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GROWTH RATES FOR POTATO IN INDIA AND THEIR IMPLICATIONS FOR INDUSTRY

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ABSTRACT: As potato output increased from 1.3 million t to over 34 million t over the last six decades, India became the planet´s second largest potato producer. Nonetheless, this spectacular increase masks a series of less readily apparent tendencies in the growth rates for potato production, area, and yields. While area harvested expanded, the growth for area harvested experienced a series of peaks and valleys; as yields per hectare continuously rose, the growth rate for productivity gradually ground to a halt. This paper analyses the evolution of these and other growth rates for potato in an effort to provide sharper insights into the driving factors behind the increases in production, area harvested, and yields; the most likely future scenario for the potato sector; and, the implications for industry intended to sustain output and utilization in the years ahead. Sub-sector specific recommendations include greater eco-efficiency in cold storage, efforts to explore niches for small-scale processing of French fries to complement industrial scale operations, and renewed promotion of the potato´s nutritional attributes.

KEYWORDS: production, consumption, processing, trade

INTRODUCTION

The expansion of potato cultivation in the Indo-Gangetic plain has been among the most remarkable developments in the evolution of the crop worldwide during the last half century (Bardhan *et al.*, 1999). From a meagre 1.285 million tonnes (t) and 205,000 hectares (ha) in 1949 (Srivastava, 1980), potato production in India now has passed 34 million t (FAO, 2011a) with projections forecasting 50 million t by 2020 (CPRI, 1997). As output continued to expand in recent decades, India has raced up the charts to become the world's second largest potato-producing country.

In the wake of these developments, a growing number of studies have examined the growth in potato production in all or parts of the country. Some have done so as part of a broader look at the evolution of the food systems for potato in the economy (Walker *et al.*, 1999; Scott, 2002; Pandey and Sarkar, 2005; Pandey, 2007), in particular states (Bardhan *et al.*, 1999; Pandey *et al.*, 2005), or as part of a look at regional food production trends (Thiele *et al.*, 2010). Nearly all these previous publications have been handicapped by their shorter time horizons. With noteworthy exceptions (Pandey, 2007), previous studies have also tended to truncate their analysis of production and consumption trends by treating one topic or the other instead of both together.

This paper presents a new set of estimates for previous growth rates for potato in India and in so doing seeks to provide an up-dated assessment of past performance and a sharper vision of future prospects. Among the key questions addressed are the extent to which the long-term evolution of these growth rates foreshadows the most likely future scenario for potato production and utilization and the role of industry in sustaining potato output and use in the future.

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MATERIALS AND METHODS

This study uses a food systems approach and the linkages between production, marketing and consumption in order to analyze potato production and use in India over nearly the last half century. The study employs FAO times-series data for key foods system indicators for the entire 1961-09 period as well as for sub-periods in the overall time-series.

As referencing a particular set of years or a given set of time periods is arbitrary in nature, this study also estimated the evolution of the growth rates themselves (Scott, 2011). Hence, average annual compound growth rates (ACGRs) for potato production, area harvested, and yields were calculated for every ten-year period beginning with 1961-70. In other words, growth rates were calculated on a moving ten-year basis, *i.e.* 1961-70, 1962-71, on up to 2000-09. These growth rates were then plotted and analysed in relation to earlier studies in order to ferret out the factors behind these tendencies. In addition, trend lines were estimated for the ACGRs in an effort to assess the evolution of the growth rates and not just the tendencies for production, area, and yield. Trends in consumption and use were also identified. The combined set of growth rates, utilization trends, and a synthesis of the related literature provide an empirical basis on which to evaluate previous projections and proposed future scenarios for potato production and utilization in India in the decades ahead.

RESULTS AND DISCUSSION

Potato production in India averaged over 32 million t in 2007-09—over ten times the 2.8 million t harvested in 1961-63, nearly half a century earlier (**Table 1**). India alone harvested 10% of global potato output in 2007-09 and accounted for nearly 25% of the total increase in potato production in developing countries worldwide over the last five decades.

This increase in output resulted from an ACGR for potato production of 5.4% for nearly the last half century. More noteworthy, ACGRs for potato production computed on a moving ten-year basis were estimated at 4.0% or higher in 32 of the 40 ten-year periods examined (**Table 2**). Furthermore, they actually rebounded since 1992-2001 (**Fig. 1**) even as annual output continued to increase. This latest boom in potato production runs counter to recent, rather more pessimistic assessments (Chandran, *et al.* 2005; Pandey *et al.*, 2005; Singh, 2010).

