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What Will It Take for Biofortification to Have Impact on the Ground?

Theories of Change for Three Crop-country Combinations

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INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

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ABSTRACT

These theories of change were developed to help the HarvestPlus program deliver on its planned outcomes and impacts. HarvestPlus expects to contribute to the reduction in micronutrient deficiency among women and children in rural areas of developing countries through the breeding and dissemination of staple crop varieties with increased levels of key micronutrients. After ten years of breeding, economic, and nutrition research to develop and assess varieties and their potential impact on human nutritional outcomes, HarvestPlus is entering a third five-year phase focused on delivering micronutrient-rich varieties at scale in nine target countries. To support program design, implementation, and evaluation in the "delivery" phase of the HarvestPlus program (2014–2018), theories of change were developed for three crop-country combinations—maize in Zambia, beans in Rwanda, and cassava in Nigeria—to describe how HarvestPlus expects to contribute to the outcome of reducing inadequate micronutrient intake among women and children in different agricultural and socioeconomic contexts in which HarvestPlus works. The evidence supporting the assumptions and risks for each link in the pathway is summarized and assessed. The results show that for some parts of the impact pathway, outcomes and causal links are well defined and supported by evidence. In other areas, the program logic needs to be better articulated so that hypotheses can be formulated and evidence generated. Addressing these gaps through research, adaptations in delivery activities, and monitoring can increase the likelihood of achieving expected outcomes as well as improve the ability of HarvestPlus and other nutrition-sensitive agricultural programs to learn from current activities to inform a broader scaling up.

Keywords: impact pathways, improved varieties, technology adoption, micronutrient deficiency, Africa, gender, biofortification, nutrition-sensitive agriculture

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ABBREVIATIONS AND ACRONYMS

A4NH	CRP on Agriculture for Nutrition and Health
CIAT	International Center for Tropical Agriculture
CRP	CGIAR Research Program
EAR	estimated average requirement
FISP	Farmer Input Support Programme
NGO	nongovernmental organization
OPVs	open-pollinated varieties
ppm	parts per million
RAB	Rwanda Agriculture Board
ToC	theory of change
VAD	vitamin A deficient

1. INTRODUCTION

HarvestPlus[1] began in 2004 as a CGIAR Challenge Program, coordinated jointly by the International Food Policy Research Institute and the International Center for Tropical Agriculture (CIAT). The goal of the program is to decrease micronutrient deficiency by increasing the amount of micronutrients in the staple foods that millions of the world's poor and malnourished rely on every day. HarvestPlus focuses on three micronutrients that are deemed most limiting by the World Health Organization—iron, vitamin A, and zinc—and has developed nutrient-rich varieties of bean, cassava, maize, pearl millet, rice, sweet potato, and wheat. In 2012, HarvestPlus became a part of the CGIAR Research Program (CRP) on Agriculture for Nutrition and Health, which helps realize the potential of agricultural development to deliver gender-equitable health and nutritional benefits to the poor.

The Discovery Phase of HarvestPlus (2004–2008) focused primarily on nutrition and breeding research intended to identify target populations, set and validate nutrient targets, and screen crop genes. HarvestPlus partnered with researchers and breeders around the globe to find varieties of staple crops that would be suitable for breeding with increased nutrient content (Bouis et al. 2011; Meenakshi et al. 2010). The Development Phase (2009–2013) began the work of evaluating and testing how well the new nutrient-rich crops performed in the field, as well as what happened to the nutrients when biofortified foods were eaten. HarvestPlus also collaborated with impact specialists and economists to study farmer adoption and consumer acceptance behavior for new crop varieties (Hotz, Loechl, de Brauw, et al. 2012; Hotz, Loechl, Lubowa, et al. 2012). The current HarvestPlus phase—Delivery (2014–2018)—begins the work of releasing the planting materials and promoting production and consumption of the crops in target countries as a "proof of concept" of the approach and learning lessons for scaling up. The goal is to reach more than 14 million households by 2018.

To date, HarvestPlus and its partners have facilitated the release of six crops in eight countries in Africa and South Asia. HarvestPlus plans to implement a monitoring, learning, and action system that will seek to monitor seed dissemination, farmer adoption, household consumption and sale, and other key variables. Where full-target varieties are available, rigorous impact evaluations are conducted to measure impacts on outcome variables, such as micronutrient intake and nutritional status of target beneficiaries.

The pathway from research; to seed and planting materials multiplication and dissemination, adoption, and consumption; to improved diet and micronutrient status is long and complex. It will play out in different ways in different countries. A theory of change (ToC) can help researchers and development organizations manage complexity by articulating expected outcomes and the logical links between research outputs and development impact, identifying underlying assumptions and risks associated with each link. The results can be used to refine delivery strategies, prioritize further research, and design the monitoring, learning, and action system to better support learning about how the intervention is working and how it can be improved.

ToCs were developed for three crop-country combinations—provitamin A (orange) maize in Zambia, iron beans in Rwanda, and provitamin A (yellow) cassava in Nigeria. The three cases cover different crops, micronutrients, and agricultural and socioeconomic contexts, thus providing examples of the range of challenges and opportunities biofortification is likely to face and lessons for the broader program. Particular emphasis is placed on outcomes and impacts since the objective is to clarify what it will take for biofortified varieties to contribute to improved nutritional outcomes. This paper reviews the evidence relating to the assumptions and risks and assesses its strength using three categories: strong, medium, or weak (Table 1.1). On the basis of the assessment, the likelihood that each outcome will occur is also ranked as high, medium, or low (Table 1.2). The implications of the findings are identified for program design and monitoring as well as for future exploratory and evaluation research.

[1] See http://www.harvestplus.org/.

Table 1.1 Categories applied for assessing the strength of the evidence

Category	Definition
Strong	On the basis of available evidence, it is likely that the assumption(s) will hold.
Medium	The available evidence is consistent with the assumption holding, but the evidence is incomplete.
Weak	The evidence suggests that the assumption is unlikely to hold or, more common, that there is no available evidence to support the assumption.

Source: Authors.

Table 1.2 Categories for assessing the likelihood of outcomes along the impact pathway

Category	Definition
High	The outcome is plausible, and the evidence for the assumption is generally strong.
Medium	The outcome is plausible, and the evidence for the assumptions is of medium strength.
Low	The outcome is not plausible, the evidence for the assumptions is weak, or both.

Source: Authors.

The paper is organized as follows. Section 2 provides background on ToC and its use in agricultural development and in the CRPs, Sections 3 through 5 present the country-level ToCs, and Section 6 summarizes and concludes the paper's findings.

2. USING THEORY OF CHANGE

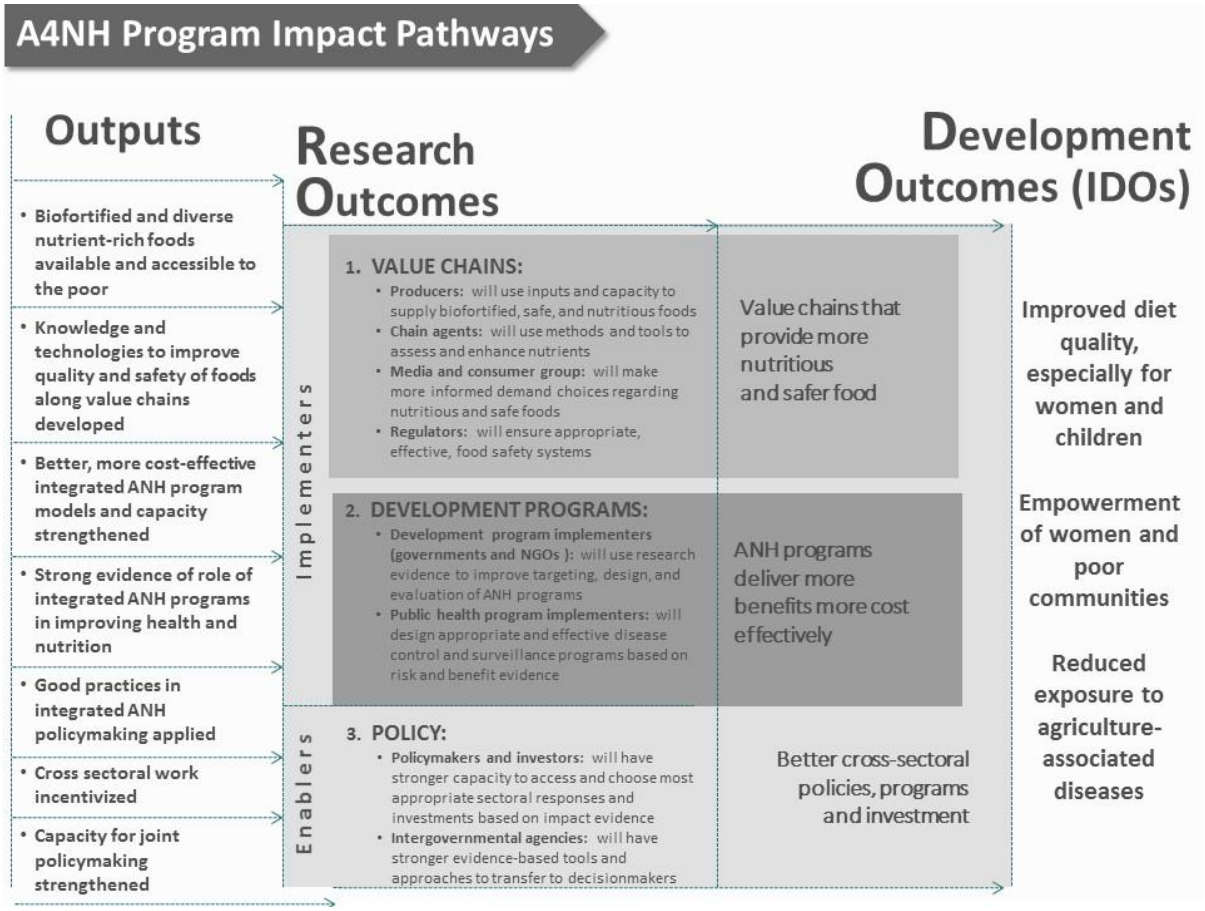
Understanding how and if an intervention is working, or is likely to work, necessitates understanding how the activities of the intervention are expected to lead to the desired results. ToCs and impact pathways set out the causal links between the activities undertaken, the outputs produced, and the subsequent chain of outcomes leading to the desired higher-level impacts. *Impact pathways* describe these outcome chains—from outputs to immediate outcomes, such as capacity or behavioral changes to intermediate outcomes to impacts, showing the linkages between the sequence of steps toward realizing the impact. A *ToC* adds to an impact pathway by describing the causal assumptions and highlighting the possible risks (economic, environmental, political, and so forth) and external influences that underlie the links in the pathways. The *causal link assumptions* identify what events and conditions have to occur for each link in the causal pathway to work as expected: What has to happen or not happen in the case of a risk? What factors influence these processes? Articulating causal link assumptions entails a mix of stakeholder experience and social science theory and evidence.

There is widespread use of ToCs in development settings, and their use in development evaluations has been the subject of several reviews (James 2011; Vogel 2012; Stein and Valters 2012). However, as these reviews point out, while there is general agreement on the big picture about ToCs, there is a proliferation of interpretations of what a ToC is in practice and how best to depict it.

For several reasons, ToCs and related impact pathways have become important tools in CGIAR reform efforts. With CGIAR's significant focus on making a difference in the development agenda, there is a need for the CRPs to articulate the relevance of their research efforts and how they are expected to contribute to development impacts. The CRPs need to understand their pathways to impact and the models or ToCs behind the pathways (Mayne and Johnson 2014). While in some cases researchers and partners have clearly identified these pathways, in most cases they are implicit. The process of making them explicit can reveal logical inconsistencies, evidence and capacity gaps, or the critical roles of previously unrecognized actors. As their research progresses, the CRPs will need to address these gaps, as well as monitor their progress along their pathways, and ultimately show that their research has contributed to development outcomes. In many cases, they will need to use theory-based approaches in evaluating their impact (Mayne and Stern 2013; UNEG 2013; White 2009), for which ToCs are essential.

The CRP on Agriculture for Nutrition and Health (of which HarvestPlus is a part) identifies three types of impact pathways—*value chains* for nutritious foods, *nutrition or public health programs* that include agricultural components, and cross-sectoral *policy processes* that create a supporting environment for other pathways (Figure 2.1). Through these pathways, the CRP expects its research outputs and other activities (for example, capacity building, policy engagement) to contribute to achieving development outcomes related to diet quality, empowerment, and reduced exposure to agricultural-associated diseases. The pathways differ in terms of the types of actors whose capacities and behaviors are expected to change for outcomes to be achieved. Research outputs can be disseminated through more than one type of pathway, and pathways can be complementary, as illustrated by the fact that the policy pathway is shown as supporting the other two. Despite their complementarity, it is often useful to focus analysis on specific pathways for specific outputs to be able to go into sufficient detail about the desired outcomes and underlying assumptions and risks.

Figure 2.1 Agriculture for Nutrition and Health Program impact pathways



Source: Adapted from IFPRI (2011, 3).
Note: A4NH = Agriculture for Nutrition and Health. ANH refers to programs that integrate nutrition, health, or both components with agricultural components. Such programs are typically implemented by government agencies or by nongovernmental organizations.

This paper discusses biofortified crop varieties in a value chain type of pathway, in which the main actors to be influenced are farmers, intermediaries (for example, traders, processors), and consumers, especially in farm households. These same technologies are also disseminated through "program" pathways—for example, an international nongovernmental organization (NGO) implementing a food aid program or a maternal and child health program distributing biofortified foods or crops. The ToC for a program pathway would explicitly consider changes in the capacity and behavior of program implementers and program beneficiaries, who may or may not be smallholder farmers.

Through research, capacity building, and policy engagement, HarvestPlus is also seeking to create a supportive enabling environment for biofortification in (1) research—for example, by promoting mainstreaming of human nutrition criteria in staple crop breeding—and (2) policy—for example, by incorporating biofortification in national agricultural, nutrition, or health policies and standards of international organizations like Codex that influence investment and trade in food products. A policy ToC for HarvestPlus work would focus on how decisions about breeding criteria, government policies, or international regulatory standards are made and which partners HarvestPlus should work with to most effectively provide information and evidence to inform and influence policy process outcomes.

For simplicity, these complementary activities are not discussed in detail in this paper, but it is important in practice to keep the links in mind, especially in terms of the potential for impact at scale. It is also important to keep in mind that ToCs are meant to be used and updated regularly as conditions change

and new experiences and information become available. While the ToCs presented here are works in progress, they provide useful insights into the potential of biofortification—and agriculture in general—to contribute to nutritional and health impacts and what can be done to increase the likelihood of those impacts' occurring.

Three Theories of Change

From the 11 crop-country combinations in HarvestPlus's delivery phase (Table 2.1), 3 were selected for ToC development. The objective was to capture the diversity of the HarvestPlus crops, micronutrients, and agroecological and socioeconomic contexts. The decision was made to focus on African countries since a HarvestPlus strategic gender assessment was being conducted simultaneously with a focus on Africa and the draft ToCs were an input into that assessment.

