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Future Scenarios for Potato Demand, Supply and Trade in South America to 2030

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Abstract This paper presents estimates for potato demand, supply and trade in South America to the year 2030 according to three scenarios: baseline, high demand and limited supply. The results highlight the importance of Brazil with its massive population and low per capita consumption of potato as a key driver of regional outcomes. According to the baseline and high demand scenarios, improved productivity in Andean countries such as Ecuador and Colombia will influence output and consumption increases in those locations as well. The potential adverse effects of the advent of climate change on the potato sector in more vulnerable growing areas in the region will result in much more modest increases in output in those locations according to the low supply scenario. While domestic potato marketing will continue to expand, foreign trade in potatoes remains small in absolute terms and as a percentage of national and sub-regional output. The findings call attention to opportunities for agribusiness initiatives in input markets as well as for both fresh and processed potato products for human consumption in the decades ahead.

Keywords Innovation · Markets · Postharvest · Processed products · Technology

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Introduction

Among the many by-products of trade liberalization—loosely defined as policies, programs and practices that promote greater market integration—have been the different growth rates and related shifts in production, utilization and marketing of different food crops around the globe. A variety of interlocking contributing factors have driven these tendencies worldwide over the last several decades. Rising real incomes, increasing concerns about health and nutrition and lifestyle changes have all influenced evolving tastes and preferences contributing to greater and more diversified demand for an ever broader array of foods (Wilkinson and Rocha 2009; GO-Science 2011; Nielsen 2014). At the same time, concerns about continued population growth, urbanization, declines in investment in agricultural research and the advent of climate change have raised concerns about the capacity of different countries and regions to feed themselves in the decades ahead (Nelson et al. 2010; Alexandratos and Bruinsma 2012; Fuglie and Pratt 2013; Jalloh et al. 2013). Falling tariffs and non-tariff barriers combined with incentives to private foreign and domestic investment have complemented, if not catalyzed, many of the structural changes in different food systems to satisfy the increasingly diversified food demand (Anderson and Valenzuela 2010). Moreover, given that an estimated 95% of all food consumed in developing countries is produced in the countries themselves (Reardon and Timmer 2012), lifting restrictions on *internal* trade and promoting public investments to facilitate private commerce have perhaps had even more of an impact on food production and marketing activities in many diverse locations around the globe (de Althaus 2007; Diao et al. 2012; Reardon et al. 2012).

In the wake of these developments, attention has tended to focus on specific crops and locations, the prospects for technological innovation in particular production systems (Escobal and Cavero 2012; Haverkort et al. 2014) and associated value chains (Devaux et al. 2011; Proexpansión 2011; Shimuzu and Scott 2014). Interest has also been sparked regarding the capacity of the various actors to respond to the changes in eating habits that many of these same countries and regions (Rosegrant et al. 2012) are experiencing in light of the challenges, if not threats, that many of these food systems are seeking to overcome as well as capitalize on the opportunities that are seen emerging now and in the near future (Truitt and Ziegler 2014).

Among the foremost examples of these changes in food production and consumption on a global scale has been the case of potato. Although developing countries now account for the bulk of global potato output, relatively less has been written about the future prospects for potato in Asia, Africa and Latin America than for the cereals even as the increase in output, expansion in domestic marketing and rise in potato consumption have attracted increasing attention in many developing countries into the twenty-first century (Christian and Gereffi 2010; Scott and Suarez 2012a; Scott et al. 2013a).

Partly in response to these emerging trends, projections of future potato demand and supply have been the focus of a small number of earlier studies (Anonymous 1995; Scott et al. 2000). However, the historical databases that these studies drew upon are now outdated with their projection horizons already well in the past or within relatively close proximity. Furthermore, in more recent commodity projections, the high level of geographic and commodity aggregation precludes insights on potato in specific sub-regions and countries (Alexandratos and Bruinsma 2012). Agribusinesses, research scientists and national policymakers—among others—need such figures to capitalize fully on the estimates for future scenarios.

This paper presents projections for demand, supply and trade for potato in South America (SAM) to the year 2030 for several reasons. First, potato is not only of South American origin, it is also among the most important food crops on the continent in terms of the annual volume of production (Scott 2011a).

Second, noteworthy shifts in the location of production and consumption within the region have taken place over the last two decades (Scott 2011a, b) suggesting a more distinct future trajectory than perhaps that previously envisioned. As global trade in processed potato products has mushroomed into a billion dollar business (Guenthner 2001; AAFC 2007), SAM has witnessed growing interest in export markets and the possible impact of potato imports on domestic production and consumption (Muchnik and Tejo 1997; Espinal and Martinez 2006; Rodríguez 2006; Scott and Ocampo 2013). Efforts to develop and diffuse technological innovations at various stages in the value chain, from pre-production (e.g. multiplication of planting material), to cultivation (e.g. improved irrigation), to postharvest practices (e.g. new product development, processing, storage and packaging), have captured attention as different actors try to ensure competitiveness in response to commercial developments such as the emergence of new market niches for different potato products at home and abroad (Devaux et al. 2011; Proexpansión 2011).

Third, the present study, in contrast to previous efforts (Rosegrant et al. 2009, 2012; Tokgoz et al. 2012), provides specific outcomes for the major potato-producing countries and sub-regions of SAM, thereby explicitly recognizing the diversity of circumstances and prospects for the crop and related business initiatives across the region.

Fourth, the estimates in this paper go beyond the previous largely agro-climatic based projections for future potato scenarios (Hijmans 2003; Haverkort et al. 2013a, b), by including the impact of socio-economic factors in the form of changes in income, tastes and preferences, population growth and prices for a multitude of other commodities as incorporated in the modelling exercise. At the same time, they represent the inverse of some earlier efforts that projected much farther forward (2050) from a shorter previous base (Alexandratos and Bruinsma 2012), by drawing on longer-term past trends to project over a shorter future period (2030). In that regard, while the paper does present a set of alternative future scenarios based on the accumulated knowledge to date and some key assumptions about factors driving the potato sector in SAM in the years ahead, it by no means aims to provide an exhaustive collection of all possible scenarios. Furthermore, while the 2010–2030 time period allows for estimates of alternative scenarios, we do so acknowledging that these calculations are part of a long-term, continuous process and in the case of climate change, before much greater potential impact might occur. A much longer period for projections raises the prospect of more known and unknown uncertainties (Scrieciu et al. 2013), with the associated estimates becoming more problematic to incorporate into the modelling exercise thereby undermining the credibility of the results (Rosen and Guenther 2015).

