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Strategic Assessment of Research Priorities for Potato

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International Potato Center (CIP)

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Strategic Assessment of Research Priorities for Potato

1. Introduction

The following report presents an ex-ante evaluation of priority research options for potato carried out in the scope of the strategic assessment of research priorities for the CGIAR Research Program on Roots, Tubers, and Bananas (RTB). It contains the results from the economic surplus model used for the assessment, which are extended to include estimations of the number of beneficiaries and poverty reduction effects.

The report identifies and describes the potato research options considered for and included in the assessment. The socioeconomic and technological parameters used as input data for the analysis are described and information on the elicitation process and data sources is provided. Results are presented so as to explain the outputs obtained and interpreted with respect to the relevant differences between research options.

2. List of candidate research options for ex-ante impact assessment

The selection of the research options started with an analysis of the expert survey results. To arrive at these results, a large number of experts internal and external to CIP scored and assessed the importance of each of 91 potato research options (Kleinwechter et al. 2013). A total of 411 responses were received.

In August 2013, after the final results of the expert surveys were available, we conducted a first round of consultation with CIP scientists, in groups and in meetings of CIP's Science Leaders Team. These results were presented and discussed, and an initial list of candidate research options for the ex-ante impact assessment was produced. This consultation process also included an initial discussion of aggregation of different research options identified in the expert survey into research options (or technologies) for the ex-ante assessment. For example, management and breeding strategies that address similar constraints can be combined into a single research option.

The initial list was further enriched with inputs from two separate but related processes: the RTB definition of flagships and CIP's identification of strategic objectives (SOs) for the new Corporate and Strategy Plan for the period 2014–2023 (CIP 2014). The process ensured that the RTB flagships and CIP SOs were aligned and that the respective research options were included in the list to be assessed.

Some potential candidate research options were dropped from this initial list for three reasons. There was not enough information about the decisions of making research investments in the near term, nor was there information that would enable the correct modeling of the research option. And there was uncertainty about whether the research option can be considered a global public good—for example, integrated pest management technologies, biofortification in potatoes with iron (Fe) and zinc (Zn). These are areas of current CIP research endeavors that are not included in the present analysis.

A final list of candidate research options identified eight top priorities for the ex-ante assessment using an economic surplus model. This list of candidate research options was compared with the previous CIP priority-setting exercise (Fuglie 2007) in order to identify similarities and differences. Further individual discussions and consultations with CIP's resource scientists experts in the field for each of the research options helped to refine the definition and scope of each of the research options. The list of eight research options was also discussed in several RTB meetings, such as the RTB annual meeting in September 2013 in Montpellier, a RTB workshop in Cali, Colombia, in March 2013, and in the CIP science annual meeting in November 2013.

Of the eight research options identified for the final list, based on considerations of data availability and methodological suitability, a subset of six research options was selected to be included in the economic surplus assessment (Table 1). Two of the research options correspond to CIP's SOs and also to RTB potato flagships: the agile potato and the potato seed systems. The other four research options are linked to crosscutting or discovery flagships: varieties resistant to late blight (LB), bacterial wilt (BW), and other virus diseases, and development of potato value chains. Together, the six research options selected for assessment represent a wide range of technology types, including development of new varieties as well as knowledge-intensive technologies. All eight research options were previously assessed by Fuglie (2007), although not all the results were reported and some were only included in the model dataset.

TABLE 1: LIST OF POTATO RESEARCH OPTIONS INCLUDED IN ECONOMIC SURPLUS ASSESSMENT

Research option	Short name	Link to RTB flagships	Global score and rank of expert survey[a]
Intensification of cereal-based systems: introducing the *agile* potato (70–100 days)	Agile potato	PO2: 70- & 100-day potato	4.49 (Breeding for earliness), rank #4
Seed systems: improving seed production and distribution	Potato seed systems	PO1: "3G" (three generations approach) CC4: Framework for analyzing and intervening in RTB seed systems	4.45 (Improving production and distribution of elite planting material (formal), rank #5; 4.23 (Improving technologies for farmer-based production and distribution of planting material), rank #21
Development of potato varieties resistant to BW	BW-resistant varieties	CC4: Framework for analyzing and intervening in RTB seed systems	4.09 (Breeding for BW resistance), rank #32
Development of virus-resistant potato varieties (PVY, PLRV, PVS, PVX)	Virus-resistant varieties	CC4: Framework for analyzing and intervening in RTB seed systems	4.28 (Control and management of virus diseases), rank #18; 4.08 (Breeding for virus resistance), rank #35
Development of potato value chains	Potato value chains	CC3: Demand-oriented solutions for value adding through improved postharvest and risk management	4.32 (Development of competitive potato value chains), rank #12
Development of LB-resistant potato varieties	LB-resistant varieties	DI1: RTB transformational breeding platform utilizing genomics, metobolomics, and phenomics	4.60 (Breeding for LB resistance), rank #1

[a]Research options were assessed with scores ranging from 1 = not important to 5 = very important.

The two remaining research options of the initial list (improving water-use efficiency and drought tolerance, and breeding for high-yielding varieties) were not included for this round of the ex-ante assessment (Table 2). Water-use efficiency and drought tolerance were not included due to the difficulty of finding suitable data at the global level about the extent of the constraint. Scientists considered breeding for high yield to be a difficult research option to model and to assess the technology parameters needed (i.e., productivity and cost changes, and adoption domain).

Tables 1 and 2 also present the global score of corresponding research options from the expert survey, the original name of that research option, and the global rank within the 91 options included.

TABLE 2: LIST OF POTATO RESEARCH OPTIONS NOT INCLUDED IN ECONOMIC SURPLUS ASSESSMENT

Research option	Short name	Link to RTB flagships	Global score and rank of expert survey[a]
Improved water-use efficiency, including drought-tolerant varieties	Water use and drought	PM1: Production models and planting material alternatives suited to different markets, production and livelihood systems resulting from yield gap, market and gender analysis	4.51 (Breeding for drought tolerance/ water-use efficiency), rank #3
Breeding for high yield	High-yielding varieties	DI1: RTB transformational breeding platform utilizing genomics, metobolomics, and phenomics	4.38 (Breeding for high yield), rank #8

[a]Research options were assessed with scores ranging from 1 = not important to 5 = very important.

3. Description of the research options

3.1 INTENSIFICATION OF CEREAL-BASED SYSTEMS: INTRODUCING THE *AGILE* POTATO

This research option refers to potato varieties with very early (70–80 days), early (80–90 days), and medium (90–100 days) maturity; improved stress tolerance (heat, drought, salinity, virus, LB); and improved quality characteristics (high dry matter, processing quality, biofortification with Fe and Zn) to improve systems productivity and incomes. These varieties would fit into windows currently left fallow in the cereal-based systems of sub-tropical lowland, highland, and temperate regions of Asia.