While estimated long-term trends in the growth rate for potato production also show deceleration from 6.3%/yr during 1961-63 to 1985-87) to 4.5%/yr during 1985-87 to 2007-09 (**Table 1**), the growth rates themselves remain decidedly positive over the last five decades and over double those found in other developing regions such as in Latin America (Scott, 2011). However, these growth rates nevertheless obscure how the increases in potato output in India have actually been marked by periodic massive surges in supply rather than steady expansion. Output of potato jumped by 25% from 8.2 to 10.1 million t from 1978 to 1979 (Srivastava, 1980). Twelve of the nearly thirty-million-t increase in production over the last fifty years took place in two, six-million-t expansions: one from 1996 to 1997 (Bardhan *et al.*, 1999), then again from 2007 to 2008 (**Fig. 1**). Such surges in output are less likely to be evident when analyzing the evolution of potato production by specific time periods (Pandey *et al.*, 2005; Pandey, 2007; Singh, 2010).

Annual area harvested in potatoes in India expanded from 384,000 ha in 1961-63 to nearly 1.8 million ha in 2007-09. Moreover, the ACGR for area harvested in potatoes was 3.4% over the period, thereby accounting for the bulk of the increase in output during the last half century. More specifically, every one of growth

Table 1. Average annual growth rates for potato in South Asia, 1961-2009.

	2007-09			Growth rate[1]								
	Production	Area	Yield	Production			Area			Yield		
Country	(000t)	(000ha)	(t/ha)	1	2	3	1	2	3	1	2	3
India	32,550	1,789	18.2	6.3	4.5	5.4	3.4	3.4	3.4	2.9	1.1	2.0
Bangladesh	5,694	381	15.0	5.3	7.3	6.3	2.9	5.5	4.2	2.3	1.6	2.0
Pakistan	2,687	144	18.6	6.9	7.1	7.0	6.2	4.2	5.2	0.7	2.7	1.7
Nepal	2,141	164	13.0	2.2	7.7	4.9	2.0	4.1	3.0	0.2	3.5	1.8
Afghanistan	294	21	14.3	3.1	0.7	1.9	0.5	0.9	0.7	2.6	-0.1	1.2
Sri Lanka	71	5	14.9	13.8	-0.5	6.4	10.4	-1.5	4.3	3.1	1.0	2.1
Bhutan	56	6	9.8	3.0	2.8	2.9	2.4	1.5	1.9	0.6	1.4	1.0

[1] 1=1985-87 vs 1961-63; 2=2007-09 vs 1985-87; 3=2007-09 vs 1961-63.
Source: FAOSTAT (accessed June 2011) and calculations for this study.

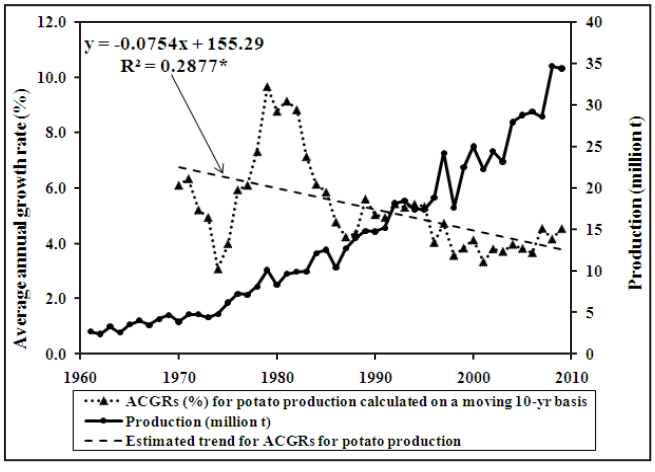

Fig. 1. Production and ACGRs for potato in India, 1961-2009.[1]
Source: FAOSTAT and calculations for this study
[1] ACGRs are calculated on a moving 10-year interval basis, see text for details.
**significant at the 1% level.*

