.2	9934.5	6165.0	7401.1	8548.0	9119.5
					52.7	*52.7*	*52.4*	*52.1*	*47.3*	*47.3*	*47.6*	*47.9*
Philippines	9872.0	11679.2	13018.6	13507.0	7307.5	8848.9	9855.8	10237.0	2564.5	2830.5	3162.8	3270.5
					74.0	*75.8*	*75.7*	*75.8*	*26.0*	*24.2*	*24.3*	*24.2*
Thailand	19097.0	20386.1	19940.9	18986.5	9814.6	10932.4	10818.5	10472.5	9282.4	9453.8	9122.5	8514
					51.4	*53.6*	*54.3*	*55.2*	*48.6*	*46.4*	*45.7*	*44.8*
Timor-Leste	221.0	257.0	298.9	368.0	123.5	146.5	165.8	202.5	97.6	110.5	133.2	165.5
					55.9	*57.0*	*55.5*	*55.0*	*44.2*	*43.0*	*44.6*	*45.0*
Viet Nam	20029.3	24498.6	27905.0	30070.5	9841.1	12100.4	14036.3	15344.5	10188.3	12398.2	13868.7	14725.5
					49.1	*49.4*	*50.3*	*51.0*	*50.9*	*50.6*	*49.7*	*49.0*

Table 8. 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
China	60%	35%	-	30%	42%	HIGH
India	30%	10%	60%	20%	25-30%	HIGH
Indonesia	low	low	low	low	-	LOW
South Korea	high	high	high	high	>70%	HIGH
Nepal	-	low	low	9 units of combine harvesters	low	MEDIUM
Philippines	13.20%	0.20%	69%	low	-	LOW
Sri Lanka	low	low	low	low	low	LOW
Thailand	high	medium	-	-	medium	MEDIUM
Vietnam	72%	20%	100%	-	-	MEDIUM

Source: Taken from Soni and Ou

Total Factor Productivity (**in progress**)

The estimated TFP for Rice, Wheat and edible oils are provided in Tables 5 to 7 below:

Table 5. Average TFP (in %) in Rice Net Value (in 1000 International US$; Constant Price)

	TFP in RICE Estimate (in %)			
Region	1981-2010	1981-1990	1991-2000	2001-2010
Asia-Pacific	1.40	1.27	0.15	2.70
South Asia	2.02	0.08	2.42	3.52
Southeast Asia	1.49	-1.48	1.75	3.1

Table 6. Average TFP (in %) in Wheat Net Value (in 1000 International US$; Constant Price)

	TFP in Wheat Estimate (in %)			
Region	1981-2010	1981-1990	1991-2000	2001-2010
Asia-Pacific	-0.67	4.94	-0.39	3.15
East Asia	-2.90	4.69	-5.44	4.44
Pacific	-	-	-	-

South Asia	-0.03	5.95	6.12	-7.25
Southeast Asia	5.35	-18.35	3.71	7.56

Table 7. Average TFP (in %) in Edible Oil Net Value (in 1000 International US$; Constant Price)

	TFP in Edible Oil Estimate (in %)			
Region	1981-2010	1981-1990	1991-2000	2001-2010
Asia-Pacific	-0.32	-1.05	0.80	0.84
East Asia	1.95	-35.90	0.22	-0.27
Pacific	-0.65	-3.69	0.48	2.08
South Asia	-0.65	1.71	0.64	3.76
Southeast Asia	-0.47	-2.35	0.62	0.11

Country TFP discussion and analysis in progress

IV. Constraints to Achieving More Sustainable Production (in progress)
V. Policy Recommendation and Conclusion (to be developed)

References

Ahearn, M., J. Yee, E. Ball, and R. Nehring. Agricultural Productivity in the United States. USDA, ERS, Agr. Infor. Bull. No. 740, Jan. 1998.

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 and London: Cornell University Press.

China Statistics Yearbook 2009.

Dawe, D., A. Dobermann, P. Moya, S. Abdulrachman, P. Lal, S.Y. Li, B. Lin, G. Panaullah, 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,* 66:175-193.

Evenson, Robert.E. and Carl.E. Prey, 1991, *Research and Productivity in Asian Agriculture*. Ithaca, N.Y, Cornell University Press.

FAO Trade and commodities Division. 2004. http://www.fao.org/es/esc/common/ecg/125/en/The_role_of_soybeans.pdf

FAO, online. *FAOSTAT*

Flinn, J.C. and De Datta, S.K. 1984. Trends in irrigated rice yields under intensive cropping at Philippines research stations. *Field Crops Research,* 5: 201-216

Fukai, S., Sittisuang, P. and Chanphengsay, M. 1998. Increasing production of rainfed lowland rice in drought prone environments—a case study in Thailand and Laos. Plant Production Science, 1, 75–82.

Greenlands, D. L. (1997), *The Sustainability of Rice Farming*, CAB International (UK) and International Rice Research Institute, Manila (Philippine), p.115 and p.273.

Islam, Md. S. (2008). Farm mechanization for sustainable agriculture in Bangladesh: problems and prospects. BARI, Joydebpur, Gazipur, Bangladesh.

Kulkarni, (2009). Mechanization of Agriculture - Indian Scenario. Central Institute of Agricultural Engineering (CIAE), Bhopal, India.

Kumar, A., and D.S. Yadav. 2001. Long-term effects of fertilizers on the soil fertility and productivity of a rice-wheat system. *J. Agron. Crop Sci*. 186:47 -54.

Soni, P. and Y. Ou. Agricultural Mechanization at a Glance in Selected Country Studies in Asia on Agricultural Machinery Development

Thoenes, P. 2011. *Recent Trends and Medium-Term Prospects in Global Vegetable Oil Market*. A PPTpresentation in the 10th International Conference on Fat and Oil Industry-2011, 23-25 November 2011, Ukraine, Kiev.

http://jxb.oxfordjournals.org/content/early/2011/09/30/jxb.err248.full.pdf+html

The importance of the region in the rice economy cannot be disputed as it accounts for over 80% of the global production, almost 90% of its use and much of its trade. The importance of wheat, on the other hand, stems from its increasing demand as food not only in East and South Asia where the commodity has been extensively grown but also in Southeast Asia where the supply of wheat is mostly imported.