The core component of the research carried out is variety improvement through breeding, backed up by enhanced and accelerated breeding methods, fast-track systems for variety identification and release, the development of strategies for ecological intensification of farming systems with potato, and awareness raising and advocacy work to expand consumer demand for higher adoption.

The research option extends ongoing research efforts related to breeding for early and medium maturity, from which improved clones characterized by this trait are already available. The principal new focus of this research effort is seeking to fit potatoes with early and medium maturity into cereal-based production systems. This implies complementing the research option with other elements and technological adjustments—for example, adjustments in the duration of the other crops in the cropping cycle of the target farming systems.

Impacts to be quantified in the assessment include increases in production from expansion of potato cropping area and increases in productivity of the potato-cereal systems through incorporation of improved agile potato varieties. Intensification of potato-cereal systems will certainly imply increases in the production costs of both potato and the system as a whole. For example, there will be additional labor requirements during the potato-cropping season and in the transition period between two crops for land preparation. The final cost effects of the technology are, however, still unknown; so the productivity change in the model is assumed to be net of any possible cost changes.

3.2 Seed systems: improving seed production and distribution

The major bottleneck to increasing potato productivity in sub-Saharan Africa (SSA) is the poor quality of the seed (Gildemacher 2011; Gildemacher et al. 2009a, 2009b). This research option addresses this constraint. It aims to increase potato productivity by reducing yield losses from seed-borne diseases through better quality and access to seed potato tubers and improved potato varieties with robust traits (drought, heat, and disease tolerance, and/or biofortified with essential micronutrients—specifically Fe and Zn). It applies the three-generation (3G) approach which combines rapid multiplication technologies with decentralized seed production and on-farm seed maintenance for target countries in Africa, Asia, and Latin America. This approach contrasts with the five generations that current seed systems require in providing quality planting material (Labarta 2012; Schulte-Geldermann 2012, 2013).

In the past, CIP has invested in developing methods and approaches for providing quality seed materials to farmers. In early stages, this work helped to strengthen formal seed systems and to provide certified seed. More recently, CIP has focused its technical assistance on developing farmer-based approaches for the improvement of seed quality (e.g., positive selection and quality declared seed). The most recent work in this area is the development of rapid multiplication technologies that reduce the number of generations needed to produce quality seed. This research option integrates these various elements into a unified and coherent seed systems approach that involves private sector players as the key agents in the multiplication and distribution of high-quality seed.

Impacts to be quantified include the increases in productivity in potato production in the target regions from the use of quality seeds of improved varieties. Likewise, potential increases in production costs due to higher cost of planting material are considered.

3.3 Development of potato varieties resistant to bacterial wilt

This research option aims to develop resistant varieties to tackle the yield losses caused by bacterial wilt (*Ralstonia solanacearum*). The adoptable innovations from this research option are new, improved potato varieties resistant to BW, to be released to target countries in Africa, Asia, and Latin America.

CIP has worked on the development of BW-resistant varieties since the 1980s and 1990s, but the trait was excluded from breeding lines around 1995 (Thiele et al. 2008). However, production constraint is still considered highly relevant in the production areas where CIP is working, and there is a renewed and increased interest in resuming work on that constraint. This reflects both the results from the global expert survey, which gave BW a high ranking, and the relevance of the disease across other crops in RTB.

Impacts to be quantified are productivity increases from BW resistance; changes in production costs are not expected.

3.4 Development of virus-resistant potato varieties

This research option aims to reduce yield losses caused by potato virus diseases through virus-resistant potato varieties. The adoptable innovations from this research option are new, improved potato varieties resistant to potato virus Y (PVY), potato leafroll virus (PLRV), potato virus S (PVS), and potato virus X (PVX) to be released to target countries in Africa, Asia, and Latin America.

Breeding for virus resistance has a long tradition at CIP, where it has been an integral component of the Center's breeding work for over 30 years. Since 1995, virus resistance is the characterizing trait of one of CIP's two major breeding populations. So far, acceptable levels of virus resistance have not yet been incorporated into the advanced clones that have been released as varieties (Thiele et al. 2008). Accordingly, the research component of this option is to increase the levels of resistance to viruses in new varieties to be released in the coming years.

Impacts to be quantified include productivity increases from growing virus-resistant varieties. Further, a small reduction in production costs is assumed to account for lower labor costs due to reduced need for roguing of infected plants.

The technology is modeled in a way that virus-resistant varieties can substitute for high-quality seed clean of viruses. The development of virus-resistant varieties is more complex and therefore has lower probability of success. But once developed, such varieties should have higher adoption rates.

3.5 Development of potato value chains

Development of potato value chains refers to the application of several methods to improve the linkages and integration of small potato farmers into potato value chains as a way to improve gender equity, add value to their potato production, and increase farm incomes. Value chains methods include, but are not limited to, participatory market chain approach, inclusive business models such as farmer business schools, and corporate social responsibility, as well as the identification and development of new, marketable potato products.

Most of CIP's work with potato value chains in the past 15 years has been in Latin America (Devaux et al. 2011). Expansion of this work includes scaling-up of the previous work in Latin America and moving into some countries in SSA and Asia.

Impacts to be quantified in the assessment include increases in benefits from higher productivity per hectare due to the application of better farm production practices (e.g., crop management and use of varieties with high market demand) and higher output prices received by farmers. These per-hectare benefits can be quite large, although the application of the methods in general is limited to a small number of farmers and therefore relatively small adoption areas. For the purpose of modeling, productivity effects and changes in production costs are distinguished from demand increases for the new potato products. The productivity effects can be quite large due to increased farmer specialization.

3.6 Development of potato varieties resistant to late blight

Yield losses from late blight (*Phytophtora infestans*) are still considered to be the most important constraint to potato production worldwide (Birch et al. 2012; Haverkort 1990). Improved potato varieties resistant to the disease are expected to reduce these losses and increase productivity in potato production. LB-resistant varieties are targeted to several countries in Africa, Asia, and Latin America.

Resistance to LB is the original breeding objective of CIP and hence has been at the core of the Center's breeding programs since its inception. Today, it is the primary trait of one of the two major breeding populations of CIP. LB resistance has been successfully included in a number of popular varieties released worldwide using CIP germplasm (Thiele et al. 2008). LB resistance, however, breaks down a few years after the varieties are introduced into the field, making continuous breeding efforts necessary.

Impacts to be quantified include productivity increases from growing LB-resistant varieties and lower production costs as a result of reduced use of fungicides. Although cost reductions could be high, farmers generally fail to realize the full benefits of the technology (e.g., they continue to spray against LB as if the varieties were susceptible). Therefore, the cost reductions included in the assessment reflect only a small proportion of the full potential that can be achieved in experimental trials.