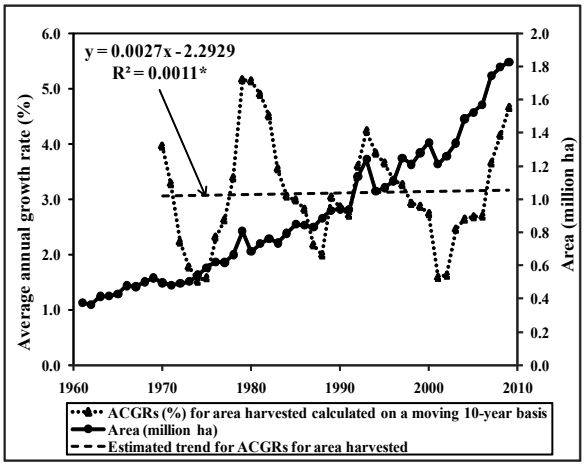

Fig. 2. Area harvested in potato and ACGRs for area in India, 1961-2009.[1]
Source: FAOSTAT and calculations for this study
[1] ACGRs are calculated on a moving 10-year interval basis, see text for details.
**not significant.*

rates for the 40 ten-year periods analysed was at or in excess of 1.5%, half were at or above 3%, and 32 of the 40 estimated ACGRs for area harvested exceeded that for yields suggesting that strong demand was calling forth additional supply (**Table 2**). Notwithstanding these remarkably high growth rates, ACGRs for area harvested in potato have experienced a series of peaks and valleys over the last 50 years that taken together defy a particular linear trend (**Fig. 2**).

ACGRs for area harvested were particularly strong in the 1970s (**Table 2**). 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). 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 potato varieties

spurred greater area under cultivation and consequently the associated ACGRs (Horton, 1987; Scott, 2002; Pandey and Sarkar, 2005). Rapid ACGRs during the 1970s were also that much easier to attain because of the relatively more modest area harvested in potato at that time—roughly one third of the total in 2009 (**Fig. 2**).

While area harvested continued to increase in subsequent decades and at highly respectable rates all in excess of those found in other developing regions (Scott, 2011), the ACGRs showed considerable volatility. They initially fell from over 5% in the 1970s to 2% during the 1980s, to recover to 4.2% by the mid-1990s, only to fall again as the 1990s progressed into the current century (**Table 2**). Area harvested continuously adjusted to improvements in yields, favourable or adverse growing conditions resulting in periodic bumper crops or production shortfalls in relation to steady increases in demand given slowly rising population and changes in income. In that context, the most recent upward surge in the ACGRs for area harvested is that much more remarkable. ACGRs accelerated from an estimated 1.6% yr during 1992-01 to nearly triple that from 2000-09 even as absolute increases in area harvested continued to rise. In this latter instance, strong economic growth and the associated rising incomes of India´s growing middle class meant increasing domestic demand called forth additional potato area (Pingali, 2006). As a result, according to FAOSTAT data India harvested an increasingly larger share of potato output among the developing countries of Asia reaching 24% in 2007-09 versus 14% in 1961-63.

Growth in output of potato in India has also been aided by increases in average yields. Average potato yields in India reached 18.2 t/ha during 2007-09 (**Table 1**) as growth rates for potato yields--uneven across different states and over time--averaged 2.0%/yr for nearly the last half century. ACGRs were particularly strong from the late 1960s to mid-1980s (**Table 2**). Factors most frequently cited as accounting for these sharp increases in productivity include the release of high-yielding varieties, the development of region-specific technological packages, and the introduction of the seed plot production technique (Pandey and Sarkar, 2005). The massive expansion of cold-storage facilities and improvements in transport infrastructure combined with a benign policy environment also served to facilitate the adoption of improved technology (Walker *et al.*, 1999; Scott, 2002; Pandey and Sarkar, 2005).

Compound growth rates for average annual yields have declined sharply in recent years actually going negative during 2000-09. More specifically, in only one out of 18 ten-year periods since 1982-91 did the estimated ACGR exceed 2.2% whereas in the previous 22 ten-year periods all of the estimated ACGRS were 2.2%/yr or higher (**Table 2**). It apparently has become increasingly difficult to improve productivity at a more rapid pace at higher levels of output per hectare and over a much larger land area under cultivation (**Fig. 2 and 3**), particularly as the ACGRs for area harvested accelerated sharply during 2000-09. As a result, the estimated long-term trend in the ACGR in productivity is decidedly decelerating.

