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THE RISE OF ASIA AS THE CENTRE OF GLOBAL POTATO PRODUCTION AND SOME IMPLICATIONS FOR INDUSTRY

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ABSTRACT: Potato production in the developing countries in Asia now accounts for a greater share of global output than all the industrialized countries combined. This paper examines the divergent peaks, valleys, and spikes in output that characterized the 120 million t expansion in potato production in Asia during the last half century. New technology, improvements in production and postharvest infrastructure, and government policy along with the inherent traits of the crop itself all contributed to these trends. A shift toward more diverse diets and the cash income derived from potato production played an equally, if not more important role. After assessing alternative scenarios for future development of the potato sector in the region, the paper concludes by highlighting opportunities for industry before identifying some key topics for future research.

KEYWORDS: innovation; policy; technology; consumption; trade

INTRODUCTION

The process of globalization is most often associated with the shift in the locus of economic activity towards those countries that have developed a competitive advantage driven by a combination of resource endowments, technological innovation, entrepreneurial endeavour, and government policies. Decades of rapid economic growth in the developing economies of Asia has given rise to a greater interest in how the different elements underpinning that growth have manifested themselves. In the case of potato, growth in production has been a widespread phenomenon throughout much, albeit not all, of Asia for decades (Srivastava, 1980; Anonymous, 1995; Guenthner, 2010). China became the world´s largest potato producer in 1993 due a surge in output there (Wang and Zhang, 2004), the implosion of potato output in Europe (CEC, 2007), and the break-up of the former Soviet Union (Scott, 2002). Only 7% of world totals in the early 1960s, potato production in the developing countries of Asia now accounts for 46% of global output.

Growing recognition of the potato´s global importance (FAO, 2009) and in developing countries in Asia in particular has focused attention on the crop´s potential for continued rapid expansion in the decades ahead (Singh, 2008; Walker *et al.*, 2011). Opportunities for industry are a topic of added interest given the magnitude of future food requirements in the wake of rising incomes, growing urbanization, and the sheer numbers of Asian consumers.

A variety of previous publications have analyzed potato production, area harvested, and yields in developing countries in Asia over the years. Nearly all these studies have been handicapped either by their shorter time horizons or more narrow geographic focus (*e.g.*, Anonymous, 1995; Chandran *et al.*, 2005). This paper presents the results of an analysis of FAO annual secondary data to identify changes in growth rates in potato production,

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area, and yields in the developing countries of Asia over nearly the last half century. The paper also traces the evolution in the utilization of potato and the linkages between income changes, consumption patterns, and production trends. In that regard, the paper seeks to highlight the most important trends, place them in a broader context to garner a better sense of their collective impact, and offer references to the corresponding literature for those interested in more detail on any particular topic. One key theme is the extent to which the long-term evolution of these growth rates foreshadows the most likely future scenario for regional potato production and the role of the private sector in sustaining increases in output and productivity.

MATERIALS AND METHODS

In order to identify and then analyze average annual compound growth rates (ACGRs) in potato production, area harvested, and yields in the developing countries of Asia over nearly the last half century, this study follows the method presented in Scott (2011), then further developed in Scott and Suarez (2011a). To that end, the paper first utilizes FAO times-series data for these key indicators first to calculate annual averages for the beginning (1961-63) and the end (2008-10) of the period, and then to calculate the ACGRs over the entire period, first for the region as a whole and then for particular sub-regions, *e.g.*, South Asia, Southeast Asia. Subsequently, ACGRs were also calculated over the first (1961-63 to 1984-86) and second (1984-86 to 2008-10) halves of the times-series in an initial attempt to determine if these growth rates were slowing down or speeding up.

A second dimension to this study involved tracking the rate of change in the ACGRs for production, area harvested, and yields on a continuous basis during the last five decades. ACGRs therefore were calculated using all the annual data for every ten-year period beginning with 1961-71 at first the regional and then country level (for China and India). In other words, growth rates were calculated on a moving ten-year basis, *i.e.* 1961-71, 1962-72 and so on up to 2000-10. These growth rates were then plotted to observe the changes in their trajectory over the last five decades, examined to compare the shifting relative importance of growth rates for area versus those for yields in relation to those for production, and used to estimate an overall trend for each of the three variables for Asia, China, and India respectfully.

A third key component of this study was to analyze the results of estimating 1) the evolution of the absolute levels of production, area, and yields and 2) the associated changes in their respective growth rates in relation to the findings reported in earlier regional studies and individual country reports, in order to gain insights into the factors driving these trends. The combined set of growth rates and synthesis of the related literature provide an empirical basis on which to evaluate previous projections and proposed future scenarios for potato production in developing countries in Asia. In that regard, the paper does not pretend to provide an exhaustive treatment of all topics, but rather it lays out the broad regional trends in potato production as well as utilization over the last half century and provides a set of references for those readers interested in more detail on specific countries and topics.

RESULTS AND DISCUSSION

Potato production in the developing countries of Asia averaged over 144.6 million t in 2008-10 over seven times the 19.7 million t harvested in 1961-63, nearly half a century ago **(Table 1)**. As a result, by 2010 developing countries in Asia produced nearly 50% more potatoes than Europe and a higher percentage

Table 1. Average annual growth rates for potato in developing countries in Asia, 1961-2010.

	2008-10			Growth rate (%)[1]								
	Production	Area	Yield	Production			Area			Yield		
Region[2]/Country	(000t)	(000ha)	(t/ha)	1	2	3	1	2	3	1	2	3
Asia	144,623	8,825	16.4	4.1	4.5	4.3	2.6	3.2	2.9	1.5	1.3	1.4
China	72,969	4,942	14.8	3.2	4.3	3.8	2.4	2.9	2.7	0.8	1.3	1.1
South Asia	47,451	2,582	18.4	6.0	5.2	5.6	3.3	3.7	3.5	2.6	1.4	2.0
India	35,209	1,820	19.3	6.3	4.7	5.5	3.4	3.3	3.4	2.9	1.3	2.1
Bangladesh	6,615	411	16.0	5.3	7.6	6.5	2.9	5.6	4.3	2.3	1.8	2.1
West Asia	11,311	439	25.8	5.3	2.1	3.7	2.9	0.6	1.7	2.4	1.5	1.9
Iran	4,290	159	27.0	8.2	3.3	5.7	6.3	1.0	3.6	1.8	2.3	2.0
Turkey	4,381	144	30.5	4.1	0.6	2.3	1.5	-1.3	0.0	2.6	2.0	2.3
Central Asia[3]	8,175	509	16.1	n.a.	4.5	n.a.	n.a.	1.5	n.a.	n.a.	2.9	n.a.
Kazakhstan[3]	2,555	171	15.0	n.a.	0.7	n.a.	n.a.	-1.9	n.a.	n.a.	2.6	n.a.
Kyrgyzstan[3]	1,356	85	15.9	n.a.	9.3	n.a.	n.a.	6.9	n.a.	n.a.	2.1	n.a.
Other East Asia	2,352	184	12.9	2.2	2.3	2.2	0.5	2.8	1.6	1.7	-0.4	0.6
Korea, DPR	1,596	149	11.0	2.7	3.3	3.0	2.0	4.1	3.1	0.7	-0.6	0.0
Southeast Asia	2,366	169	14.0	7.1	4.0	5.5	3.8	2.7	3.2	3.2	1.3	2.2
Indonesia	1,094	67	16.4	8.4	4.3	6.3	5.3	2.8	4.1	2.9	1.4	2.2

n.a. = not available.

[1]1=1984-86 vs. 1961-63; 2=2008-10 vs. 1984-86; 3=2008-10 vs. 1961-63.