4. Description of parameter elicitation process and sources of information

The estimation and elicitation of parameter values started with a review of the previous priority-setting study carried out by CIP in 2005 (Fuglie 2007). For most of the selected technologies, this study provided appropriate and very useful benchmarks, which were used as the starting points for the parameter estimation for the current analysis. Further, the descriptions of the RTB flagships and the drafts of CIP's SOs were used to adjust the original parameters. The information from these two latter sources in particular helped to extend and adjust the selection of target countries and the estimation of adoption ceilings. On the basis of the three sources combined, a first set of initial estimates was developed and a first set of model results was generated.

These first results and the underlying parameters were presented to and discussed with individual scientists at CIP and in group consultations with CIP experts. In particular, we took advantage of the CIP science meetings in November 2013, where CIP's regional scientists gathered at the Center's Lima headquarters. During this event three group meetings and individual consultations were held to revise the parameter estimates with the corresponding CIP experts in each of the fields. In these meetings, scientists were given the current parameter values and asked to review them and discuss potential adjustments. Through this process the set of parameters used for generating the results presented in this report was defined. The adoption estimates arising from the discussions with scientists are used as the "higher adoption" scenario in the assessment.

For the remaining parameters, such as production, area, and prices, we generally rely on FAO statistics (FAO 2013).

5. Parameter estimates

5.1 Data on area and production and socioeconomic parameters

The data on area and production, as well as the socioeconomic parameters for the individual countries used in the analysis, are presented in Table 3. For production and prices, three-year averages of the period from 2010 to 2012 were taken from FAO (2013). Where indicated, adjustments were made in cases where FAO data were either not available or significantly departed from information available from other sources[1]. In the case of China, provincial production and area data are taken from national agricultural statistics. For Ethiopia, area data were adjusted based on information provided by CIP experts in the region. Poverty data and data on agricultural value added were taken from the World Development Indicators database (World Bank 2013).

The data on potato area per household and household size that were used to estimate the numbers of beneficiaries were taken from a dataset used for the preliminary estimation of the potential number of beneficiaries of RTB (CGIAR 2011). Data for individual countries in this dataset were based on specific sources of published information or expert opinion.

TABLE 3: DATA ON AREA AND PRODUCTION AND SOCIOECONOMIC PARAMETERS USED FOR EX-ANTE IMPACT ASSESSMENT

Country	Total potato area ('000 ha)[a]	Quantity ('000 t/yr)[a]	Area/HH (ha)[b]	HH size[b]	Price (US$/t)[a]	Number of poor ('000)[c,d]	Agricultural value added (US$ bn)[c,d]
Angola	98.0	778.9	0.25	6	320	9,030	10.6
Armenia	29.4	562.2	0.75	4	346	73	2.0
Azerbaijan	65.7	953.6	0.75	5	542	40	4.0
Bangladesh	476.4	8,665.5	0.25	5	144	66,906	20.3
Bhutan	5.5	50.4	0.75	5	382	76	0.3
Bolivia	179.4	947.3	0.40	4	324	1,638	3.4
Burundi	12.6	35.2	0.25	5	264	8,010	0.9
Cameroon	67.7	195.0	0.25	5	391	2,074	4.9
China (Gansu)	648.8	9,853.3	1.00	4	320	159,382	840.0
China (Guangxi)	60.1	1,164.7	0.30	4	320	159,382	840.0
China (Guizhou)	628.9	7,420.5	0.40	4	320	159,382	840.0
China (Nei Mongol)	674.8	8,547.0	1.00	4	320	159,382	840.0
China (Ningxia)	224.3	2,065.0	1.00	4	320	159,382	840.0
China (Qinghai)	87.2	1,862.5	1.00	4	320	159,382	840.0
China (Sichuan + Chongqing)	439.6	4,150.3	0.50	4	320	159,382	840.0
China (Yunnan)	484.5	7,484.2	0.40	4	320	159,382	840.0
Colombia	102.9	1,808.3	0.80	4	499	3,893	24.1
Congo, DRC	21.7	96.8	0.25	5	264	57,637	8.1

[1] The individual country adjustments made are reported in the parameters files used for the economic surplus model calculations.

Country	Total potato area ('000 ha)[a]	Quantity ('000 t/yr)[a]	Area/HH (ha)[b]	HH size[b]	Price (US$/t)[a]	Number of poor ('000)[c,d]	Agricultural value added (US$ bn)[c,d]
Ecuador	40.7	337.0	0.50	4	276	714	8.5
Ethiopia	164.0	1,301.1	0.25	5	130	28,115	20.0
Georgia	22.3	250.8	0.75	4	327	812	1.5
India	1,724.9	39,019.6	0.75	5	137	404,149	320.3
India (Bihar)	314.4	5,744.4	0.75	5	137	35,023	13.1
India (West Bengal)	384.4	10,654.8	0.75	5	137	18,251	28.5
Indonesia	62.0	1,041.7	1.00	4	579	39,992	129.4
Kazakhstan	184.3	2,919.0	1.00	4	344	18	11.1
Kenya	129.4	3,563.7	0.25	5	409	18,726	11.0
Kyrgyzstan	83.4	1,343.8	0.40	4	261	281	1.2
Laos	1.7	34.4	0.50	4	361	2,252	2.9
Madagascar	40.0	216.3	0.25	5	288	18,123	2.9
Malawi	49.9	826.7	0.18	6	264	9,805	1.3
Mozambique	13.2	191.2	0.25	5	264	15,016	4.4
Myanmar	38.3	579.1	0.25	5	361	13,516	26.7
Nepal	186.1	2,536.7	0.50	5	197	6,819	7.1
Nigeria	260.7	1,116.7	0.25	4	391	114,773	85.9
Pakistan	161.0	3,579.2	0.75	5	164	37,695	46.4
Peru	299.5	4,120.1	0.45	4	229	1,472	12.7
Philippines	8.1	121.6	0.75	5	581	17,813	32.1
Rwanda	161.5	2,099.5	0.15	4	230	7,238	2.3
Tajikistan	36.7	871.1	0.50	7	220	525	1.9
Tanzania	195.4	1,602.7	0.25	5	264	32,430	7.8
Uganda	108.6	758.8	0.25	5	264	13,815	4.7
Uzbekistan	72.6	1,784.6	0.80	5	275	13,697	9.8
Vietnam	38.6	420.0	0.50	4	361	14,959	30.2

Sources: [a] FAO (2013); [b] all countries CGIAR (2011), except for Indonesia (Pangaribowo 2011); [c] Own calculations based on World Bank (2013) (number of poor was calculated as the product of population and the poverty headcount ratio at US $1.25/day, agricultural value added is the share of agriculture in total GDP); [d] in case of China, total national values were divided equally among the provinces.