Table 2.1 Crop-country combinations, target nutrients, and status of varietal releases

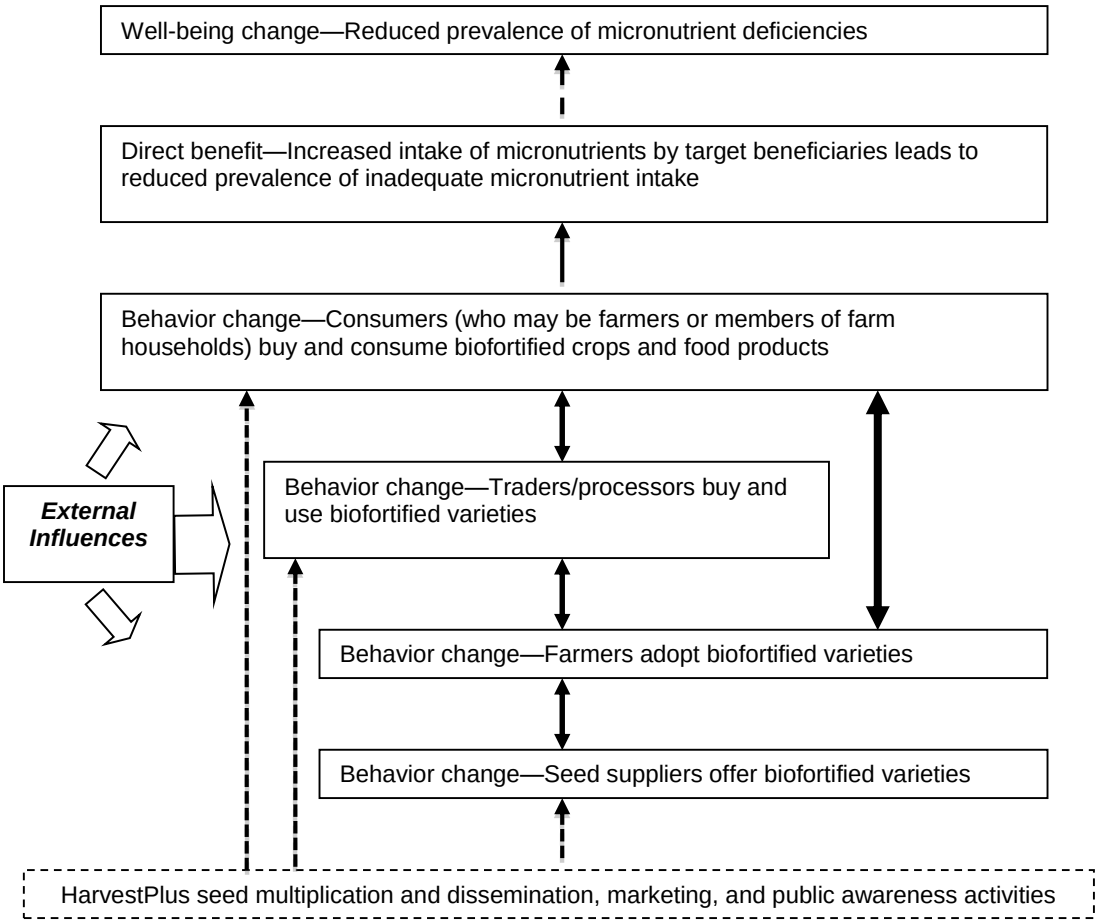
Crop/nutrient Country	Status of varietal release
Beans/iron	
Rwanda	4 varieties released in 2010; 5 varieties released in 2012
Democratic Republic of the Congo	3 varieties released in 2008; 1 variety released in 2011 and 2012; 5 varieties released in 2013
Cassava/vitamin A	
Nigeria	3 varieties released in 2011 with 50% of target levels; 3 more released in 2014 with higher levels
Democratic Republic of the Congo	1 variety released in 2008 with 50% of target level
Maize/vitamin A	
Zambia	3 hybrid varieties released in 2012; available in market in 2014
Ethiopia	Varieties in trials; official release expected in 2017
Pearl millet/iron	
India	1 open-pollinated variety released in 2013 with 80% of target level; 2 hybrid varieties test marketed in 2014
Wheat/zinc	
India	6 varieties commercialized in 2014
Pakistan	Release of up to 3 varieties expected in 2015
Rice/zinc	
Bangladesh	1 variety released in 2013 and another in 2014
India	Varieties in national trials; release expected in 2015

Source: HarvestPlus program data.

Each country impact pathway has the same basic structure (Figure 2.2). The types of behavior changes and development outcomes are similar to the program theory developed by Masset et al. (2011) in their systematic review. The ultimate goal of biofortification is to improve micronutrient status by reducing the prevalence of inadequate dietary micronutrient intakes. Home consumption within farm households is expected to be the major pathway through which target consumers (members of rural farm households)—especially target beneficiaries (micronutrient-deficient women and children)—will obtain biofortified crops. The market is, however, expected to play a role both in reaching target consumers and in making biofortified varieties commercially sustainable. Farmers are expected to access and adopt biofortified varieties and to consume them in their households and sell any surplus on the market. Ultimately, local seed systems (formal or informal) will need to ensure the supply of seed. However, during the delivery phase, HarvestPlus undertakes production of initial quantities of seed, which are then

distributed to farmers either directly or through actors in local seed systems.[2] HarvestPlus is also engaging in marketing, public awareness, and advocacy activities in support of dissemination efforts in the target countries.

Figure 2. 2 Generic impact pathway for HarvestPlus delivery



Source: Authors.

Initial drafts of the ToCs were developed by staff of the Agriculture for Nutrition and Health evaluation unit and HarvestPlus, drawing on substantial background research and knowledge gathering. Draft ToCs were then shared with country managers in each of the three countries and were revised according to their input. The ToCs were then presented at a meeting of HarvestPlus country managers and other senior members of the HarvestPlus team in February 2014.

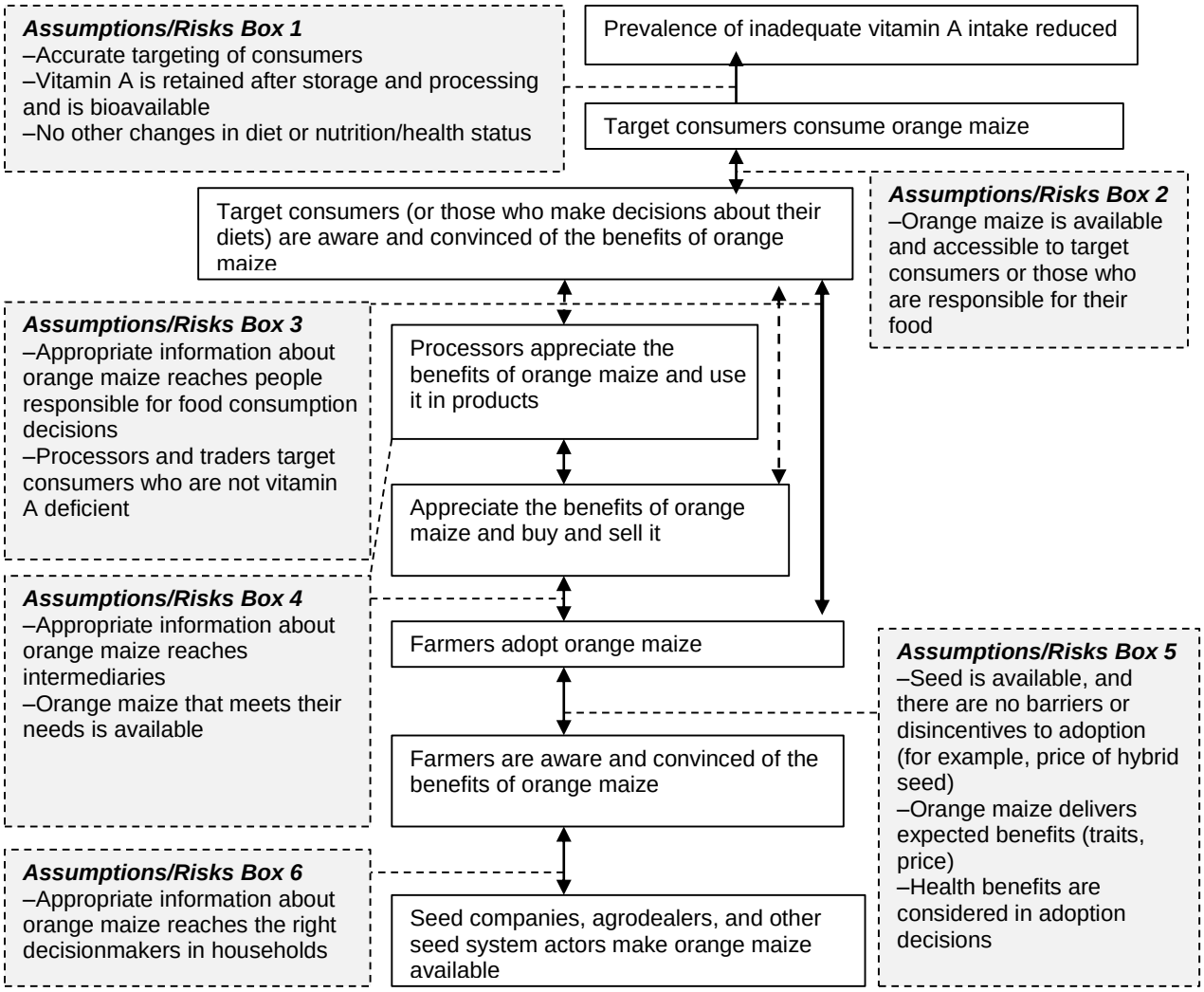
[2] The theory of change on which the HarvestPlus monitoring, learning, and action framework is based includes inputs and activities that lead to the output of seeds being made available to farmers and other seed system actors. For the purposes of this paper, which focuses on the higher-level outcomes, details of input, activities, and outputs are not included but are available on request from the authors.

3. ORANGE MAIZE IN ZAMBIA

Vitamin A deficiency is an important public health problem in Zambia. A recent analysis has estimated that 83 percent of rural inhabitants of Zambia do not have enough vitamin A in their diets (Fiedler and Lividini 2013). Maize is the most important food crop for Zambians, who consume a thick porridge called *nshima* at almost every meal. Annual maize consumption was estimated at 1.4 million metric tons in 2011, averaging 108 kilograms per capita per year (Food and Agriculture Organization of the United Nations 2014). In 2012, three varieties of orange maize developed by HarvestPlus and its partners were released by the Zambian Seed Control and Certification Institute, and they are expected to reach 500,000 maize-producing households by 2018.

Figure 3.1 presents the ToC that explains how orange maize is expected to contribute to reducing the prevalence of inadequate vitamin A intake in Zambia. The remainder of this section describes the outcomes along the impact pathways and the hypothesized links between them. Because we are interested in the potential for impacts on diet-related outcomes, we start at the top with the outcome of a reduction in the prevalence of inadequate vitamin A intake.

Figure 3. 1 Theory of change for provitamin A orange maize in Zambia



Source: Authors.

Will Target Consumers' Consumption of Orange Maize Reduce the Prevalence of Inadequate Vitamin A Intakes?

For consumption to contribute to a reduction in the prevalence of micronutrient deficiency, several assumptions need to hold (Assumption/Risk Box 1 in Figure 3.1). Target consumers need to be deficient in vitamin A, they need to eat sufficient quantities of orange maize, and the vitamin A in orange maize needs to be retained in the food after storage, processing, and cooking and be bioavailable. In addition, achieving a reduction in the prevalence of inadequate vitamin A intakes will require that increases in vitamin A intake from orange maize not be offset by reductions in vitamin A intake from other sources.

Assumption/Risk: Accurate Targeting of Consumers

Target areas for promotion of orange maize in Zambia were selected based on health and poverty indicators and on concentration of maize-growing households, whose members are the program's target consumers. Using these criteria, two districts—Mkushi and Nyimba, in the eastern and central provinces, respectively—were identified. In 2009, HarvestPlus conducted a nutrition survey in these districts to gather information about the diets and nutritional status of the target population for orange maize (Hotz, Loechl, Lubowa, et al. 2012). The results showed that 48 percent of children 24 to 59 months of age were vitamin A deficient (VAD) (when adjusted for infection) (Hotz, Loechl, Lubowa, et al. 2012). Despite finding slightly lower maize consumption levels among women and children—287 grams per day (105 kilograms per year) for women and 172 grams per day (63 kilograms per year) for children 2 to 5 years of age—than originally assumed when breeding targets were set, the findings generally supported the decision to concentrate delivery of orange maize in Zambia's central, eastern, and southern provinces.

Zambia has had a universally mandated sugar fortification program since 1998. A 2003 impact study found that nearly 60 percent of households reported buying fortified sugar but that more than 80 percent of sugar samples taken did not meet the official minimum fortification level, which provides on average 15 percent of the required dietary allowance (Clewes and Kankasa 2003). There is no external quality control of fortified sugar, and Zambia's Food and Drugs Control Laboratory does not have the funding and capacity needed to analyze sugar samples. A recent analysis of vitamin A programs in Zambia by Fiedler and Lividini (2013) estimates that fortified sugar provides only 19 percent of the estimated average requirement (EAR) for Zambians living in rural areas.

Zambia also distributes high-dose vitamin A supplements to children younger than 5 years of age twice a year through health clinics as part of Child Health Weeks. This costly and labor-intensive approach can fail to reach older children and adults who suffer from vitamin A deficiency. Even among the children who do receive supplements, the benefits of supplements may last only 3 to 4 months (Dalberg and World Bank 2013).

Strength of the Evidence: Medium

The evidence supports selection of the target areas. However, the evidence could be strengthened by showing a stronger correlation between target consumers (members of maize-producing households) and target beneficiaries (VAD women and children). Through its ongoing contacts with staff in other agricultural and nutrition programs, it will be important for the HarvestPlus team in Zambia to maintain an awareness of which programs are being implemented where to assess the implications for program assumptions and outcomes.

Assumption/Risk: Retention and Bioavailability of Vitamin A

Studies conducted with different varieties of orange maize found that total carotenoid remained stable in the first 3 to 4 months, depending on storage conditions, then declined significantly thereafter (Burt et al. 2010; De Moura, Miloff, and Boy 2013). To investigate losses resulting from processing and cooking, Li, Tayie, and Young (2007) analyzed retention in porridge that was prepared using methods typical of the target area.

To assess the bioavailability of provitamin A in orange maize when consumed by humans, a study involving six healthy American women indicated a 6.5 to 1.0 conversion rate of beta-carotene (the form of vitamin A found in orange maize) to retinol (the form of vitamin A used by the body). This is twice as efficient as the 12 to 1 rate assumed in setting the original target (Li et al. 2010). Another study found a lower ratio (3.2 to 1.0); however, the difference could be explained by differences in study techniques, the sex of the subjects, or the genetic makeup of the study populations (Muzhingi et al. 2011).

Strength of the Evidence: Strong

While consumption and retention figures were lower than originally assumed, the higher-than-expected bioconversion rate means that the nutrition target (50 percent of the EAR of vitamin A for adult women) can still be met with the current breeding target (15 parts per million [ppm]) of provitamin A in maize.

Assumption/Risk: No Adverse Changes in Diet

The breeding target for orange maize was developed based on current diets, so it will be important to assess whether the diets of target consumers change over time. Changes could occur in response to the introduction of orange maize or for other reasons. To monitor diet at scale, HarvestPlus included a 24-hour, seven-day dietary diversity module in the varietal adoption surveys (de Groote et al. 2011), which provided information about the diets of women in farm households. This module can be used to track changes in future surveys. The impact of adoption of orange maize on diets and on other nutrition- and health-related outcomes will also be assessed in impact evaluations. An evaluation of the impact of the distribution of orange sweet potato vines in Mozambique and Uganda did not observe any dietary changes (HarvestPlus 2012).

Strength of the Evidence: Strong

Past evaluations did not find changes in diets, and baseline data are available against which changes can be assessed.

Likelihood that Consumption of Orange Maize Will Reduce Prevalence of Inadequate Intakes: Medium to High

Will Target Consumers Eat Orange Maize?

Assuming that target consumers are willing to consume orange maize, consumption will happen only if orange maize is available and accessible to them or to the people who make the decisions about which foods are eaten, and by whom, in their households (Assumption/Risk Box 2 in Figure 3.1).

Assumption/Risk: Availability and Accessibility

The primary ways consumers are expected to access orange maize are through home production and, to a lesser extent, by buying it in the market. Other means of acquiring food, such as gifts or government programs, are not expected to constitute a significant share of consumption. A 2007 study found that three-quarters of farming households in Zambia were subsistence oriented and did not regularly sell maize (Zulu, Jayne, and Beaver 2007). About 35 percent of smallholder households purchased maize, while about 20 percent sold maize. Prior to the availability of orange maize in the market, 1,100 households were surveyed (42 percent female respondents) in five maize-growing areas of Zambia to inform the design of interventions for promoting the adoption of orange maize (de Groote et al. 2011). Referred to as the varietal adoption survey and considered to be representative of maize-producing households in Zambia, the survey found that most households were self-sufficient in maize throughout the year, with purchasing of maize ranging from 11 percent in the northern and northwestern parts of the country to 35 percent in the southern region. The survey also found that 50 percent of households sold maize, but this

higher figure could be due to there being a bountiful harvest in the year of the survey and farmers' having more maize to sell (de Groote et al. 2011; E. Birol, pers. comm., 2014). About 20 percent of households purchased maize for a period of four months (de Groote et al. 2011).

HarvestPlus is promoting the development of a market for orange maize and orange maize products by participating in AgResults, an initiative that uses "pull mechanisms," which are financial rewards for successful development and dissemination of innovations. This initiative is designed to overcome market failures and provide an incentive for private- and public-sector innovators to develop and bring to market products and services that have social as well as private benefits. Orange maize is an example of such a product.

A three-stage pull strategy focused on industrial millers has been developed for Zambia. Dalberg and World Bank (2013) found that millers are the best-positioned actors to influence both supply of orange maize and demand for orange maize products. The first stage will attract interested millers to submit a business plan demonstrating how they will source, produce, market, and sell orange maize meal to consumers. Successful applicants will receive a grant to cover the initial costs of implementing the business plan. The second stage focuses on the sale of orange maize by providing eligible millers per-unit subsidies for every metric ton of maize meal sold. The third stage has a goal of ensuring a 10 percent market share for orange maize meal. Millers are awarded prizes out of a fixed reward pool, based on their respective contribution to the total amount of maize meal sold. At each stage, HarvestPlus will work with the AgResults implementation team to ensure a sufficient supply of orange maize for the millers.