[2]South Asia consists of Afghanistan, Bangladesh, Bhutan, India, Maldives*, Nepal, Pakistan, and Sri Lanka; West Asia includes Bahrain*, Cyprus, Iran, Jordan, Kuwait, Lebanon, Occupied Palestinian Terr., Oman, Qatar*, Saudi Arabia, Syria, Turkey, United Arab Emirates, and Yemen; Central Asia is made up Of Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan; Other East Asia consist of Dem.People's Rep. of Korea, Rep. of Korea, and Mongolia; Southeast Asia includes Brunei Darussalam*, Cambodia*, Indonesia, Lao's People Dem. Rep., Malaysia*, Myanmar, Philippines, Singapore*, Thailand, Timor-Leste, and Viet Nam.

*According to FAO, these territories reported producing either no potatoes or less than 50 t/yr on average for 2008-10.

[3]Growth rates are for the period 1992-94 to 2008-10 only.

Source: FAOSTAT (accessed January 2012) and calculations for this study.

(46%) of worldwide output than in all the industrialized countries (41%) combined (FAOSTAT, accessed January 2012).

Notwithstanding the massive increase in output, the evolution of the absolute levels of potato production in the developing countries of Asia over the last half century was by no means continuous. Rather it included periods of relatively slow growth as well as intermittent, spectacular surges in output, *e.g.*, production jumped from 60.4 to 83.9 million t between 1990 and 1993, then from 116 to 150 million t from 2006 to 2010 **(Fig. 1)**. The shifting nature of the evolution of potato production in the developing countries in Asia suggests a need to analyze the long-term trends more carefully.

The increase in total potato output in Asia over the last half century resulted from an overall ACGR for potato production of 4.3% for nearly the last 50 years. More significantly, the growth in potato output was a widespread phenomenon throughout much, albeit not all, of Asia as ACGRs in potato production averaged at or above 3.7% in five of the seven largest potato-producing countries in the region over the same period **(Table 1)**. Despite these overall trends, growth rates for potato were far from stable over time and space. Instead, ACGRs for regional

potato production evolved in quasi cyclical fashion-rising rapidly in the 1960s, 1970s, and 1990s while slackening considerably in the 1980s and again in the 2000s **(Fig. 1, Table 2)**. Moreover, the last half century saw growth rates in some of Asia´s sub-regions continue to accelerate while those in others declined. In a few noteworthy countries, potato output has yet to take off. These different trends, recurrent peaks, valleys, and spikes therefore merit closer examination.

Growth rates for area harvested in potato evolved roughly parallel those for production for nearly all the last 50 years and, except from the mid-1960s to mid-1970s, largely accounted for the bulk of the increase in output over time **(Fig. 1 and 2, Table 2)**. Potato cultivation spread rapidly in much of the region for agronomic, economic, and nutritional reasons. Potato produces more calories per hectare per day, has a far superior harvest index *i.e.*, edible yield as a percentage of total yield, and yields more calories per unit of water than any other major food crop (Scott 2002; FAO, 2009). Given rising man/land ratios-including millions of rural landless in some parts of the region, *e.g.*, Bangladesh (Scott, 1988), and massive numbers of underemployed elsewhere, *e.g.* western China, India (World Bank, 2007), the potato´s intensive labour requirements make the crop almost ideally suited to regional human resource endowments. Potato has generally, albeit not always, proven to be highly profitable crop even for small farmers (Scott, 1988; Brown and Kennedy, 2005; Xie *et al.*, 2007; Ahmadi, 2008). Furthermore, besides bringing diversity to the region´s traditionally cereal-based diets, the potato harvest often provides food to rural households when supplies may be seasonally low and contributes important vitamins (vitamin C) and minerals as well (Scott, 2002).

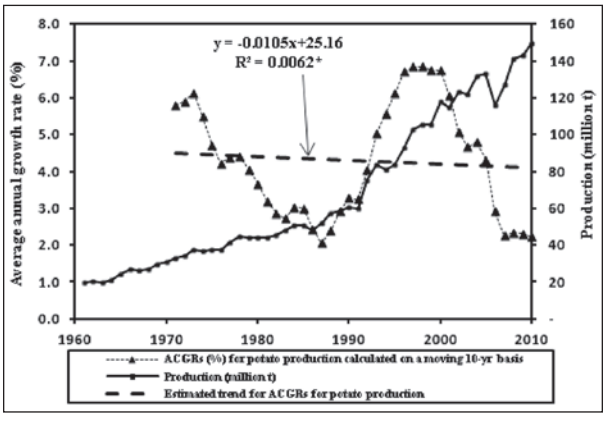

Fig. 1. Production for potato and ACGRs for production for developing countries in Asia, 1961-2010.[1]
Source: FAOSTAT and calculations for this study.
[1]ACGRs are calculated on a moving 10-year interval basis, see text for details.
**not significant.*

Growth in output of potatoes in the developing countries of Asia has also been aided by increases in average yields. Average potato yields in the region reached 16.4 t/ha during 2008-10 **(Table 1)** as ACGRs for potato yields, while uneven across the region and over time, averaged 1.4% per yr for nearly the last half century. However, ACGRs for average yields experienced widespread declines- in some cases by over 50%, in recent years. It simply became increasingly difficult to improve productivity at a more rapid if not comparable pace, at higher levels of output per hectare, and over a much larger land area under cultivation **(Fig. 2 and 3)** - particularly in some sub-regions whereas area harvested surged ahead in more recent years to include less favourable growing areas (Pandey *et al.*, 2008; Scott and Suarez, 2011a) or in countries such as the Democratic Republic of Korea where quality seed and chemical fertilizers remain in short supply (FAO, 2009). More importantly, over the last decade growth rates for total area harvested in potato in the developing countries of Asia fell to lows not seen in forty years **(Table 2)**.

Table 2. Average compound growth rates (ACGRs) for potato in developing countries in Asia, 1961-2010.[1]

Years	Production			Area			Yield		
	R^2	ACGR (%)	Significance	R^2	ACGR (%)	Significance	R^2	ACGR (%)	Significance
1961-71	.95	5.8	***	.89	3.9	***	.62	1.8	***
1962-72	.96	5.9	***	.89	3.5	***	.82	2.3	***
1963-73	.96	6.1	***	.78	2.9	***	.84	3.2	***
1964-74	.96	5.5	***	.67	2.1	***	.85	3.3	***
1965-75	.96	4.7	***	.66	1.6	***	.81	3.0	***
1966-76	.94	4.2	***	.66	1.1	***	.82	3.1	***
1967-77	.95	4.4	***	.67	1.1	***	.83	3.2	***
1968-78	.95	4.4	***	.70	1.5	***	.80	2.9	***
1969-79	.95	4.1	***	.73	2.0	***	.63	2.0	***
1970-80	.93	3.7	***	.75	2.1	***	.45	1.5	**
1971-81	.89	3.2	***	.77	2.3	***	.19	0.9	n.s.
1972-82	.87	2.9	***	.80	2.5	***	.06	0.4	n.s.
1973-83	.87	2.7	***	.92	2.8	***	.01	-0.1	n.s.
1974-84	.90	3.0	***	.90	2.6	***	.09	0.4	n.s.
1975-85	.89	3.0	***	.88	2.5	***	.16	0.5	n.s.
1976-86	.80	2.4	***	.87	2.4	***	.00	0.1	n.s.
1977-87	.82	2.1	***	.86	2.1	***	.00	-0.1	n.s.
1978-88	.80	2.4	***	.93	1.9	***	.15	0.5	n.s.
1979-89	.86	2.9	***	.93	1.9	***	.48	1.0	**
1980-90	.90	3.3	***	.97	2.2	***	.52	1.1	**
1981-91	.90	3.2	***	.97	2.2	***	.48	1.0	**
1982-92	.83	4.0	***	.90	2.9	***	.49	1.1	**
1983-93	.82	5.0	***	.91	3.5	***	.55	1.5	***
1984-94	.86	5.6	***	.93	3.7	***	.63	1.8	***
1985-95	.91	6.1	***	.94	3.9	***	.79	2.2	***
1986-96	.94	6.7	***	.95	4.2	***	.87	2.5	***
1987-97	.94	6.9	***	.96	4.4	***	.87	2.4	***
1988-98	.94	6.9	***	.96	4.5	***	.85	2.3	***
1989-99	.93	6.8	***	.96	4.8	***	.65	1.8	***
1990-00	.93	6.7	***	.97	5.1	***	.56	1.6	***
1991-01	.91	6.1	***	.96	4.9	***	.40	1.2	**
1992-02	.95	5.1	***	.95	4.2	***	.35	0.8	*
1993-03	.93	4.7	***	.92	4.0	***	.30	0.7	*
1994-04	.94	4.8	***	.89	3.7	***	.49	1.1	**
1995-05	.93	4.3	***	.88	3.3	***	.45	1.0	**
1996-06	.74	2.9	***	.74	2.4	***	.16	0.5	n.s.
1997-07	.66	2.3	***	.66	1.8	***	.12	0.4	n.s.
1998-08	.67	2.3	***	.66	1.5	***	.35	0.8	*
1999-09	.67	2.3	***	.68	1.3	***	.43	1.0	**
2000-10	.66	2.2	***	.70	1.5	***	.37	0.7	**