Updated Version of IMPACT

This study uses the updated 2013 version of the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) (Rosegrant and the

IMPACT Development Team 2012).[1] IMPACT is an integrated modelling framework designed for the analysis of future developments of global food supply, demand, trade and prices. IMPACT combines an economic global agricultural sector model with a water simulation model. The food module of IMPACT—the economic agricultural sector model—projects agricultural production, demand, trade flows and prices. The food model is connected to a water simulation model, which simulates the availability of water for agriculture and other uses. The modelling framework works as a multi-period model. In this instance, the projection horizon is from 2009–2011 to 2030.

Key Parameters

In this updated version of IMPACT, several key parameters required for the supply and demand functions are obtained from econometric analysis, assessment of past and changing trends, synthesis of existing literature and expert judgement. The key exogenous assumptions for any scenario analysis with IMPACT are population growth, income growth and climate change. Both population and income growth rates are major determinants of future scenarios for demand (see Appendix Table 8 for the rates used in this study). Climate change, mediated via the water module of IMPACT, is an important determinant of future agricultural production.

The calculations employed the medium population growth projections provided by the United Nations Population Statistics division in its 2010 revision of the World Population Prospects (UN 2010). The income growth estimates utilized in the modelling were based on the 'Global Orchestration' scenario of the Millennium Ecosystem Assessment (MEA 2005). Msangi et al. (2010) subsequently updated these estimates to better reflect the kind of economic growth observed in recent years. This implies moderately high economic growth up to 2030, with an optimistic outlook for East and South Asia and Sub-Saharan Africa and moderately optimistic developments in Latin America.

Databases and Other Adjustments to IMPACT for This Study

Apart from the previous considerations, for this application of IMPACT, the base period was moved forward from 2000 to 2009–2011. To that end, on the supply side, the IMPACT model output for the 2009–2011 period was compared with updated statistics on production, area and yield from FAO for that period, with 2009 data from the FAO Food Balance Sheets (FAO 2013), and prevailing growth rates in production (1999–2001 to 2009–2011) and consumption (1997–1999 to 2007–2009—the latest available at the time). These figures were then cross-checked against national statistics and detailed reviews of country reports and unpublished documents. As a result, where necessary, the database which underlies IMPACT was adjusted downward so that in the base year the then current growth rates in production generated by the model coincided more precisely with actual statistics and estimates of then prevailing growth rates available for 1999–2001 to 2009–2011.

[0] This section mainly draws on Rosegrant and the IMPACT Development Team (2012). See the Appendix to this paper and that document for more details on the IMPACT model.

On the demand side, estimated income elasticities of demand for potato as food in the original IMPACT database for potatoes were revised and adjusted for Argentina (downward) and Brazil (upward) to obtain estimates for utilization and demand more in line with observed trends than those generated in the preliminary iterations. These adjustments were based on historical (Horton 1987; Anonymous 1995; Scott et al. 2000) as well as more recent research (Rodríguez 2006; Scott 2011b) and the impact of the core drivers of income and population growth used in the simulations (see Appendix Table 8 for select estimates of income elasticities used in this study).

The estimates of income elasticities used in this study reflected the highly differentiated nature of the roles that potato plays in diets in SAM. These vary from basic staple amongst producer/consumers in the Andean highlands, to complementary vegetable for urban households in much but not all of South America, to a relatively expensive complimentary vegetable and popular fast food in the form of French fries in urban markets throughout the region (Woolfe 1987; Guenthner 2001; Scott and Ocampo 2013). Rather than reflecting the traditional role of the potato as a starchy staple as found in much of Europe and one where rising incomes have led to a decline in per capita potato consumption over the last 20 years (Haase and Haverkort 2006), a review of national and international databases as well as published and unpublished literature over the previous quarter century (Scott 2002, 2011b) noted a clear tendency for Brazil with a low level of per capita potato consumption to see average per capita potato consumption rise noticeably with income increases, more like Mexico, the countries of Central America and the Caribbean (Fig. 1). By way of contrast, those countries in SAM with relatively high levels of per capita consumption such as Argentina witnessed a tendency, albeit much less well-defined given noteworthy exceptions (e.g. Peru), for levels of average per capita potato consumption to stagnate or increase only modestly with an increase in income (Fig. 2). That key distinction among countries within SAM persists in recent years and has been incorporated into this modelling exercise.

Scenario-Specific Parameters

For this study, we utilized the updated version of IMPACT with the adjustments mentioned above to quantify three scenarios: the baseline, high demand (HD) and more limited supply (LS), each with their respective parameters.

With respect to climate change, the baseline and more optimistic HD scenario assumed full mitigation. Alternatively, the LS scenario contains estimates of more adverse effects of climate change on the potato sector in SAM to 2030. The adjustments to supply-related IMPACT parameters were derived partly from Hijmans (2003) and Haverkort et al. (2013a, b) and more recent historical trends in output and technological change. In effect, more volatile and less favourable climatic conditions in more tropical growing areas discourage increases in area harvested and productivity in Ecuador, Colombia and Venezuela with the combined effect being an increase in output half that envisioned in the baseline scenario and more in line with the downward trends for these indicators in these locations in recent years (Scott 2011a). Only modest changes in average productivity were foreseen elsewhere in SAM in the LS scenario, in part as adverse effects in certain locations are offset by developments elsewhere in these same countries or sub-regions (see the Appendix for further modelling details regarding the LS scenario).

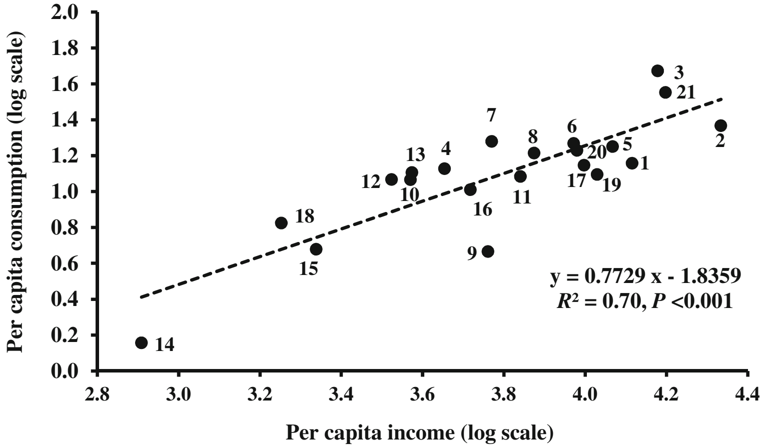

Fig. 1 Potato consumption in relation to income in Brazil, Mexico, Central America and selected Caribbean countries. *1* Antigua and Barbuda, *2* Bahamas, *3* Barbados, *4* Belize, *5* Brazil, *6* Costa Rica, *7* Cuba, *8* Dominica, *9* Dominican Republic, *10* El Salvador, *11* Grenada, *12* Guatemala, *13* Guyana, *14* Haiti, *15* Honduras, *16* Jamaica, *17* Mexico, *18* Nicaragua, *19* Panama, *20* Suriname, *21* Trinidad and Tobago. Source: FAOSTAT (2013) and World Bank Development Indicators (2015), averages for 2009–11

With respect to the evolution of potato demand, the baseline scenario incorporated assumptions in line with historical tendencies regarding the relation between income growth and potato intake in SAM (see Appendix Table 8). The HD scenario assumed a more optimistic path for potato demand in particular Brazil, but including Colombia, and Ecuador in light of more recent and anticipated trends in consumption, marketing (e.g. advertising) and income. Other locations are left largely unchanged (see the Appendix for details). In the LS scenario, potato demand was adjusted downward in light of more limited supply and the resulting higher prices, among other considerations.