5.2 Research options parameters

The economic surplus model used for this analysis represents a closed economy model with no demand shift. Accordingly, the technology effects that are directly captured by the model and for which explicit parameter values have been estimated are changes in yields and costs of production. For some of the technologies these two parameters may not represent all sources of benefits. In these cases, the appropriate changes in the basic economic surplus model or the use of alternative modeling approaches was identified. The specific values for yield and costs changes for each research option and country are listed in Tables 7–11 in the Annex.

Agile potato

In the case of the agile potato we use a 7% yield increase across all countries except for India, where we use 8% (Table 7). These values were taken from Fuglie (2007) and are meant to represent the productivity shift of the entire potato-cereal production system. No other sources of information for this parameter were found. The adjustments and the estimation of this system productivity change remain a task for future field research. In addition to this productivity effect, the agile potato is expected to lead to an expansion in potato production area in the target farming systems as a new potato crop is introduced into cereal-based systems where potato was not grown before. Although this is a simplifying assumption, it is possible that in some areas in some countries potato is already being grown in cereal systems. Lack of data and expert opinion indicate that this area is small with respect to both the traditional potato area and the total area of cereal-based systems.

To accommodate the assumption of an expansion in potato production area, the economic surplus model is adjusted. In contrast to the other research options for which a constant production area is assumed over the entire evaluation period, the potato area is modeled to increase with the introduction of the agile potato. The adoption rates for this technology represent increase in this area as a percentage of final aggregate expected crop area. No cost changes are assumed for this technology as information on the final effects of the technology is lacking. The productivity change is assumed to be net of any possible cost changes and includes any potential effects on overall system productivity.

Potato seed systems

For the assessment of potato seed systems, a yield increase of 20% is assumed for all countries except for Peru (Table 8). The assumed yield increase for this research option is lower than reported by Fuglie (2007) and is also lower than the 30% that this research option was found to achieve in field trials. However, according to expert opinions, the values chosen for the present assessment more accurately represent the average yield increases on larger adoption areas in a larger number of countries. Maximum adoption rates for this research option are one third of the estimated adoption domains reported in CIP's Strategy and Corporate Plan (CIP 2014).

For seed systems, costs are assumed to increase by 20%. This is due to higher cost for quality seed material and, possibly, higher costs from increased use of other inputs. These cost increases are higher than those assumed by Fuglie (ibid.).

Potato varieties resistant to BW

In case of BW-resistant varieties, yield increases range between 10% and 30%, based on expert opinions about the incidence of the disease in the different target countries (Table 9). The upper bound of the range is applied to target countries in SSA, where the incidence of the disease is found to be higher than in the rest of the regions. Yield increases in Asian and Latin American countries vary between 10% (India, Nepal, Philippines, Indonesia, and Bhutan; Peru and Colombia) and 20% (China, Bangladesh, Vietnam, and Pakistan; Bolivia). Compared with those of Fuglie (2007), these assumptions reflect higher potential yield increases for the SSA region. As no chemical treatment for BW is available, resistant varieties are expected to result in no changes in input use and hence no cost changes are expected.

Potato varieties resistant to virus diseases

Virus-resistant varieties are assumed to lead to the highest yield increases—40% across all countries—of all potato technologies assessed. This reflects the recent expert opinions of the prominent role of virus diseases in causing yield losses in potato production. The estimate also exceeds the assumptions made by Fuglie (2007) regarding the productivity effects of virus-resistant varieties. On the cost side, a reduction in cost by -5% across all countries is assumed. This reflects potentially lower costs for seed replacement, as virus-resistant varieties are less prone to seed degeneration.

Potato value chains

The development of potato value chains is assumed to have a significant effect on yields of the potato crop due to increased farmer specialization. The yield increase is expected to range from 35% to 50%, with the upper bound found in the countries in Latin America where CIP has already worked for several years (Peru, Bolivia, and Ecuador). Cost changes modeled for the value chains option range from 7% to 11%. These increases are caused by higher input costs incurred by farmers to boost productivity. In addition, improvements in quality are expected to lead to higher market demand and higher prices. The demand effect is assumed to be +20% in Peru and +10% in the other countries. This assumption is based on findings about increases in per capita consumption of potato in Peru in the past 15 years, which were found to be around 30% (Scott 2011), and attributing two thirds of this increase to the value chain work. For the depiction of the demand shift in the economic surplus model, we follow the two-step approach proposed by Norton et al. (1987) and Alston et al. (1998). We first estimate the new equilibrium prices and quantities after a proportionate shift in demand holding the supply curve constant. Second, the economic surplus changes due to the technology-induced supply shift are calculated based on the new set of prices and quantities.

LB-resistant varieties

The productivity changes assumed for LB-resistant varieties in this study are lower than those proposed by Fuglie (2007) and range from 12% to 32%. The lower values as compared to the earlier CIP assessment reflect more recent expert opinions which recognize that farmers in the field have not realized the full potential yield benefits of the LB resistance trait. Similarly, the cost savings from these varieties are assumed to be lower than in the earlier study, with a maximum of -5%. It has been found that farmers have not reduced the application of fungicides by the maximum possible extent. Instead, they have continued to apply them at a rate unnecessary for the resistant varieties.

5.3 Parameters related to research and dissemination process

In addition to the technological parameters described above, the economic surplus model uses a number of parameters that relate to the research and dissemination process. These parameters comprise the duration of research phase (i.e., the research lag), the number of countries and the regions that are targeted by the research option, the annual costs for research and development, an assumption on the costs of dissemination per unit of area on which the technology is adopted, and the probability of research success. Table 4 summarizes these parameters for each of the research options.

The (remaining) duration of the research phases—that is, the time until the resulting technology will be released—ranges 2–10 years for the research options included in the assessment. The research options with the shortest duration are virus-resistant varieties and LB-resistant varieties, each with a research lag of two years. This relatively short time until release is because research on these options is already in an advanced stage at CIP. Similarly, potato seed systems and potato value chains have relatively short research lags of three years. Both are relatively well-developed technologies that require some adjustment to the local conditions in the target countries. The research lag of five years for potato value chains in Asia underlines this, because work on this technology is just starting in that region. With the agile potato, advanced clones with short maturity have already been developed by CIP breeding programs. However, this maturity period still has to be shortened, which requires further breeding work. Also, once the clones with the desired maturity period have been developed, they have to be integrated into their targeted cereal systems and further adjustments in the remaining components of the systems have to be made (e.g., shorter duration of the cereal component). Therefore, the research lag for this option is set at five years. The 10-year research lag of BW-resistant varieties is the longest, largely because breeding efforts targeting this trait would have to be newly initiated.

