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Strategic Assessment of Research Priorities for Sweetpotato

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Strategic Assessment of Research Priorities for Sweetpotato

1. Introduction

The following report presents an ex-ante evaluation of priority research options for sweetpotato 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 sweetpotato research options taken into consideration for and included into 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 the 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 86 options for sweetpotato research (Kleinwechter et al. 2013). A total of 351 responses were received.

In September 2012, after a first set of results of the expert survey were available,[1] we conducted a first round of consultation with sweetpotato scientists, which took place in Nairobi, Kenya. From these discussions, a first preliminary list of 11 research options for assessment was identified. A second round of discussions with CIP sweetpotato scientists and program leaders was held in April 2013. The list of previously identified research options was reassessed against an extended set of results from the expert survey. At this meeting, the description of the research options of the preliminary list was improved and two more research options were identified as potential candidates for the assessment.

This expanded list was further refined after the full set of expert survey results was available and additional discussions in groups and in meetings of CIP's Science Leaders Team took place. The list was also enriched with inputs coming 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 flagship related to sweetpotato and the corresponding CIP SO were aligned with the research options included in the assessment.

The final list of candidate sweetpotato research options identified the eight top priorities for the ex-ante assessment with the economic surplus model. Some potential candidate research options were dropped from this initial list for three reasons. There was not enough information about the decisions of

[1] These first results comprised around 80 responses from CIP researchers and other partners associated with the Sweetpotato for Profit and Health Initiative in Africa.

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 and non-sweet sweetpotato.

The list of eight candidate research options was cross-checked with the previous CIP priority-setting exercise (Fuglie 2007) in order to identify similarities and differences. Further individual discussions and consultations with CIP's science experts in the field for each of the research options helped to refine the definition and scope of each of the research options. Except for breeding for early harvest, all eight sweetpotato research options were previously assessed by Fuglie (2007). 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 initial eight research options identified, a subset of four was selected to be included in the economic surplus assessment based on considerations of relevance, data availability, and methodological suitability (Table 1). One of the research options, breeding for orange-fleshed sweetpotato (OFSP), corresponds to one of CIP's SOs and to the RTB sweetpotato flagship "Candidate OFSP varieties." The other three research options selected are linked to crosscutting or discovery flagships in RTB: breeding for resistance to sweetpotato virus disease (SPVD); quality planting materials and improved seed systems, including SPVD management; and the development of weevil-resistant sweetpotato varieties. In conjunction, the four research options selected for assessment represent a broad range of technology types, including development of new varieties as well as knowledge-intensive technologies.

The four remaining research options of the initial list of eight (breeding for high dry matter, breeding for early harvest, breeding for high yield only, and breeding for drought tolerance and other abiotic stresses) were not included for this run of the ex-ante assessment (Table 2). Two of these options, however, are implicitly taken into account since they form integral part of the OFSP research options. The options are breeding for high dry matter and early harvest. They also are reflected in the parameters of the economic surplus model by being key traits that drive the adoption process and productivity effects of the OFSP. Only breeding for high yield has not been considered at all in the current analysis. This was because at present no corresponding research is being conducted at CIP and it was difficult to arrive at a sufficiently precise definition of this technology among CIP scientists. Breeding for drought tolerance and other abiotic stresses, on the other hand, is a research program that is just being initiated at CIP, and we lack the necessary information for parameter specification.

Tables 1 and 2 also present the global score obtained by the linked research option in the global expert survey, the original name of that research option, and the global rank within the 86 options included.

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

Research Option	Short Name	Link to RTB Flagships	Global Score and Rank of Expert Survey[a]
Breeding for OFSP with high content of pro-vitamin A and other micro-nutrients	OFSP	SW2: Candidate OFSP (orange-fleshed sweetpotato) varieties	4.27 (Breeding for pro-vitamin A (beta-carotene), rank #2
Breeding for sweetpotato virus disease (SPVD)-resistant varieties	SPVD-resistant varieties	CC4: Framework for analyzing and intervening in RTB seed systems	4.18 (Control and management of SPVD), rank #5 4.12 (Breeding for SPVD resistance), rank #10
Quality planting materials and improved seed systems, including SPVD management	Sweetpotato seed systems	CC4: Framework for analyzing and intervening in RTB seed systems	4.35 (Improving the quality of planting material (elimination of diseases, etc.), rank #1 4.21 (Improving production and distribution of elite planting materials [formal seed systems]), rank #4 4.01 (Improving technologies for farmer-based production and distribution of planting materials [informal seed systems]), rank #13
Development of weevil-resistant sweetpotato varieties	Weevil-resistant varieties	DI2: Genetically improved RTB varieties with game-changing traits	4.18 (Control and management of sweetpotato weevils), rank #6 4.17 (Breeding for sweetpotato weevil resistance), rank #7