Strength of the Evidence: Medium

While the majority of maize-producing households appear to be self-sufficient in maize, some households rely on the market. It will be important to know who these households are and why they purchase maize because if purchasing maize is related to poverty and undernutrition, it is likely that many target consumers will be found in these households. Unless maize is available in the markets they use—which may depend on who in the household makes purchasing decisions—they may be only partly reached. Markets seem to be especially important in target areas. The potential for market-development activities, such as AgResults, to reach target consumers should also be assessed, along with any unintended negative consequences associated with building a strong market demand for orange maize and orange maize products, for example, that target households sell rather than consume their orange maize. Many rural households purchase maize meal (Tschirley et al. 2014); however, more information is needed to know whether target households would likely be among these buyers.

Once sources of maize are identified for target households, the people who make the decisions about which varieties to plant (in case of home consumption) and which varieties to buy (in case of purchase) should be identified through gender research, and their specific constraints to accessing orange maize (as seed or grain) should be assessed. This research information could then better inform the design of interventions. The delivery phase is an important opportunity to learn about how people and markets are likely to react to what is essentially a new product. Therefore, developing clear, gendered hypotheses about what is expected to happen and why will be important so that they can be monitored and assessed.

Likelihood that Target Consumers Will Eat Orange Maize: Medium

Will Target Consumers Be Aware of and Willing to Eat Orange Maize?

Orange maize is a new crop and visibly different from the maize that people typically consume. Given resistance to yellow maize and its association with "drought" food in Zambia (Muzhingi et al. 2008), consumers and others who make decisions about food choices in households may be reluctant to try it, unless they are first made aware of its benefits (Assumption/Risk Box 3 in Figure 3.1).

Assumption/Risk: Consumer Acceptance of Orange Maize

HarvestPlus has conducted several consumer acceptance studies to examine how consumers perceive orange maize as compared with yellow and white varieties. In a study of male and female "small-scale consumers" in central and southern Zambia, Meenakshi et al. (2012) found that consumers who tasted cooked samples of nshima made from orange maize preferred it to nshima made from yellow maize and rated it equal to nshima made from white maize. For the sample of participants who were also provided with nutrition information along with food samples, nshima made from orange maize was preferred to nshima from white maize, suggesting that people value the nutrition benefit. Similar results were found in other studies conducted in conjunction with a farmer field day (Chibwe et al. 2013). No significant gender differences were detected in this research.

To stimulate demand for orange maize meal in urban settings and complement the activities of AgResults and other initiatives, HarvestPlus is using media outreach, including television, radio, and print, to introduce the new product to urban consumers.

Strength of the Evidence: Strong

Experimental consumer acceptance results are promising, but it will be important to track whether they are confirmed by actual behavior and whether orange maize reaches target consumers.

Assumption/Risk: Consumer Awareness of Orange Maize

In addition to the national-level activities described above, HarvestPlus is building awareness among targeted populations and promoting orange maize in communities in target areas. Given the expected link between production and consumption decisions (in households producing primarily for home consumption), information about orange maize's agronomic and nutritional benefits is disseminated through both agricultural and health channels to individuals responsible for maize production and for health and nutrition decisions (HarvestPlus 2013d).

With support and training from HarvestPlus, extension agents of the Ministry of Agriculture and Cooperatives explain the agronomic and health benefits of orange maize as well as identify "lead" farmers who grow demonstration plots of orange maize that are on display at farmer field days. The plots of lead farmers are expected to provide tangible exposure to orange maize to local farmers, allowing them to witness firsthand the performance attributes of the new varieties. In the 2012/2013 growing season, 9,000 lead farmers grew orange maize on test plots, and in the 2013/2014 season, 10,000 farmers grew demonstration plots ahead of orange maize seed's being available on the market for the 2014/2015 growing season.

HarvestPlus has also developed partnerships with a large group of local and international NGOs working in rural Zambia to further awareness of orange maize. The understanding is that these organizations are reaching the target beneficiaries with their programs focused on poorer rural households. The ministries of health and education are also playing a role in promoting the adoption and consumption of orange maize by growing test plots of orange maize at rural health clinics and schools. Having the plots on site is expected to help integrate nutrition messages on the benefits of orange maize for women and children who frequent both facilities. To ensure consistency of messaging, extension agents and government health workers are trained together.

Strength of the Evidence: Medium

The strategy of delivering joint agriculture-nutrition messaging through both agriculture and health channels appears to be an appropriate approach for reaching multiple decisionmakers in different types of households. It will be important not only to assess the (cost-) effectiveness of the messages in building awareness and influencing attitudes but also to monitor whether the messages are reaching the right decisionmakers and target households. "Lead farmer" approaches may not be effective at reaching women

and the poor (Hillenbrand 2010). Similarly, if VAD women and children are less likely to visit health clinics or attend schools, the messages disseminated through these channels may not reach them.

Likelihood that Target Consumers Will Be Aware of and Willing to Eat Orange Maize: Medium to High

Will Processors and Traders Buy and Use Orange Maize?

As mentioned above, some target beneficiaries may access orange maize through markets. The existence of a market for surplus production is expected to encourage adoption by target farmers. In the long run, significant adoption by small or large farmers is assumed to be necessary to justify investment by seed companies in supplying seed and in maintaining and improving the orange maize varieties in the future. Therefore, even though the primary pathway to impact is expected to be through home consumption within farm households, intermediaries such as traders and processors may play key roles both in reaching target consumers and in ensuring the commercial viability of orange maize.

In theory, the market should provide incentives for market agents to get involved with orange maize. However, the fact that it is a new product and is expected to deliver both economic and public health benefits justifies a more proactive approach to reaching and engaging with intermediaries to ensure that they are informed about orange maize and that it meets their needs (Assumption/Risk Box 4 in Figure 3.1). A risk associated with the existence of a thriving market for orange maize and orange maize products is that target households may prefer to sell orange maize and buy less expensive maize or other products for their own home consumption.

Assumption/Risk: Information about Orange Maize Reaches Traders and Processors in Target Value Chains

In addition to the AgResults initiative described above, HarvestPlus is engaging in other activities that would generate demand for orange maize from farmers and for orange maize seed from seed companies. HarvestPlus has reached out to the United Nations World Food Programme and is exploring the possibility of including orange maize in Zambia's school feeding program. Also, several lobbying activities are under way to include orange maize in Zambia's Farmer Input Support Programme (FISP).

HarvestPlus is working with the Zambian Bureau of Standards to develop standards for orange maize to ensure that orange maize meal and other products on the market meet certain criteria and provide the claimed health benefits.

Strength of the Evidence: Medium to Strong

The demand and promotion strategies appear to be well designed and to be generating demand for orange maize. The economic viability and sustainability of these initiatives should be tracked, as should their ability to reach and benefit target farmers and consumers. AgResults has a monitoring and evaluation system in place that should provide information about whether the pull-mechanism approach is likely to be effective with maize millers.

Likelihood that Traders and Processors in Target Value Chains Will Buy and Use Orange Maize: Medium to High

Will Target Farmers Grow Orange Maize?

To grow orange maize, farmers will need to have access to the seed. To sustain and expand adoption, the seed will need to deliver the expected benefits, which may include nutrition benefits, under farm household conditions (Assumption/Risk Box 5 in Figure 3.1).

Assumption/Risk: Access to Seed

Farmers will access seed mainly through agrodealers, though some seed will also be made available through government and NGO agricultural development programs. To ensure sufficient multiplication and stock of provitamin A orange maize seed, HarvestPlus is an "interested party" in a partnership between the Zambian Agricultural Research Institute and three Zambian seed companies (ZamSeed, SeedCo, and Kamano Seed Company). Each company is licensed to sell one of the three released varieties, and all three companies have agreed to produce orange maize seed for the 2015/2016 growing season. HarvestPlus depends on these seed companies to ensure that a sufficient quantity of quality orange maize seed will be produced, marketed, and sold to farmers, mainly via agrodealers (Smale and Birol 2013), beginning in 2014. A member of the HarvestPlus team works closely with the seed companies to ensure quality standards are met. Seed companies may engage in additional marketing, beyond what HarvestPlus is doing through extension agents and health workers.

As mentioned earlier, all three orange maize varieties that have been released in Zambia are hybrids, though provitamin A–rich open-pollinated varieties (OPVs) are also in the breeding pipeline. The varietal adoption survey found that one-third of farmers grew local varieties, including recycled hybrids (de Groote et al. 2011). While hybrids tend to be higher yielding than OPVs the need to purchase seed raises the costs of production and could act as a barrier to access for some farmers. Recent research by Smale and Birol (2013) suggests that the poorest smallholder farmers are not buying improved or hybrid varieties but instead rely on OPVs or recycled seed. Women tend to be less likely to purchase hybrids than are men (Smale and Mason 2012).

The Zambian government is encouraging use of hybrid seed. Most hybrid seed is provided through Zambia's FISP, which reached 250,000 farmers throughout Zambia with subsidized input packages in the 2011/2012 season (Dalberg and World Bank 2013). As expected, hybrid use is much higher among FISP recipients than non-FISP recipients (73.8% v 26.2%) (deGroote et al, 2014). Inclusion of orange maize in FISP and the Food Reserve Agency is being explored. Inclusion of orange maize is FISP should substantially reduce the cost of seed to farmers; however, additional efforts may still be required to reach the poor. Smale and Birol (2013) found that households receiving FISP subsidized seed tend to be wealthier and have larger areas of land. FISP is currently undergoing changes, such as the use of e-vouchers over mobile phones, which are intended to address some of these inequalities. Monitoring their effectiveness will be important.

Strength of the Evidence: Weak

Significant efforts are being made to make seed available. However, there appear to be significant barriers to reaching target farmers (and through them target consumers) with hybrid seed. Evidence is needed that it is possible to reach target farmers cost-effectively and sustainably with hybrids. Generating this evidence should be a priority for HarvestPlus to inform future breeding and delivery decisions.

Assumption/Risk: Varieties Perform as Expected

Orange maize varieties were developed with farmer and consumer involvement. However, as with all improved varieties, the conditions under which farmers and their families grow, store, process, and consume them may differ from those under which they were initially evaluated. Therefore, it is always important to follow up with adopters to assess how they are performing.

Agrodealers are expected to keep records of all farmers who buy seed so that HarvestPlus can track them and follow up with a subsample for a farmer feedback survey. HarvestPlus is working with agrodealers on the best ways to keep track of farmers. One area that will be interesting to track is how consumers perceive varieties are performing in terms of nutrition benefits. Consumer acceptance studies suggest that nutrition is important to consumers, but it is unclear how consumers will know if the varieties are delivering this benefit, which could be important for continued adoption.

Strength of the Evidence: Strong

HarvestPlus has a system in place to track farmer perceptions of varietal performance. Incorporation of consumption characteristics, especially nutrition, in this system and making sure that information is collected from appropriate decisionmakers should make the results more useful.

Likelihood that Target Farmers Will Grow Orange Maize: Medium

Will Target Farmers Be Aware and Convinced of the Benefits of Orange Maize?

Before adopting orange maize, farmers need to be aware of it and convinced that growing it either instead of or in addition to their current varieties will be worth any additional costs or risks. As discussed above, many factors influence the decision about which maize variety to grow, which means that multiple strategies may be needed to reach the right people with the right information (Assumption/Risk Box 6 in Figure 3.1).

Assumption/Risk: Farmer Awareness

The strategies that HarvestPlus is using to reach farmers through extension agents, health clinics, and NGOs have already been described. Presumably, seed companies and agrodealers will market orange maize as well.

Strength of the Evidence: Strong

Given the widespread awareness-raising activities targeted at consumers and producers, it is likely that farmers will be reached by information about orange maize. The effectiveness of different approaches, including social networks, should be investigated and monitored.

Assumption/Risk: Farmer Acceptance

Researchers have hypothesized that any provitamin A–rich varieties developed not only would have to be more nutritious but also would have to compete agronomically and economically with maize varieties already on the market. The three released orange maize varieties all compare favorably with current varieties in terms of yield, disease and virus resistance, and drought tolerance. As part of the participatory evaluation of orange maize varieties, farmers were introduced to the new varieties that were being grown on test plots by fellow farmers. The evaluation found that farmers appreciated the yield, cob size, and cob-filling characteristics of the new varieties and rated them much higher than their own variety. For color, there was a significant preference for the white varieties; however, evidence from consumer acceptance studies indicates that color preferences can be flexible.

Orange maize must compete in a highly saturated maize seed market. The numerous varieties and actors (for example, seed companies, agrodealers, government programs) have resulted in small area shares for each variety. Of the 203 varieties released in Zambia, 106 varieties were grown by farmers responding to the varietal adoption survey (de Groote et al. 2011). More than half of farmers planted more than 1 variety during the main rainy season, but few (less than 10 percent) grew more than 2 varieties, and the maximum number of varieties grown during that season was 5. According to the survey, no single improved variety covers more than 10 percent of the maize area, and only 2 varieties cover more than 5 percent. The top 20 varieties combined cover less than half the total maize area, with local varieties covering about 15 percent of the total maize area. Similarly, the top 20 varieties are spread throughout the country and do not have a clear geographic pattern. This is one reason HarvestPlus and its partners are focusing on a long-term strategy of "mainstreaming" vitamin A in maize breeding so that it is included in all varieties produced for target areas, farmers, or both.

HarvestPlus has drafted ideas for the creation of a "brand" for orange maize in Zambia. Given the saturation of the maize market in Zambia, developing and maintaining a brand for orange maize could

play a key role in distinguishing it from the competition and ensuring its sustainability (Smale and Birol 2013). Results from this and other HarvestPlus research could strengthen the marketing being done by the seed companies.

Strength of the Evidence: Medium

Evidence from farmer and consumer evaluations suggests that the orange maize varieties could be attractive to farmers. The challenge would seem to be getting enough farmers, and especially enough target farmers, to grow orange maize and to grow it in sufficient quantities to make a difference in diets. The varietal adoption data suggest that farmers view maize varieties as differentiated products. In such an environment, niche varieties may be sustainable long term. This would appear to challenge some of the assumptions underlying efforts both for stimulating market demand and possibly also for mainstreaming vitamin A in breeding. Hypotheses about which farmers are expected to adopt orange maize and what is expected to happen with other varieties need to be more clearly articulated so they can be empirically validated.

Likelihood that Target Farmers Will Be Aware and Convinced of the Benefits of Orange Maize: Medium to High

Summary of Provitamin A Orange Maize in Zambia

Table 3.1 presents the study's findings for provitamin A orange maize in Zambia. If HarvestPlus reaches target consumers with orange maize, and if consumers regularly and continuously consume it, there is strong evidence that it will contribute to reducing the prevalence of inadequate vitamin A intake. Evidence suggests that the varieties are attractive to consumers and producers and that the orange color may not be as much of a barrier to consumption as previously expected.

Table 3. 1 Summary of findings for provitamin A orange maize in Zambia

Research questions and likelihood of occurrence	Assumptions and risks	Strength of evidence
Will target consumers' consumption of orange maize reduce the prevalence of inadequate vitamin A intakes? ***Likelihood: medium to high***	Accurate targeting of consumers	Medium
	Retention and bioavailability of vitamin A	Strong
	No adverse changes in diet	Strong
Will target consumers eat orange maize? ***Likelihood: medium***	Availability and accessibility	Medium
Will target consumers be aware of and willing to eat orange maize? ***Likelihood: medium to high***	Consumer acceptance	Strong
	Consumer awareness	Medium
Will processors and traders buy and use orange maize? ***Likelihood: medium to high***	Traders and processors reached with information about orange maize	Medium to strong
Will target farmers grow orange maize? ***Likelihood: medium***	Access to seed	Weak
	Varieties perform as expected	Strong
Will target farmers be aware and convinced of the benefits of orange maize? ***Likelihood: medium to high***	Farmer awareness	Strong
	Farmer acceptance	Medium

Source: Authors.

A more precise characterization of target consumers and their households within the population of smallholder maize-growing households would strengthen the evidence base for several of the links in the impact pathway. Once it is confirmed that the target consumers (members of smallholder, maize-producing households) include large numbers of target beneficiaries (VAD women and children), the relevant decisionmakers—men and women who make decisions regarding maize consumption, purchase, production, and sale—need to be identified, and their preferences, needs, and constraints need to be assessed. Results can be used to confirm or refine current strategies to ensure they effectively reach the right decisionmakers in target households. It appears that much of the information necessary to do this analysis is available.

The role of the market in reaching target consumers and in contributing to the economic viability of orange maize needs to be clarified. For this area, hypotheses still need to be defined so that they can be tested. Given the variety of market development initiatives under way in Zambia, there would appear to be opportunities to examine how they are influencing uptake and use of orange maize in target households.