With respect to the years to maximum adoption (the adoption lag), we assume that most of the technologies related to the improvement, release, and diffusion of germplasm (varieties) will take 10 years from the year of release to reach the adoption ceiling. This follows CIP's standard practice in this type of assessment and is supported by data that CIP has collected regarding the adoption of improved varieties. With respect to potato seed systems and potato value chains, reaching maximum adoption is expected to take only five years. This shorter period is assumed because adoption of these technologies is faster once they are developed, even though adoption ceilings might sometimes be lower.

Regarding target countries, the agile potato has the most limited adoption domain, as it is aimed specifically at 13 Asian countries where cereal-based farming systems are located. Potato value chains also have a relatively limited adoption domain of 10 countries in Latin America, Asia, and SSA. These are countries where institutional and market conditions are conducive to working with this research option. The remaining three technologies are targeted to a larger number of countries across these same three regions. This broad geographic coverage reflects the worldwide relevance of the constraints being addressed by the different technologies.

The annual costs for research and development included in Table 4 are an estimation of both costs incurred by CIP in developing the technologies and the national agricultural research systems. These costs reflect current or anticipated patterns of investment and are based on different sources of information: current CIP budget and allocation across crops (potato and sweetpotato), estimation of the proportion of CIP's budget allocated to the different research programs, and CIP's recent proposals for program development in the near future.[2] The figures reflect an assumption that CIP's expected investment in these technologies will require similar aggregate investment from national programs (Fuglie 2007).

For the dissemination cost, a fixed figure per hectare of adoption is assumed. This cost is assumed to be incurred only once (i.e., only for the marginal area of adoption). Depending on the type of technology, different dissemination costs are assumed: variety technologies require an investment of US $50/ha of finally adopted area, whereas more knowledge-intensive technologies (e.g., the value chains or seed systems interventions analyzed herein) require US $80.

The probability of success expected for the different research options ranges between 50% and 90%. The latter probability is given to potato value chains, which is a technology that is already developed and only needs minor adaptation to local contexts. LB- and virus-resistant varieties are parts of research programs that CIP has been working on for decades. Accordingly, relatively high probabilities of success of 80% and 70%, respectively, are given to these research options. As such, virus-resistant varieties are given a lower probability because the development of this trait is proving more challenging than LB resistance. The lower probabilities of success of 50–60% are given to technologies for which different components have yet to be developed (i.e., which require more upstream research and coordination with other technology developments). An example of this latter aspect is the agile potato, which has to be complemented by refinements in the rest of the target production systems. In the case of potato seed systems in Kenya, CIP has already accomplished more advanced research by having developed the proof of concept in that country compared with the other target countries. Therefore, a higher probability of success of 80% can be expected.

6. Results of the ex-ante assessment using economic surplus model

The results of the ex-ante assessment of the selected potato technologies using the economic surplus model show great disparities in terms of net present value (NPV) and internal rate of return (IRR) on the investments across the different research options (Table 5). The largest economic impacts are found for those research options that are characterized by well-established research programs at CIP (and a correspondingly high probability of success), that are expected to have large productivity impacts across all countries in all regions, and that have a short duration until the technology is available (Table 4). The latter aspect leads to benefits that materialize early in the assessment period. Also, past research costs are not considered in the analysis, thus allowing for higher rates of return for these research options. Therefore, LB- and virus-resistant varieties have expected net benefits of US $4.7 billion and US $3.9 billion, respectively, in the high-adoption scenario. According to the large expected benefits, the rates of return to both technologies are high, too. Virus-resistant varieties, where strong expected productivity impacts outweigh a relatively smaller final adoption area, have an IRR of 104%; LB-resistant varieties provide an IRR of 87%.

A second group of technologies includes the agile potato and BW-resistant varieties. The expected NPVs of the economic benefits of these research options are slightly above US $0.5 billion each (almost

[2] In the case of seed systems, the current assumption of a total annual research and development investment of US $8 million reflects the status of knowledge of how proposals submitted by CIP have been considered by potential donors, although intended investments by CIP were initially much higher.

six times lower than virus-resistant varieties, for example). For each of the two technologies, different reasons explain these results. In both cases, the uncertainty in the development of the technologies, as reflected by a low probability of success of around 50%, reduced the magnitude of the economic impacts relative to LB- and virus-resistant varieties. With the agile potato, the expected productivity impact is also low—the lowest, in fact, among the research options assessed. With BW, the long duration of the research phase reduces the benefits that are realized farther in the future more heavily (Table 4). Despite these reduced economic benefits compared to those of LB- and virus-resistant varieties, the results still indicate reasonable returns of investments on these technologies, which are near 35%.

Potato value chains are an interesting case. Owing to a very small final adoption area, which dominates the high expected impacts on productivity and a high probability of research success, the NPV of expected benefits from this research option is relatively low (US $0.4 billion). The IRR offered by investment in the technology, however, is high at 87%, because relatively low investments are needed in terms of research expenses (Table 4).

The NPV of benefits for potato seed systems is only US $0.23 billion in the high-adoption scenario, the lowest of all technologies assessed in this analysis. As for the benefits, the expected adoption rates in several countries are low, even in the high-adoption scenario, reflecting historic low adoption rates for high-quality seeds in the countries and that large increases are expected to be moderate. This is due to the weakness of seed systems, resulting in a limited supply of high-quality seed in most of the countries and the high costs of distribution of these seeds to farmers. Also, adopting this technology will most likely increase farmers' seed costs. As well, the effects on yields will be highly dependent on how farmers will eventually make decisions on how they will purchase, multiply, and use the improved seeds. Nevertheless, an IRR of 34% is still comparable with that of the agile potato and BW, because the benefits will be realized sooner. To arrive at more robust results and to obtain more reliable estimates of this research option, better information, particularly on the cost parameters, is needed.

With respect to the results for the lower adoption scenario, results in general correspond to the assumed reductions in adoption. The NPVs are about halved with respect to the higher adoption scenario, except for the cases of the agile potato and potato seed systems, for which NPVs are reduced more strongly. Explanations for the changes in the results for these two research options are more complex and not straightforward, due to several factors intervening simultaneously in the model. These factors include the relative cost of research and development and dissemination, the discount rate applied, the size of the k-shift brought about by the assumptions about productivity and cost effects, and the probability of success.

TABLE 4: SUMMARY OF RESEARCH AND DISSEMINATION RELATED PARAMETERS OF RESEARCH OPTIONS

Research option	Duration of research phase from onset of assessment (years)	Adoption lag[a] (years)	Number of countries targeted	Regions targeted	Total annual R&D costs (US$'000)	Dissemination costs (US$/ha)	Probability of success (%)
Agile potato	5	10	13	1 (Asia)	10,000	50	50–60
Potato seed systems	3	5 (Peru: 9)	27	3 (Latin America, Asia, SSA)	8,000	80	60 (Kenya: 80)
BW-resistant varieties	10	10	22	3 (Latin America, Asia, SSA)	4,000	50	50
Virus-resistant varieties	2	10	27	2 (Asia, SSA)	8,000	50	70
Potato value chains	3 (Asia: 5)	5	10	3 (Latin America, Asia, SSA)	2,000	80	90
LB-resistant varieties	2	10	32	3 (Latin America, Asia, SSA)	16,000	50	80

[a] Adoption lag refers to the number of years from the first year of adoption until maximum adoption is reached.