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

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

Research Option	Short Name	Link to RTB Flagships	Global Score and Rank of Expert Survey[a]
Breeding for high dry matter	High dry matter	SW2: Candidate OFSP (orange-fleshed sweetpotato) varieties	4.01 (Breeding for high dry matter), rank #14
Early harvest (2.5–3 months after planting)	Early harvest	SW2: Candidate OFSP (orange-fleshed sweetpotato) varieties	4.06 (Breeding for early harvest (2.5–3 months after planting), rank #12
Breeding for high yield only	High yield breeding	DI1: RTB transformational breeding platform utilizing genomics, metobolomics, and phenomics	4.26 (Breeding for high yield), rank #3
Breeding for drought tolerance and other abiotic stresses	Abiotic stress tolerance	PM1: Production models and planting material alternatives suited to different markets, production, and livelihood systems resulting from yield gap and market and gender analysis	4.15 (Breeding for drought tolerance/ water-use efficiency), rank #9

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

3. Description of the research options

3.1 Breeding for OFSP with high content of pro-vitamin A and other micro-nutrients

This research option works to reduce vitamin A deficiency (VAD) through resilient, nutritious OFSP varieties adapted to local environments, with good performance and high consumer acceptance. The varieties are characterized by high beta-carotene content and locally important traits like virus and drought resistance, vine survival, high dry matter, low sugar content, salinity tolerance, weevil resistance or avoidance, and early maturity.

Research on this option consists of variety improvement through the use of accelerated breeding methods and tools, which is supplemented by the development of improved seed system approaches, the development of options for the sustainable intensification of sweetpotato production systems, value chain work, nutritional education, and improvement of consumer acceptance.

The impacts to be quantified are a reduction of VAD as a result of consumption of sweetpotato with higher beta-carotene content and improvements in productivity due to traits that address important biotic and abiotic production constraints. The economic surplus model analysis presented in this report only captures effects of higher productivity from improved crop traits as well as higher production costs, which arise from higher costs of vines (Labarta 2009; Low et al. 2013).

The assessment of the impacts of higher beta-carotene content requires the application of the Disability Adjusted Life Years (DALY) method, which is not part of the present report. However, during the discussion of the results of the economic surplus model, we cite other studies to arrive at an approximate estimation of the additional benefit generated from improved nutrition and health.

OFSP is directed to target regions in Africa, Asia, and Latin America and the Caribbean (LAC), specifically Haiti. In Africa, the work is most advanced, with OFSP projects ongoing for more than 10 years. Countries in Asia, as well as Haiti, are envisaged as new target countries with potential for OFSP interventions in the new CIP Strategy and Corporate Plan (CIP 2014). Individual target countries are specified in Table 7.

3.2 Breeding for SPVD-resistant varieties

SPVD is the most important biotic constraint to sweetpotato production in Africa and worldwide. SPVD is caused by a virus complex that is commonly a mixed infection of sweetpotato feathery mottle virus and sweetpotato chlorotic stunt virus. It is considered to be the most destructive viral disease of sweetpotatoes in Africa and perhaps worldwide (Carey et al. 1998).

Owing to the high pressure of SPVD, the key trait to enhance sweetpotato production is SPVD resistance. This research option consists of the reduction of yield losses caused by SPVD with resistant varieties obtained through conventional and/or transgenic breeding. The adoptable innovations from this research option are new sweetpotato varieties with resistance to SPVD, to be released to target countries in Africa, Asia, and LAC (Haiti).

The types of impacts from this research option to be analyzed include increases in productivity and production costs. As with OFSP, changes in cost are considered due to higher costs of vines of the new varieties.

3.3 Quality planting materials and improved seed systems, including SPVD management

A major problem in sweetpotato production is yield loss from seed degeneration, primarily caused by SPVD. Cultivation practices that involve the use of cuttings from the previous crop as planting material as well as the abundance of weed vegetation ensure that sweetpotato plants can be infected by SPVD year round (Karyeija, Gibson, and Valkonen 1998). The improvement in the quality and supply of sweetpotato planting material and SPVD management in the field envisaged by this research option are aimed at dealing with this problem.

The research option includes research and development (R&D) efforts on the upgrading of informal and formal sweetpotato seed systems for the provision of clean planting material, the introduction of new technologies for vine multiplication (e.g., net tunnels) and conservation (3S: storage in sand and sprouting), improved management in the field for the control of SPVD (isolation, roguing of infected plants), and the development of diagnostic tools for affordable and effective quality control.

This research option is directed to target regions in Africa, Asia, and LAC (Haiti). The impacts that are quantified in the assessment are increases in the production of sweetpotato and marketable surplus due to reductions of yield losses from seed degeneration. In addition, increases in production costs that stem from higher cost for planting material are taken into consideration.

Tackling the same constraint as the previous research option (SPVD-resistant varieties), this option is expected to lead to lower productivity improvements with lower expected adoption due to the inherent complexity involved when working with seed systems of clonally propagated crops. The success of this research, however, is more certain.