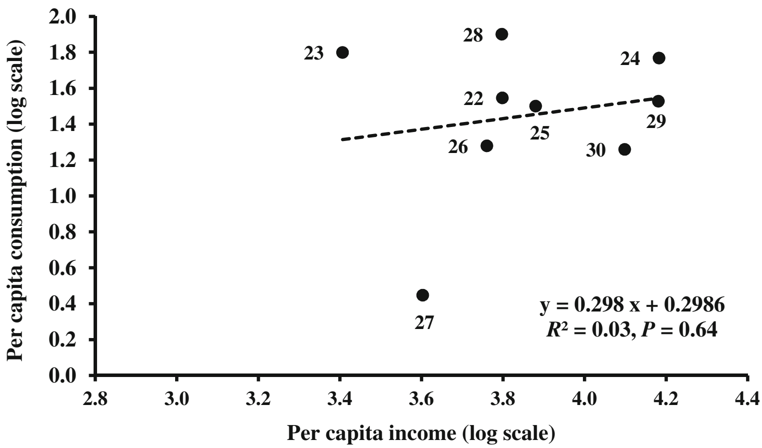

Fig. 2 Potato consumption in relation to income in selected South American countries. *22* Argentina, *23* Bolivia, *24* Chile, *25* Colombia, *26* Ecuador, *27* Paraguay, *28* Peru, *29* Uruguay, *30* Venezuela. Source: FAOSTAT (2013) and World Bank Development Indicators (2015), averages for 2009–11

Results

Baseline Scenario

In the baseline scenario, the total demand for potato as food in SAM is projected to increase at rates between 0.7 and 1.7% over the two decades (Table 1). Growth rates will be highest in Brazil—where per capita potato consumption levels (16 kg/year) have been relatively modest (Table 2)—and that reflects a desire to continue to diversify diets with rising real incomes. In contrast, growth rates in total potato demand in the Southern cone including Argentina are projected to be nearly flat (<1%). Diets in those countries are seen as stabilizing at lower levels of potato use (35–50 kg/year) than in earlier decades (Scott 2011b) as evolving tastes and preferences along with rising incomes continue to dampen potato consumption, but at a progressively lower rate.

Total demand for potato in SAM is projected to increase by over 4.6 million Mg to 19.6 million Mg in 2030 (Table 3). Some 55% of that increase will take place in Brazil and Peru following a pattern of demand increasingly influenced by regional demographics and sharp differences in per capita consumption that began to emerge towards the end of the last century. Relatively low levels of per capita intake of potato in Brazil (Table 2) combined with a relatively high estimated income elasticity of demand and projected economic growth will drive much of this increase (Appendix Table 8). These trends will be further reinforced by the vast numbers of consumers in Brazil—half of all the consumers in SAM. Potato demand will remain strong in Peru, given the tuber's unique cultural, economic and gastronomic heritage among other reasons in that country (Woolfe 1987; Zimmerer 1996; Ordinola et al. 2009; Proexpansión 2011).

Conversely, the baseline scenario envisions near stagnant total per capita potato demand in Argentina and only modest increases in other Southern cone countries such as Chile and

Table 1 Projected average annual growth rates (%/year) for food, other uses and total demand for potato in South America 2010–2030, according to different scenarios

Country/sub-region	Food[a]			Other uses[b]			Total demand		
	2030A	2030B	2030C	2030A	2030B	2030C	2030A	2030B	2030C
Argentina	0.7	0.7	0.5	0.7	0.7	0.5	0.7	0.7	0.5
Peru	1.3	1.3	1.1	1.3	1.3	1.1	1.3	1.3	1.1
Brazil	1.7	2.7	1.5	1.7	2.7	1.5	1.7	2.7	1.5
Other Andean[c]	1.4	2.0	1.3	1.5	2.0	1.3	1.4	2.0	1.3
Other Southern cone[d]	0.8	0.8	0.7	0.8	0.8	0.7	0.8	0.8	0.7

A = baseline scenario, B = high demand scenario, C = limited supply scenario; figures for 2030 represent the 3-year average for 2029–2031. Source: IMPACT model projections for this study

[a] Following FAO terminology, this includes fresh and processed potatoes for human consumption

[b] Following FAO terminology, this includes seed, animal feed, industrial uses, losses and waste

[c] For this study, the other Andean sub-region includes Bolivia, Colombia, Ecuador and Venezuela; to simplify the modelling exercise, this sub-region also includes Guyana, Paraguay and Suriname—countries that produce little or no potato

[d] For this study, the other Southern cone sub-region refers to Chile and Uruguay

Table 2 Annual average food demand (kg/capita) for potato in South America in 2010 and estimates to 2030, according to different scenarios

Country/sub-region	2010A	2020A	2020B	2020C	2025A	2020B	2025C	2030A	2030B	2030C
Argentina	39.3	39.4	39.4	39.4	39.5	39.5	39.0	39.1	39.0	37.9
Peru	79.4	81.8	81.8	81.8	82.9	82.8	81.9	83.8	83.7	81.3
Brazil	16.4	17.9	19.2	17.9	18.5	21.2	18.2	20.2	24.7	19.5
Other Andean[b]	29.0	29.8	31.0	29.8	30.2	32.7	29.9	30.7	34.4	29.8
Other Southern cone[b]	47.9	49.0	49.0	49.0	49.5	49.5	48.9	49.9	49.8	48.3

A = baseline scenario, B = high demand scenario, C = limited supply scenario; figures for 2030 represent the 3-year average for 2029–2031. Source: IMPACT model projections for this study

[a] Based on FAO Food Balance Sheet data for 2009

[b] See footnotes of Table 1 for specifications of countries included in the different sub-regions

Uruguay. These results reflect the higher and more mature consumption levels of these wealthier economies. They also are aligned with the declines from relatively high per capita consumption levels over the previous two decades as incomes increased (Scott 2011b).