*** = Significant at 1% level; ** = Significant at 5% level; * = Significant at 10% level; n.s. = not significant.

[1]using the following expression: $\ln Y = \ln b_0 e^{b_1 t}$, *i.e.* $\ln(Y)=\ln(b_0)+b_1 t$; where, Y = Variables (Production, Area or Yield); ln= natural log; and b_1=ACGR.

Source: FAOSTAT (accessed January 2012) and calculations for this study.

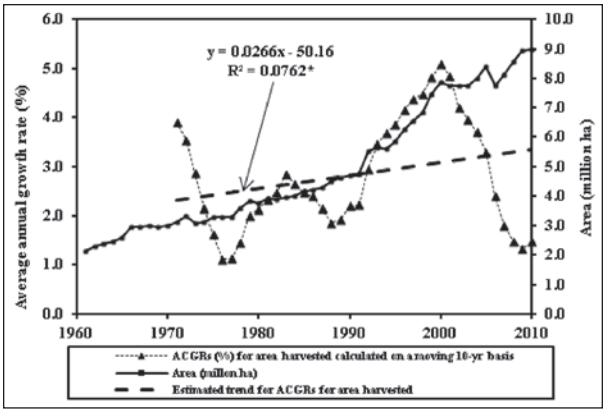

Fig. 2. Area harvested for potato and ACGRs for area in developing countries in Asia, 1961-2010.[1]
Source: FAOSTAT and calculations for this study.
[1]ACGRs are calculated on a moving 10-year interval basis, see text for details.
**significant at the 1% level.*

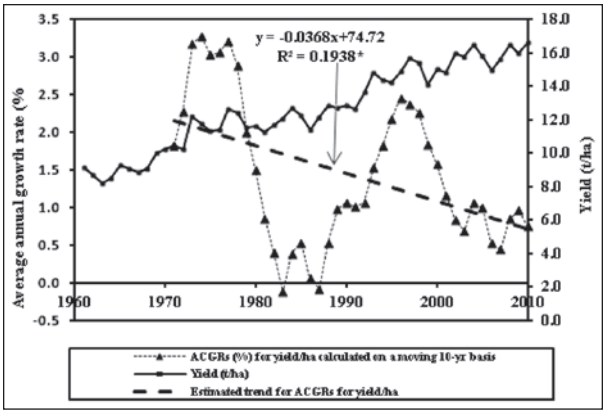

Fig. 3. Yield/ha for potato and ACGRs for yields in developing countries in Asia, 1961-2010.[1]
Source: FAOSTAT and calculations for this study.
[1]ACGRs are calculated on a moving 10-year interval basis, see text for details.
**significant at the 1% level.*

Concentration of regional production

Within the developing countries of Asia, potato production and area harvested remain highly concentrated. China and India alone account for 74% of regional output and 77% of area planted. China and India also witnessed over 75% of the increase in regional production during the last five decades (FAOSTAT, accessed January 2012).

Whereas China harvested 68% of regional production and 65% of area in 1961-63, those percentages shrank to 50% of production and 57% of area in 2008-10–even as growth rates for potato output and area in China continued to accelerate (Scott and Suarez, 2012). With growth rates well in excess of those of China in the last quarter century **(Table 1)**, South Asia´s share of regional totals rose to 34% of production and 29% of area planted. The emergence of Central Asia as a separate sub-region within Asia (Carli, 2008) accounted for the remaining shift in potato production and area away from China toward other sub-regions.

Potato has also become among the most important food crops in terms of annual production in diverse nations across the region including, with the ranking for potatoes in parenthesis, Armenia (1), Iraq (4), Lebanon (1), Republic of Korea (3), Saudi Arabia (3), Tajikistan (2) and Turkey (4) (CIP, 2010). In other cases, such as Laos, the Philippines, and Thailand, potatoes have remained a relatively minor vegetable crop (Singh, 2008). Despite decades of efforts to expand production and improve productivity, neither traditional diets, the demand for new food commodities or even exports favoured potatoes as farmers and consumers focused greater attention on other commodities (FAOSTAT, accessed January 2012).

Growth rates and their evolution at the country level

Two developments overshadow all others regarding growth rates for potatoes in the developing countries in Asia during the last five decades: 1) the surge in output in China and the expansion of production in the Indo-Gangetic plain, and 2) growth rates for potato output in both locations experienced a series of peaks and valleys. In the Chinese case–and contrary to the characterization of potato production as presented in much of

the literature (Walker *et al.*, 1999; Wang and Zhang, 2010), the evolution of potato output went through four distinct periods (Scott and Suarez, 2012). It doubled between 1961 and 1973; went flat through the rest of the 1970s until the late 1980s; boomed in the 1990s; and then slowed markedly from 2000 to 2010 **(Fig. 4)**.

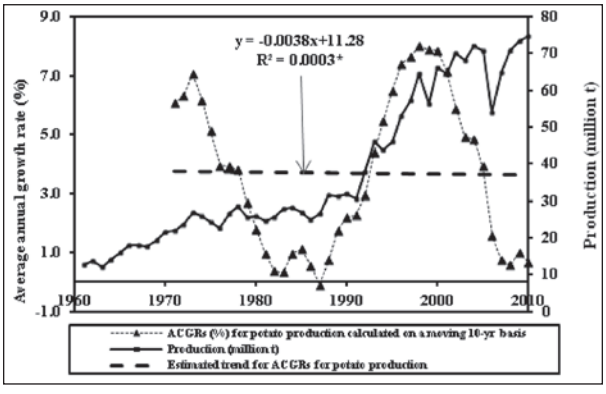

Fig. 4. Production for potato and ACGRs for production in China, 1961-2010.[1]
Source: FAOSTAT and calculations for this study.
[1]ACGRs are calculated on a moving 10-year interval basis, see text for details.
**not significant.*

While the famines of 1959 and 1961–along with the hunger resulting from the failures of the Great Leap Forward (1958-60)–spurred greater potato output into the 1960s and early 1970s (Gitomer, 1996), the most significant jump in potato production in China over the last half century took place after the adoption of improved technology for rice and wheat that began in the 1960s and 1970s (Fan and Pardey, 1997). These technological improvements were later complemented by a series of shifts in government policies and regulations that began in the countryside in the late 1970s only to reach fruition some 15 years later. Essentially, with cereal stocks replenished, the reforms allowed growers more freedom to decide what to plant and consumers what to eat (Scott and Suarez, 2011b). In the wake of these developments, and with the adoption of technological innovations in the potato sector itself including the release of improved varieties and better access to inputs such as chemical fertilizers for at least some growers (Xie *et al.*, 2007; Jansky *et al.*, 2009), annual production in China expanded by 34.2 million t between 1991 and 1998 **(Fig. 4)**, or over 50% of the entire increase in output over the last nearly half century.