3.4 Development of weevil-resistant sweetpotato varieties

Sweetpotato weevil (*Cylas puncticollis and C. brunneus*) is the most important insect pest affecting the crop at a global level (Sutherland 1986). They are of particular importance in areas with significant dry periods. Although sweetpotato weevils do not cause reductions in root yields (Talekar 1982), they damage the storage roots, both cultivated and stored, and the larvae cause roots to produce terpenoids and phenols, rendering them unpalatable. With yield damages ranging 10–100%, sweetpotato weevils can cause high economic losses (Chalfant et al. 1990; Smit 1997; Talekar 1982). As reported by Drok (2011) for cases in Kenya, these losses can be so high that farmers quit growing sweetpotato at all.

The objective of this research option is to reduce yield losses due to unpalatable roots caused by the sweetpotato weevil. This is achieved through weevil-resistant varieties developed by either transgenic approaches introducing insecticidal *Bt* (Cry proteins) proteins or through conventional breeding to exploit other biological sources of resistance. In addition, weevil-resistant varieties are supplemented by management technologies for weevil control, such as integrated pest management—for example, "attract-and-kill" or biological control (Andrade et al. 2009).

Expected impacts comprise increases in farm-level productivity. As with SPVD-resistant varieties, a small increase in production costs due to the cost of vines is anticipated. The research option is directed to target regions in Africa, Asia, and LAC (Haiti).

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. Further, the descriptions of the RTB flagships and the drafts of CIP's SOs (CIP 2014) 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 parameter 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 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 2010–2012 were taken from FAO (2013). Adjustments were made in cases where FAO data were either not available or significantly departed from information available from other sources.

The data on sweetpotato 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 the RTB program (CGIAR 2011). Data for individual countries in this dataset were based on specific sources of published information or expert opinion.

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

Country	Total sweetpotato area ('000 ha)[a]	Quantity harvested ('000 t/yr)[a]	Area/HH (ha)[b]	HH size (persons)[b]	Price (US$/t)[a]	Number of poor ('000)[c,d]	Agricultural value added (US$ bn)[c,d]
Angola	146.0	892.2	0.40	6	274	9,030	10.6
Bangladesh	31.1	306.4	0.25	5	136	66,906	20.3
Benin	11.7	78.4	0.20	5	350	4,756	2.5
Burkina Faso	8.0	127.5	0.11	5	111	7,341	3.5
Burundi	125.8	860.3	0.15	5	219	8,010	0.9
Cameroon	54.5	305.6	0.20	5	130	2,074	4.9
China (Anhui)	147.8	1,895.0	0.50	4	309	159,382	840.0
China (Sichuan + Chongqing)	848.5	19,075.0	0.50	4	309	159,382	840.0
Congo, DRC	50.3	257.9	0.30	5	274	57,637	8.1
Cuba	57.1	340.5	0.20	5	274	n.a.	3.4
Ethiopia	58.2	770.5	0.20	5	100	28,115	20.0
Ghana	73.6	128.3	0.20	4	274	7,252	9.2
Haiti	65.3	234.2	0.20	5	274	6,278	2.0
India (Orissa)	46.1	420.6	0.75	5	214	13,671	9.1
India (Uttar Pradesh)	17.0	220.2	0.75	5	214	58,736	45.4
India (Uttar Pradesh + Orissa)	63.1	640.7	0.75	5	214	72,407	54.5
India (West Bengal)	22.8	234.6	0.75	5	214	18,251	28.5
Indonesia	179.1	2,242.3	0.90	4	214	39,992	129.4
Kenya	70.4	813.3	0.25	5	274	18,726	11.0
Laos	6.5	91.9	0.50	4	214	2,252	2.9
Madagascar	133.3	974.0	0.25	5	201	18,123	2.9
Malawi	178.1	2,939.0	0.15	6	274	9,805	1.3
Mozambique	123.0	893.3	0.12	5	341	15,016	4.4
Niger	3.1	50.6	0.11	5	274	7,484	2.6
Nigeria	1,105.0	3,333.3	0.30	4	284	114,773	85.9
Papua New Guinea	124.1	596.2	0.10	6	214	2,129	5.9
Peru	16.5	288.8	0.45	4	162	1,472	12.7

Country	Total sweetpotato area ('000 ha)[a]	Quantity harvested ('000 t/yr)[a]	Area/HH (ha)[b]	HH size (persons)[b]	Price (US$/t)[a]	Number of poor ('000)[c,d]	Agricultural value added (US$ bn)[c,d]
Philippines	104.7	524.7	0.20	4	214	17,813	32.1
Rwanda	108.8	896.8	0.15	4	163	7,238	2.3
South Africa	18.6	60.5	1.00	4	274	7,049	9.9
Tanzania	658.4	3,215.8	0.25	5	274	32,430	7.8
Uganda	563.9	2,680.7	0.25	5	274	13,815	4.7
Vietnam	146.3	1,367.7	0.50	4	214	14,959	30.2
Zambia	13.6	217.7	0.17	5	274	10,479	4.0