Due to the degree of differentiation in maize seed markets, knowing more about the preferences and constraints of decisionmakers within households could inform current delivery and future breeding efforts. Evidence that target households can be reached with hybrids is needed.

4. IRON BEANS IN RWANDA

Rwanda has a relatively high prevalence of anemia, a common consequence and easily measured indicator of iron deficiency. According to the 2010 Rwanda Demographic and Health Survey, 38 percent of children 6 to 59 months of age and 17 percent of women are anemic. Iron deficiency is highest in the eastern province for both groups (43 percent and 23 percent, respectively) (NISR, Rwanda, MOH, and ICF International 2012). These figures are considerably lower than those found in the 2005 Rwanda Demographic and Health Survey, when national anemia prevalence was 52 percent for children and 26 percent for women (NISR and ORC Macro 2006). Aggressive health interventions, for example, for malaria, have been implemented in Rwanda during the past decade, and improvements in health indicators are being seen throughout the country. Dedicated Child Health Weeks, during which children receive routine vaccinations and deworming medication, have led to dramatic decreases in infant mortality and increases in vaccination coverage (M. Moursi, pers. comm.).

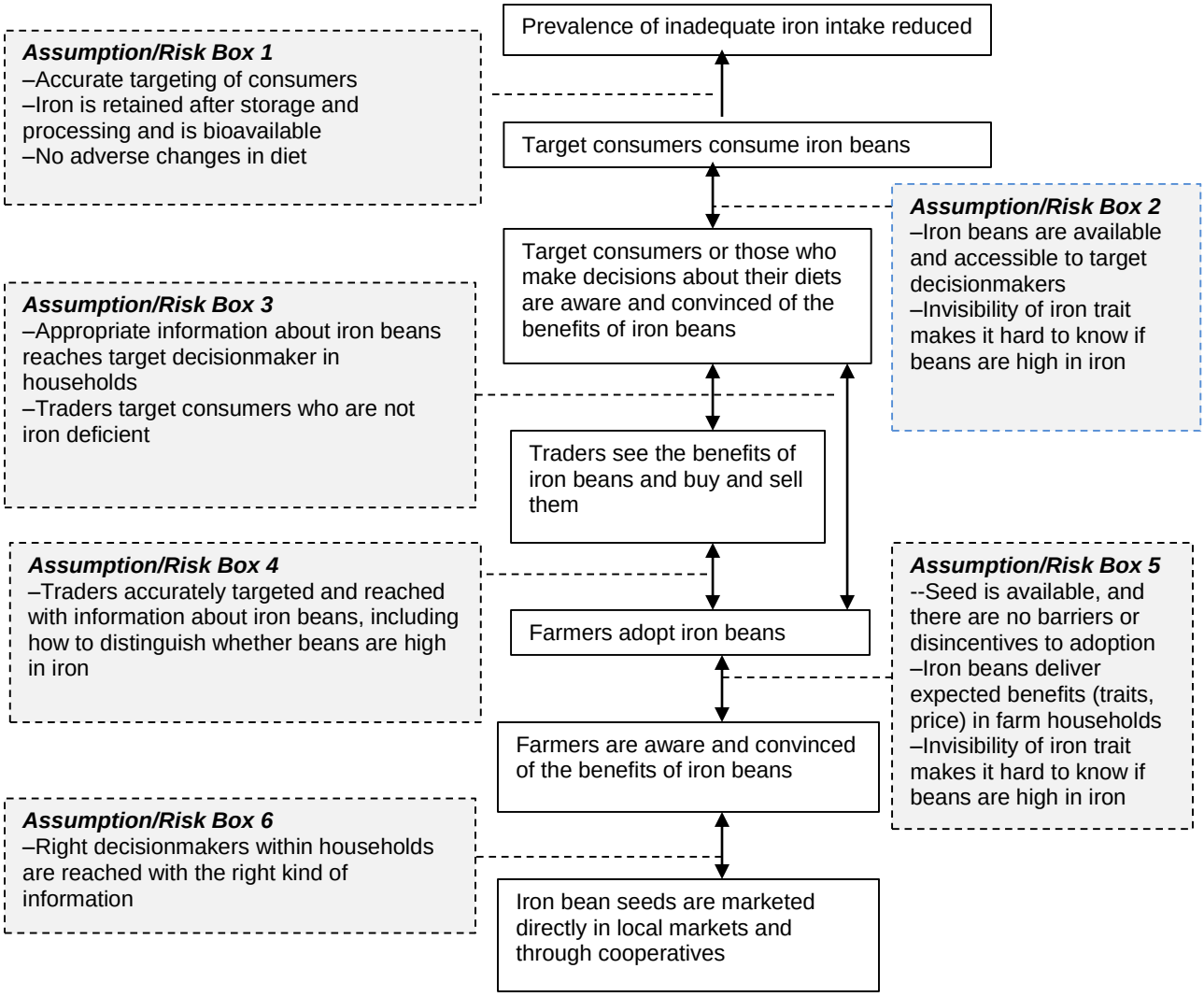
While improvements in the health systems have contributed to a reduction in the prevalence of anemia, the typical Rwandan diet still appears to be "broadly inadequate and an improved diet (more variety and quantity) will be key to improved health" (Berti n.d.). The Rwandan diet does not have a dominant staple crop; rather it is based on a mix of cereals, legumes, and tubers that are poor sources of readily absorbed iron.

Although not a dominant staple, beans are important for Rwandan households, accounting for 65 percent of protein intake and 32 percent of calorie intake (CIAT 2004). In 2004, 86 percent of farming households in Rwanda grew beans (CIAT 2008). In 2010, the government of Rwanda released four first-wave, fast-track, high-iron varieties (two bush, two climbers), and in 2012, it released five second-wave climbing bean varieties that could meet 45 percent of daily iron needs. These new varieties were developed by the Rwanda Agriculture Board (RAB) and CIAT, in partnership with HarvestPlus. Varieties are being developed with the full increment of added iron that could provide 60 percent of the daily EAR for adult women (this includes the amount already present in beans). HarvestPlus aims to have 4,750,000 Rwandans eating iron beans by 2015. Figure 4.1 depicts the ToC for iron beans in Rwanda.

Will Target Consumers' Consumption of Iron Beans Reduce the Prevalence of Inadequate Iron Intake?

For consumption to contribute to a reduction in the prevalence of micronutrient deficiency, several assumptions need to hold (Assumption/Risk Box 1 in Figure 4.1). Consumers need to be iron deficient; they need to eat sufficient quantities of high-iron beans; and the iron needs to be bioavailable and retained in the food after storage, processing, and cooking. It will also be important that increases in iron intake from iron beans not be offset by reductions in iron intake from other sources.

Figure 4. 1 Theory of change for iron beans in Rwanda



Source: Authors.

Assumption/Risk: Accurate Targeting of Consumers

Unlike in Zambia where HarvestPlus focuses on target regions, in Rwanda the program is nationwide. To better understand target consumers and their households, a varietal adoption survey among bean-producing households in rural areas of Rwanda was conducted in 2011 (Asare-Marfo et al. 2011). The survey, which was representative at the district level, collected farm household–level data from a randomly selected sample of about 1,300 households, located across all 30 districts of the country. The major decisionmaker was asked food frequency questions regarding food choices, and other questions were directed to the head of the household. The food frequency data from the survey found that in the past seven days, only about 25 percent of bean-producing households consumed red meat and 4 percent consumed poultry, supporting the assumption that these households may not regularly consume iron-rich animal food sources (Asare-Marfo et al. 2011).

The average daily consumption of beans (dry weight) measured among women, children 6 to 24 months, and children 36 to 59 months in rural households was 123 grams, 47 grams, and 65 grams, respectively (Beebe and Andersson 2014). These findings were somewhat lower than estimates initially used to set breeding targets.

While health program coverage has grown significantly in Rwanda, iron supplementation is not routinely given to young children or nonpregnant women at health centers in Rwanda, and food fortification is not widely practiced at this time. However, Rwanda-specific fortification standards for maize and wheat flour, edible oils, sugar, and salt were adopted by the Bureau of Standards in September 2011, and the rollout is forthcoming (Project Healthy Children 2013). Supplementation and industrial fortification are considered to be complements to rather than substitutes for biofortification. However, it will be important to be aware of the coverage and quality of these programs among HarvestPlus target consumers since they also will be contributing to increases in iron intake.

Beyond the issue of distinguishing the contribution of biofortification from other interventions to the observable outcomes, a concern in the case of iron is that it has been shown that too much iron can be harmful to iron-sufficient children, especially those living in high-malaria-transmission areas. A large, randomized iron supplementation trial on the Tanzanian island of Pemba at a time of a malaria epidemic found that iron supplementation of infants and children who were not iron deficient caused increased morbidity and mortality (Mebrahtu et al. 2004). However, the limited existing evidence suggests that these results would be less likely to occur from iron-biofortified crops or industrially fortified foods (Bhargava 2013).

Strength of the Evidence: Strong

The majority of bean farmers in rural areas have diets low in iron and could benefit from iron beans. Whether it would be cost-effective to target areas with higher deficiency should be assessed. Ex post research or forward-looking ex ante simulation studies regarding likely future programs concerning the quality and coverage of micronutrient supplementation and fortification programs will also be important to enhance synergies and reduce potential overlap. HarvestPlus is currently undertaking studies to compute subnational biofortification prioritization indexes, which aim at identifying geographic areas within a given country where micronutrient deficiencies are high and staple crop production and home consumption is high as well. Ongoing studies cover Ethiopia, India, and Nigeria and are under consideration for other large intervention countries with significant heterogeneity (for example, in malaria prevalence) so as to guide geographic targeting of HarvestPlus crop delivery.

Assumption/Risk: Retention and Bioavailability of Iron

In Rwanda, beans are typically not presoaked. They are cooked in pots, not pressure cookers, and they are cooked until practically no broth is left. As a result, there is minimal loss of iron (1 percent) from cooking beans, even with nonbiofortified beans (Kigali Institute of Science and Technology 2012). Similar retention results were obtained in experiments conducted by Brazilian collaborators (Carvalho et al. 2012). However, the absorption of iron is constrained by the presence of phytate (a form of dietary fiber and an iron absorption inhibitor), as seen in a study among iron-deficient, nonpregnant women by Petry et al. (2012). The absolute amount of phytates in beans does not inhibit bioavailability; rather, the ratio of phytates to iron concentration is the determining factor for bioavailability.

Preliminary findings from a feeding trial among Rwandan university women suggest that the higher levels of iron in the latest wave of iron beans sufficiently overcome the negative effects from the phytates (HarvestPlus 2013b). A feeding trial among rural Mexican schoolchildren was also conducted over the span of five months. Unpublished results from the study demonstrate that regular consumption of biofortified beans improved iron status among schoolchildren when compared with the group that consumed regular, nonbiofortified beans.

Strength of the Evidence: Strong

While consumption was lower than originally assumed, higher-than-expected retention and bioavailability mean that the nutrition target can still be achieved with the current breeding target for iron beans. The iron in iron beans appears to be retained and sufficiently bioavailable to achieve nutrition targets.

Assumption/Risk: No Adverse Changes in Diet

Since target levels for iron beans were developed based on current diets, it will be important to assess whether the diets (and iron intake) of target consumers change over time. As with maize in Zambia, information about diets of target consumers is included through varietal adoption surveys. Changes in a range of direct and indirect factors that affect nutrition and health outcomes are measured in impact evaluation research once the biofortified varieties have reached their full target level.

Strength of the Evidence: Strong

Research studies have been undertaken or will be undertaken to capture information about the diets of target consumers before and after the introduction of biofortified varieties.

Likelihood that Consumption of Iron Beans by Target Consumers Will Reduce Prevalence of Inadequate Iron Intake: High

Will Target Consumers Eat Iron Beans?

Assuming that target consumers are convinced of the benefits of iron beans, they will be able to consume them only if the beans are available and accessible to them or the people who make food choices in their households (Assumption/Risk Box 2 in Figure 4.1). Since iron is an invisible trait, decisionmakers may also need to be able to differentiate between which beans are high in iron and which are not.

Assumption/Risk: Availability and Accessibility

As with maize, the assumption behind the HarvestPlus strategy is that people eat what they grow. While most farm households grow beans, there is evidence that the market plays an important role in supplying beans, even to bean-growing households. A recent analysis by Murekezi, Katsvairo, and Birol (2013) found that the majority of bean-producing households in Rwanda are net buyers, meaning they buy more beans than they sell. The exception is the eastern province, where only one-third of households are net buyers.

Of the one-third of bean-producing households that reported selling beans in the past 12 months, most sold them in local markets and to traders. Due to an active regional trade in beans, beans sold to traders may not be purchased by consumers in local markets, and beans bought in local markets may not have been produced locally. The movement of beans between Rwanda and neighboring countries Tanzania and Uganda varies throughout the year based on demand. Kenya is not a major producer of beans and relies on imports from Rwanda to help meet consumer demand. Anecdotal evidence shows that biofortified beans have traveled as far as South Sudan via informal traders who have purchased them from local markets (L. Katsvairo, pers. comm., 2014).

There are price differences in Rwanda between single-variety and mixed-variety bean grains. Poorer consumers in Rwanda are more likely to purchase mixed bean grains since they are cheaper. In urban markets, consumers are willing to pay more for single-variety beans, but this is a smaller market that does not include HarvestPlus's target beneficiaries (Murekezi, Katsvairo, and Birol 2013). Biofortified beans are sold as single-variety beans, but HarvestPlus is attempting to overcome any pricing challenges through the dissemination strategies outlined below.

According to the HarvestPlus varietal adoption survey, women are the main decisionmakers regarding bean varietal adoption, sowing, harvesting, sorting, storing, and cooking (Asare-Marfo et al.

2011). This suggests that where home consumption is the main way that target consumers access beans, women will be the key target group that HarvestPlus will need to reach. Where markets are important, more information is needed about who in the household makes decisions about buying and selling in bean and iron bean value chains and how decisionmaking might change in response to interventions.

Strength of the Evidence: Medium

As with orange maize, a better understanding of how target consumers will access high-iron beans—via home consumption or the market—will be important to ensuring that iron beans (as seed or grain) are available and accessible to the people who make bean production, consumption, or both decisions in target households. When production and consumption decisions are made separately, the decisionmakers and the constraints they face may be different.

More information is needed about gendered control of income. Beans are an important source of income for households (Asare-Marfo et al. 2011). There is evidence that past interventions to "upgrade" the bean value chains have reduced women's control over beans and bean-related income (Njuki et al. 2011). Therefore, it will be important to design delivery strategies to avoid negative consequences for women and to ensure the effectiveness of the strategies.

Assumption/Risk: Consumer Confidence that Beans Are High in Iron

Unlike vitamin A crops, iron beans do not change color with additional iron. While this trait is an advantage in that the risk of rejection by consumers on the basis of appearance is low, farmers and consumers may not have a way to confirm whether a bean being promoted as high in iron actually is high in iron. This could be important if consumers value the iron trait and are willing to pay a premium for it, thus providing traders with an incentive for "false advertising." Machines that verify iron content in beans are being used to support agrodealers, though it remains to be seen whether they can be cost-effective. The HarvestPlus marketing team is aware of the challenges and is working on solutions (Tomlins, Oparinde, et al. 2013; Tomlins, Salivo, et al. 2013).

Strength of the Evidence: Medium

The challenges of quality assurance in bean markets, as in most informal markets in developing countries, are potentially significant. As long as the iron bean varieties are preferred by target consumers for other, visible traits, the practical implications of the problem may not be large. Monitoring quality assurance will be important, especially how "high iron" is used in the marketing of beans. If HarvestPlus could identify cost-effective solutions to the quality assurance problem in iron bean markets, it would be an important contributor to knowledge and practice in this area.

Likelihood that Target Consumers Will Eat High-iron Beans: Medium

Will Target Consumers Be Aware and Convinced of the Benefits of Iron Beans?

Before making the decision to consume iron beans, target consumers or those who make their food choices need to be aware of the beans and convinced of their benefits, which may or may not include the fact that they are high in iron (Assumption/Risk Box 3 in Figure 4.1).

Assumption/Risk: Consumer Acceptance

An expert panel evaluated a mixture of high-iron and conventional beans on the basis of 17 sensory attributes ranging from taste and odor to shape and size. The panel found little to no difference between high-iron beans and conventional beans in terms of taste, suggesting that taste will not be a barrier to consumers' eating high-iron beans (Tomlins, Oparinde, et al. 2013; Tomlins, Salivo, et al. 2013). Unpublished results of a 2013 consumer acceptance study in Rwanda in the western and northern

provinces suggest that iron bean varieties compare favorably with local varieties in terms of taste (Birol et al. 2014). Unlike with vitamin A maize, nutrition information did not have a clear impact on consumers' preference for the iron-rich varieties. The same study was also conducted in urban wholesale and retail markets, and in this case, nutrition information did increase consumers' preference for both iron bean varieties over the local variety (Birol et al. 2014).