The evolution of ACGRs for potato output in China over the last five decades was largely driven by the rise and fall in growth rates for output as opposed to yields (Scott and Suarez, 2012). Since 2000, however, growth rates for potato production in China turned sharply downward as expansion of both area harvested and yields plummeted **(Fig. 5 and 6)**. With area harvested in potato doubling over the last twenty years to pass five million hectares–and pushing into less favoured areas, growth rates for productivity became harder to sustain. Growth rates also were dampened at least in part because consumption of meat, dairy products and other vegetables garnered relatively greater attention from

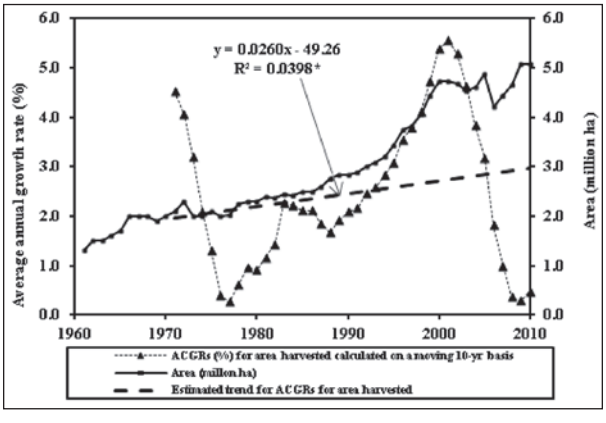

Fig. 5. Area harvested for potato and ACGRs for area in China, 1961-2010.[1]
Source: FAOSTAT and calculations for this study.
[1]ACGRs are calculated on a moving 10-year interval basis, see text for details.
**significant at the 1% level.*

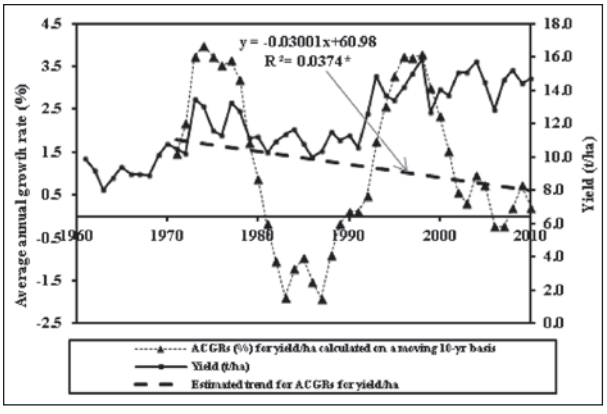

Fig. 6. Yield/ha for potato and ACGRs for yields in China, 1961-2010.[1]
Source: FAOSTAT and calculations for this study.
[1]ACGRs are calculated on a moving 10-year interval basis, see text for details.
**significant at the 1% level.*

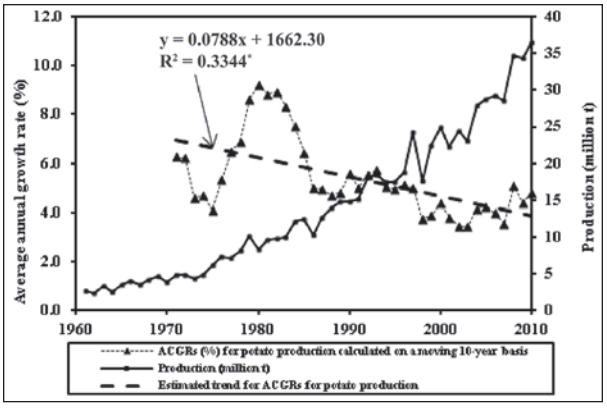

Fig. 7. Production for potato and ACGRs for production in India, 1961-2010.[1]
Source: FAOSTAT and calculations for this study.
[1]ACGRs are calculated on a moving 10-year interval basis, see text for details.
**significant at the 1% level.*

consumers and alternative crops assumed greater importance for growers (Scott and Suarez, 2011b). Additional factors limiting potato production in China include: technical (*e.g.*, poor quality seed; limited genetic base for generating new varieties; and, pests and diseases most notably late blight, see Jansky *et al.* 2009); natural resource (*e.g.*, declining water tables combined with more erratic and lower rainfall particularly in the northern provinces); institutional (*e.g.*, land tenure that confines the vast majority of potato farmers to utilizing roughly one hectare of farmland); and, economic (*e.g.*, uncertainty about the future differences between rural and urban incomes and the capacity of different households to purchase different types of food) considerations (Scott and Suarez, 2012).

Potato production in India expanded from 2.7 million t in 1961 to 36.6 million t in 2010 **(Table 1)**. The trend in growth rates includes booms, momentary busts, and then renewed expansion punctuated by occasional huge spurts in output **(Fig. 7)**, *e.g.*, jumping 25% from 8.2 to 10.1 million t from 1978 to 1979 (Srivastava, 1980). ACGRs for area harvested were particularly strong in the 1970s **(Fig. 8)** as the spread of shorter duration cereal varieties facilitated by the expansion of irrigation infrastructure opened up space in the annual agricultural calendar for potato cultivation in the lowland plains (Pandey, 2007, 2008). Those trends combined with the diffusion of the seed plot production technique, the expansion of cold storage facilities to ensure seed availability, and the release of improved

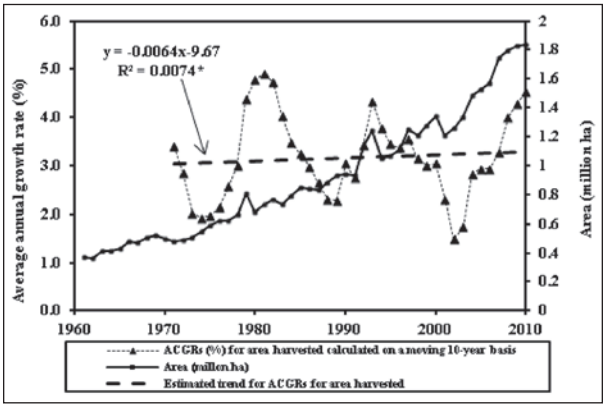

Fig. 8. Area harvested for potato and ACGRs for area in India, 1961-2010.[1]
Source: FAOSTAT and calculations for this study.
[1]ACGRs are calculated on a moving 10-year interval basis, see text for details.
**not significant.*

potato varieties spurred greater area under cultivation and consequently the associated ACGRs (Pandey and Sarkar, 2005; Scott and Suarez, 2011a).