Food demand including the demand for processed potatoes utilized for human consumption, e.g. fresh potatoes, French fries and potato flakes, will continue to account for the overwhelming bulk (75%) of the total demand for potatoes in SAM (Table 3). Very few potatoes will be used for animal feed or industrial purposes, e.g. as starch in the manufacture of building materials. Entering the new millennium, these uses have long accounted for 2 and 0% of regional potato demand, respectively (Scott 2011b). The baseline scenario sees this pattern as unlikely to change as the tubers will be too expensive to compete with alternative sources of raw material for either feed or industrial use. Instead, 'other uses' in this instance will largely refer to seed, losses and waste with a progressively lower percentage going to the latter two sub-categories. The disproportionate share of 'other uses' as a percentage of total demand in Peru and other Andean countries is noteworthy but should be considered with caution as the FAO data on postharvest losses on which they are partly based are hard to corroborate (Scott 2011b).

The baseline scenario also envisions continued improvements in the supply chain for potatoes. It anticipates the further expansion of transportation networks and technological improvements in postharvest handling driven by pressure to improve quality control and minimize shrinkage (e.g. from weight loss in shipping, spoilage) between the farm gate and the consumer, for the actors involved to remain competitive (Devaux et al. 2011; Shimizu and Scott 2014). Rising real incomes, continued strong female participation in the work force, the down-sizing of kitchen cooking and refrigeration appliances will all help expand the demand for pre-cooked, carry-out and frozen meals, adding to the consumption of potatoes as food in a variety of forms and presentations (e.g. side-dishes, snacks) for breakfast, lunch and dinner. These drivers will be reinforced by, among other things, expanding tourism by consumers from potato-producing, industrialized countries to SAM; travel by other Latin Americans to these same countries for work, education of leisure; and telecommunications (movies, television, the Internet), all adding to the demonstration effect, to say nothing of advertising, involving a growing array of formats and actors, e.g. fast food chains, processors and supermarkets (Devaux et al. 2011).

Table 3 Total demand (million Mg) for potato in South America in 2010 and estimates to 2030, according to different scenarios

Country/sub-region	Food[a]				Other uses[b]				Total demand			
	2010[c]	2030A	2030B	2030C	2010[c]	2030A	2030B	2030C	2010[c]	2030A	2030B	2030C
Argentina	1.59	1.83	1.83	1.77	0.31	0.36	0.36	0.35	1.90	2.19	2.19	2.12
Peru	2.31	2.97	2.97	2.88	1.53	1.97	1.97	1.91	3.84	4.95	4.94	4.80
Brazil	3.19	4.44	5.44	4.29	0.55	0.77	0.94	0.74	3.75	5.21	6.38	5.03
Other Andean[d]	3.12	4.15	4.66	4.03	1.29	1.71	1.85	1.67	4.40	5.87	6.52	5.70
Other Southern cone[d]	0.98	1.15	1.15	1.12	0.21	0.25	0.25	0.25	1.19	1.41	1.41	1.36
Total	11.19	14.54	16.05	14.09	3.89	5.06	5.37	4.92	15.08	19.63	21.44	19.01

A = baseline scenario, B = high demand scenario, C = limited supply scenario; figures for 2030 represent the 3-year average for 2029–2031. Source: IMPACT model projections

[a] Following FAO terminology, this includes fresh and processed potatoes for human consumption

[b] Following FAO terminology, this includes seed, animal feed, industrial uses, losses and waste

[c] Based on FAO Food Balance Sheet data for 2009

[d] See footnotes of Table 1 for specifications of countries included in the different sub-regions

During 2010–2030, according to the baseline scenario, growth rates for potato production across SAM will range from less than 1%/year to double that (Table 4). Such growth rates are roughly in line with the secular decline in growth rates in production over the previous half century. Nearly all of that growth in output will come from increases in productivity. Area harvested is projected to stagnate, although that actually implies a slight increase from the negative trends in area harvested that prevailed over the previous two decades (Scott 2011a). Building on success stories in terms of the diffusion of improved varieties and cultural practices (Walker and Crissman 1997), these projected growth rates envision growers seizing a series of opportunities to improve productivity, in particular quality planting material, and achieve a reduced environmental footprint.

After decades of only limited success with alternative seed production schemes (Almekinders et al. 2009), it appears that minituber production (AAFC 2004), aeroponics and fibre-cement tiles technology—the latter developed in Brazil (Mateus-Rodriguez et al. 2013)—offer different avenues towards increasing the availability of better quality seed in a shorter period of time thereby relaxing a longstanding, key constraint to better productivity in the region (Fuglie 2007). A related benefit is the reduced use of pesticides. Both foreign and local private industry are moving into the business of producing quality potato planting material using new technology in other developing country regions (Scott and Suarez 2012b; Scott et al. 2013b), suggesting that a similar trend as has begun to emerge in Brazil and Peru may well expand there and in other SAM countries.

The baseline scenario also foresees comparable investments by industry to help enhance productivity by using more environmentally friendly cultural practices for table potatoes. For example, more sophisticated techniques to optimize the use of water and pesticides seem likely to be increasingly attractive to both farmers and consumers in response to a growing interest in both protecting the environment and eating healthier, more nutritious foods (Haverkort et al. 2014). These improvements will be facilitated by the expansion of the telecommunications infrastructure that in many countries in SAM up to now has been concentrated largely in urban areas. Going forward, we envision that mobile phone connectivity, Internet and broadband services will become widely available in rural production zones (Mendoza 2015).