Sources: [a] FAO (2013), prices for 2010–2012 were used where available, last three years of the price series; otherwise, for countries with missing prices, regional averages were used. [b] All countries CGIAR (2011), except for Indonesia (Pangaribowo 2011). 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 technology effects that are directly captured by the economic surplus model and for which explicit parameter values have been estimated are changes in yields and costs of production. For the OFSP research option these two parameters do not represent all sources of benefits. In this case, the use of alternative modeling approaches will be identified and discussed below. The specific values for yield and costs changes for each research option and country are listed in Tables 8–11 in the Annex.

Orange-fleshed sweetpotato

In the case of OFSP we use a 20% yield increase across all countries (Table 8). These values are based on Fuglie (2007), who established a general increase in yields by 20%, with the exception of a few countries where productivity effects of up to 40% were expected. After revision by CIP sweetpotato experts, the productivity change was set to 20% for all countries in this analysis.

In addition to this productivity effect, OFSP is expected to lead to improvements in nutrition, which is considered to be the principal impact of the technology. Nutritional improvements are not captured by the economic surplus model. An appropriate model to capture this type of impact is the DALY model, which has been used in the past for the specific country assessments of OFSP impacts (Fuglie and Yanggen 2007; Fuglie 2007). In this report, we refer to these previous studies to discuss potential implications of the nutritional dimension for the assessment of the research option.

With respect to production costs, estimates by Fuglie (2007) are followed and slight increases in the range of 1–2% arising from higher costs of vines are assumed (Labarta 2009; Low et al. 2013).

The maximum adoption rates for OFSP range between 10% and 70% of the sweetpotato production area in the higher adoption scenario. This wide range of maximum adoption rates represents the status of work with OFSP in different countries. In some countries, such as Mozambique, work has been going on for more than 10 years and adoption is expected to be high. In other countries, work with OFSP is only beginning and is at the proof-of-concept stage. For these countries, lower rates of adoption are expected.

Since the OFSP technology is already well developed and only adaptation to local varieties is needed, a relatively high probability of success of 70–80% is assumed. Also, the time to the first year of adoption is short, 1–2 years. The time until maximum adoption is assumed to be 10 years for all countries.

SPVD-resistant varieties

With SPVD-resistant varieties, yield increases range 10–40%, based on Fuglie (2007) and the expert opinions about the potential productivity effects (Table 9). Target countries with the higher values (20–40%) are found 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 LAC countries range from 10% (Indonesia, Philippines, and Vietnam) to 20% (Haiti) and 30% (Bangladesh, India-Orissa).

As a consequence of higher costs for planting material, production costs are expected to increase slightly by 1–2%. The same assumptions as for OFSP have been used for each country.

Consistent with expectations of relatively high potential adoption rates for the technology once it is finally released, maximum adoption rates are assumed to range 20–40% in the higher adoption scenario. Since improved sweetpotato varieties with moderate levels of resistance to SPVD are already available, the basic technology can be released quickly. The time until the first year of adoption is one year. For higher levels of resistance, however, further breeding efforts are needed. This is reflected in a probability of success that varies across different countries according to the estimated difficulties of carrying out breeding efforts. The range of the probability of success is 50–80%.

The time from the first year of adoption until maximum adoption is reached is five years for Burkina Faso, India (Orissa), Malawi, Mozambique, Nigeria, South Africa, and Uganda; and 10 years for the remaining target countries. These values are expert estimates for the different target countries.

Sweetpotato seed systems

For the assessment of sweetpotato seed systems, yield increase of 20–30% is assumed (Table 10). The yield increases for this research option correspond to the assumptions made by Fuglie (2007). They are somewhat lower than productivity effects observed with farmers in Rwanda and Tanzania, who were found to achieve up to 40–50% higher yields (Sindi 2013). They are, however, in line with expert opinions about the average yield increases on larger adoption areas in a larger number of countries.

Production costs are assumed to increase by 20%. This is due to higher cost for quality seed material. These cost increases are higher than those assumed by Fuglie (2007).

For the individual countries, maximum adoption rates for this research option differ widely over a range from 1% (Angola) to 60% (Mozambique). The differences between countries reflect expert estimates on the current strength of the seed systems and the anticipated conditions for carrying out effective sweetpotato seed systems work. Countries with a history of CIP work on sweetpotato typically are expected to achieve higher maximum rates of adoption.

Since the concepts and technologies for sweetpotato seed systems are already well developed and may only need local adjustments, the research lag is only one year. Maximum adoption is expected to be reached 10 years after the first year of adoption. The probability of success of developing the technology ranges 50–80%, with the highest probability assigned to those countries where CIP has been working on sweetpotato for many years.