Experimental results were confirmed by a farmer feedback study in three provinces among farmers who had received or purchased iron-rich bean seed in 2012. When asked to compare four of the biofortified varieties with the major variety they grow, farmers preferred the cooking time and taste of three of the four biofortified varieties to the other major variety (Murekezi et al. 2013).

Strength of the Evidence: Strong

Both experimental and actual data suggest that the consumption characteristics of high-iron beans are likely to be acceptable to consumers and in some cases even preferred to their current varieties. There is some experimental evidence that iron content is valued by urban consumers, but target consumers do not appear to value it, which suggests that iron content may not need to be emphasized in marketing. While this is promising and suggests that the "invisibility" of iron may not be a problem (as long as people can recognize the variety somehow), the fact that poor households generally consume mixtures of beans means that just because they prefer one to another in a taste test doesn't mean they will replace all beans with that variety. The potential nutrition impact will depend on how many varieties target consumers eat and how many might be rich in iron. This is an issue for all crops but is particularly important for beans in Rwanda, where mixtures are common and likely to persist. A strategy of mainstreaming iron into improved varieties is likely to be particularly effective in this case.

Assumption/Risk: Consumer Awareness

To date, iron beans have been promoted primarily to farmers on the basis of agronomic and non-nutrition-related consumption characteristics. The HarvestPlus strategy relies on three approaches: direct marketing, a payback system through farmer cooperatives, and agrodealers.

When rural farmers purchase seed, most of the purchases come from the local market, where grain is also purchased for consumption, rather than from a dedicated seed system (CIAT 2008). Therefore, HarvestPlus sells iron-rich bean seed directly in local markets. HarvestPlus visits each of Rwanda's 416 sectors on one of the local market days and sells small quantities of iron bean seed.

Strength of the Evidence: Medium

The approaches seem appropriate for households that primarily access beans through home consumption, and the direct market approach also could reach consumers. Since women seem to be the main decisionmakers about bean production and consumption in these households, the effectiveness of this system would depend on its ability to reach them. If women are not the main buyers, then future research should include information about who in the household finances bean purchases, who buys the seed, and who makes the decisions about the end use of beans (as some of the beans purchased in the market are actually for seed use and not only for consumption). It will also be important to monitor whether iron beans are available in local markets and, if so, who purchases them and at what price.

It is not clear that a separate consumer awareness strategy is necessary (or possible) at the moment regarding high-iron beans. However, one might be necessary in the future to reach consumers who buy beans in markets or to influence consumer behavior, for example, regarding mixtures. Future research about who makes consumption decisions and what their needs and preferences are will be necessary to design awareness strategies.

Likelihood that Target Consumers Will Be Aware of and Convinced of the Benefits of Iron Beans: Medium to High

Will Retailers and Traders in Target Value Chains Buy and Sell Iron Beans?

The market is expected to play an important role in making iron beans available to consumers and providing farmers with an economic incentive to grow them. For this to happen, it will be important to target the type of traders who sell to and buy from target consumers and convince them that selling the beans will be profitable for them (Assumption/Risk Box 4 in Figure 4.1). This may be more challenging if there are additional requirements related to the marketing, labeling, and storage of iron beans. There is also a risk that where market demand is strong, target households will sell rather than consume their iron beans.

Assumption/Risk: Traders in Target Value Chains Are Reached with Appropriate Information about Iron Beans

To date, HarvestPlus has engaged with traders focused on single varieties and urban retailers, high-volume wholesalers, and contract growers who supply government export and grain reserve or United Nations agencies. HarvestPlus has been in negotiation with the World Food Programme for the purchase of biofortified beans (HarvestPlus 2013b). HarvestPlus advocacy is also focused on building support for biofortification, including promoting the beans to the private sector to create a dynamic and sustainable environment for biofortification in Rwanda. Following the inclusion of iron beans and orange maize in the Nutrition Action Plan of the Strategic Plan for Agricultural Transformation (2013–2018), HarvestPlus is working to transmit this commitment into funding and programs for biofortification.

Strength of the Evidence: Strong

The current HarvestPlus strategies targeted at creating an institutional market for iron beans are likely to be successful. Anecdotal evidence already suggests that iron beans are popular with farmers and traders.

Likelihood Retailers and Traders in Target Value Chains Will Buy and Sell Iron Beans: High

Will Target Farmers Grow Iron Beans?

To grow iron beans, farmers in target households will need to have access to the seed (Assumption/Risk Box 5 in Figure 4.1). To sustain and expand adoption, the seed will have to perform as expected, or even better than expected, under household conditions. As is the case with consumers, farmers will need to be able to differentiate the iron beans from other beans, though not necessarily for their iron content.

Assumption/Risk: Access to Seed

There is no formal seed sector for beans in Rwanda. The majority of farmers surveyed in the varietal adoption survey (85 percent) recycled their seed from previous seasons, with only 15 percent acquiring new seed at the beginning of the season (Asare-Marfo et al. 2011). Farmers can recycle beans for up to three to five years, with marginal loss in iron levels (and yield). While recycling will not immediately affect iron intake, it does create a challenge for introducing new varieties. Previous research suggested that 85 percent of farmers got their new seeds from local markets and local shops or through gifts or exchange with fellow farmers (CIAT 2008). As mentioned above, HarvestPlus is distributing seed via direct market to farmers in local markets and through the payback system via farmer cooperatives. To date, more than 700,000 households have directly received high-iron seed.

Through direct marketing, farmers are expected to be able to purchase and experiment with a small quantity of seed, although seed packs are available at a variety of price points. Due to government restrictions and consumers' preferences, HarvestPlus packages the seeds in paper bags with a label showing a picture of the variety and its color. HarvestPlus estimates it can to reach 900 to 1,500 famers per day at these markets.

HarvestPlus is conducting a census of farmers who purchase seed through the direct-marketing scheme. It will follow up with these farmers on their impressions of this new approach to packaging bean seed and will obtain information about area planted with high-iron beans and the amount of harvested iron beans consumed at home, sold, saved as seed for the next planting season, and given to friends and family. While the small seed packs cover only a small area of land, an important finding from the farmer feedback study was that farmers saved a significant proportion (average 30 percent) of their harvested grain and plan to use it in the next season (Murekezi et al. 2013). Almost one-quarter of farmers surveyed shared some grain within their networks, and more than half (56 percent) recommended it to others (Murekezi et al. 2013).

In the payback system, farmers in cooperatives that have signed a contract with HarvestPlus receive iron bean seed from a sector agronomist. After harvesting the iron-rich varieties, farmers are required to pay back a quantity of harvested grain, which is usually double what they received in seed. For example, farmers who received 1 kilogram of seed are required to return 2 kilograms of grain to HarvestPlus. Farmers also receive support and training from the sector agronomist on best practices to enhance bean production. While iron beans already outcompete local varieties grown under local conditions, farmers who apply these best practices benefit from higher yields of both iron-rich and conventional varieties. With these higher yields, farmers are able to pay back what they received as grain and still have plenty left to eat, sell, or give to neighbors. So far, the program has been popular among farmers, has increased grain production, and has shown payback rates of iron-rich grain of up to 80 percent (HarvestPlus 2013a). The grain received as part of the program is being sold on the grain market or to the World Food Programme, with the money reinvested to expand the program.

Agrodealers are also being used as a private-sector channel for farmers to purchase seed throughout the year (versus an annual direct-marketing approach). However, the major risk for agrodealers is in ensuring that farmers are getting quality, high-iron beans and not a substitute. To address this risk, HarvestPlus is training agrodealers to enable them to distinguish high-iron bean varieties from local varieties through, for instance, random spot checks and making available an additional X-ray fluorescent machine that customers can use to ensure the beans they are purchasing are in fact higher in iron.

To make it easier for farmers to afford to buy good-quality seed, HarvestPlus proposed a new class of seed—"Quality Declared Seed"—that was ratified in 2012 in the seed law and is now referred to as Certified II seed. This new class is priced between Certified I seed and the price of grain (HarvestPlus 2013b). While the quality of Certified I and II seed is currently the same, Certified II is made from Certified I seed instead of the basic seed used to make Certified I seed. HarvestPlus has partnered with local seed growers and cooperatives to produce Certified II seed. These partners are trained in agronomic, business, and marketing best practices (HarvestPlus 2013b). This should reduce the price of certified seed, which costs two to four times more than uncertified seed from local markets (Rubyogo et al. 2007). However, there is a risk of decreasing quality if disease becomes a problem (L. Katsvairo, pers. comm., 2014).

Strength of the Evidence: Strong

The approaches to disseminating seed would seem to be effective ways to get seed into the hands of farmers. More research on how varietal adoption decisions are made and by whom could help refine strategies for making sure that varieties are available to target decisionmakers. It will be especially important to track, through farmer feedback surveys and other complementary research, whether the

introduction of a new category of quality seed leads to greater adoption of seed of better quality by target households.

Assumption/Risk: Varieties Perform as Expected

Iron beans were developed with farmer and consumer involvement. However, as with all improved varieties, the conditions under which farmers and their families grow, store, and consume them may differ from those under which they were initially evaluated. Therefore, it is always important to follow up with adopters to assess how they are performing. As mentioned above, a system is in place to track farmers who have been given seed to obtain feedback on varietal performance. This will provide early evidence about how varieties are performing.

Strength of the Evidence: Strong

Likelihood that Target Farmers Will Grow Iron Beans: High

Will Target Farmers Be Aware and Convinced of the Benefits of Iron Beans?

Before adopting iron beans, farmers will need to be aware of their existence and convinced that growing them either instead of or in addition to current varieties will be worth any associated costs or risks (Assumption/Risk Box 6 in Figure 4.1). This will require reaching the right person in the household with useful information about the variety. It may or may not be necessary to provide the identified person with information about anemia or the iron content of beans.

Assumption/Risk: Farmer Awareness

Farmers eagerly seek access to improved varieties and new technologies. Rwandan farmers try on average 75 to 100 varieties in their lifetimes (Sperling 1992). More than half of all bean farmers (57 percent) choose to grow multiple varieties as they look for suitability to different growing conditions, have different uses for different varieties, want to minimize production risks, and have a high willingness to experiment (Asare-Marfo et al. 2011). The RAB/CIAT study found this figure to be even higher (71 percent) and noted that bean farmers grow an average of 5 varieties (CIAT 2008).

According to the varietal adoption survey, most farmers (88 percent) rely on their social networks (neighbors, extended family, and friends) for information about new varieties, whereas less than 10 percent get information from extension officers, NGOs, and RAB (Asare-Marfo et al. 2011).

Strength of the Evidence: Strong

Farmers seem eager to experiment with new varieties, and the agronomic qualities alone would appear to make iron beans interesting for farmers. Though relatively few farmers receive information from official sources, there appears to be an active informal exchange of information and seed, which is tracked in research studies, such as farmer feedback studies, farmer field day studies, varietal adoption surveys, and impact assessment studies.

Assumption/Risk: Farmer Acceptance

In Rwanda, the most important trait farmers look for in a bean variety is yield (Murekezi et al. 2013); other traits are market demand and taste. In the farmer feedback study, HarvestPlus found that farmers rated three of the four biofortified varieties as having better yields than the varieties they currently grow. The survey also found that farmers were more drawn to iron beans because of the promise of higher yields and the curiosity of trying a new variety, rather than the added nutritional benefit (Murekezi et al. 2013).

As mentioned earlier, farmers like to experiment with and grow multiple varieties. The HarvestPlus varietal adoption survey identified 99 bush varieties and 74 climbing bean varieties on farmers' fields (Asare-Marfo et al. 2011). There is no single bush or climbing variety that is popular across Rwanda.

Strength of the Evidence: Strong

In the long run, the strategy of mainstreaming iron into many improved varieties would seem appropriate, given the degree of differentiation in the bean market. However, in the short run, it is important to understand why farmers prefer to mix their bean varieties and determine whether iron beans can, by meeting multiple needs, account for a larger share of the area farmers devote to beans.

Likelihood that Target Farmers Will Be Aware and Convinced of the Benefits of Iron Beans: High

Summary of Iron Beans in Rwanda

High-iron beans are popular and are already disseminating quickly. There appear to be few barriers to adoption among households that have access to the beans. Evidence on the assumptions and risks associated with achieving outcomes along the impact pathway are summarized in Table 4.1. Priority gaps that need attention could include the following:

- Addressing how iron beans can have an impact on iron intake when target households consume and produce mixtures of beans.
- Ensuring that the beans are available in local markets for households that purchase a significant share of the beans they consume.
- Understanding the impact of strong market demand, with a potential price premium, for high-iron beans on accessibility to target households and on gender relations in the iron bean value chain.

Table 4. 1 Summary of findings for iron beans in Rwanda

Research questions and likelihood of occurrence	Assumptions and risks	Strength of evidence
Will target consumers' consumption of iron beans reduce the prevalence of inadequate iron intake? ***Likelihood: high***	Accurate targeting of consumers	Strong
	Retention and bioavailability of vitamin A	Strong
	No adverse changes in diet	Strong
Will target consumers eat iron beans? ***Likelihood: medium***	Availability and accessibility	Medium
	Consumer confidence that beans are high in iron	Medium
Will target consumers be aware and convinced of the benefits of iron beans? ***Likelihood: medium to high***	Consumer acceptance	Strong
	Consumer awareness	Medium
Will retailers and traders in target value chains buy and sell iron beans? ***Likelihood: high***	Traders reached with appropriate information about iron beans	Strong
Will target farmers grow iron beans? ***Likelihood: high***	Access to seed	Strong
Will target farmers be aware and convinced of the benefits of iron beans? ***Likelihood: high***	Farmer awareness	Strong
	Farmer acceptance	Strong

Source: Authors.

5. YELLOW CASSAVA IN NIGERIA

Nigeria has one of the highest mortality rates for children younger than five years of age in Africa south of the Sahara (ICF International 2012). According to the most recent data available, 30 percent of Nigerian children younger than five were estimated to be VAD in 2001 (Maziya-Dixon et al. 2006).

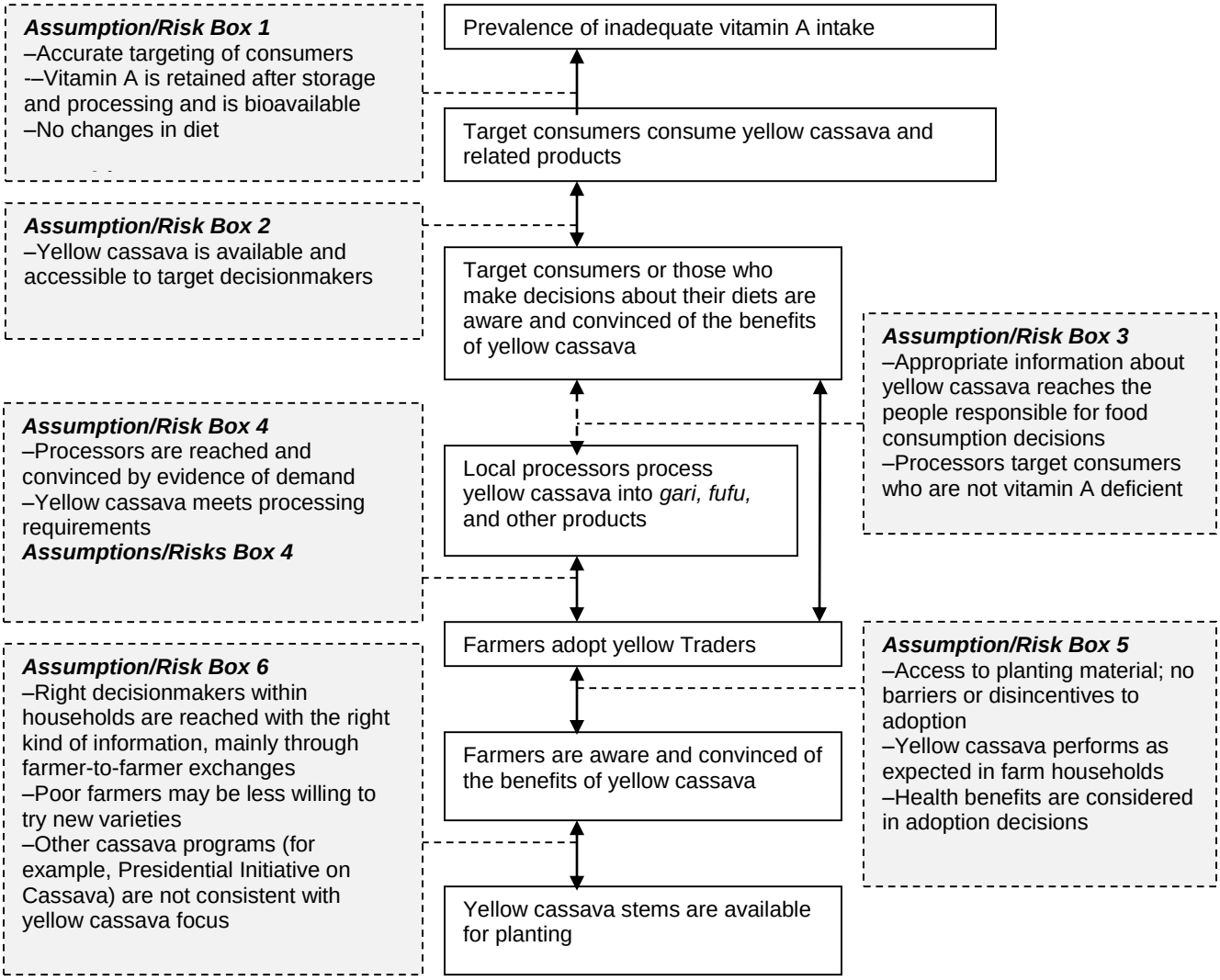
Cassava is a mainstay in most Nigerian homes, particularly in central and southern Nigeria, where it accounts for 40–50 percent of all calories consumed (Maziya-Dixon et al. 2004). Cassava is consumed in a variety of forms in Nigeria, the most common being *gari* (roasted flour with a slightly fermented and sour taste) and *fufu* (fermented wet paste widely consumed in eastern and southwestern Nigeria (PIND 2011). Raw (or boiled) cassava roots are rarely eaten in Nigeria primarily because of the high levels of cyanide present in some cassava varieties. Production of *gari*, in particular, is concentrated among smallholder households, and *gari* is generally sold in village markets (PIND 2011).