Table 4 Annual growth rates (%/year) for area, yield and production of potato in South America 2010–2030, according to different scenarios

Country/sub-region	Area			Yield			Production		
	2030A	2030B	2030C	2030A	2030B	2030C	2030A	2030B	2030C
Argentina	−0.7	−0.7	−0.7	1.7	2.0	1.6	1.0	1.3	0.9
Peru	0.1	0.1	0.2	1.3	1.3	1.3	1.4	1.5	1.5
Brazil	0.0	0.0	0.0	2.0	2.8	1.9	2.0	2.8	1.8
Other Andean[a]	0.3	0.3	0.1	1.2	1.5	0.9	1.4	1.9	0.9
Other Southern cone[a]	0.0	0.0	0.0	1.0	1.0	1.0	0.9	0.9	0.8

A = baseline scenario, B = high demand scenario, C = limited supply scenario; figures for 2030 represent the 3-year average for 2029–2031. Source: IMPACT model estimates for this study

[a] See footnotes of Table 1 for specifications of countries included in the different sub-regions

Within SAM, the baseline scenario foresees a highly differentiated array of growth rates for potato yields. Productivity growth (2.0%/year) will be highest in Brazil (Table 4) as access to irrigation, improved technology for specialized potato production and the trend towards greater farm size that began in recent decades, among other factors, continue to play themselves out. Annual growth in productivity will also be strong in Argentina (1.7%). However, in the case of Argentina, the continued decline in area (−0.7%)—albeit at a much more modest rate than in the recent past (Scott 2011a)—will halve the impact of yields on output. Yields will expand at a more intermediate rate—roughly 1.2%/year—in the Andean region including Bolivia, Ecuador and Peru as productivity in the base period 2009–2011 starts at the lowest levels in the region (Fig. 3) and will continue to reflect both the significant relative importance of lower-yielding, native potato varieties as well as their complex and challenging growing environments (de Haan 2009) and the pressure to remain competitive among the more commercially oriented growers. As a composite result of these various countervailing tendencies envisaged according to the baseline scenario, total production

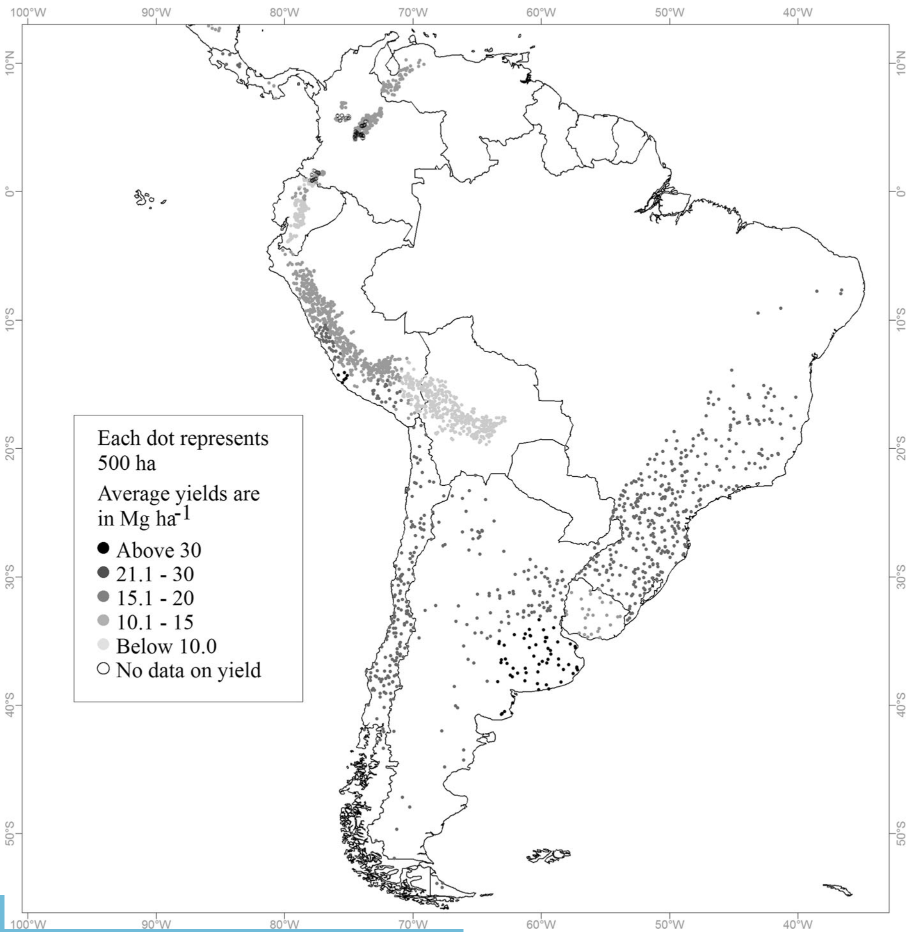

Fig. 3 Potato area and yields in Latin America in the base period 2009–2011

Table 5 Area, yield and production of potato in South America in 2010 and estimates to 2030, according to different scenarios

Country/sub-region	Area (million ha)				Yield (Mg ha[1])				Production (million Mg)			
	2010	2030A	2030B	2030C	2010	2030A	2030B	2030C	2010	2030A	2030B	2030C
Argentina	0.07	0.06	0.06	0.06	29.01	40.49	42.77	40.06	1.93	2.34	2.48	2.32
Peru	0.29	0.30	0.30	0.30	13.15	16.87	17.10	16.95	3.80	5.00	5.07	5.07
Brazil	0.14	0.14	0.14	0.14	25.57	37.79	44.16	36.95	3.61	5.34	6.24	5.17
Other Andean	0.37	0.39	0.39	0.37	10.77	13.49	14.69	12.56	3.97	5.29	5.77	4.71
Other Southern cone[a]	0.06	0.06	0.06	0.06	19.45	23.35	23.35	22.94	1.10	1.31	1.31	1.29
Total	0.93	0.95	0.95	0.93					14.41	19.28	20.87	18.56

A = baseline scenario, B = high demand scenario, C = limited supply scenario; figures for 2010 represent the 3-year average for 2009–2011; for 2030, the 3-year average for 2029–2031. Source: IMPACT model estimates for this study

[a] See footnotes of Table 1 for specifications of countries included in the different sub-regions

of potatoes in SAM as a whole is projected to rise 34% to 19.3 million Mg/year by 2030 (Table 5).

The most significant increase in production in percentage terms will occur in Brazil where a 23% increase will translate into 20.2 kg/capita of potatoes eaten per year, increasingly in the form of French fries, other processed food products made from potatoes (e.g. snacks) and a greater segmentation within the market for fresh potatoes (Table 2). Given Brazil's population, it will effectively drive upward the trend in regional average per capita potato consumption even as other countries such as Argentina experience stagnation in the level of potato intake. In addition, the baseline scenario anticipates that these increases in consumption will be made possible in part by greater net product availability for each Mg harvested as postharvest losses decline.

From a broader commodity perspective, it is noteworthy that of the five major food crops given particular attention in IMPACT—potato, maize, wheat, rice and cassava—only potato is projected to show a significant increase in direct human consumption as food in SAM with rice, maize and cassava intake foreseen to stagnate or decline (Table 6). The main reason for this regional trend is that in Brazil, per capita potato consumption begins at a lower level and the rise in per capita intake reflects a gradual, but steady trend towards diets continuing to diversify away from traditional staples following a pattern observed in other developing country regions (Pingali 2006; Reardon et al. 2012). The baseline scenario also foresees the recuperation of consumption in Colombia and Ecuador (Scott 2011b).