Recent studies have suggested that steady drop in ACGRs for potato yields over nearly the last two decades (**Fig. 3**) may signal the onset of a plateau for potato productivity in India (Pandey, 2007), contending as well that this slowdown is by no means peculiar to India. While a similar phenomenon has been observed in the case of potato in Bangladesh (Azimuddin *et al.*, 2009), Thiele *et al.* (2010) note that the absence of major constraints to potato production leave little room for raising yields by developing and introducing new technology.

Table 2. Average annual compound growth rates (ACGRs) for potato in India, 1961-2009[1].

Years	Production			Area			Yield		
	R^2	ACGR(%)	Significance	R^2	ACGR(%)	Significance	R^2	ACGR(%)	Significance
1961-70	.69	6.1	***	.91	4.0	***	.31	2.1 *	
1962-71	.71	6.3	***	.77	3.3	***	.46	3.1	**
1963-72	.66	5.2	***	.65	2.2	***	.45	3.0	**
1964-73	.62	4.9	***	.55	1.8	**	.49	3.2	**
1965-74	.58	3.1	***	.52	1.5	**	.28	1.6	n.s.
1966-75	.61	4.0	***	.52	1.6	**	.46	2.4	**
1967-76	.72	5.9	***	.62	2.3	***	.64	3.6	***
1968-77	.73	6.1	***	.67	2.6	***	.63	3.5	***
1969-78	.80	7.3	***	.78	3.4	***	.68	3.9	***
1970-79	.91	9.7	***	.89	5.2	***	.77	4.5	***
1971-80	.86	8.8	***	.89	5.1	***	.70	3.6	***
1972-81	.88	9.1	***	.86	4.9	***	.81	4.3	***
1973-82	.87	8.8	***	.83	4.5	***	.83	4.3	***
1974-83	.81	7.1	***	.74	3.5	***	.79	3.6	***
1975-84	.85	6.1	***	.70	3.1	***	.87	3.1	***
1976-85	.85	5.9	***	.69	3.0	***	.87	2.9	***.
1977-86	.69	4.8	***	.67	2.8	***	.45	2.0	**
1978-87	.67	4.2	***	.59	2.2	***	.46	2.1	**
1979-88	.68	4.4	***	.57	2.0	**	.52	2.4	**
1980-89	.84	5.6	***	.92	3.0	***	.56	2.6	**
1981-90	.82	5.0	***	.92	2.9	***	.49	2.2	**
1982-91	.81	4.9	***	.90	2.7	***	.50	2.2	**
1983-92	.81	5.4	***	.85	3.6	***	.41	1.8	**
1984-93	.81	5.3	***	.82	4.2	***	.17	1.1	n.s.
1985-94	.83	5.4	***	.75	3.8	***	.33	1.6	*
1986-95	.82	5.3	***	.71	3.7	***	.36	1.7	*
1987-96	.83	4.0	***	.65	3.3	***	.31	0.7	*
1988-97	.79	4.7	***	.65	3.3	***	.41	1.5	**
1989-98	.55	3.6	**	.60	2.9	***	.06	0.6	n.s.
1990-99	.58	3.8	**	.59	2.9	***	.13	1.0	n.s.
1991-00	.60	4.1	***	.57	2.7	**	.22	1.4	n.s.
1992-01	.50	3.3	**	.35	1.6	*	.32	1.7	*
1993-02	.57	3.8	**	.37	1.6	*	.42	2.2	**
1994-03	.56	3.7	**	.71	2.5	***	.19	1.3	n.s.
1995-04	.58	4.0	**	.71	2.6	***	.21	1.3	n.s.
1996-05	.57	3.8	**	.72	2.7	***	.16	1.1	n.s.
1997-06	.55	3.7	**	.72	2.7	***	.46	2.4	**
1998-07	.76	4.5	***	.81	3.7	***	.10	0.9	n.s.
1999-08	.78	4.2	***	.84	4.2	***	.00	0.0	n.s.
2000-09	.81	4.5	***	.90	4.7	***	.00	-0.1	n.s.

*** = Significant at 1% level; ** = Significant at 5% level; * = Significant at 10% level.
n.s. = Not significant.
[1] Calculated using the following expression: $InY = Inb_0e^{b_1 t}$, *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 October 2011) and calculations for this study.