TABLE 5: RESULTS OF EX ANTE ASSESSMENT OF POTATO RESEARCH OPTIONS

Technology	Adoption Ceiling		All Benefits				Number of Beneficiaries				Poverty Reduction	
	Lower adoption	Higher adoption	Lower adoption		Higher adoption		Lower adoption		Higher adoption		Lower adoption	Higher adoption
	'000 ha	'000 ha	NPV (US$ million)	IRR (%)	NPV (US$ million)	IRR (%)	'000 households	'000 persons	'000 households	'000 persons	'000 persons	'000 persons
Agile potato	461.3	922.6	191.9	24	553.6	34	700	3,183	1,401	6,365	24.21	58.03
Potato seed systems	434.4	868.8	88.43	23	231.5	34	996	4,423	1,992	8,846	21.75	43.54
LB resistance	773.8	1,547.6	2,303.3	68	4,742.6	87	2,109	9,466	4,217	18,932	349.96	704.60
BW-resistant varieties	635.0	1,270.1	252.9	29	534.8	35	1,719	7,847	3,438	15,693	199.96	401.71
Virus-resistant varieties	355.8	711.6	1,908.7	82	3,898.3	104	870	3,826	1,740	7,652	305.43	616.48
Potato value chains	36.8	73.5	193.0	67	400.4	87	113	497	226	993	23.05	46.14

Higher/lower adoption: analysis estimated on expert assessment/50% reduced adoption rates. NPV calculated using an interest rate of 10%.

The estimation of the number of beneficiaries of these technologies offers an alternative perspective of the potential impact of the research options that helps to overcome some of the issues discussed in the context of the results from the economic surplus model. The results for the higher adoption scenario show that 0.2–4.2 m households, or from 1 m to almost 19 m people, may benefit from the different research options. The differences in the number of beneficiaries between most of the research options are not as large as the contrast found in the economic surplus analysis. LB-resistant varieties still offer the option of reaching the largest number of beneficiaries, because of the largest area coverage in all the regions. Second to LB, BW-resistant varieties might benefit 3.4 m households around the world, although adoption may not begin until 10 years after the beginning of the research. Potato seed systems, virus-resistant varieties, and the agile potato are expected to reach similar numbers: 1.4–2 m households. Potato value chains is the technology with the lowest reach and is expected to benefit around 0.2 m households. That is because massive adoption is not expected in any of the countries.

The poverty reduction effects take into account the impacts of growth in the agricultural sector on poverty in a particular country. It weighs the economic surplus results according to the poverty levels in each of the countries, the share of agriculture in total GDP, and the agricultural growth elasticity of poverty. Therefore, research options will have, all else being equal, higher impacts on poverty reduction in countries with higher poverty incidence and higher share of agriculture in total GDP. Moreover, the larger the agricultural growth elasticity of poverty, the larger the poverty impacts of the research options. For the purpose of this analysis, the NPV of the benefits is interpreted as agricultural growth and the extent of poverty reduction resulting from this growth is calculated. The results thereby reflect not only the magnitude of the benefits, but also the poverty levels in each country, the relative size of the agricultural sectors, and the population. A final effect is the size of the elasticity of poverty reduction with respect to agricultural growth (i.e., the percentage of poverty reduction brought about by 1% growth in the agricultural sector). This effect is strongest in SSA (0.72), followed by Asia (0.48) and Latin America (0.15). The approach draws on Alene et al. (2009).

The results on poverty reduction presented in Table 5 show that the expected reductions in poverty from the different research options range between 43,000 and more than 700,000 persons in the higher adoption scenario. The expected3 number of poor persons lifted out of poverty is partly determined by the size of the NPV as the basic input used for these calculations. The highest poverty reduction, for example, can be expected from LB- and virus-resistant varieties. However, in spite of a relatively low NPV of benefits, BW-resistant varieties may contribute relatively much to poverty reduction. This is partly because most of the adoption is expected to take place in Africa, where the elasticity of poverty reduction is high. In contrast, the agile potato with similar results on the NPV leads to much lower poverty reduction—by around 58,000 people—because adoption is constrained to Asian countries, where the elasticity of poverty reduction there is lower than in Africa.

It is interesting to note that varieties resistant to biotic constraints show the highest expected poverty effects. The technologies that are based on management packages in the broadest sense and changes in production systems, on the other hand, appear to have weaker effects on poverty. This is related to lower and more localized adoption in specific areas for the agile potato, seed systems, and potato value chains. Resistant varieties, in contrast, are expected to be adopted in all three regions covered by the analysis. Moreover, the research options with relatively weak poverty effects tend to be

[3] We speak about expected numbers because the NPVs of benefits include the probability of research success.

adopted more in Latin America and Asia, which are the regions with lower elasticities of poverty reduction.

An interesting case is the research on development of potato value chains, which yields relatively high rates of returns (87% in the high-adoption scenario), making it (along with LB resistance) the second most important research option based on this result. However, it drops to the second to last place in the rank based on poverty impacts because most of the target areas are in Latin America, where population, poverty rates, and the agricultural growth elasticity are the lowest.

In general, the figures on poverty reduction obtained in the analysis might appear low. But note that they represent an estimate of only the number of people that are fully lifted out of poverty solely because of technology adoption (i.e., the contribution to the reduction in the poverty headcount). The number of poor that benefit and whose situation will be improved, albeit without being fully lifted above the poverty line, in turn, may be much higher.

Table 6 provides information about the regional distribution of the adoption area of the different research options across the three target regions. The table also identifies the relative importance of China with respect to the rest of the Asia/Pacific region. An interesting conclusion from Tables 5 and 6 is that for most technologies, aggregate adoption area is higher in Asia/Pacific and China than in Africa and Latin America. However, regional distributions of benefits, number of beneficiaries, and poverty reduction are not only driven by final adoption area, but also by other parameters used in the model such as productivity and cost effects or average cropping area per household.