High Demand Scenario

According to the HD scenario, gradual changes in preferences for potato consumption, e.g. more and more diversified consumption of processed potato products, culminate in higher levels of aggregate potato demand by 2030 in Brazil and the other Andean region in SAM than those calculated in the baseline set of projections. As a corollary, greater potato intake in these locations is seen as catalyzing additional increases in the domestic supply of potatoes, albeit with 20–25% of those increases in demand being met by greater imports (Tables 3, 5 and 7).

The HD scenario projects an average annual growth rate in food demand for potatoes in Brazil of 2.7 versus 1.7%/year posited initially. The HD scenario posits similar developments in parts of the Andean region—in this latter instance reflecting more of a rebound in per capita consumption levels that have fallen sharply in Bolivia, Colombia and Ecuador in recent years—following an upward trend observed previously in Peru (Scott 2011b). In operational terms, for example, industry sources indicate that one international fast food chain operating in Brazil plans to double the number of restaurants operating there by 2019 to capitalize on the future demand for fast foods including French fries with this development coming in the wake of a noteworthy expansion in potato processing facilities in a number of countries across the region over the previous two decades (Muchnik and Tejo 1997; Mateos and Capezio 2001; Espinal and Martínez 2006).

The HD scenario anticipates that trends towards more convenience foods, snacks and eating out made possible by higher incomes will bolster growth in potato demand over the 20-year period. New frontiers in agribusiness in the potato sector include more differentiated, value-added products as the volume and percentage of domestic trade as a share of output increases over time. Recent examples include washed, graded and

Table 6 Annual average food demand (kg/capita) for potato, maize, wheat, rice and cassava in Latin America, 2010 and estimates to 2030, according to different scenarios scenario

Country/sub-region	Potato				Maize				Wheat		Wheat		Rice				Cassava			
	2010	2030A	2030B	2030C	2010	2030A	2030B	2030C	2010	2030A	2030B	2030C	2010	2030A	2030B	2030C	2010	2030[a]	2030B	2030C
Argentina	39.3	39.1	39.0	37.9	8.0	8.4	8.4	8.5	95.9	96.5	96.5	96.5	13.8	15.1	15.1	15.1	1.9	1.9	1.9	1.9
Peru	79.4	83.8	83.7	81.3	20.9	20.5	20.5	20.6	55.2	55.1	55.1	55.1	70.8	71.4	71.4	71.4	30.8	26.6	26.6	26.6
Brazil	16.4	20.2	24.7	19.5	23.4	23.0	23.0	23.1	53.2	54.1	54.1	54.1	51.4	48.9	48.9	49.0	42.2	36.1	36.1	36.1
Other Andean[a]	29.0	30.7	34.4	29.8	41.4	40.8	40.8	40.9	40.2	40.2	40.2	40.3	49.1	48.2	48.2	48.2	29.9	27.6	27.6	27.7
Other Southern cone[a]	47.9	49.9	49.8	48.3	27.4	27.0	27.0	27.1	111.0	110.9	110.9	111.0	17.4	17.5	17.5	17.5	0.8	0.7	0.7	0.7

A = baseline scenario, B = high demand scenario, C = limited supply scenario; figures for 2010 represent the 3-year average for 2009–2011; for 2030, the 3-year average for 2029–2031. Source: IMPACT model estimates for this study

[a] See footnotes of Table 1 for specifications of countries included in the different sub-regions

Table 7 Current and projected net trade (million Mg) of potato in South America, 2010–2030, according to different scenarios

Country/sub-region	2010	2030A	2030B	2030C
Argentina	0.02	0.14	0.28	0.18
Peru	−0.02	0.08	0.15	0.30
Brazil	−0.26	0.00	−0.26	0.02
Other Andean[a]	0.23	−0.23	−0.37	−0.55
Other Southern cone[a]	−0.28	−0.28	−0.28	−0.28

A = baseline scenario, B = high demand scenario, C = limited supply scenario; figures for 2010 represent the 3-year average for 2009–2011; for 2030, the 3-year average for 2029–2031. Source: IMPACT model estimates for this study

[a] See footnotes of Table 1 for specifications of countries included in the different sub-regions

packaged tubers sold by specific variety (Shimizu and Scott 2014) following similar trends in the USA and Europe (Haase and Haverkort 2006); these efforts would complement those oriented to capitalize renewed consumer interest in locally popular varieties associated with small-scale, rain-fed, traditional potato cultivation such as in highland growing areas, e.g. the yellow-flesh, 'golden' potato popular in Colombia. Such potatoes are likely to fit well with growing consumer interest worldwide in local, traditional foods with proven traceability (Lang 2015).

Increased consumption of processed potatoes such as chips, French fries or other products made from popular local or native varieties as proven successful in Peru (Ordinola et al. 2009; Scott 2011c) will most likely be extended to include more baked, rather than fried, finished products facilitated by renewed interest in potato on the part of professional chefs and cooking/training schools. Supermarket chains (via advertising, new product promotion, sponsorship of gastronomic fairs, expansion of postharvest infrastructure, etc.) along with more restaurants serving potatoes in an expanded set of menus for both eating in and carrying out will continue to act as an additional catalyst complementary to public sector initiatives (Proexpansión 2011). These include investments in roads, telecommunications and policies facilitating further varietal development and diffusion along with renewed efforts aimed at the conservation of biodiversity fostered in part by more effective exploitation of particular nutritional traits (Escobal and Cavero 2012).

At the same time, the HD scenario sees these developments as a function of particular circumstances in specific locations. Hence, it projects no change in potato demand in Argentina, other Southern cone countries or Peru, relative to the baseline scenario. Annual per capita consumption of potatoes will reach 25 kg in Brazil—roughly 50% higher than the levels reached in 2010 but still below the average found in neighbouring countries (Table 2), half those found in Europe, the USA or Canada (Haase and Haverkort 2006; AAFC 2007), and in line with the rise in per capita potato consumption in previous 20-year periods (Scott 2011b).

The HD scenario also projects faster growth in potato production (Table 5). Regional output is estimated to increase by an additional 1.6 to 20.9 million Mg as a result. Practically, all of that increase will be due to higher yields. As such, the HD scenario is more optimistic about the prospects for the development and diffusion of new production technology for potato and the requisite public and private investment in agricultural research necessary to make this a reality. Reasons for this optimism include the following:

- Possibilities of faster rates of innovation offered by biotechnology;
- Knowledge and research infrastructure it took the previous decades to establish, but now exists in the region;
- Much greater access to information via email and the Internet, making crop- and consumer product-related innovations developed elsewhere much easier to access because of technological innovation in the communications domain; and,
- Stronger demand for potatoes that will generate greater private sector interest in the potato sector to capitalize on the associated commercial opportunities.