Weevil-resistant varieties

In case of weevil-resistant varieties, yield increases range 10–30%, similar to parameter values in Fuglie (2007) (Table 11). The upper bound of the range is applied to target countries in SSA, India, and Bangladesh, where pest incidence is expected to be higher than in the rest of the regions. Yield increases in South Eastern Asian countries (Indonesia, Philippines, and Vietnam) are the lowest at 10%.

As with SPVD-resistant varieties and OFSP, slightly higher costs for planting material are estimated. Production costs are expected to increase slightly by 1–2%.

Expectations of adoption of the technology once it is finally released are high. Maximum adoption rates are assumed to range 30–60% in the higher adoption scenario. However, unlike SPVD-resistant varieties, conventional and transgenic varieties resistant to weevils are still under development and not expected to be released until after a research lag of five years. The time from the first year of adoption until maximum adoption is reached is 10 years for all countries. Hurdles in the development of the technology found in the recent years are reflected in a lower probability of success (50%) than the one assumed in Fuglie (2007).

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 R&D, 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 parameters related to adoption lags and probabilities of success have already been discussed in detail in the previous section for each research option.

Regarding target countries, all four research options have similar adoption domains, with 23–24 countries targeted. Similarly, adoption extends across SSA and Asia for all research options; LAC is represented by Haiti.

The annual costs for R&D 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. The figures reflect an assumption that CIP's expected investment in these technologies will require similar aggregate investment from national programs (Fuglie 2007).

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

Research option	Duration of research phase (years)	Adoption lag (years) [a]	Number of countries targeted	Regions targeted	Total R&D costs/year ('000)	Dissemination costs ($ per ha)	Probability of success (%)
OFSP	1-2	10	23	3 (SSA, Asia, + Haiti)	24,000	50	60-80
SPVD-resistant varieties	1 (Angola: 5)	5-10	23	3 (SSA, Asia, + Haiti)	4,000	50	50-80
Sweetpotato seed systems	1	10	24	3 (SSA, Asia, + Haiti)	4,000	80	50-80
Weevil-resistant varieties	5	10	23	3 (SSA, Asia, + Haiti)	4,000	50	50

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

As Table 4 indicates, annual total R&D costs for developing OFSP are at US $24 million. For the remaining three research options, R&D costs of US $4 million per year are assumed. The R&D cost for OFSP is significantly higher as compared to the other options. This is because it entails not only the development of new varieties or production technologies but also market development of new products and the need to influence consumer behavior in order to expand the consumption of OFSP varieties, including nutritional education and the promotion of OFSP.

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 adopted area, while more knowledge-intensive technologies, such as the seed systems interventions analyzed herein, require US $80/ha of adoption.

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

The results on net present value (NPV) and internal rate of return (IRR) in general indicate positive economic benefits from all research options. As shown in Table 5, all research options have positive NPV and high rates of return. The two research options with the highest benefits are OFSP and SPVD-resistant varieties, with comparable NPVs of US $1.30 billion and $1.38 billion, respectively. However, in terms of returns on investment as indicated by the IRR, OFSP yields 51% and SPVD-resistant varieties 154%. Although these two rates of returns are relatively high compared to those typically found in assessments of agricultural technologies (Alston et al. 2000), OFSP appears less favorable than SPVD. This difference in the IRR of the two research options can be explained by the significantly higher R&D costs of OFSP.

TABLE 5: RESULTS OF EX-ANTE ASSESSMENT OF SWEETPOTATO 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 (m US$)	IRR (%)	NPV (m US$)	IRR (%)	('000 households)	('000 persons)	('000 households)	('000 persons)	('000 persons)	('000 persons)
OFSP	673.1	1,346.3	563.2	35	1,297.7	51	2,999	14,597	5,998	29,194	481	968
SPVD-resistant varieties	481.8	963.5	673.3	116	1,380.7	154	1,963	9,407	3,925	18,814	339	682
Sweetpotato seed systems	612.3	1,224.5	211.1	44	450.8	57	2,639	12,824	5,278	25,648	156	313
Weevil-resistant varieties	722.7	1,445.3	362.8	41	756.3	51	2,944	14,111	5,888	28,222	362	727

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

Sweetpotato seed systems and weevil-resistant varieties, in contrast, have significantly lower NPV of benefits of $0.45 billion and $0.76 billion, respectively, in the higher adoption scenario. Different factors lead to the relatively low value of benefits of these two options. While the increases in productivity are similar for both research options, higher increases in production costs that happen in case of sweetpotato seed systems lead to lower net productivity effects from that technology.[2] Despite lower NPV, the IRR, which reaches 57% in seed systems and 51% in weevil-resistant varieties, are comparable to that of OFSP because of lower R&D costs in the case of seed systems and weevil-resistant varieties. Another interesting result is that although the seed systems research option has a higher NPV than weevil-resistant varieties, the IRR of the former is lower because positive net benefits are realized later in time, which leads to a less favorable assessment in the cost-benefit analysis.