TABLE 6: REGIONAL DISTRIBUTION OF ADOPTION AREAS ACCORDING TO RESEARCH OPTIONS (HIGHER ADOPTION SCENARIO)

Technology	Higher Adoption							
	Africa		LAC		Asia/Pacific*		China	
	'000 ha	Share (%)	'000 ha	Share (%)	'000 ha	Share (%)	'000 ha	Share (%)
Agile potato	0	0	0	0	443	48	480	52
Potato seed systems	146	17	32	4	380	44	311	36
LB resistance	359	23	199	13	523	34	466	30
BW-resistant varieties	343	27	63	5	587	46	277	22
Virus-resistant varieties	241	34	0	0	144	20	327	46
Potato value chains	17	23	46	62	11	15	0	0

*Excluding China.

7. Conclusions and outlook

This report presents the results of the strategic assessment of potato research options for RTB. The results highlight the potential for impact of future investments in potato research and points to important differences in the potential benefits between different research options:

- All technologies produce positive economic impacts in terms of both NPVs and the rates of return to investments, showing the potential for potato research for development.
- The research options with the highest potential impacts in terms of NPV are LB- and virus-resistant varieties. This is due to the potentially global scale of adoption of these technologies and the high expected effects on productivity at the farm level.
- The remaining research options have lower NPVs, due to the interplay of different factors (e.g., the lower productivity effects of the agile potato and seed systems, the low adoption levels of value chains, and the late research lag of varieties resistant to BW).
- The analysis also shows that research options with relatively low NPVs of benefits may yield high rates of return due to the relatively low investment costs. The principal example here is the potato value chains research option.
- In terms of the number of beneficiaries expected to be reached, LB- and BW-resistant varieties stand out among the research options assessed. This reflects the high potential of both options for adoption in all countries and regions. Agile potato, potato seed systems, and virus-resistant varieties come second with respect to the number of beneficiaries because of their more limited geographical coverage (agile potato in Asia, potato seed systems and virus resistance in Africa).
- In the case of potato value chains, a relatively low number of beneficiaries reflects the focus of this research option on a small number of target countries in Latin America and SSA and comparatively low anticipated adoption areas.
- Improved varieties with resistance to biotic constraints show the highest potential for poverty reduction among the research options. There is a close link with the size of the expected economic benefits, except for BW. In this case, high levels of poverty reduction can be achieved with relatively modest economic benefits because of the strong deployment of this technology in countries where agricultural growth has the highest potential for reducing poverty. This underscores the role of geographic targeting in agricultural research for development.

The analysis also shows that the potential benefits and the differences between them are the outcome of a set of assumptions on farm-level effects, technology dissemination, and the research process required to develop the technologies that reflect the current expectations of the research programs. The analysis makes the assumptions and the potential for generating impact that results from these assumptions transparent. For each research option this transparency allows us to identify the factors that are conducive to an option's success or to explain possible weaknesses that are due to, for example, uncertainty of the parameters, and thereby can support program planning.

There are, however, still potential areas to improve the analysis:

- The discussions of the analyses presented in this report are limited and only hint at some of the most important determinants of the results. Further efforts should be dedicated to elaborate on the factors and drivers that explain the differences in the results between research options and between regions. These factors and drivers include the assumptions behind the analyses of each of the research options and the logics of the model being used. A closer look at the distribution of the benefits from each technology in each of the target countries can also give further insights into the aggregate results discussed in the present report.
- For some of the research options, available information has been limited or the information used was beset by a high degree of uncertainty. This shortcoming concerns the agile potato and potato seed systems in particular. A revision of these research options as new information (e.g., on productivity effects at the farm level) becomes available would be warranted and welcomed.
- Further discussion with the experts who provided information for the values of the parameters being used in all research options analyzed is highly desirable. Best practice in this kind of exercise is to develop an iterative process in which results of the first model runs inform experts about the effects of the initial parameters estimation. An example would be the estimates on expected adoption. Allowing for subsequent refinements can improve scientists' understanding and confidence in the final results and their interpretation.
- For the calculations of the NPVs in the present analysis, only real interest rates of 5% and 10% have been used as discount rates (and only results for the 10% case have been reported). Owing to the relatively high discount rate, research options with larger research lags are at a disadvantage compared with technologies whose benefits are realized earlier in the assessment period. Lower discount rates may make options that are in the earlier stages of research process more attractive and therefore may elevate the strategic component of such research options.
- Treatment of prices could be improved in the general methodology by transforming market prices in the FAO database to purchasing power parity prices for each of the countries.
- In the case of potato value chains, although we have a model that accounts for the demand shift, further efforts should be dedicated to refining the model for better capturing demand effects. A possible option would be the application of a multi-market approach.
- In this analysis, we have included results that extend the traditional economic surplus model results (i.e., estimation of the number of beneficiaries and poverty) that are based on the similar basic parameters. However, these additional results imply new assumptions and data that are scant and whose rigor could be improved. Having more robust baseline data on some of the assumptions, such as average crop area per household, would make the estimations more reliable.
- Finally, the analysis should be extended to additional technologies, starting with the two research options identified in Table 2.

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Annex: Parameters tables

TABLE 7: PARAMETER VALUES FOR AGILE POTATO

Country	Maximum adoption rate (% of total area)	Year of first adoption	Adoption lag (years)	Maximum area increase ('000 additional ha)*	Yield increase (%)	Cost change (%)	Probability of success (%)
India (West Bengal)	50	5	10	192.2	8	0	60
Bangladesh	7	5	10	34.3	7	0	50
Nepal (plains)	34	5	10	62.1	7	0	50
Pakistan	18	5	10	28.7	7	0	50
Vietnam (North)	34	5	10	13.6	7	0	50
Laos	10	5	10	0.2	7	0	50
China (Yunnan)	16	5	10	78.5	7	0	50
China (Guangxi)	19	5	10	11.1	7	0	50
China (Qinghai)	46	5	10	39.9	7	0	50
China (Gansu)	54	5	10	350.4	7	0	50
Tajikistan	60	5	10	22.0	7	0	50
Kyrgyzstan	36	5	10	30.0	7	0	50
Uzbekistan	82	5	10	59.5	7	0	50

*Base areas are as follows (in '000 ha): India (West Bengal): 384.3; Bangladesh: 476.4; Nepal (plains): 182.6; Pakistan: 160.1; Vietnam (North): 40.1; Laos: 1.7; China (Yunnan): 484.5; China (Guangxi): 60.1; China (Qinghai): 87.2; China (Gansu): 648.8; Tajikistan: 36.7; Kyrgyzstan: 83.4; and Uzbekistan: 72.6.