As part of the HD scenario, the associated additional public and private investment will be focused on such things as production of improved quality seed and varietal development for particular end-uses. Examples of such investments that have already begun to emerge include one multinational's US$200 million plus project in Peru aimed at varietal development (CORREO 2010).

Whereas the corresponding HD average annual growth rate in production of 2.8% for Brazil may appear to be high, it represents an attempt to capture what we perceive to be the supply response to the potential growing demand under the same HD scenario made possible by the continued shifting location of production to bigger farms in more favourable growing areas. Brazil also has the strongest agricultural research capabilities in the region and, given its sheer size, considerable potential economic benefits.

Despite the marked increase in yields and output, higher demand for potatoes translates into an estimated increase in imports in several locations across the region by 2030 (Table 7). Furthermore, the HD scenario incorporates increases in intraregional trade as well, e.g. to Brazil from Argentina. Some countries such as Peru will emerge as modest net exporters of potatoes as cross border trade links with parts of Brazil develop (Rodríguez 2006) and those with Bolivia expand still further (Fonseca and Ordinola 2011). However, even under the more robust HD trade scenario than that projected in the baseline, estimated net imports actually will decline in several locations when compared to 2010 and represent only a very minor share (4–5.5%) of estimated total potato demand in Brazil and the Andean region where that is not the case (Tables 5 and 7). Having said that, given the

- Existence of both formal and informal (unregistered) trade and cross shipments between countries in SAM;
- Multiple types of both fresh (table potatoes and seed) and processed products (French fries, chips, traditional Andean foods) that are shipped between countries as well as imported from outside SAM with their different respective conversion rates to fresh weight equivalents; and,
- The leakage in the system in place for tracking these transactions and separating out trade from inside versus outside SAM, to say nothing of the complexities of modelling such product flows,

these trade estimates derived from differences between aggregate figures for domestic supply and demand at the country and sub-regional level defy regional aggregation.

In concluding the discussion of the HD scenario, it should be emphasized that these projections are contingent on the additional increases in future demand materializing given that, as noted above, the previous projection of an annual average growth rate in production from 1993 to 2020 of 1.73%/year currently appears too ambitious in light of the evolution of actual growth rates over the period 1982–2007 (Scott 2011a). Put somewhat differently, the factors driving the HD scenario include developments that both support and call into question its probability.

Limited Supply Scenario

The LS scenario attempts to quantify a more pessimistic future for potato production and use in SAM than that foreseen in the baseline scenario by, among other things, incorporating the effects of climate change. For example, following Hijmans (2003), the LS scenario envisions that rising temperatures combined with the more erratic availability of water will hamper productivity in selected locations closer to the Equator, e.g. Colombia, Ecuador, Venezuela and in mid-highland (2500 m) and lower growing areas. These factors will be partly offset in other growing areas where the impact of rising CO_2 levels will contribute to improved water use efficiency and crop productivity as suggested by Haverkort et al. (2013a, b) for more temperate, developing country, potato-growing environments. In the LS scenario, this would include production zones in Argentina and some of the higher altitude growing areas in Bolivia and Peru (see the Appendix for additional details about the modelling for this scenario).

The contours of the projected growth rates according to the LS scenario also reflect historical differences in yield levels, public and private research and development capacity, and the economic forces influencing supply response to the evolution in potato demand as well as opportunities to grow other, more commercially attractive crops such as what occurred in Argentina over the last two decades (Scott 2011a), or use the land for other purposes, e.g. farmland absorbed by urban sprawl or adjacent to highways on the expanding rural road network. The combined effect is slower growth in output but a slowdown that reflects the assumption that any more significant impact from climate change is more likely to materialize after 2030.

In addition, the LS scenario is more pessimistic about the growth in potato demand. In effect, the LS scenario posits a further extension of the downward trend in potato consumption observed in Argentina and the rest of the Southern cone over the period 1990–2010 (Scott 2011b) as tastes and preferences gradually continue to favour less intake of potatoes by consumers. Furthermore, rival exporters' competitiveness dampens the growth in potato shipments abroad from these countries. At the same time, Brazil exhibits much more expansive growth rates in potato demand (1.4–1.8%/year) than that for Argentina, but less so than otherwise envisaged (Table 1). Given these growth rates, one possible corollary to the LS scenario is that weaker growth in domestic supply helps to restrict the potato's role in food consumption patterns to more that of an expensive vegetable or pricey snack than that of a regular part of the daily diet.

The LS scenario envisions a slower average annual growth rate in productivity and production for potatoes in SAM from now to 2030 (Table 4), but also one that reflects noteworthy differences across the region. The growth rate for yields projected to average 1.8%/year for Brazil represents a 45% lower rate than that achieved during the previous five decades and a noteworthy drop-off from the 2.98%/year observed over the most recent quarter century (Scott 2011a). However, this outcome is due at least in part to the difficulties in sustaining yield increases at much higher levels of output per hectare over a much larger land area over a prolonged period of time in these locations during a period of increased climatic variability, e.g. rainfall or the migration of potato cultivation to less favourable growing areas. The LS scenario envisions that productivity increases will be particularly hard hit in the other Andean sub-regions with growth rates for yields less than half the level projected by the baseline scenario, but more in line with the recent weak (0.63%/year in Colombia) to dismal (−2.34%/year in Ecuador) performance in those countries over the previous quarter century (Scott 2011a).

With annual production projected to reach 18.6 million Mg in 2030, the LS scenario nonetheless envisions a very diverse impact on trade. Potato exports are estimated to expand in Peru and decline in Argentina, while a trade deficit in potato will turn into a slight surplus in Brazil (Table 7). In contrast, the other Andean sub-region (e.g. Colombia, Ecuador) is projected to import 180,000 Mg more of potatoes per year or in total roughly 10% of annual total potato demand by 2030 (Tables 5 and 7).

Discussion

The growing public and private sector interest in demand and supply for food commodities in developing countries in the decades to come motivated an exploration of different future scenarios for potato in SAM. Given estimated increases in real incomes and current consumption levels, all three future scenarios projected by this study—baseline, HD and LS—envision higher levels of average per capita intake of potatoes in the region beyond the levels achieved at the outset of the projection period (2010), albeit with a series of important qualifiers. The largest increase in production and consumption of potatoes in SAM in the decades ahead is projected to occur in Brazil, the region's most populous country. In Brazil, current potato consumption is still relatively modest compared to other countries, estimated income elasticities are relatively high and potato production continues to expand. In contrast, Argentina and other Southern cone countries are projected to see consumption and production remaining fairly flat or, under the more pessimistic scenario, decline in per capita terms.