Looking at the adoption ceilings, weevil-resistant varieties and OFSP reach similar areas. However, with productivity effects also comparable between the two options, weevil-resistant varieties are at a disadvantage because of the lower probability of research success of 50% across all countries, which leads to a lower NPV.

The assessment of OFSP in the economic surplus model does not include the nutrition and health effects brought about by the higher beta-carotene content. The appropriate method to estimate these effects is the DALY method (Zimmermann and Qaim 2004). Although carrying out a thorough analysis with this method goes beyond the scope of this study, results from earlier work on OFSP can be used to inform the current analysis (Fuglie and Yanggen 2007; Fuglie 2007). In his 2007 research priority assessment study, Fuglie provides a value of $150/ha of adopted area and year for the reduction in DALY.[3] Applying this value to the adoption area in each year and adding it to the net benefits of the OFSP research option allows us to calculate NPV and IRR adjusted for the health effects. As shown in Table 6, the NPV of the benefits from OFSP increases to $2.3 billion in the high adoption scenario and the IRR to 73%. This result, although still to be considered a first approximation, shows that the potential impacts of OFSP are increased even further and highlights the importance of including health effects into the analysis.

In the lower adoption scenario, the values of the NPV range 43–49% of those of the higher adoption scenario. This is consistent with the assumed reductions in adoption. The IRR are reduced less drastically and still range between 35% (OFSP) and 116% (SPVD). These results imply that even with more conservative assumptions about adoption, investments into the four sweetpotato research options that have been analyzed still yield positive benefits and are worthwhile undertakings from an economic point of view.

The potential numbers of beneficiaries follow the tendency of the expected adoption areas. The three research options that share relatively high areas of adoption (OFSP, sweetpotato seed systems, and weevil-resistant varieties) also reach the highest numbers of beneficiaries. The numbers of households that can benefit are estimated to be 5.3–6.0 million (seed systems and OFSP, respectively) in the higher adoption scenario. Some 25.6–29.3 million persons can be reached. Owing to a lower area of

[2] The net productivity effects take into account not only increases in productivity, but also possible changes in costs. Cost increases work contrary to increases in productivity and decrease the net productivity effects. This joint effect of both types of impacts is called per-unit cost reduction in the economic surplus analysis and drives the supply shift (k-factor) in the model.

[3] The estimate of US $150/year and ha derives from the annual estimate of the number of 21,048 DALY saved by OFSP with an adopted area of 140,000 ha (Fuglie 2007). With an assumed value of $1,000 per DALY saved/year based on Stein et al. (2005), this leads to the stated amount of annual DALY benefits per ha.

adoption, SPVD-resistant varieties have lower numbers of beneficiaries—3.9 million households and 18.8 million persons, respectively. This puts the high NPV and IRR of this latter research option somewhat into perspective.

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 LAC (0.15). The approach draws on Alene et al. (2009).

Table 6: Results of assessment of OFSP including DALY benefits.

Technology	All Benefits			
	Lower adoption		Higher adoption	
	NPV (m USD)	IRR (%)	NPV (m USD)	IRR (%)
OFSP economic surplus only	563.2	35	1,297.7	51
OFSP incl. DALY benefits	1,069.6	51	2,310.5	73

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

With respect to the estimated potential for poverty reduction of the sweetpotato research options, OFSP appears to have the greatest contribution, with almost 1 million people lifted out of poverty in the higher adoption scenario. As a general explanation, this aggregate result is mainly due to the high share of adoption that is expected to take place in Africa, where the agricultural growth elasticity of poverty reduction is highest and therefore growth in the agricultural sector has the strongest effects on poverty (Table 7). With a 93% share of adoption in Africa, OFSP can outpace SPVD-resistant varieties in spite of the higher values of the NPV and IRR of the latter. SPVD-resistant varieties, which are estimated to reduce poverty by around 0.7 million persons in the higher adoption scenario, have a larger share of adoption in Asia (13% vs. 6%), where the elasticity of poverty reduction is lower. Comparing weevil resistant and sweetpotato seed systems, the latter yields the weakest poverty effects (0.3 million persons) despite adoption being also mostly expected in Africa. This is consistent with having the lowest economic impact measured by the NPV results.

Table 7 as a whole provides information about the regional distribution of the adoption area of the different research options across the three target regions. One conclusion from the table is that for all four technologies, aggregate adoption area is mostly concentrated in SSA. Much lower shares of adoption are in Asia/Pacific and adoption in LAC (only Haiti) is of low significance.

TABLE 7: REGIONAL DISTRIBUTION OF ADOPTION AREAS ACCORDING TO RESEARCH OPTIONS (HIGHER ADOPTION SCENARIO).