TABLE 8: PARAMETER VALUES FOR POTATO SEED SYSTEMS

Country	Maximum adoption rate (% of total area)	Year of first adoption	Adoption lag (years)	Yield increase (%)	Cost change (%)	Probability of success (%)
Peru	7	3	9	20	20	70
Ecuador	7	3	5	20	20	70
Bolivia	3	3	5	20	20	70
Colombia	3	3	5	20	20	70
China (Guizhou)	20	3	5	20	20	60
China (Yunnan)	20	3	5	20	20	60
China (Sichuan + Chongqing)	20	3	5	20	20	60
Vietnam	0	3	5	20	20	60
Philippines	20	3	5	20	20	60
Indonesia	0	3	5	20	20	60
Uganda	10	3	5	20	20	70
Nigeria	8	3	5	20	20	70
Congo, DRC	7	3	5	20	20	70
Tanzania	7	3	5	20	20	75
Madagascar	8	3	5	20	20	70
Burundi	10	3	5	20	20	70
Rwanda	20	3	5	20	20	70
Angola	2	3	5	20	20	70
Malawi	13	3	5	20	20	70
Mozambique	13	3	5	20	20	70
Ethiopia	13	3	5	20	20	70
Kenya	20	3	5	20	20	80
Cameroon	7	3	5	20	20	70
India	20	3	5	20	20	70
Bhutan	20	3	5	20	20	60
Uzbekistan	20	3	5	20	20	60
Armenia	20	3	5	20	20	60
Tajikistan	20	3	5	20	20	60
Georgia	20	3	5	20	20	60

TABLE 9: PARAMETER VALUES FOR BW-RESISTANT VARIETIES

Country	Maximum adoption rate (% of total area)	Year of first adoption	Adoption lag (years)	Yield increase (%)	Cost change (%)	Probability of success (%)
Peru	0	10	10	10	0	50
Bolivia	18	10	10	20	0	50
Colombia	30	10	10	10	0	50
China (Yunnan)	30	10	10	20	0	50
China (Sichuan + Chongqing)	30	10	10	20	0	50
Vietnam	0	10	10	20	0	50
Philippines	20	10	10	10	0	50
Indonesia	0	10	10	10	0	50
Uganda	40	10	10	30	0	50
Nigeria	10	10	10	30	0	50
Congo, DRC	20	10	10	30	0	50
Tanzania	20	10	10	30	0	50
Madagascar	10	10	10	30	0	50
Burundi	40	10	10	30	0	50
Rwanda	60	10	10	30	0	50
Ethiopia	40	10	10	30	0	50
Kenya	40	10	10	30	0	50
Cameroon	10	10	10	30	0	50
India (Bihar)	60	10	10	10	0	50
Nepal	20	10	10	10	0	50
Bangladesh	20	10	10	20	0	50
Bhutan	20	10	10	10	0	50
India (West Bengal)	60	10	10	10	0	50
Pakistan	20	10	10	20	0	50

TABLE 10: PARAMETER VALUES FOR VIRUS-RESISTANT VARIETIES

Country	Maximum adoption rate (% of total area)	Year of first adoption	Adoption lag (years)	Yield increase (%)	Cost change (%)	Probability of success (%)
Peru	0	2	10	40	-5	70
Bolivia	0	2	10	40	-5	70
Colombia	0	2	10	40	-5	70
China (Gansu)	20	2	10	40	-5	70
China (Qinghai)	20	2	10	40	-5	70
China (Ningxia)	20	2	10	40	-5	70
China (Nei Mongol)	20	2	10	40	-5	70
Uzbekistan	40	2	10	40	-5	70
Armenia	35	2	10	40	-5	70
Tajikistan	30	2	10	40	-5	70
Kazakhstan	35	2	10	40	-5	70
India (North/West/East)	0	2	10	40	-5	70
Bangladesh	0	2	10	40	-5	70
Nepal (plains)	0	2	10	40	-5	70
Pakistan	0	2	10	40	-5	70
Vietnam (North)	0	2	10	40	-5	70
Laos	0	2	10	40	-5	70
Kyrgyzstan	35	2	10	40	-5	70
Kenya	35	2	10	40	-5	70
Rwanda	55	2	10	40	-5	70
Mozambique	5	2	10	40	-5	70
Malawi	5	2	10	40	-5	70
Tanzania	15	2	10	40	-5	70
Uganda	35	2	10	40	-5	70
Angola	5	2	10	40	-5	70
Ethiopia	5	2	10	40	-5	70
Burundi	35	2	10	40	-5	70
Cameroon	5	2	10	40	-5	70
Madagascar	5	2	10	40	-5	70
Nigeria	5	2	10	40	-5	70

TABLE 11: PARAMETER VALUES FOR POTATO VALUE CHAINS

Country	Maximum adoption rate (% of total area)	Year of first adoption	Adoption lag (years)	Yield increase (%)	Cost change (%)	Probability of success (%)
Peru	8	3	5	50	7	90
Bolivia	8	3	5	50	11	90
Ecuador	8	3	5	50	9	90
Colombia	4	3	5	35	10	90
Indonesia	2	5	5	35	10	90
Bangladesh	2	5	5	35	10	90
Kenya	4	3	5	35	10	90
Rwanda	4	3	5	35	10	90
Ethiopia	2	3	5	35	10	90
Uganda	2	3	5	35	11	90

TABLE 12: PARAMETER VALUES FOR LB-RESISTANT VARIETIES

Country	Maximum adoption rate (% of total area)	Year of first adoption	Adoption lag (years)	Yield increase (%)	Cost change (%)	Probability of success (%)
Peru	40	2	10	32	-5	80
Ecuador	40	2	10	32	-5	80
Bolivia	18	2	10	32	-5	80
Colombia	30	2	10	32	-5	80
China (Guizhou)	30	2	10	16	-5	80
China (Yunnan)	30	2	10	16	-4	80
China (Sichuan + Chongqing)	30	2	10	16	-4	80
Myanmar	10	2	10	32	-5	80
Vietnam	30	2	10	16	-5	80
Philippines	20	2	10	32	-5	80
Indonesia	10	2	10	32	-5	80
Uganda	40	2	10	24	-5	80
Nigeria	10	2	10	24	-5	80
Congo, DRC	20	2	10	24	-5	80
Tanzania	20	2	10	24	-5	80
Madagascar	10	2	10	24	-5	80
Burundi	40	2	10	24	-5	80
Rwanda	60	2	10	24	-5	80
Angola	10	2	10	24	-5	80
Malawi	10	2	10	24	-5	80
Mozambique	10	2	10	24	-5	80
Ethiopia	40	2	10	24	-5	80
Kenya	40	2	10	24	-5	80
Cameroon	10	2	10	24	-5	80
Nepal	20	2	10	32	-5	80
Bangladesh	20	2	10	16	-5	80
Bhutan	20	2	10	32	-5	80
India (West Bengal)	60	2	10	16	-2	80
Pakistan	20	2	10	16	-4	80
Armenia	40	2	10	12	-4	80
Azerbaijan	40	2	10	12	-4	80
Uzbekistan	60	2	10	12	-4	80
Tajikistan	36	2	10	12	-4	80
Georgia	40	2	10	12	-4	80

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