While the potato sector throughout SAM is expected to become increasingly more market-oriented due to improvements in productivity as well as in transportation and telecommunications infrastructure, trade in potatoes and potato products is projected to decline as a share of national and sub-regional output under both the baseline and high demand scenarios, thereby suggesting that future commercial opportunities for potatoes in SAM will be overwhelmingly, albeit by no means exclusively, in the region's domestic markets.

Finally, it should also be reiterated that these scenarios are highly period- and place-bound, i.e. they are based on information available when they were generated for the years and locations indicated with the model and its parameters specified for that purpose. Rather than the last word on the issues covered, they are best interpreted as part of an on-going process aimed at continuous improvement of our understanding of potato production and utilization patterns in SAM and the socio-economic as well as climatic factors influencing their evolution. Future studies will hopefully find them useful benchmarks both for their assessment of actual developments as they unfold and possible efforts aimed at generating future scenarios going forward.

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Appendix

The food module of the IMPACT model is a partial equilibrium representation of the global agricultural sector. It comprises 45 agricultural commodities and distinguishes 115 geopolitical regions and 126 water basins, which combine to 281 food production units (FPUs), thus offering a disaggregation of the analysis at the sub-national level. Crop production takes place at the level of the FPUs. For each period *t*, FPU *n* and commodity *i*, agricultural production is depicted by isoelastic functions for area AC and yield YC:

$$\mathrm{AC}_{tni} = \alpha_{tni} \times (\mathrm{PS}_{tni})^{\varepsilon iin} \times \prod_{j\neq i}(\mathrm{PS}_{tnj}) \times (1 + \mathrm{gA}_{tni}) \tag{1}$$

$$\mathrm{YC}_{tni} = \beta_{tni} \times (\mathrm{PS}_{tni})^{\gamma iin} \times \prod_{k}(\mathrm{PF}_{tnk})^{\gamma ikn} \times (1 + \mathrm{gCY}_{tni}) \tag{2}$$

The two functions together represent QS, the supply of each commodity for each region:

$$\mathrm{QS}_{tni} = \mathrm{AC}_{tni} \times \mathrm{YC}_{tni} \tag{3}$$

As shown by Eqs. (1)–(3), agricultural production is assumed to be a function of input prices PS and output prices PF. Specific shifters gA and gCY incorporate intrinsic changes in area and yields and allow capturing anticipated trends in both variables. The production of livestock is represented by a similar set of functions for the number of animals and yields per head.

On the demand side, for each region, a set of separate functions is used to represent different demand components, namely food, feed, biofuels, crush demand for oilseeds and other uses, which add up to total demand. In this system, food demand QDF, again represented by an isoelastic function, is a function of own and cross prices PD, income INC and population size POP (see Appendix Table 8 for the key parameter estimates used for this study):

$$\mathrm{QDF}_{tni} = \alpha_{tni} \times (\mathrm{PD}_{tni})^{\varepsilon iin} \times \prod_{j\neq i}(\mathrm{PD}_{tnj})^{\varepsilon ijn} \times (\mathrm{INC}_{tn})^{\eta_{in}} \times \mathrm{POP}_{tn}. \tag{4}$$

In which remaining components of demand are modelled as follows: feed demand is a fixed share of total supply, adjusted for price effects and technological progress in feed efficiency. Demand for biofuels is a function of government blending mandates, energy prices and policy support provided to producers. Crush demand for oilseeds derives from specific oil and meal processing ratios and the prices of oil and meal by-product and the oilseed commodity. For additional details on the demand components other than QDF, the interested reader should refer to Rosegrant et al. (2012). The individual regions for which supply and demand is calculated are connected to each other via trade. Net trade adds to domestic supply and stocks to equilibrate domestic supply and demand. Global demand and supply for each commodity is brought into equilibrium for each subsequent year by an iterative process to calculate an endogenous world market price, which clears the world market and determines the domestic producer and consumer prices for all commodities and all regions. When an exogenous shock is applied to the model, such as the HD scenario presented in this study, the world market price adjusts to those changes to establish new market equilibrium with a new set of country level prices, demand, supply and trade. As a result, estimated annual series of projected market-clearing prices, commodity and country-specific levels of crop utilization, production area, yield and production levels by crop and country, and net trade flows are produced (Scott et al. 2000).

In the HD scenario, the increase in food demand for potatoes is introduced into the model from 2015 onwards as a 1% shift in the demand functions (Eq. 4) of the countries and sub-regions under consideration. This shift is increased over the subsequent years by 1% steps to reach its maximum of 15% by 2029.

For the LS scenario, slower productivity growth is introduced by reducing the intrinsic yield growth rates (Eq. 1) of the baseline scenario to obtain 1% lower yields in Argentina and Chile, 2% lower yields in Brazil and 6.9% in the other Andean sub-region (e.g. Ecuador, Colombia, Venezuela). For Peru, yields remain unchanged. Finally, it is assumed that not only potato production in SAM is negatively affected in that scenario but that the rest of the world also suffers from adverse supply and demand conditions. Accordingly, a reduction in potato yields in 2030 compared to the baseline scenario is introduced for the rest of the world. This, again, is implemented by the mean of lower intrinsic yield growth rates in Eq. 1.

Table 8 Key IMPACT parameters used for this study

Country	Average annual growth rates (%) 2010–2030		Income elasticities of demand									
			Maize		Cassava		Rice, paddy		Wheat		Potatoes	
	Population	Income	2010	2030	2010	2030	2010	2030	2010	2030	2010	2030
Argentina	0.7	3.0	0.18	0.17	0.10	0.10	0.26	0.22	0.08	0.07	−0.04	−0.08
Brazil	0.6	3.2	0.05	0.04	−0.18	−0.20	−0.02	−0.04	0.11	0.10	0.43	0.32
Chile	0.7	3.3	0.09	0.09	−0.13	−0.18	0.12	0.09	0.08	0.07	0.12	0.08
Colombia	1.0	2.9	0.08	0.08	−0.10	−0.10	0.08	0.05	0.08	0.07	0.10	0.05
Ecuador	1.1	3.0	0.09	0.08	−0.14	−0.18	−0.03	−0.06	0.08	0.07	0.22	0.18
Peru	1.0	3.1	0.09	0.08	−0.14	−0.19	0.12	0.08	0.08	0.07	0.18	0.13
Uruguay	0.3	3.2	0.09	0.08	−0.14	−0.19	0.12	0.08	0.08	0.07	0.27	0.21

Source: IMPACT model database for this study

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