In contrast to China, however, growth rates in area harvested in potato in India were exceptionally strong in the 1980s; fell in the 1990s; and then rebounded in recent years even as the rate of increase in yields plunged **(Fig. 8 and 9)**. Rising incomes and modest per capita consumption levels helped drive growth rates in area harvested to meet continued strong demand. The crop flourished in large part because its relatively short vegetative cycle of 75-110 days squeezes into a niche in the annual cropping calendar thereby, in effect, expanding the agricultural frontier and enabling greater food production in a land-scarce, labour-abundant rural economy (Scott, 2002). The availability of good quality seed from the developing world´s most successful national potato program enabled even small growers to gain access to planting material and continue to account for the bulk of the harvest (Walker *et al.*, 1999). Additional production incentives for potatoes in India included the benign policy environment (*i.e.*, lack of price controls, public procurement programmes, or food rationing schemes that occasionally dampened producer enthusiasm for cereal production), over 23 million t of cold storage for potatoes along with the prospect of economic gains from doing so (Fuglie *et al.*, 1997), and India´s extensive rural road network that facilitates the supply of inputs and the shipment and sale of a bulky product at harvest. Factors contributing to the recent slowdown in productivity growth include the most recent rapid expansion in cultivated area; the closing of the agricultural frontier for irrigated potato production; and, loss of soil fertility due to multiple cropping over decades and the resulting compacting (Thiele *et al.*, 2010; CPRI, 2011; Scott and Suarez, 2011a). In light of these developments, various authors (Pandey, 2007) have outlined an ambitious agenda for innovation in various domains ranging from improved varieties with early bulking, heat tolerance and disease resistance to post-harvest technology (e.g., better temperature control in cold storage, new processed product development). Others have called for more aggressive diffusion of existing techniques such as mini-irrigation schemes and better supply of improved quality planting material (Pandit *et al.*, 2010). Biotechnology is seen as a way to overcome the difficulties associated with generating improved productivity utilizing conventional scientific paradigms when the vegetative cycle for the crop has shrunk to as short as 75 days (Pandey and Sarkar, 2005).

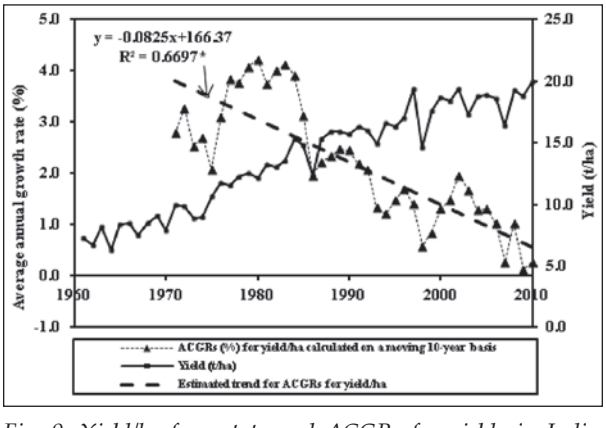

Fig. 9. Yield/ha for potato and ACGRs for yields in India, 1961-2010.[1]
Source: FAOSTAT and calculations for this study.
[1]ACGRs are calculated on a moving 10-year interval basis, see text for details.
**significant at the 1% level.*

Potato production in Bangladesh also expanded in remarkable fashion: from 343,000 t in 1961 to 7.9 million t in 2010. Area harvested jumped from 56,000 to 435,000 ha during the same period (FAOSTAT, accessed January 2012). Various factors outlined above in the case of India also apply to Bangladesh. In addition, one key element catalysing the potato´s expansion in Bangladesh was the successful introduction of shorter duration,

high–yielding rice varieties. The cropping sequence means that potatoes are often grown with sub-surface water still left after flooding the rice, enabling potatoes to benefit as well from residual soil nutrients still present from fertilization of the rice crop (Scott, 1988). Most importantly, given the high yields and the short vegetative cycle, potato cultivation is a "commercial crop" in much of Asia in that the bulk of production is harvested for sale and eventual use off the farm, even by small growers harvesting less than half a hectare (Scott, 1988; Azimuddin *et al.*, 2009). Recent research indicates that more could be done to improve productivity and profitability by more efficient use of available inputs (Hossain *et al.*, 2008; Baset *et al.*, 2009).

The evolution of potato production in other sub-regions of Asia was more mixed. In West Asia, Iran witnessed strong, albeit moderating growth rates in production **(Table 1)** as the crop's profitability proved particularly attractive (Ahmadi, 2008). Turkey´s output more than doubled 1980-99, only to fall by 25% over the last decade as domestic consumer demand, already among the highest in region on a per capita basis, shifted to include alternative foods and growers shifted their attention to more lucrative export crops (Çalişkan *et al.*, 2010). In Central Asia, production evolved in diverse ways over the last two decades in a number of former Soviet Republics each with a long history of potato production and use. Kyrgyzstan witnessed both a rapid expansion in area harvested and a sharp increase in yields (FAO, 2009) only to see both practically stagnate in recent years. Alternatively, Kazakhstan saw output drop by half from 1992 to 1998. It then took until 2010 to recover to previous highs (FAOSTAT, accessed January 2012) as seed imports from Russia became more problematic after independence from the Soviet Union and quality planting material remains a major constraint (Carli, 2008). In Southeast Asia, production in Indonesia doubled every ten years from 1960s to 1998 to reach nearly one million t (Scott, 2002). Since then, however, output stalled in part because potato cultivation has yet to achieve the expansion to lower elevation production zones as took place in South Asia (Walker *et al.*, 1999) or on the islands beyond Java (Nurdin, 2003) as had been earlier envisioned might happen given the modest levels of domestic per capita potato consumption and the potential for exports to nearby markets. Potato production in Vietnam reached 872,000 t in 1980 as output surged to meet food security concerns in the late 1970s (Fuglie *et al.*, 2003), but now stands at roughly half that level as growers focused their efforts on other crops. Annual output in Laos has yet to pass 50,000 t while it is reportedly non-existent in Cambodia in spite of mountainous areas seemingly conducive to growing potatoes.

Utilization

The fundamental driving force behind the growth in potato production in many developing countries of Asia has been the shift in consumption patterns away from strictly cereal-based diets (Pingali, 2006; Scott and Suarez, 2011a, 2011b). In the 1960s and 1970s, per capita potato consumption in numerous–but by no means all–parts of the region was relatively low. As incomes increased in subsequent decades, per capita consumption of potatoes rose sharply in a number of major potato-producing countries including Bangladesh, China, India, and Iran **(Fig. 10)** as anticipated in various studies that estimated the effect of greater income on potato in-take across the region (Fuglie *et al.*, 2003; Liu and Chern, 2003; Scott and Suarez, 2011b). Furthermore, except in Central Asia where potato often serves more as a staple

food (FAO, 2009), a progressively higher percentage of output was utilized for food over the last three decades and particularly since 1991-93 **(Table 3)**. The emergence of potato consumption in the form of snacks or French fries has been a noteworthy phenomenon given the explosive growth (Pingali, 2006) and apparent potential for continued expansion