Nigerian farmers on the whole committed almost 4 million hectares of land to cassava production in 2012 and produced 54 million metric tons of cassava, making Nigeria the world's largest producer of cassava (Food and Agriculture Organization of the United Nations 2014). The majority of cassava production and processing is done by small farmers with 1 to 5 hectares of land. Cassava is intercropped with yams, maize, or legumes in the rainforest and savannah agroecologies of southern, central, and most recently northern Nigeria (HarvestPlus 2013c). Cassava in Nigeria plays a major role in providing income for farmers, a low-cost food source for rural and urban populations, and a level of stability in terms of household food security (Nweke 1996).

HarvestPlus and its partners have chosen four target states—Oyo, Imo, Akwa Ibom, and Benue—for the rollout of yellow cassava. These states represent four of Nigeria's six administrative geopolitical zones (south-west, south-east, south-south, and north-central) and were selected based on data regarding cassava production and consumption preferences. Oyo and Benue are the largest cassava producers in their zones, while Akwa Ibom and Imo have the highest national per capita consumption of cassava. By selecting a mixture of target states with differing preferences and habits, HarvestPlus expects to be able to develop strategies that will meet the diverse needs of the Nigerian population.

In 2011, the Nigerian government released three varieties of provitamin A (yellow) cassava, developed by the International Institute for Tropical Agriculture and the Nigerian National Root Crops Research Institute with support from HarvestPlus, with roughly half the target provitamin A level. Second-wave varieties with higher levels of provitamin A were released in 2014. HarvestPlus and its partners aim to reach 2 million farming households by 2018 and to ensure a 10 percent market share for yellow cassava. Figure 5.1 shows the ToC for yellow cassava in Nigeria.

Figure 5. Theory of change for yellow cassava in Nigeria



Source: Authors.

Will Target Consumers' Consumption of Yellow Cassava Reduce the Prevalence of Inadequate Vitamin A Intake?

For consumption of yellow cassava by target consumers to contribute to a reduction in the prevalence of inadequate vitamin A intake, several assumptions need to hold (Assumption/Risk Box 1 in Figure 5.1). Target consumers need to be deficient in vitamin A and to eat sufficient quantities of yellow cassava; the vitamin A in yellow cassava needs to be retained in foods after storage, processing, and cooking, and the vitamin A needs to be bioavailable. It will also be important that increases in vitamin A intake from yellow cassava not be offset by reductions in vitamin A intake due to reduced consumption of other nutrient-rich foods.

Assumption/Risk: Accurate Targeting of Consumers

The target beneficiaries of yellow cassava are women of reproductive age and children four to six years of age. As mentioned above, HarvestPlus has targeted four states for the delivery phase—Oyo, Imo, Akwa Ibom, and Benue—based on cassava production and consumption data. While no state-specific data are available on vitamin A deficiency prevalence, it may be lower in Akwa Ibom and other areas where vitamin A–rich red palm oil is often added to *gari*. In Akwa Ibom, roughly 70 percent of the cassava was consumed as *gari*, and nearly all of it contained red palm oil, the result being that the consumption of yellow *gari* accounted for approximately half of the daily vitamin A intake in Akwa Ibom (HarvestPlus 2013c). The reason these areas were selected is that the addition of palm oil gives the *gari* a yellow color, which may facilitate acceptance of yellow biofortified cassava (HarvestPlus 2013c).

According to the varietal adoption survey, roughly three-quarters of households in Benue and Oyo states ate cassava in the 24 hours preceding the survey (Bamire et al. 2013). Across all four states, cassava was eaten at least five times in the week preceding the survey (Bamire et al. 2013; Oparinde et al. 2013a, 2013b). A statewide food intake survey of rural households in Akwa Ibom indicated that cassava consumption is higher than originally assumed (200 grams per day, fresh weight, for three- to five-year-olds and 400 grams per day for adult women). The average daily consumption of cassava by women and children two to five years of age was 900 grams and 350 grams, respectively (HarvestPlus 2013c.) Because this survey data indicated that consumption in some states may be higher than estimates used to set breeding targets, HarvestPlus revised its provitamin A target increments in cassava based on consumption levels—15 ppm in lower-consumption areas and 10 ppm in higher-consumption areas. The different increments should provide about 50 percent of the EAR for preschool children four to six years of age and adult women of childbearing age (HarvestPlus 2013a).

Strength of the Evidence: Medium.

The strategy is based on available data and designed to test some assumptions about how consumers are likely to react to yellow cassava. However, it does not appear to target women and children with inadequate vitamin A intakes. Better information about which cassava-growing households are most likely to contain VAD women and children could be used to improve the likelihood of reaching target consumers. Information on the coverage and quality of supplementation and fortification programs in target areas should be monitored.

Assumption/Risk: Retention and Bioavailability of Vitamin A

Harvesting of fresh roots and storage of cassava depend on the intended use. If the household is making *gari* or *lafun*, which require intensive drying, it will often harvest cassava and prepare *gari* and lafun in the dry season, leading to cassava's being stored for longer periods. Fufu is made from fresh roots and does not store as long as *gari*, so households will often harvest cassava piecemeal to make *fufu* at home. Boiled cassava is also made from fresh roots, resulting in "as needed" harvesting. The varietal adoption surveys found that 87 percent of households in Oyo and 94 percent in Akwa Ibom processed their cassava into *gari*, while 72 percent of households in Benue processed their cassava into *fufu* (Bamire et al. 2013; Oparinde et al. 2013a, 2013b).

Processing and storage of yellow cassava can degrade provitamin A by as much as 65–80 percent (Chávez et al. 2007; Thakkar et al. 2009). A study completed by the Natural Resources Institute in collaboration with the International Institute for Tropical Agriculture and the Nigerian National Root Crops Research Institute of Nigeria measured how much provitamin A is retained following different local methods of processing and cooking of yellow-fleshed cassava storage roots into *gari*. Results indicate that freshly made *gari* had, on average, 40 percent less beta-carotene than the roots and that beta-carotene continued to decrease during storage, which typically lasts four to six weeks in rural Nigerian households.

As with orange maize, studies on yellow cassava have found overall that the human body is able to convert the beta-carotene to retinol (the form of vitamin A used by the body) at a higher rate than originally assumed (Liu 2009; La Frano et al. 2013). According to these results, 50 percent of the vitamin A EAR (the HarvestPlus target) could be supplied by *gari* that has been stored for up to 15 days for a child three to five years of age or up to 45 days for a woman of childbearing age when cassava with 10 ppm beta-carotene was used and eaten daily by these groups (as in Akwa Ibom).

HarvestPlus and its partners began a feeding trial in 2014 with yellow cassava varieties with higher levels of vitamin A than those being distributed. In addition, researchers at Wageningen Agricultural University conducted a feeding trial among rural schoolchildren in Kenya in 2013, with preliminary results showing increased serum retinol levels in children who ate yellow cassava (Talsma 2014).

Strength of the Evidence: Medium

The potential losses of vitamin A due to postharvest handling of cassava is a concern that should be monitored carefully among adopters. It might make sense to include information about the importance of proper storage, processing, and cooking to retain as much vitamin A as possible in dissemination materials. Research on ways to improve retention could also be useful, especially if it produced findings on other benefits, such as how to increase shelf life or reduce labor in processing. Any changes that would increase women's labor should obviously be avoided.

Likelihood that Consumption of Yellow Cassava Will Reduce the Prevalence of Inadequate Vitamin A Intake: Medium

Will Target Consumers Eat Yellow Cassava?

For target consumers to eat yellow cassava, it needs to be available and accessible to them or the people making their food choices (Assumption/Risk Box 2 in Figure 5.1).

Assumption/Risk: Availability and Accessibility

As in the other cases, the primary way consumers are expected to access yellow cassava is through home consumption. It is estimated that more than 95 percent of cassava production and processing is by rural communities (Adesina et al. 2011). Cassava processing takes place primarily at home, though some households reported taking their cassava to a local processing center or using a combination of both home and local production.

If home consumption is the norm, then the decision about which variety or varieties to consume is made together with the decisions about which varieties to produce. Results show that men and women play different roles in cassava production and processing, with most men being responsible for the planting and harvesting of cassava and women doing the processing and cooking, although levels of responsibility and engagement in the different steps can vary regionally (Bamire et al. 2013; Oparinde et al. 2013a, 2013b).

Purchasing of cassava varied by state. In the past year, 42 percent of households in Oyo purchased *gari*, compared with 10 percent in Benue and 21 percent in Akwa Ibom (Bamire et al. 2013; Oparinde et al. 2013a, 2013b). In Akwa Ibom, 40 percent of households bought fresh roots, which they presumably processed at home; purchase of fresh roots was much lower in the other two states. Regardless of the type of purchase, almost all purchases of cassava and cassava products were from friends and neighbors or from the village or town market. Farmers also were likely to sell their own roots or processed cassava. In Oyo, 77 percent of farmers indicated that they sell fresh roots, compared with 47 percent in Akwa Ibom and 28 percent in Benue (Bamire et al. 2013; Oparinde et al. 2013a, 2013b).

Strength of the Evidence: Medium

As in Rwanda and Zambia, home consumption is important, but many households access cassava for consumption through the market. More information is needed about how important this is for target consumers to confirm whether delivery strategies need to be adapted to ensure that these households are reached. The fact that markets are very local, often between neighbors and friends, suggests that if markets for yellow cassava work the same way they do for white cassava, then this assumption should hold. Good information is available on the gender division of labor in production and processing, but more needs to be known about varietal adoption, purchase, and sale, in particular who makes decisions and who controls income.

As mentioned in the other cases, the effect of strong market demand for yellow cassava and processed products on target households is ambiguous. It could provide incentive for production, but whether that translates into increased consumption would depend on what happens with sales. Given the important role that poor women currently play in cassava processing, it is possible that they could benefit from innovations in this area. However, it is also possible that the upgrading of cassava value chains could make them more attractive to men, resulting in women's losing control of this source of income and food. Intervening in this area without a good understanding of the objectives and the potential implications for women, and without a deliberate strategy to ensure that women would benefit, seems risky.

Likelihood Target Consumers Will Eat Yellow Cassava: Medium

Will Target Consumers Be Aware and Convinced of the Benefits of Yellow Cassava?

Like orange maize, yellow cassava is a new crop that looks different from what consumers are used to. With the possible exception of states where yellow *gari* is consumed, consumers (or the people who make decisions about their food) will need to learn about yellow cassava and be convinced of its benefits before they are willing to try it (Assumption/Risk Box 3 in Figure 5.1).

Assumption/Risk: Consumer Acceptance

A sensory evaluation of *gari* conducted by Maziya-Dixon et al. (n.d.) found that *gari* from yellow-fleshed cassava varieties was preferred and that there were no perceptible differences in sensory attributes, except for appearance.

HarvestPlus and its partners conducted consumer acceptance studies among the target population in Imo and Oyo states. Preliminary results from the studies show that nutrition information plays a key role in consumers' acceptance of yellow cassava, particularly in Imo, where consumers already eat yellow *gari* (Oparinde et al. 2014). Without nutrition information, consumers in Imo preferred their yellow *gari* made with red palm oil to the *gari* made from yellow cassava. However, once nutrition information was provided, one yellow cassava variety, TMS 01/1371 (deep-yellow cassava), had the highest willingness to pay from consumers. Even without nutrition information, consumers in Oyo preferred *gari* made from the other yellow cassava, TMS 01/1368 (light-yellow cassava), to *gari* made with their traditional white cassava (Oparinde et al. 2014).

The study also examined the effect of the entities delivering the planting materials and whether they had an impact on consumer preference. In Imo, the authority delivering the planting material did not have an impact, while in Oyo state, consumers preferred the delivery of yellow cassava to be made by an international rather than a national authority (Oparinde et al. 2014).

The amount of vitamin A that *gari* with red palm oil can provide depends on how much red palm oil is added. On average, the addition of the palm oil increases the cost of the *gari* by about 10 percent. Since adding more palm oil raises both nutritional value and cost, some consumers might opt for yellow cassava for financial reasons. Assessing this properly would require information about the relative costs of the different *garis* and who in the household is responsible for paying them.

In local markets, cassava products are sold in open containers to allow buyers to touch, smell, and even taste them (HarvestPlus 2013c). Any packaging of yellow cassava products needs to be designed not only to accommodate local preferences but also to take into account the fact that exposure to sunlight decreases the amount of vitamin A in the product.

Strength of the Evidence: Strong

There is reasonable evidence that if consumers receive information about the nutritional value of yellow cassava, they will pay a premium for it (and hence will consume it). Cost may also favor consumption of *gari* made with yellow cassava. Monitoring can observe whether consumers actually purchase biofortified varieties and at which price.

Assumption/Risk: Consumer Awareness

Prior to the initiation of stem distribution in 2013, several outreach activities were undertaken to inform consumers about the nutritional benefits of yellow cassava. These activities included providing consumption and nutrition information during farmer field days (at which farmers could learn about the yellow cassava varieties) and a direct-marketing campaign that used radio, print media, and television targeted at consumers in the four target states. It is estimated that more than 30 million Nigerians have already received information about biofortification, with an emphasis on vitamin A cassava (Ilona 2014). Recently, several Nollywood movies were released that feature yellow cassava.

According to the varietal adoption surveys, health clinics were an important source of information for nutrition and health among target households (Bamire et al. 2013). The surveys also found that among respondents who belonged to groups—group membership varies widely by state—their groups were also a trusted source of information about health and nutrition. While HarvestPlus has opted to adopt more mass media marketing approaches, it is possible that the messages will be passed on through these other channels that are used more by target households.

Strength of the Evidence: Medium

Significant efforts have been made to raise awareness. Future research should focus on determining whether target decisionmakers—who could be women responsible for processing and food preparation or men responsible for production—have been reached and convinced, either directly or indirectly through people in the social networks. The results will be important for designing future market efforts as cost-effectively as possible.

Likelihood that Target Consumers Will Be Aware and Convinced of the Benefits of Yellow Cassava: Medium to High

Will Local Processors Process and Sell Yellow Cassava?

Where local processing is important for reaching target consumers, because they purchase cassava products or processing services, it will be important that the characteristics of the varieties, including price, are sufficiently attractive for processors to be willing to process them (Assumption/Risk Box 4 in Figure 5.1). If there are differences with processing conventional cassava—for example, in terms of maximizing beta-carotene retention—some awareness raising may be necessary to reach processors with information about yellow cassava and with technical details about how to optimally process it.

Assumption/Risk: Processors Reached with Appropriate Information about Yellow Cassava

HarvestPlus estimates that of the 7,000 metric tons of roots harvested in 2013, 90 percent was consumed locally, with the remainder being sold in local and international markets (HarvestPlus 2014). To expand the market for processed cassava and cassava products, HarvestPlus provided support for a commercial *gari* and flour factory built by the government of Akwa Ibom State and the development of 15 vitamin A cassava products (HarvestPlus 2014). However, according to HarvestPlus's assessment, other yellow products, such as yellow *fufu* from yellow cassava varieties, which do not have direct competitors could ultimately have higher potential than *gari* to create markets for yellow cassava (HarvestPlus 2013c).