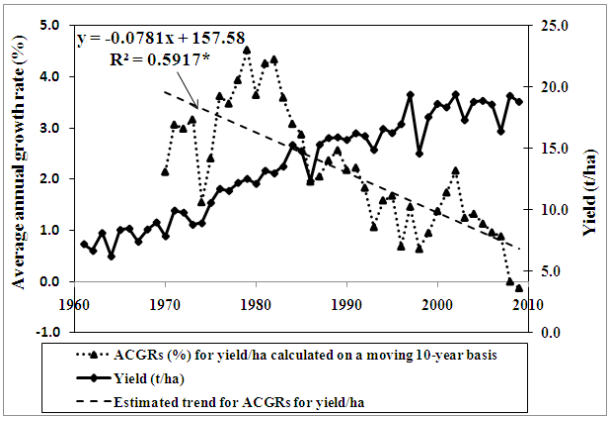

Fig. 3. Yield/ ha in potato and ACGRs for yields in India, 1961-2009.[1]
Source: FAOSTAT and calculations for this study
[1] ACGRs are calculated on a moving 10-year interval basis, see text for details.
**significant at the 1% level.*

Earlier studies (Chandran *et al.*, 2005; Pandey *et al.*, 2005) of productivity trends at the state level in India point to a similar slowdown. These latter studies then mention that relative prices and yields for different commodities partly explain growers' interest in maximizing potential overall agricultural income rather than simply potato yields. Growers opt to harvest potatoes before maximum bulking has occurred (Pande *et al.*, 2008) to capture higher farm-gate prices, to avoid the crash in producer prices at the peak of the harvesting period, and to achieve early planting for the subsequent crop. Other studies imply that the declining ACGRs for yields may also be partly due to the closing of the agricultural frontier for irrigated potato production in India and conversely the recent expansion of output in the hilly areas or warmer, non-traditional production zones where off-season prices may compensate for lower yields (Pandey and Sarkar, 2005). Research reviews also cite the misuse of fertilizer, the declining water table, water and soil contamination, and the loss of soil fertility due to compacting and the lack of organic matter as additional factors potentially contributing to the collapse of growth rates for yields in potato (Scott *et al.*, 2000a; Pandey, 2007; CPRI, 2011). All these groups propose more detailed data analysis of yield statistics to confirm or refute this interpretation of the recent trend and to possibly identify where lower yields in different states might point the way toward a strategy to raise productivity nationwide. Possible alternative scenarios (see below) suggest that both on- and off-farm considerations may well foment higher yields in the years ahead.

Utilization and trade

Despite an emphasis on production in much of the literature on potato in India, the fundamental driving force behind the growth in production has been the shift in consumption patterns away from strictly cereal-based diets toward more vegetables such as potatoes (Scott, 2002; Pingali, 2006). As the per capita food production index in India increased, consumers sought more variety in their food in-take (Pandey and Sarkar, 2005). In addition to the rapid growth in area harvested, the strong demand for potatoes as food is manifest in several different additional dimensions. A progressively larger share of estimated annual domestic available supply has been utilized for food over the last three decades (**Table 3**). In effect, the food system for potato has squeezed out an additional percentage of the harvest and made it available for human consumption. Estimated per capita consumption of potatoes has risen sharply (**Fig. 4**). The emergence of potato consumption in the form of snacks (*e.g.*, potato chips) or French fries has been an added, albeit to date relatively minor, contributing factor in India (Pandey *et al.*, 2006; Rana, 2011).

Contrary to earlier attempts to characterize the evolution of potato consumption in India as destined to follow patterns observed in Europe and North America (Walker *et al.*, 1999), the

Table 3. Food Balance Sheets for potato in South Asia, 1961-2007.

Region	Particulars	Year			
		1961-63	1976-78	1991-93	2005-07
India	Domestic apparent supply (thousand t)	2,832	7,514	17,283	28,763
	Food (%)	66	68	72	73
	Feed (%)	0	0	0	0
	Seed (%)	17	15	11	9
	Processing (%)	0	0	0	0
	Other uses[1]	17	17	17	17
Other	South Asia[2] domestic appsrent supply (thousand t)	786	1,481	2,998	9,260
	Food (%)	73	77	78	82
	Feed (%)	0	0	0	0
	Seed (%)	14	11	10	7
	Processing (%)	0	0	0	0
	Other uses[1]	13	11	11	11

[1] According to FAOSTAT "other uses" refers to "waste" and "other uses", although in previous years it referred only to waste (Horton, 1988; Anonymous, 1995).
[2] Other South Asia consists of Afghanistan, Bangladesh, Bhutan, Maldives*, Nepal, Pakistan, and Sri Lanka.
*According to FAOSTAT, Maldives reported producing no potatoes during 1961-2007.
Source: FAOSTAT (accessed June 2011) and calculations for this study.