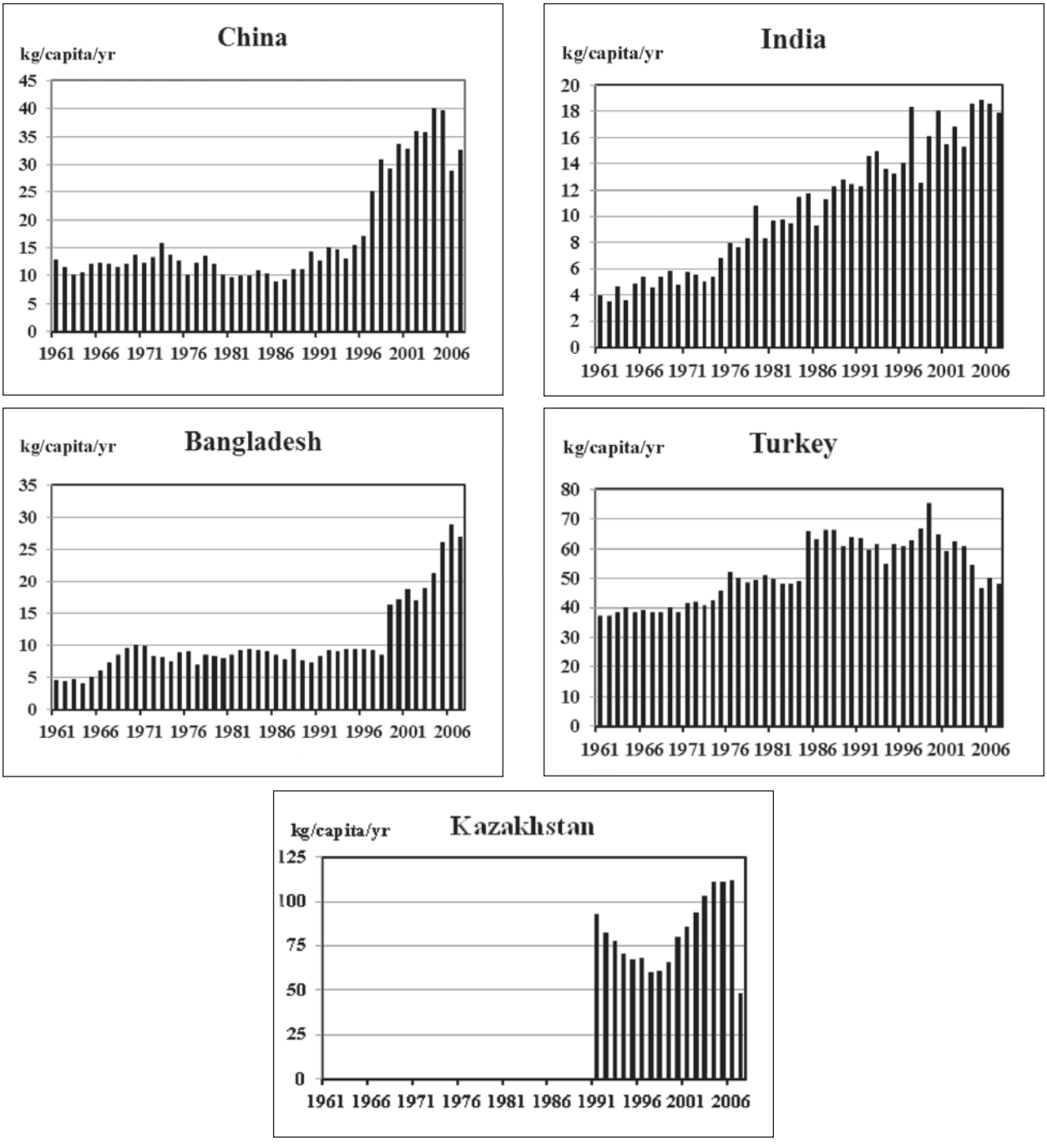

Fig. 10. Annual average potato consumption for developing countries in Asia, 1961-2007. Source: FAOSTAT (accessed January 2012).

Table 3. Food Balance Sheets for potato in Asia, 1961-63 to 2005-07.[1]

Region	Category	Year			
		1961-63	1976-78	1991-93	2005-07
Asia Developing	Domestic supply (million t)	19.6	40.4	72.9	126.3
	Food (%)[2]	63	54	59	73
	Feed (%)	12	20	12	6
	Seed (%)	11	9	8	6
	Processing (%)	6	8	12	6
	Other utilization (%)[3]	8	8	9	10
China	Domestic supply (million t)	13.0	25.6	38.4	63.8
	Food (%)[2]	59	44	43	70
	Feed (%)	18	31	22	10
	Seed (%)	10	8	7	4
	Processing (%)	8	12	22	11
	Other utilization (%)[3]	5	5	6	6
South Asia	Domestic supply (million t)	3.6	9.0	20.3	38.0
	Food (%)[2]	68	70	73	75
	Feed (%)	0	0	0	0
	Seed (%)	16	14	11	9
	Processing (%)	0	0	0	0
	Other utilization (%)[3]	16	16	16	16
West Asia	Domestic supply (million t)	2.0	3.9	8.4	11.0
	Food (%)[2]	74	77	82	83
	Feed (%)	2	2	0	0
	Seed (%)	13	10	7	6
	Processing (%)	1	2	0	0
	Other utilization (%)[3]	10	10	11	11
North Asia	Domestic supply (million t)	n.a.	n.a.	4.5	7.5
	Food (%)[2]	n.a.	n.a.	71	63
	Feed (%)	n.a.	n.a.	3	9
	Seed (%)	n.a.	n.a.	19	15
	Processing (%)	n.a.	n.a.	1	1
	Other utilization (%)[3]	n.a.	n.a.	6	11
East Asia	Domestic supply (million t)	0.8	1.1	1.4	3.2
	Food (%)[2]	62	71	70	65
	Feed (%)	10	14	16	15
	Seed (%)	7	6	5	2
	Processing (%)	11	0	0	9
	Other utilization (%)[3]	10	10	10	9
Southeast Asia	Domestic supply (million t)	0.2	0.8	1.3	2.8
	Food (%)[2]	77	80	86	85

Region	Category	Year			
		1961-63	1976-78	1991-93	2005-07
	Feed (%)	0	0	0	
	Seed (%)	15	13	6	5
	Processing (%)	1	0	0	0
	Other utilization (%)[3]	6	6	7	10

n.a. = not available.
[1]Three-year average.
[2]Includes processed food products.
[3]Includes "other uses" and waste; in previous years refers only to waste, see Horton (1988), Anonymous (1995).
Source: FAOSTAT (accessed January 2012)

(Rana, 2011; Scott and Suarez, 2011b). But consumption of these products started from very modest levels in per capita terms; hence, they have had a relatively minor impact on increases in total potato consumption to date (Guenthner, 2001; Pandey *et al.*, 2006; Xie *et al.*, 2007; Rana *et al.*, 2010).

In contrast to growing use of potato as food, feed use has declined significantly as an estimated share of annual regional available supply **(Table 3)**. Potatoes for feed is confined largely to China (84% of the regional total), but with some use in the DPR of Korea and parts of North Asia such as Kazakhstan where it still serves as fodder (FAO, 2009). Although the data are sketchy because such use is overwhelmingly on farm, it appears that as the livestock sector in China converts to industrial inputs and processes to meet increased demand for meat and dairy products (Rae, 2008), the effective cost of potato became increasingly expensive in comparison to other local feed sources such as cassava, maize, and sweet potato (Scott, 2002; Fuglie, 2003, 2004) or imported soybean cake (Alexandratos, 2008). Hence, FAO data indicate absolute quantities of potatoes used for feed in China dropped from nearly an estimated 16 million t in the late 1990s to less than half of that by 2007 helping to dampen the growth in demand for potatoes and growth rates in area harvested in the process (Scott and Suarez, 2012).

Processing of potato for industrial uses (*e.g.*, starch for industrial uses) remained at one percent or less of total available supply over the last five decades in every sub-region except China and Other East Asia **(Table 3)**. Nevertheless, processing of potatoes for industrial use is frequently mentioned as a potential area for expanded utilization (Khurana, 2006; Xie *et al.* 2007) because as economies develop, the demand for starch for diverse uses in industry increases (Fuglie *et al.*, 2006). With pockets in Central Asia as an exception (FAO, 2009), however, several trends discouraged the use of potatoes to make processed products for industry. Relative prices for starch in the broader Asian market (Fuglie, 2003, 2004; Fuglie *et al.*, 2006), the implosion of the potato processing industry in Europe due to restructuring of the industry after the expansion of the EU (Haase and Haverkort, 2006) thereby tending to push down export prices, and in the Chinese case supply chain complications along with the relaxation of forced procurement of raw material in the countryside (Fan and Pardey, 1997) and the emerging alternative outlets for fresh tubers all combined to reduce potato´s competitiveness vis-à-vis local substitutes or imports and to induce growers to sell their potatoes through other marketing channels (Scott and Suarez, 2011a, 2011b).