Technology	Higher Adoption					
	Africa		LAC		Asia/Pacific	
	'000 ha	Share (%)	'000 ha	Share (%)	'000 ha	Share (%)
OFSP	1,249	93	13	1	84	6
SPVD-resistant varieties	827	86	13	1	124	13
Sweetpotato seed systems	1,152	94	7	1	66	5
Weevil-resistant varieties	1,240	86	20	1	186	13

7. Conclusions and outlook

This report presents the results of the strategic assessment of sweetpotato research options for RTB. The results highlight the potential for impact of future investments in sweetpotato research:

- All technologies produce positive economic impacts in terms of both NPVs and the IRR, showing the potential for sweetpotato research for development.
- OFSP comes out high on all three dimensions of impacts analyzed: economic (as indicated by the NPV), the number of beneficiaries, and the potential for poverty reduction. Only in terms of the IRR does it drop in the comparison, due to comparatively high R&D cost.
- Although providing only a first approximation, the inclusion of results from the DALY model shows that if health benefits are considered, the economic benefits from the OFSP research option can almost double.
- SPVD has the largest economic impacts in terms of NPV and the rates of return. However, it ranks last in terms of number of beneficiaries and second to last in terms of poverty reduction, owing to a lower share of adoption in Africa.
- Sweetpotato seed systems and weevil-resistant varieties, although having low economic impact measured by NPV and IRR, have high contributions in the dimension of the number of potential beneficiaries reached by the technologies. A notable aspect of this result is the insight that the indicator of the number of beneficiaries decouples the assessment of impacts from the time dimension of when benefits occurs. This could therefore be seen as a strategic indicator of potential impacts in the long run.

- Sweetpotato seed systems in terms of poverty reduction have the lowest contribution because the low NPV of the impacts estimated are partially driven by the low net productivity effects. These are due to increases in production costs that counteract the anticipated productivity gains.
- In general, adoption estimates provided by experts for the assessment of the sweetpotato research options are comparatively high. This reflects, on the one hand, the optimism of the experts brought about by increasing investments that are currently going on in sweetpotato research in SSA. On the other hand, the scarcity of data on historical adoption of sweetpotato technologies makes it difficult for experts to assess potential future adoption based on rigorous evidence of the past.
- Compared to the priority assessment study carried out by Fuglie (2007), the results for OFSP and weevil-resistant varieties are very similar regarding the economic impacts as measured by NPV and IRR. However, results of the current study are based on estimates of the final adopted area that are more than double those of the earlier assessment.
- For the SPVD-resistant varieties and the sweetpotato seed systems, the results of the current study are much more conservative in terms of both the expected economic impacts and final adoption area than those reported by Fuglie (2007). This reflects a different way of defining the research options and more conservative assumptions about the changes in production costs and the probability of success. Moreover, in Fuglie’s estimates China accounts for nearly 70% of the total expected economic benefits, yet China was not included in the current study. The case of China will have to be dealt with once more rigorous information on potential technology development and adoption in the country and by province is available.
- Compared with estimated benefits from potato research (Hareau et al. 2014), the analysis for sweetpotato research options finds relatively high number of beneficiaries. This is due to higher adoption estimations and lower sweetpotato cropping area per household compared to potatoes.

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 transparent the assumptions and the potential for generating impact that results from these assumptions. This transparency allows the identification of each research option the factors that are conducive to its success or that explain possible weaknesses due to, for example, uncertainty of the parameters, and thereby can support program planning.

There is still potential for the improvement of the analysis. Possible areas for improvement include:

- 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.

- 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 to technologies whose benefits are realized earlier in the assessment period. Lower discount rates may make options that are in the earlier stages of research more attractive and therefore may better 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 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, available would make the estimations more reliable.
- An important dimension of the benefits of OFSP is the health impacts arising from the higher beta-carotene content of the orange-fleshed varieties. The current assessment provides an approximation of these impacts based on results from past research. However, a more thorough analysis to more adequately capture these benefits should be carried out using the DALY method with more precise data on the incidence of VAD and the expected adoption of OFSP on a country-by-country basis.
- There are several factors that contribute to the aggregate results on poverty reduction between research options: the difference in the estimated adoption for each research option in each country, the weight of the agricultural sector in each of these targets countries, and their initial poverty levels. To give more detailed explanations of the results and observed differences between them, explicit information on results by individual countries should be presented and compared, which is beyond the scope of the aggregate results presented in this report.

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Annex: Parameters tables

TABLE 8: PARAMETER VALUES FOR OFSP.