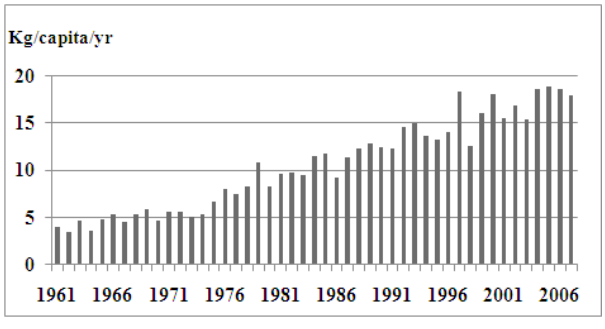

Fig. 4. Annual average potato consumption in India, 1961-2007.
Source: FAOSTAT.

potato´s role in the diet is most commonly that of a complementary vegetable in India with three noteworthy exceptions. At the peak of harvest in the major potato-producing states in the Indo-Gangetic plain, potatoes can become a "seasonal staple" for the very poor and/or migrant labourers as a flood of supplies appear when other staples are less readily available. Early potatoes in India—harvested in November, December also receive premium prices for their superior taste and the social status their scarcity value conveys. These tubers are more like a high priced, seasonal vegetable than a relatively cheap complementary or staple food. French fries in large metropolitan areas (Mumbai, New Delhi) are a relatively expensive, modern, Western food adopted by the more affluent, younger generation for their taste and convenience (Guenthner, 2001; Scott, 2002; Pandey and Sarkar, 2005; Pandey *et al.*, 2006).

While per capita consumption levels for potato have risen sharply in India in recent years, at less than 20kg/capita/yr they remain well below levels found in other parts of Asia including Turkey at 43.5 kg/capita/yr and China at 39.5kg/capita/yr (Xie *et al.*, 2007; Çahşkan *et al.*, 2010). Furthermore, unlike many other parts of the developing world, India is dominated by a vegetarian culture. This fundamental gastronomic trait suggests that with future increases in income,

consumers will spend less than they might otherwise would on meat and meat products and more on vegetables like potato than in countries where increased meat consumption is more culturally acceptable (Pingali, 2006). These various considerations indicate ample potential for increases in intake of potatoes not to mention the pressure on food supplies to simply maintain prevailing consumption levels in the wake of continued population growth. Thus, while acknowledging the impact of seasonal gluts on producer prices and incomes (Pandey 2007; Pandey *et al.*, 2009), the fundamental constraint to the potato sector in India is to achieve the necessary increases in supply to satisfy future demand.

Trends in the utilization of potato over the last nearly five decades also point to efforts to economise on seed use and the search for alternative supply technologies. Estimated seed use as a percentage of total available supply has fallen to single digits. One reason has been the spread in the use of cut seed. Another is the differences in seeding rates depending on farm size (Singh and Singh, 2007). The emergence of alternative, potentially more economical schemes to produce and multiply good quality has generated mixed results. Planting material in the form of true potato seed (TPS) (Ilangantileke *et al.*, 2001; Ezeta, 2009) has yet to achieve the technological breakthrough needed to have more than marginal impact (van Loon, 2007; Almekinders *et al.*, 2009). By way of contrast, mini-tuber production has generated increasing interest and participation on the part of the private sector with more than a dozen companies engaged in rapid multiplication of planting material (van Loon, 2007; Guenthner, 2010; CPRI, 2011).

In contrast, estimated "other uses" as a percentage of total available supply has remained at 16% of annual available supply over the last five decades, where FAO has defined "other uses" in the past as simply "waste" and "losses" (Horton, 1988; Anonymous, 1995). Nevertheless, those studies that have attempted to quantify where, when, and how such losses actually occur and in what relative quantities have tended to focus on storage (Fuglie *et al.*, 1997; Pande *et al.*, 2008) or simple processing (Nave and Scott, 1992) with less attention being given to wholesaling forward to final human consumption. Furthermore, persistent estimated waste and losses of 16% of total available domestic supply are double or even triple comparable percentages for other countries in South Asia (**Table 3**)—estimates for China are 6% according to FAOSTAT-- suggesting that the magnitude of such other uses are perhaps exaggerated, but nonetheless a prime target for efforts to make more potatoes available for productive utilization.