Strength of the Evidence: Medium

In the short run, investments in processing capacity and research and development are likely to lead to increases in sales and demand for yellow cassava. However, plans for long-term sustainability are not clear, nor is the role that small local processors are expected to play in achieving increases in sales. Given that creating new opportunities for processed cassava products—mainly white cassava but potentially also yellow—is a priority for the Nigerian government, better information in this area could also help inform those investments.

Likelihood that Local Processors Will Process and Sell Yellow Cassava: Medium

Will Target Farmers Grow Yellow Cassava?

Assuming that they are convinced of its benefits, target farmers will adopt yellow cassava if they are able to obtain planting material at a reasonable cost and if the yellow cassava delivers expected benefits, including consumption and possibly also nutrition characteristics, in their farming systems and households (Assumption/Risk Box 5 in Figure 5.1).

Assumption/Risk: Access to Planting Material

The initial dissemination strategy for yellow cassava in Nigeria focuses primarily on giving planting materials to the target households, with support from nutrition information campaigns as described above. In 2013, HarvestPlus and its partners began distributing yellow cassava planting materials to 100,000 farming households in the four target states (Ilona 2014). For this first round of distribution, cassava varieties with the lower levels of provitamin A were distributed to households in the high per capita consumption areas. Once varieties with full target levels of provitamin A are available, these will be distributed in areas where cassava consumption is lower.

One of the major barriers to increasing access to specific cassava varieties is stem multiplication. In response to this challenge, HarvestPlus has developed two low-tech solutions that have had a dramatic impact on stem multiplication. Traditionally, farmers used cutlasses, shears, or saws to cut stems, resulting in only 600 stem cuttings a day. HarvestPlus designed a new method for mass cutting that involves piling stems on a specially designed rack and cutting them with a small gas-powered chainsaw. Using this method, two people can cut through the pile of stems, producing 80,000 cassava cuttings a day. This has reduced the labor cost for cutting stems from $35 to $5 per hectare. HarvestPlus has provided chainsaws and racks to all of its multiplication partners to facilitate stem multiplication.

HarvestPlus has also increased the shelf life of cassava stems and their performance after planting through the simple adaptation of transparent plastic bags. Once stems are cut, they are bundled and sealed in clear plastic bags rather than being tied together with twine as is the common practice. This simple step produces a mini–greenhouse effect that increases shelf life of the stems and prompts the stems to produce roots and sprout leaves, speeding up their growth once planted.

The varietal adoption surveys in Oyo, Benue, and Akwa Ibom showed that the majority of farmers acquired their stems for planting from informal and immediate networks. Three-quarters of farmers in Benue relied on stems from their own stock for planting, and 86 percent of farmers in Akwa Ibom used their own supplies. Only 2 percent of farmers in Oyo acquired their stems from a formal source, such as the village or town market, extension officer, or agro-input dealer. Because of the short shelf life of harvested stems, farmers are very likely to acquire their stems shortly before planting, usually less than two weeks. Farmers will typically harvest the cassava roots and then immediately replant the stems on the same piece of land (Oparinde et al. 2013b).

Given the findings from the varietal adoption surveys, it is clear that HarvestPlus must find strategies that tap into the informal networks that farmers rely on for their planting materials and for their information. One strategy that HarvestPlus has employed is to require farmers receiving free planting materials to share these with their neighbors and friends. Farmers who receive a demonstration stem pack must share a similarly sized stem pack with a neighbor, after which they are welcome to sell any excess cassava to local traders.

According to HarvestPlus's estimates, farmers sharing stems with their neighbors will account for 20 percent of dissemination in 2014 and less going forward. HarvestPlus expects that traders will account for more than 50 percent of the stems disseminated starting in 2014 and that this will increase to 80 percent by 2017. Therefore, the HarvestPlus strategy is focused on working with stem traders to bulk up and sell yellow cassava stems, especially in the nontarget states.

Strength of the Evidence: Strong

Direct distribution in target areas should ensure that yellow cassava stems get into the hands of target farmers. Also, efforts to ensure sharing and improve the productivity of stem multiplication are promising but will require further research as well as monitoring. More research evidence is needed on whether the improvements in productivity of stem multiplications will be sustainable and cost-effective in the long term in a context where people are not accustomed to paying for cassava stems. The current estimates of trader share of market seem very optimistic. However, gender-responsive research on how this segment of the value chains can be strengthened could be useful for HarvestPlus and for cassava development in general (assuming technologies can be used for white and yellow cassava).

Assumption/Risk: Varieties Perform as Expected

Varieties are developed with farmer input, and HarvestPlus Nigeria has implemented a robust record system to track the name, location, and gender of all farmers who have received planting material. From this list, researchers will select a representative sample to interview for the farmer feedback study, which will provide data on area planted, yield, consumption, and diffusion of yellow cassava.

Strength of the Evidence: Strong

Given the gendered nature of cassava production, it will be important to obtain feedback from both men and women.

Likelihood that Target Farmers Will Grow Yellow Cassava: High

Will Target Farmers Be Aware and Convinced of the Benefits of Yellow Cassava?

Before adopting yellow cassava, farmers will need to be convinced of its benefits. As discussed above, many factors influence the decision about which variety to plant, which means that multiple strategies may be needed to reach different household members (Assumption/Risk Box 6 in Figure 5.1).

Assumption/Risk: Farmer Awareness

The large-scale efforts to reach consumers with information about yellow cassava are likely to have reached some farmers as well, though given the gender distribution of labor it is not clear to what extent the consumption and nutrition information would be of interest to male farmers.

The varietal adoption surveys found that most farmers get their agricultural information from informal sources, such as neighbors and friends, and from the radio, which supports the design of the awareness-raising campaign. The surveys found that farmers' groups and organizations also have a significant impact on farmers and their decisions, but membership varies greatly by state (Bamire et al. 2013; Oparinde et al. 2013a, 2013b). Almost 100 percent of households in Akwa Ibom reported being members of groups (whether farmers' groups, cooperatives, or religious groups), versus 48 percent in Oyo and only 8 percent in Benue. Among those who are part of groups, their groups serve as trusted and important sources of information about agricultural technologies and cassava varieties.

Strength of the Evidence: Strong

Radio and other awareness-raising activities are likely to have reached many farmers, though their effectiveness will need to be monitored. Given the differences across regions, different approaches may be needed to support the spread of yellow cassava. Targeting strategies to local context will also provide better lessons for scaling up.

Assumption/Risk: Farmer Acceptance

According to the quantitative and qualitative varietal adoption studies conducted in Oyo State, the characteristics farmers look for in their cassava are high yield, early maturation, and root's resistance to rotting while underground (Oparinde et al. 2013b). However, it is also important that the varieties have the desirable consumption qualities in terms of dry matter content and palatability for processed cassava products, such as *gari*. The provitamin A varieties developed by HarvestPlus and its partners offer farmers competitive yield and better resistance to major pests and diseases, compared to their current varieties.

Nigerian farmers typically grow up to three varieties of cassava (Bamire et al. 2013; Oparinde et al. 2013b). In addition, farmers are likely to try new varieties and do so in a stepwise manner. If output from their first trial of a new variety is found to be acceptable and marketable, they will plant the produced stems again on a larger farm size and also share them with other farmers (Oparinde et al. 2012).

Findings from the varietal adoption survey in Oyo State show that the household head is the primary decisionmaker when it comes to planting and harvesting cassava as well as deciding which variety to cultivate (Oparinde et al. 2013b). HarvestPlus has little information about the influence that women as the processors of cassava have over men, who make decisions about which variety to plant. The production and consumption characteristics of varieties in development should be evaluated by both men and women to inform further breeding.

Strength of the Evidence: Strong

The varieties appear to be acceptable to farmers. However, given the novelty of the product and the limited information about intrahousehold decisionmaking, monitoring the rollout carefully will be important. The farmer feedback surveys are an opportunity way to do this within households that received varieties.

Likelihood that Target Farmers Will Be Aware and Convinced of the Benefits of Yellow Cassava: High

Summary of Yellow Cassava in Nigeria

Table 5.1 presents the study's findings for yellow cassava in Nigeria. Large numbers of consumers and producers have been reached with information about vitamin A deficiency and yellow cassava, and important improvements in stem multiplication have the potential to dramatically increase the amount of improved planting material available to farmers, which has been a perennial bottleneck for dissemination of improved cassava materials. Key areas for additional work are the following:

- Current targeting strategies are consistent with available information. However, as in other cases, it would be important to confirm that consumers are being accurately targeted and that the key decisionmakers within the target households are identified and understood.
- Good information is available about losses in storage and processing so the program is well aware of the challenges. However, it is not clear that these challenges can be overcome in practice. Storage and beta-carotene losses under farm household conditions should be studied in small samples to obtain accurate data, perhaps supported by additional research or information dissemination, to reduce the losses.
- Clear, testable hypotheses need to be developed about the role that markets are expected to play in reaching target consumers with yellow cassava and how HarvestPlus activities are expected to contribute to specific outcomes. Given the important role that women play in cassava processing, and given the interest of the government in developing (white) cassava value chains, this is an urgent area to ensure that women benefit and are not disadvantaged.

Table 5. 1 Summary of findings for yellow cassava in Nigeria

Research questions and likelihood of occurrence	Assumptions and risks	Strength of evidence
Will target consumers' consumption of yellow cassava reduce the prevalence of inadequate vitamin A intake?	Accurate targeting of consumers	Medium
	Retention and bioavailability of vitamin A	Medium
Likelihood: medium		
Will target consumers eat yellow cassava?	Availability and accessibility	Medium
Likelihood: medium		
Will target consumers be aware and convinced of the benefits of yellow cassava?	Consumer acceptance	Strong
	Consumer awareness	Medium
Likelihood: medium to high		
Will local processors process and sell yellow cassava?	Reaching processors	Medium
Likelihood: medium		
Will target farmers grow yellow cassava?	Access to planting material	Strong
Likelihood: high	Varieties perform as expected	Strong
Will target farmers be aware and convinced of the benefits of yellow cassava?	Farmer awareness	Strong
	Farmer acceptance	Strong
Likelihood: high		

Source: Authors.

6. SUMMARY AND CONCLUSIONS

This paper developed country-level ToCs for three crop-country combinations, summarized the evidence to support the causal assumptions and risks, and identified implications for delivery, monitoring, and exploratory and evaluative research. Table 6.1 summarizes the major findings by country and outcome. While many observations are crop and country specific, several general observations can be made.

Table 6. 1 Likelihood that outcome will be achieved, by crop x country combination

Outcome	Orange maize in Zambia	Iron beans in Rwanda	Yellow cassava in Nigeria
Consumption of the biofortified crop reduces the prevalence of inadequate vitamin A intakes	Medium to high	High	Medium
Target consumers eat the biofortified crop	Medium	Medium	Medium
Target consumers are aware of and willing to eat the biofortified crop	Medium to high	Medium to high	Medium to high
Processors and traders buy and use the biofortified crop	Medium to high	High	Medium
Target farmers grow the biofortified crop	Medium	High	High
Target farmers are aware and convinced of the benefits of the biofortified crop	Medium to high	High	High

Source: Authors.

In all three cases, targeting strategies are based on available evidence. However, more could be done to confirm that target beneficiaries make up a large share of target consumers (men and women in crop-producing households). Similarly, it should be confirmed whether the home consumption pathway is indeed the main way that target consumers will access biofortified crops. This information is crucial because it determines who the key decisionmakers are within the households who need to be reached with information, with planting materials, or with grain, roots, or processed food products. The gender dimensions of decisionmaking processes in households are particularly important to understand.

The role that the market is expected to play in reaching target consumers or in supporting the commercial viability of biofortified crops needs to be better articulated. Only then will it be possible to know whether the current strategies are likely to work. This would appear to be urgent not only because significant resources are being invested in this area but also because the potential for unintended negative consequences, especially related to gender, appears to be high. It is perhaps not surprising that this area is less developed, since it was not one of the areas in which HarvestPlus invested in research to build the evidence base in the early phases of the program. The delivery phase offers an opportunity to address these issues, and it makes sense to do it in an "action research" mode by monitoring and evaluating specific interventions. Doing this effectively requires clear hypotheses, based on an underlying ToC.

Much of the information needed to generate further evidence through research or monitoring is planned. However, it would be useful to review current plans for data collection (in research or monitoring) to make sure that priority needs are being met. In particular, there may be a need for more targeted research that complements monitoring and can provide information that is more timely and more focused on specific outcomes than the planned impact evaluations.

The impact evaluations provide crucial evidence covering the whole impact pathway from varietal availability to changes in the nutritional status of target beneficiaries. However, depending on how the impact evaluations are designed, the external validity with regard to outcomes in the middle of the pathway that are crucial for scaling up—for example, whether local seed systems will ensure that

varieties are available to target households, what effect strong market demand will have on prices and consumption by target households—may not be very strong. Complementary studies focused specifically on intermediate outcomes will provide important information about whether and how these linkages are likely to work.

Country managers found the ToCs, especially the graphics, a useful way to communicate to external stakeholders how the program is expected to work. An integrated and outcome-oriented approach like ToC could also be used for planning, which is currently done largely by component. Encouraging and supporting use of ToC-based approaches may require building capacity among staff and creating incentives for people to think and work across components. The HarvestPlus monitoring, learning, and action functional team is currently developing these comprehensive ToCs (at both global and country levels) to capture and summarize these issues diagrammatically and to serve as a road map for the entire program.

REFERENCES

Adesina, A., M. Adetunji, T. Odunlami, J. Odeyemi, J. Awoniyi, A. Egba, A. Oredipe, and M. Fregene. 2011. "Transforming the Cassava Sector in Nigeria." Paper presented at DATCO Shareholders Meeting, December 15.

Asare-Marfo, D., E. Birol, L. Katsvairo, J. A. Manirere, F. Maniriho, and D. Roy. 2011. "Farmer Choice of Bean Varieties in Rwanda: Lessons Learnt for HarvestPlus Delivery and Marketing Strategies." Unpublished. HarvestPlus/International Food Policy Research Institute, Washington, D.C.

Bamire, S.A., T., Abdoulaye, A. Oparinde, D., Asare-Marfo, E. Birol, M. Diressie, P. Ilona, A. Akinola and V. Manyong, 2013. *A Baseline Cassava Varietal Adoption Study to Inform Development, Delivery and Marketing of Pro–vitamin A Cassava in Akwa Ibom State, Nigeria.* Washington, D.C.: HarvestPlus/International Food Policy Research Institute.

Beebe, S., and M. Andersson. 2014. "Iron Common Bean (*Phaseolus vulgaris*)." Conference brief, Second Global Conference on Biofortification, Kigali, Rwanda, March 31–April 2. Accessed January 22, 2015. http://biofortconf.ifpri. info/files/2014/03/2a_IronBean_BeebeAndersson.pdf.

Berti, P. R. n.d. "Inadequate Diet, but Low Iron Deficiency Anemia, in Rwandan Women and Children." Unpublished. HarvestPlus/International Food Policy Research Institute, Washington, D.C.

Bhargava, A. 2013. "Iron Status, Malaria Parasite Loads and Food Policies: Evidence from Sub-Saharan Africa." *Economics and Human Biology* 11 (1): 108–112.

Birol, E., A. Oparinde, A. Banerji, J. V. Meenakshi, S. Chowdhury, K. Tomlins, H. de Groote, V. Manyong, and S. Perez. 2014. "Consumer Acceptance of Biofortified Foods." Conference brief, Second Global Conference on Biofortification, Kigali, Rwanda, March 31–April 2. Accessed January 22, 2015. http://biofortconf.ifpri.info/files/2014/03/16_ConsumerAccept_BirolOparinde.pdf.

Bouis, H. E., C. Hotz, B. McClafferty, J. V. Meenakshi, and W. H. Pfeiffer. 2011. "Biofortification: A New Tool to Reduce Micronutrient Malnutrition." *Food and Nutrition Bulletin* 32 (Suppl. 1): 31S–40S.

Burt, A. J., C. M. Grainger, J. C. Young, B. J. Shelp, and E. A. Lee. 2010. "Impact of Postharvest Handling on Carotenoid Concentration and Composition in High-carotenoid Maize (*Zea mays L.)* Kernels." *Journal of Agricultural and Food Chemistry* 58 (14): 8286–8292.

Carvalho, L., M. Correa, E. Pereira, M. Nutti, J. Carvalho, E. Riberiro, and S. Feritas. 2012. "Iron and Zinc Retention in Common Beans after Home Cooking." *Food & Nutrition Research* 56: 151–168.

Chávez, A. L., T. Sánchez, H. Ceballos, D. B. Rodriguez-Amaya, P. Nestel, J. Tohme, and M. Ishitani. 2007. "Retention of Carotenoids in Cassava Roots Submitted to Different Processing Methods." *Journal of the Science of Food and Agriculture* 87 (3): 388–393.