Processing of potatoes for human consumption for other than starch-based

products (*e.g.* French fries, chips or crisps, flakes) expanded considerably in the developing countries of Asia particularly over the last two decades (Fuglie *et al.*, 2003; Pandey *et al.*, 2009a, 2009b). China and India in particular saw considerable growth in the demand for snack foods made from potatoes (India) as well as for French fries (China). Both local firms and joint ventures involving multinational companies expanded operations to meet growing demand (Guenthner, 2001; Wang and Zhang, 2004, 2010; Rana *et al.*, 2005, 2010; Curtis *et al.*, 2007; Rana, 2011; Scott and Suarez 2011b). Rural, small-scale, rustic processing of potatoes into chips and coarse flour also captured renewed attention (Huq, 2002). But in at least some countries these activities started from a relatively small base. Nevertheless, recent estimates for India, for example, suggest that processing for human consumption may absorb up to 8% of annual domestic supply (Rana *et al.*, 2010) and that 60% of that volume (roughly 2.5 million t) goes to produce potato chips (Rana *et al.*, 2009).

Estimates of the quantities used for processing for human consumption in China range as high as 21% (Jansky *et al.*, 2009). The overwhelming bulk of such processing consists of starch-based products such as noodles produced at the farm household level. Summing how much of what is harvested is processed into starch for human consumption, eaten in fresh form, used as starch for industrial uses, fed to livestock, or lost to shrinkage is therefore much harder to estimate in total for millions of small farmers, let alone pin down by sub-category (Scott and Suarez, 2011b).

Despite growing urbanization, rising incomes, increased female participation in the formal workforce, booming tourism, and a greater demand for convenience foods, supply chain restrictions ranging from varieties apt for processing to enforcement of contracts act as one set of constraints to faster growth in utilization of potatoes for French fries and flakes (Guenthner, 2001; Xie *et al.*, 2007). On the demand side, lower per capita incomes, cheap domestic labour, and the price of industrially processed products may dampen faster expansion or open up opportunities for intermediate (*i.e.*, cheaper, less uniform quality) products as has occurred in other developing country regions (Scott 2011; Scott and Zelada, 2011).

In China, the use of tubers on-farm to make processed products for human consumption seems likely to continue given the popularity of derived products such as noodles–albeit with a progressively shrinking role–given the millions of small-scale producers, the limitations of on-farm storage for whole tubers, the popularity of certain processed potato products made from potatoes (*e.g.*, noodles) and limited off-farm employment opportunities for family labour in more isolated production regions in North and Southwest China (Fuglie *et al.*, 2006). However, such demand is tempered by rising concern about health, nutrition, and product safety, thereby making traceability increasingly important (Xie *et al.*, 2007).

Over the last several decades, numerous studies have identified the high cost of planting material as a main cause of high cost of potato cultivation (Scott, 1988; Xie *et al.*, 2007; Hossain *et al.*, 2008; Azimuddin *et al.*, 2009). Given that finding and that potato is most often produced as a cash crop in the developing countries of Asia, growers have had strong incentives to economize on seed use. Estimated seed use as a percentage of total available supply has fallen to single digits in every sub-region except Central Asia **(Table 3)**. One reason has been the spread in use of cut seed (Anonymous, 1995; Hossain *et al.*, 2008). Although of

minor relative importance, the emergence of alternative schemes to produce and multiply good quality planting material in the form of true potato seed (Fuglie, 2001; Almekinders *et al.*, 2009) or mini-tuber production (Xie *et al.*, 2007; Ezeta, 2008) has also contributed to this trend. However, in China such schemes have begun to attract greater attention given the often commercial (and unregulated) nature of these operations (Jansky *et al.*, 2009), the massive scale of some of these initiatives (Delleman, 2009) combined with the sheer magnitude of domestic seed requirements and the potential for export going forward.

Trade

Trade in potatoes and potato products also expanded in recent decades among the developing countries of Asia, particularly in the case of China and West Asia. Nevertheless, average annual total trade (imports plus exports for the combined total of frozen French fries and fresh tubers) for 2008-10 represented about less than 3% of production (FAOSTAT, accessed February 2012). Developing countries of Asia typically export modest quantities of fresh potatoes to neighbouring markets such as from Sumatra in Indonesia to Singapore (Adiyoga *et al.*, 2001); or from India to Nepal and Sri Lanka (Singh, 2010); or from Turkey to nearby Eastern Europe (Çalişkan *et al.*, 2010); or from China to eastern Russia or selected markets in Southeast Asia (Gitomer, 1996; Xie et al., 2007). Many of these same countries import seed and processed potato products *e.g.*, French fries from Europe or North America (Guenthner, 2001; Scott 2002; AAFC, 2007; van Loon, 2007; Çalişkan *et al.*, 2010). The Gulf States and Saudi Arabia have long imported both types of potato products (Scott, 1988; Çalişkan *et al.*, 2010). In China, recent years have witnessed a surge in table potato exports to reach over 400,000 t on an estimated annual average fresh weight equivalent (FWE) basis; a sharp rise in annual imports of frozen French fries to some 240,000t FWE in 2008-2009; and, an emerging trade row over imports of potato starch currently calculated to range between 300,000 to 960,000t FWE yearly (Scott and Suarez, 2011b).

Attempts to project trends in trade in processed products have proven problematic at best (Anonymous, 1995; Scott *et al.*, 2000; Khurana, 2006; Wang and Zang, 2004). Exports from India remained thin (Scott and Suarez, 2011a). Imports of frozen French fries by China were insignificant relative to total domestic production (Scott and Suarez, 2011b). Nevertheless, potato trade deficits in developing countries have captured growing attention (FAO, 2009) and interest in promoting exports (and reducing imports) remains keen (Pandey *et al.*, 2000). However, a series of technical supply chain limitations (e.g., limited cold chain infrastructure), institutional constraints (i.e., informal trade arrangements), and the sheer instability of potato markets handicap these efforts (Scott and Suarez, 20011a, 2011b). Furthermore, in the eyes of some observers (Guenthner, 2010), a continued focus on exports tends to distract attention away from even more promising commercial opportunities for potato and potato products in domestic markets.

CONCLUSIONS AND RECOMMENDATIONS

In light of these trends, earlier projections for growth rates in production (between 2.92% and 2.49% vs. over 3.5% observed), area (between 2.09% and 1.37% vs. over 2.5% observed), and yields (between 0.80% and 1.11% vs. 1.92% observed) for the period 1988-2000 were far too conservative (Anonymous, 1995). Based on more recent trends, subsequent baseline scenario projections for production for the period 1993 to 2020 (Scott *et al.*, 2000) also proved too modest as estimated totals for

the end of the period were already surpassed by 2006-08 (Walker *et al.*, 2011). These actual trends were overwhelmingly attributable to a near quadrupling in area harvested and a doubling of yields, both of which largely took place in China and India. Since 2000, however, growth rates for yields in both countries plummeted and those for area planted in China crashed as well raising questions about the future path of potato production in these countries and the region more generally.

Based on historical trends and recent developments, future prospects for potato in China and India share certain similarities, but also important distinctions. In the Chinese case, the evolution of consumption of fresh potato in the North and Southwest, where the bulk of the potatoes is harvested, is one key consideration. In that regard, the pace at which the respective interior provinces become integrated into the rest of the economy, the effect that has on household incomes and in turn on in-take of potato will be one critical driver. Slower, albeit small (<1% per yr) population growth, increased consumption of snacks and French fries, shipments of potatoes to urban markets on the eastern seaboard, exports of fresh tubers--possibly even seed–as well as processed products will offset some of the continued, steady decline in the percentage of potato output used for feed, seed, and on-farm processing to make products for human consumption. Notwithstanding, all this takes place when per capita potato consumption has already quadrupled since 1961 and when greater potato consumption does not (yet) have the status as a preferred vegetable as in South Asia (Scott and Suarez, 2011b). On the supply side, there are also optimistic and more pessimistic scenarios (Scott and Suarez, 2012). While some authors speak of the declining per capita availability of agricultural land in Asia (Singh, 2010), other estimates report 30 million ha of winter fallow paddy fields are available for potato cultivation in Southwest China (Xie, 2008) not to mention Tibet, improvements in productivity from among other things, the embrace of biotechnology, or the more widespread and effective use of conventional inputs such as chemical fertilizers in heretofore isolated growing areas. Alternatively, if potential water shortages (Makin, 2004), the ill effects of climate change, or environmental damage were all to become more pronounced, then more optimistic portrayals of the potato sector´s future in China become increasingly problematic (Hijmans, 2003; Scott and Suarez, 2012).