Processing of potato has consistently been mentioned as an area with underexploited potential in the potato sector in India (Pandey and Sarkar, 2005; Pandey *et al.*, 2006; Pandey *et al.*, 2009; Rana, 2011). In that regard, certain processed products would appear to have much greater potential than others. French fries are a case in point (Rana *et al.*, 2005; Pingali, 2006; Rana, 2011). But here the experience of other developing countries comes to mind. While French fry consumption is certain to expand, fresh peeled and cut French fries as done in Peru (Scott and Zelada, 2011) may well have considerable untapped potential given the relative cost of labour versus capital and the capabilities of local small-scale entrepreneurs in India to both manufacture and work with the associated machinery. Furthermore, trends in consumption of processed potatoes in Argentina suggest that the continued availability of cheap domestic help may temper the demand for relatively expensive frozen French fries (Rana, 2011, Scott, 2011). Rustic potato processing into such products as solar dried chips or rustic flour may well

have underexploited potential (Pandey and Sarkar, 2005; Pandey *et al.*, 2006), but the results of previous research in India (Nave and Scott, 1992) and elsewhere (Scott *et al.*, 1993) in the developing world indicate a word a caution about the economic as opposed to technical feasibility of such operations and the minimum scale to achieve sustainability among other considerations (Wheatley *et al.*, 1995). Quality control and hygiene standards for such products produced for direct human consumption under rustic conditions remain an additional challenge. Lastly, any discussion about processed potato products that touches on starch (Khurana, 2006; Rana, 2011) would do well to keep in mind recent developments in Europe where the potato starch industry has undergone a major restructuring. Less efficient producers in places like Poland were driven out of the market by very large-scale, specialized processors in Western Europe (Haase and Haverkort, 2006) leaving idle considerable excess capacity posed to re-start operations should commodity prices continue to rise in the future.

Prospects for greater potato exports have long interested both policymakers and research scientists in India (Srivastava, 1980; Dahiya and Sharma, 1994; Pandey *et al.*, 2000; Khurana, 2006; Pandey *et al.*, 2006). Trade in general was seen as a driver of economic growth and development in the post-independence era. In addition, trade in potatoes was considered desirable as one means of reducing recurrent gluts at harvest time that drive down prices and reduce farmer incomes (Pandey *et al.*, 2009). In addition, in the past potatoes were often considered as a less attractive food commodity than rice or wheat with a corollary that potato exports represented a way of offsetting the cost of cereal imports to meet domestic food requirements.

While consumption and use patterns for potato in India have gradually changed over time, average annual total trade (imports plus exports for the combined total of frozen French fries and fresh tubers) continue to represent less than one per cent of annual production. Nearly 90% of India´s exports of fresh potatoes go to neighbouring markets in Nepal and Sri Lanka (Dahiya *et al.*, 1994; Khurana, 2006; Singh, 2010). Furthermore, contrary to some earlier predictions (Khurana, 2006), the export market has remained rather thin as the ratio of weight to value, transport costs, and the potato´s enhanced perishibility under sub-tropical conditions have combined to dampen trade. Alternatively, many of these same countries designated as potential target markets for Indian potato exports also import seed and processed potato products *.e.g.*, starch, frozen French fries from Europe or North America (Vrolik, 1994; Guenthner, 2001; AAFC, 2004, 2007; Xie *et al.*, 2007). Exports of fresh potatoes did reach nearly 200,000 t in 2008 (FAO, 2011b), but have been hampered by: i) uncertainty about available supplies and export price in relation to ever-growing domestic demand; ii) limited infrastructure in the prevailing export supply chain to handle a bulky, semi-perishable commodity like fresh potato; iii) the economic and financial risks associated with trade in fresh potatoes --even under developed country circumstances (Guenthner, 2010) let alone where prevailing trade practices are much more informal and harder to enforce; and, iv) competition from other, and in some cases more established exporters that cater to many of the same potential markets (Guenthner 2001; AAFC, 2004, 2007; van Loon, 2007).