Country	Maximum adoption rate (% of total area)	Year of first adoption	Adoption lag (years)	Yield increase (%)	Cost change (%)	Probability of success (%)
Angola	20	2	10	20	2	70
Bangladesh	30	2	10	20	1	70
Benin	20	2	10	20	1	70
Burkina Faso	50	1	10	20	1	80
Burundi	25	1	10	20	1	80
Congo, DRC	10	2	10	20	2	70
Ethiopia	45	1	10	20	1	80
Ghana	45	1	10	20	2	80
Haiti	20	2	10	20	3	60
India (West Bengal)	25	1	10	20	1	80
India (Uttar Pradesh + Orissa)	25	1	10	20	1	80
Indonesia	10	1	10	20	1	70
Kenya	40	1	10	20	1	80
Madagascar	30	1	10	20	2	80
Malawi	60	1	10	20	1	80
Mozambique	70	1	10	20	1	80
Nigeria	25	1	10	20	2	70
Philippines	20	2	10	20	2	80
Rwanda	50	1	10	20	1	80
South Africa	50	1	10	20	1	80
Tanzania	35	1	10	20	1	80
Uganda	50	1	10	20	1	80
Vietnam	10	2	10	20	1	60
Zambia	30	1	10	20	1	80

TABLE 9: PARAMETER VALUES FOR SPVD-RESISTANT SWEETPOTATO VARIETIES.

Country	Maximum adoption rate (% of total area)	Year of first adoption	Adoption lag (years)	Yield increase (%)	Cost change (%)	Probability of success (%)
Angola	20	5	10	20	2	60
Bangladesh	40	1	10	20	1	60
Benin	20	1	10	10	1	60
Burkina Faso	20	1	5	20	1	80
Burundi	20	1	10	20	1	60
Congo, DRC	20	1	10	20	2	50
Ethiopia	20	1	10	20	1	65
Ghana	20	1	10	40	2	80
Haiti	20	1	10	20	3	50
India (Orissa)	40	1	5	25	1	65
India (Uttar Pradesh)	40	1	10	25	1	65
Indonesia	20	1	10	20	1	65
Kenya	20	1	10	30	1	70
Madagascar	20	1	10	30	2	80
Malawi	20	1	5	30	1	80
Mozambique	40	1	5	30	1	80
Nigeria	20	1	5	20	2	65
Philippines	20	1	10	20	2	80
Rwanda	20	1	10	20	1	80
South Africa	20	1	5	20	1	80
Tanzania	20	1	10	30	1	70
Uganda	40	1	5	30	1	80
Vietnam	20	1	10	20	1	60
Zambia	20	1	10	30	1	70

TABLE 10: PARAMETER VALUES FOR SWEETPOTATO SEED SYSTEMS.

Country	Maximum adoption rate (% of total area)	Year of first adoption	Adoption lag (years)	Yield increase (%)	Cost change (%)	Probability of success (%)
Angola	1	1	10	20	20	60
Bangladesh	20	1	10	30	20	60
Burkina Faso	45	1	10	20	20	80
Burundi	25	1	10	26	20	60
Benin	30	1	10	20	20	80
Congo, DRC	10	1	10	20	20	50
Ethiopia	45	1	10	26	20	65
Ghana	35	1	10	20	20	80
Haiti	10	1	10	25	20	50
India (West Bengal)	20	1	10	30	20	65
India (Uttar Pradesh + Orissa)	20	1	10	25	20	65
Indonesia	10	1	10	20	20	65
Kenya	40	1	10	26	20	70
Madagascar	30	1	10	28	20	80
Malawi	50	1	10	20	20	80
Mozambique	60	1	10	28	20	80
Nigeria	25	1	10	20	20	65
Philippines	10	1	10	20	20	80
Rwanda	50	1	10	26	20	80
South Africa	50	1	10	26	20	80
Tanzania	30	1	10	26	20	70
Uganda	50	1	10	26	20	80
Vietnam	10	1	10	28	20	60
Zambia	30	1	10	20	20	70

TABLE 11: PARAMETER VALUES FOR WEEVIL-RESISTANT SWEETPOTATO VARIETIES.

Country	Maximum adoption rate (% of total area)	Year of first adoption	Adoption lag (years)	Yield increase (%)	Cost change (%)	Probability of success (%)
Haiti	30	5	10	20	3	50
Indonesia	30	5	10	10	1	50
Philippines	30	5	10	10	2	50
Vietnam	30	5	10	10	1	50
Angola	30	5	10	30	2	50
Congo, DRC	30	5	10	30	2	50
Nigeria	30	5	10	30	2	50
Madagascar	30	5	10	30	2	50
Malawi	30	5	10	30	1	50
Mozambique	60	5	10	30	1	50
Zambia	30	5	10	30	1	50
Burundi	30	5	10	30	1	50
Ethiopia	30	5	10	30	1	50
Kenya	30	5	10	30	1	50
Rwanda	30	5	10	30	1	50
Tanzania	30	5	10	30	1	50
Uganda	60	5	10	30	1	50
Bangladesh	60	5	10	30	1	50
India (Orissa)	60	5	10	30	1	50
India (Uttar Pradesh)	60	5	10	25	1	50
Benin	30	5	10	25	1	50
Burkina Faso	30	5	10	25	1	50
Ghana	30	5	10	25	2	50
South Africa	30	5	10	25	1	50

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