In case of India and other parts of South Asia such as Bangladesh, pressure on food supplies are likely to be more acute as demographic growth rates are triple those in China and a larger share of the population still lives in the countryside (World Bank, 2007). Furthermore, potato is often referred to as the king of all vegetables on the sub-continent still dominated by a vegetarian culture and one where per capita consumption is half of that in China. On the supply side, the closing of the agricultural frontier for irrigated potato production, the loss of soil fertility due to compacting and the decline of organic matter and the advent of climate change with its effect on temperatures and rainfall patterns are but a few of the major constraints to increased production. Conversely, India´s agricultural research and development capabilities and the long-established, widespread and more vibrant role of the private sector in the case of potato suggest considerable unrealized potential to increase production (Scott and Suarez, 2011a). National estimates of future potato production project growth rates to 2030 will average 3.8% (CPRI, 2011). In light of these considerations and the added assumption that Central, East, West and Southeast Asia will continue on a more slow-growth track, then an average growth rate in

the range of 2.0 - 2.5% for potato production in the developing countries of Asia seems a reasonable regional scenario for the remainder of the current decade the unfolding of which should provide some key insights into more medium-to-long-term trends.

Given the vast territory and diverse circumstances that characterize the developing countries of Asia, a whole series of opportunities exist for industry related to both production and post-production of potato. In the same spirit, while much has been written about efforts to improve productivity via the development and diffusion of improved technology, relatively much less has been said about ways to lower per unit production and/or marketing costs (Hossain *et al.*, 2008; Singh and Singh, 2007; Rana *et al.*, 2009) or minimize the environmental footprint left by the potato sector. For decades, national agricultural research efforts emphasized production-related agricultural sciences such as breeding, agronomy, entomology as in many instances markets were controlled by central governments and decisions about prices were in the hands of central planners (Fan and Pardey, 1997; Scott, 2002; 2012). While these biological disciplines remain important, in the age of globalization optimizing per unit production and/or marketing costs–not just output per hectare–and protecting the natural resource base assume equal, if not greater prominence. At the farm level, this translates into seizing the opportunities at the "bottom of the pyramid", namely to provide millions of small growers better production inputs including, where appropriate, drip-irrigation, small-scale equipment for tilling fields (CIP, 2011), or extending the availability of environmentally-friendly pest and disease controls. By the same token, given the potato sector remains dominated by very small producers in most countries, greater freedom to plant or purchase potatoes to spur productivity in the past now requires more effective producer associations (Knipsheer, 2010) or market regulation to capture the benefits of group purchases and sales as well as to avoid the social costs associated with free market excesses such as virus-contaminated seed or environmental damage (Xie *et al.*, 2007; Jansky *et al.*, 2009; Scott and Suarez, 2011a, 2011b). If past experience is any indicator of future success, those firms that seize the opportunities to address these issues as part of their commercial endeavours would seem well positioned to gain a distinct competitive advantage.

At the postharvest level, the range of possibilities include more locally adopted processing varieties, more efficient rustic storage and village–level processing, more environmentally-friendly cold storage. On the sub continent alone, roughly half of the more than 25 million t of cold storage capacity is over twenty years old. Given the price of fossil fuels and concerns about the environment, ample opportunity exists to up-grade these installations to more ecologically friendly and efficient facilities to say nothing of capitalizing on that experience to satisfy the latent demand for more efficient storage in China. In a similar vein, in many, if not most, post-harvest areas, past research provides useful information to reduce the time-lag between problem identification and new technology design and diffusion (Nave and Scott, 1992; Wheatley *et al.*, 1995; Fuglie *et al.*, 1997, 2006; Pandey *et al.*, 2009a, 2009b; Scott and Suarez 2011a, 2011b). Put somewhat differently, back in the early 1960s, relatively little research had been done on potatoes in the developing countries of Asia. Furthermore, the flow of information was much more restricted for political and technological reasons. Going forward, the opportunities for industry both large- and small-scale include seizing upon the wealth of earlier studies to maximize the probability of success.

Among the foremost lessons learned by industry over the last several decades has been the willingness to make a long-term commitment to the region and an ability to adopt to local tastes, preferences, and operating procedures be they to build on a latent demand for certain new products (Scott and Suarez, 2011b) or a willingness to take the time required to establish a reliable supply chain (Xie *et al.*, 2007). While there is boom in the fast food industry underway in China (Pingali, 2006; Curtis *et al.*, 2007), these volumes are still a minor percentage of total consumption (Xie *et al.*, 2007). Furthermore, while consumption of French fries is certain to increase throughout the region–particularly in China, efforts by industry to better inform consumers about product characteristic and culinary attributes of fresh potatoes should not be overlooked. Such initiatives in other developing country regions contributed to a more informed appreciation of the potato and a rise in per capita consumption (Scott, 2011). Building on local ecological and human resource endowments, local, small-scale firms in Peru focused on peeled and cut fresh potatoes—in lieu of frozen French fries–came to dominate the restaurant trade (Scott and Zelada, 2011).

Furthermore, as the market for potato and potato products in the developing countries of Asia continues to evolve, one can readily anticipate the proliferation and growth of different product segments. Given the growing interest in health, safety and nutrition by consumers worldwide including in Asia (Pandey and Sarkar, 2005; Priestly, 2006; Xie *et al.* 2007; Wilkinson and Rocha, 2009), one segment that merits closer tracking includes specialized potatoes that would include organic potatoes (Pandey, 2007; Xie, 2008), early potatoes in India and Bangladesh–harvested in November, December as well as so-called "indigenous" varieties (cultivars introduced centuries ago, but through negative selection (*e.g.*, to enhance on-farm storage prospects through small tuber size) prized for their culinary qualities in countries such as India, Bangladesh and Iran also receive premium prices for their superior taste and the social status their scarcity value conveys (Scott, 1988; FAO, 2009; Gupta *et al.*, 2009; Pandit *et al.*, 2010).

The service industry as relates to potato production and marketing in the developing countries of Asia is just in its infancy. Given the software capabilities on the South Asia sub-continent, for example, one would expect that it is only a matter of time before private-sector driven potato information services experience proliferate growth as effective demand for data on prices in different markets at different levels in the value chain, cold storage rates and capacity in different locations, as well as product information from the price of inputs to packaging for retail sale become transformed into a more articulate source of revenues for resourceful entrepreneurs.

Three priority areas for future research are: 1) Consumption/demand including a) utilization patterns at the farm-level in North and Southwest China to get a better handle on how income patterns affect decisions to sell more fresh or processed products as well as on-farm consumption, and b) estimates of the income elasticities of demand for fresh tubers for urban consumers along China´s eastern seaboard and in major cities in India; 2) On-farm productivity and in particular the relative importance of different factors on potato yields in South Asia: soil compacting, early harvest, water availability; and, 3) Marketing and specifically the impact of supermarkets on marketing channels for potato including both procurement practices and product promotion as well as value chain research aimed at flushing out the flow of potatoes and potato products from the major producing provinces in China to more distant urban markets.

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