CONCLUSIONS AND RECOMMENDATIONS

The availability of good quality seed from the developing world´s most successful national potato program has enabled even the small growers to gain access to planting

material and continue to account for the bulk of the harvest. Additional farm-level production incentives for potatoes in India have included: i) the benign policy environment *i.e.*, lack of price controls, public procurement programs, or food rationing schemes that occasionally dampened producer/trader enthusiasm for cereal production; ii) a massive expansion in cold storage capacity to store seed and table potatoes –no other developing country has anything like India´s 23 million t of storage capacity a reported 80% of which is used for potatoes--along with the prospect of economic gains from doing so; and, iii) India´s extensive irrigation and rural road networks that facilitate the supply of inputs and the shipment and sale of a bulky product at harvest. In effect, it has been the synergy between public policy and private sector initiatives that has catalysed and sustained potato production and consumption in India during the last five decades (Pandey, 2008).

Over 90% of the IMPACT baseline projection for potato production in India in 2020 (Scott *et al.*, 2000) had already been achieved by 2007-09 (**Table 1**). Alternatively, the IMPACT high demand scenario (Scott et al., 2000b)and the slightly more ambitious CPRI projection of 50 million MT by 2020 (CPRI, 1997) seem within reach. While decades of growth rates of nearly 6% per annum are now part of the past (Anonymous, 1995), a concerted, public-private effort might well result in an ACGR in production of 3.75%/ yr over the remainder of the current decade. Furthermore, CPRI (2011) estimates the ACGR for potato production from 2009 to 2030 will reach 3.8%. Such a growth rate may well be technically feasible, but will depend critically on an even more effective set of public policies and private investments in the years ahead in light of recent trends and the battery of constraints that the sector confronts.

To sustain future growth rates in potato yields under increasingly demanding conditions in terms of the availability of water, soil conditions, and climate change will require expanding the genetic base for breeding new varieties, new approaches to breeding including biotechnology, accelerating the development of more efficient seed multiplication schemes, modernizing seed storage facilities, and exploring options for complimentary sources of new varietal material. The potential role that the private sector might play, if any, in varietal development other than the current very small scale production of TPS remains less apparent as does the potential impact of more effective public-private collaboration to optimize input (*e.g.*, seed quantity, quality and size) use.

Cold storage capacity continues to be uneven throughout the Indo-Gangetic plains. By taking advantage of the public-private partnership for development of potato in India , more might be done to get an up-to-date, quantitative understanding of the relationship between cold storage capacity and annual potato production in the high volume states and districts of India (Uttar Pradesh, West Bengal and Bihar). Such data could facilitate more informed planning of private investments in the future expansion of cold storage capacity rather than the quasi laissez-faire approach that has tended to contribute to an oversupply of potatoes and undersupply of storage in some locations, and just the opposite in others, particularly given that government operating licenses are required to open such facilities as well as facilitate the purchase of the necessary equipment to make them operational. In that regard, India´s stock of cold storage infrastructure has a hefty percentage that is over 20 years old. While trade liberalization has induced foreign investment in new processing facilities, the cold storage industry has yet to benefit in any significant way from foreign direct investment

that might facilitate introducing more energy efficient and ecologically friendly cold storage in the decades ahead. The role of micro-credit schemes to assist small growers deal more profitably with seasonal price movements for potatoes also merits consideration as part of any program to help small growers take greater advantage of traditional rustic storage .

Given the anticipated growth in food requirements in India, policymakers, researchers, and entrepreneurs may well want to focus more attention on improving domestic food marketing practices as that is where the overwhelming majority of the annual harvest is sold and will continue to be consumed in the future. In addition to the efforts to spread out production via more area harvested in early maturing varieties, plans to improve yields in more isolated production zones to take greater advantage of their potential to meet off-season supply requirements, efforts to improve the ratio between storage capacity and annual harvests in the prime potato-producing states, renewed focus on strengthening the different segments (industrial, small-scale) in the processing sector, more might be done to take advantage of the potato´s culinary versatility via recipes, training in chef and/or secondary schools on preparing potatoes and regional gastronomic festivals at different times of the year in different locations to coincide with the peak potato harvest of popular regional varieties. Similar collaboration involving processors, restaurants, catering services, supermarkets, privately-run, technical training institutes working together with regional governments (Ordinola *et al.*, 2009) have helped see per capita potato consumption in Peru rebound from less than 30kg to nearly 80kg over the last two decades (Scott, 2011).

Finally, in response to growing concerns about healthy eating among middle class consumers worldwide including those in India (Wilkinson and Rocha, 2009), more could be done to highlight the potato's nutritional attributes including its micro-nutrient content and vitamin C.

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