Chibwe, E., H. de Groote, Z. Gitonga, and E. Birol. 2013. "A Participatory Evaluation of Vitamin A Biofortified Maize in Zambia." Unpublished. HarvestPlus/International Food Policy Research Institute, Washington, D.C.

CIAT (International Center for Tropical Agriculture). 2004. "Enhancing Farmers' Access to Seed of Improved Bean Varieties in Rwanda." *Highlights: CIAT in Africa* 15 (December). Accessed January 22, 2015. http://ciat-library.ciat.cgiar.org/Articulos_Ciat/Highlight15.pdf.

———. 2008. "Farm Level Impacts of Improved Bean Varieties and Agronomic Technologies in Rwanda." *Highlights: CIAT in Africa* 41 (June). Accessed January 22, 2015. http://ciat-library.ciat.cgiar.org/Articulos_Ciat/highlight41.pdf.

Clewes, C., and C. Kankasa. 2003. "Report of the National Survey to Evaluate the Impact of Vitamin A Interventions in Zambia in July and November 2003." Unpublished report. Atlanta: Centers for Disease Control and Prevention. Accessed January 22, 2015. http://www.micronutrient.org/nutritiontoolkit/ModuleFolders/12.Data_entry_analysis_and_%20report_writing/Examples/Report_of_survey_in_Zambia_(Sept%202005).pdf

Dalberg and World Bank. 2013. "Agricultural Pull Mechanism Initiative: Biofortification Pilot." Unpublished. Washington, DC.

de Groote, H., Z. Gitonga, M. Smale, D. Asare-Marfo, E. Kasuta, E. Birol, and K. Sonder. 2011. "Adoption and Diversification of Modern Maize Varieties in Zambia in 2011: A Baseline Report Prepared for HarvestPlus." Unpublished. HarvestPlus/International Food Policy Research Institute, Washington, D.C.

De Moura, F. F., A. Miloff, and E. Boy. 2013. "Retention of Provitamin A Carotenoids in Staple Crops Targeted for Biofortification in Africa: Cassava, Maize and Sweet Potato." In *Critical Reviews in Food Science and Nutrition.* Accessed January 22, 2015. http://dx.doi.org/10.1080/10408398.2012.724477.

FAO (Food and Agriculture Organization of the United Nations). 2014. "FAOSTAT" database. Accessed January 20, 2014. http://faostat.fao.org.

Fiedler, J. L., and K. Lividini. 2013. "Evaluating Future Options for Zambia's Vitamin A Program Portfolio." Unpublished. HarvestPlus/International Food Policy Research Institute, Washington, D.C.

HarvestPlus. 2012. *Disseminating Orange-fleshed Sweet Potato: Findings from a HarvestPlus Project in Mozambique and Uganda.* Washington, D.C.: International Food Policy Research Institute.

———. 2013a. *HarvestPlus Annual Report 2012: Bridging the Delta.* Washington, D.C.: International Food Policy Research Institute.

———. 2013b. *High-iron Beans for Rwanda.* HarvestPlus Product Development and Delivery Plan. Washington, D.C.: International Food Policy Research Institute.

———. 2013c. *Provitamin A Cassava for Nigeria.* HarvestPlus Product Development and Delivery Plan. Washington, D.C.: International Food Policy Research Institute.

———. 2013d. *Provitamin A Maize for Zambia.* HarvestPlus Product Development and Delivery Plan. Washington, D.C.: International Food Policy Research Institute.

———. 2014. "Narrative of 2013 Activities: Report to the Bill and Melinda Gates Foundation." Unpublished, International Food Policy Research Institute, Washington, D.C.

Hillenbrand, E. 2010. "Transforming Gender in Homestead Food Production." *Gender &Development* 18 (3): 411–425.

Hotz, C., C. Loechl, A. de Brauw, P. Eozenou, D. Gilligan, M. Moursi, B. Munhaua, P. van Jaarsveld, A. Carriquiry, and J. V. Meenakshi. 2012. "A Large-scale Intervention to Introduce Orange Sweet Potato in Rural Mozambique Increases Vitamin A Intakes among Children and Women." *British Journal of Nutrition* 108:163–176.

Hotz., C., C. Loechl, A. Lubowa, J. K. Tumwine, G. Ndeezi, A. Nandutu Masawi, R. Baingana, A. Carriquiry, A. de Brauw, J. V. Meenakshi, and D. O. Gilligan. 2012. "Introduction of β-carotene-rich Orange Sweet Potato in Rural Uganda Results in Increased Vitamin A Intakes among Children and Women and Improved Vitamin A Status among Children." *Journal of Nutrition* 142 (10): 1871–1880.

ICF International. 2012. *MEASURE DHS STATcompiler.* Accessed January 17, 2014. http://www.statcompiler.com.

Ilona, P. 2014. "Delivery of Vitamin A Cassava in Nigeria." Conference brief, Second Global Conference on Biofortification, Kigali, Rwanda, March 31–April 2. Accessed January 22, 2015. http://biofortconf.ifpri.info/files/2014/03/23a_VitACassavaNigeriaDelivery_Ilona.pdf.

International Food Policy Research Institute. 2011. "Agriculture for Nutrition and Health: A Revised Proposal Submitted to the CGIAR Consortium Board." Accessed January 22, 2015. http://www.ifpri.org/sites/default/files/crp4proposal_final_oct06_2011.pdf.

James, C. 2011. *Theory of Change Review: A Report Commissioned by Comic Relief.* Accessed January 22, 2015. http://mande.co.uk/blog/wp-content/uploads/2012/03/2012-Comic-Relief-Theory-of-Change-Review-FINAL.pdf.

Kigali Institute of Science and Technology. 2012. "Annual Progress Report." Unpublished. Kigali, Rwanda.

La Frano, M., L. R. Woodhouse, D. J. Burnett, and B. J. Burri. 2013. "Biofortified Cassava Increases B-carotene and Vitamin A Concentrations in the TAG-rich Plasma Layer of American Women." *British Journal of Nutrition* 110 (2): 310–320.

Li, S., A. Nugroho, T. Rocheford, and W. S. White. 2010. "Vitamin A Equivalence of the ß-carotene in ß-carotene-biofortified Maize Porridge Consumed by Women." *American Journal of Clinical Nutrition* 92 (5): 1105–1112.

Li, S., F. A. K. Tayie, and M. F. Young. 2007. "Retention of Provitamin A Carotenoids in High Carotene Maize (*Zea mays*) during Traditional African Household Processing." *Journal of Agriculture Food Chemistry* 55:10744–10750.

Liu, W. 2009. "Vitamin A Equivalence of the B-carotene in Biofortified Cassava in Women." Graduate thesis, Iowa State University, Ames.

Masset, E., L. Haddad, A. Cornelius, and J. Isaza-Castro. 2011. *A Systematic Review of Agricultural Interventions that Aim to Improve Nutritional Status of Children.* London, UK: EPPI-Centre, Social Science Research Unit, Institute of Education, University of London.

Mayne, J., and N. Johnson. 2014. "Using Theories of Change in the Agriculture for Nutrition and Health CGIAR Research Program." Unpublished, International Food Policy Research Institute, Washington, D.C.

Mayne, J., and E. Stern. 2013. *Impact Evaluation of Natural Resource Research Programs: A Broader View.* ACIAR Impact Assessment Series Report No. 84. Canberra: Australian Centre for International Agriculture Research. Accessed January 22, 2015. http://aciar.gov.au/publication/ias084.

Maziya-Dixon, B. B., A. Adebowale, O. Onadipe, and A. G. O. Dixon. n.d. "Sensory Evaluation of *Gari* (Roasted Cassava Granules) Produced from Yellow-fleshed Cassava Varieties." Unpublished. HarvestPlus/International Food Policy Research Institute, Washington, D.C.

Maziya-Dixon, B., I. O. Akinyele, E. B. Oguntona, S. Nokoe, R. A. Sanusi, and E. Harris. 2004. *Nigeria Food Consumption and Nutrition Survey 2001–2003 Summary.* Ibadan, Nigeria: International Institute of Tropical Agriculture.

Maziya-Dixon, B. B., I. O. Akinyele, R. A. Sanusi, T. E. Oguntona, S. K. Nokoe, and E. W. Harris. 2006. "Vitamin A Deficiency Is Prevalent in Children Less than 5 Years of Age in Nigeria." *Journal of Nutrition* 136: 2255–2261.

Mebrahtu, T., R. J. Stoltzfus, H. M. Chwaya, J. K. Jape, L. Savioli, A. Montresor, M. Albonico, and J. M. Tiselsch. 2004. "Low-dose Daily Iron Supplementation for 12 Months Does Not Increase the Prevalence of Malarial Infection or Density of Parasites in Young Zanzibari Children." *Journal of Nutrition* 134:3037–3041.

Meenakshi, J. V., A. Banerji, V. Manyong, K. Tomlins, N. Mittal, and P. Hamukwala. 2012. "Using a Discrete Choice Experiment to Elicit the Demand for a Nutritious Food: Willingness-to-pay for Orange Maize in Rural Zambia." *Journal of Health Economics* 31 (1): 62–71.

Meenakshi, J. V., N. Johnson, V. Manyong, H. DeGroote, J. Javelosa, D. Yanggen, F. Naher, C. Gonzalez, J. Garcia,, E. Meng. 2010. "How Cost-effective Is Biofortification in Combating Micronutrient Malnutrition? An Ex Ante Assessment." *World Development* 38 (1): 64–75.

Murekezi, A., D. Asare-Marfo, E. Birol, L. Katsvairo, and J. D. Nkundimana. 2013. "Farmer Feedback Report on High Iron Bean Varieties Disseminated during the 2012B Season in Rwanda." Unpublished. HarvestPlus/International Food Policy Research Institute, Washington, D.C.

Murekezi, A., L. Katsvairo, and E. Birol. 2013. "Bean Grain Value Chain and Opportunities for High Iron Beans in Rwanda." Unpublished. HarvestPlus/International Food Policy Research Institute, Washington, D.C.

Muzhingi, T., T. H. Gadaga, A. H. Siwela, M. A. Grusak, R. M. Russell, and G. Tang. 2011. "Yellow Maize with High ß-carotene Is an Effective Source of Vitamin A in Healthy Zimbabwean Men." *American Journal of Clinical Nutrition* 94 (2): 510–519.

Muzhingi, T., A. Langyintuo, L. Malaba, and M. Banzinger. 2008. "Consumer Acceptability of Yellow Maize Products in Zimbabwe." *Food Policy* 33:352–361.

NISR (National Institute of Statistics of Rwanda), Rwanda, MOH (Ministry of Health), and ICF International. 2012. *Rwanda Demographic and Health Survey 2010*. Kigali, Rwanda, and Calverton, MD, US.

NISR (National Institute of Statistics of Rwanda) and ORC Macro. 2006. *Rwanda Demographic and Health Survey 2005*. Calverton, MD, USA.

Njuki, J., S. Kaaria, A. Chamunorwa, and W. Chiuri. 2011. "Linking Smallholder Farmers to Markets, Gender and Intra-household Dynamics: Does the Choice of Commodity Matter?" *European Journal of Development Research* 23: 426–443. doi:10.1057/ejdr 2011.8.

Nweke, F. I. 1996. *Cassava: A Cash Crop in Africa.* COSCA Working Paper No. 14. Ibadan, Nigeria: International Institute of Tropical Agriculture.

Oparinde, A., D. Asare-Marfo, S. Bamire, P. Ilona, T. Abdoulaye, D. Roy, A. Adepitan, and E. Birol. 2013a. *A Baseline Cassava Varietal Adoption Study to Inform Development, Delivery and Marketing of Pro–vitamin A Cassava in Benue State, Nigeria.* Washington, D.C.: HarvestPlus/International Food Policy Research Institute.

Oparinde, A., D. Asare-Marfo, S. Bamire, P. Ilona, T. Abdoulaye, D. Roy, A. Adepitan, and E. Birol. 2013b. *A Baseline Cassava Varietal Adoption Study to Inform Development, Delivery and Marketing of Pro–vitamin A Cassava in Oyo State, Nigeria.* Washington, D.C.: HarvestPlus/International Food Policy Research Institute.

Oparinde, A., A. Banerji, E. Birol, P. Ilona, S. Bamire, and G. Asumugha. 2014. *Consumer Acceptance of Biofortified (Yellow) Cassava in Imo and Oyo States, Nigeria.* HarvestPlus Working Paper No. 13. Washington, D.C.: HarvestPlus/International Food Policy Research Institute.

Oparinde, A., E. Birol, S. Bamire, A. Adepitan, A. Ajayi, and M. Ala. 2012. *Situation Analysis of Cassava Farmers' Current Practices in Oyo State, Nigeria.* Washington, D.C.: HarvestPlus/IFPRI.

Petry, N., I. Egli, J. B. Gahutu, P. L. Tugirimana, E. Boy, and R. Hurrell 2012. "Stable Iron Isotope Studies in Rwandese Women Indicate that the Common Bean Has Limited Potential as a Vehicle for Iron Biofortification." *Journal of Nutrition* 142 (3): 492–497.

PIND (Foundation for Partnership Initiatives in the Niger Delta). 2011. *A Report on Cassava Value Chain Analysis in the Niger Delta*. Abuja, Nigeria.

Project Healthy Children. 2013. "Food Fortification Standards Declared Mandatory in Rwanda." Accessed January 22, 2015. http://projecthealthychildren.org/food-fortification-standards-declared-mandatory-in-rwanda/.

Rubyogo, J. C., L. Sperling, L. Nasirumbi, and S. Kasambala. 2007. "Developing Seed Systems with and for the Marginalized: Case of Common Beans (*Phaseolus vulgaris L.)* in East, Central and Southern Africa." In *Farmer First Revisited Conference.* Sussex, UK: Future Agricultures Consortium, Institute of Development Studies.

Smale, M., and E. Birol. 2013. *Smallholder Demand for Maize Hybrids and Selective Seed Subsidies in Zambia.* HarvestPlus Working Paper No. 9. Washington, D.C.: HarvestPlus/International Food Policy Research Institute.

Smale, M., and N. Mason. 2012. *Demand for Maize Hybrids, Seed Subsidies, and Seed Decisionmakers in Zambia.* HarvestPlus Working Paper No. 8. Washington, D.C.: HarvestPlus/International Food Policy Research Institute.

Sperling, L. 1992. "Farmer Participation in the Development of Bean Varieties in Rwanda." In *Diversity, Farmer Knowledge and Sustainability,* edited by J. Moock and R. Rhoades, 225. Ithaca, NY, US: Cornell University Press.

Stein, D. and C. Valters. 2012. "Understanding 'Theory of Change' in International Development: A Review of Existing Knowledge: The Asian Institute and the Justice and Security Research Programme." Accessed January 22, 2015. http://www.theoryofchange.org/wp-content/uploads/toco_library/pdf/UNDERSTANDINGTHEORYOFChangeSteinValtersPN.pdf.

Talsma, E. 2014. "Yellow Cassava: Efficacy of Provitamin A Rich Cassava on Improvement of Vitamin A Status in Kenyan Schoolchildren." Dissertation Summary, Wageningen University, Wageningen, Netherlands.

Thakkar, S. K., T. Huo, B. Maziya-Dixon, and M. L. Failla. 2009. "Impact of Style of Processing on Retention and Bioaccessibility of β-carotene in Cassava (*Manihot esculanta*, Crantz)." Journal of Agricultural and Food Chemistry 57 (4): 1344–1348.

Tomlins, K., A. Oparinde, D. Salivo, P. O. Mugisha, M. Nyangoma, A. Murekezi, and E. Birol. 2013. "Report on Sensory Evaluation and Consumer Acceptance of Beans (Local and High Iron Bean Varieties) in the Raw Form." Unpublished. HarvestPlus/International Food Policy Research Institute, Washington, D.C.

Tomlins, K., D. Salivo, P. O. Mugisha, M. Nyangoma, A. Murekezi, and A. Oparinde. 2013. "Report on Sensory Evaluation and Consumer Acceptance of Beans (Local and High Iron Bean Varieties) in the Cooked Form." Unpublished. HarvestPlus/International Food Policy Research Institute, Washington, D.C.

Tschirley, D., T. Reardon, M. Dolislager, and J. Snyder. 2014. *The Rise of a Middle Class in East and Southern Africa: Implications for Food System Transformation.* UNU-World Institute for Development Economics Research Working Paper 2014/119. Helsinki, Finland: World Institute for Development Economics Research.

UNEG (United Nations Evaluation Group). 2013. Impact Evaluation in UN Agency Evaluation Systems: Guidance on Selection, Planning and Management, Guidance Document. Accessed January 15, 2015. http://www.uneval.org/papersandpubs/documentdetail.jsp?doc_id=1433.

Vogel, I. 2012. "Review of the Use of 'Theory of Change' in International Development: DFID." Accessed January 22, 2015. www.oxfamblogs.org/fp2p/wp-content/uploads/DFID-ToC-Review_VogelV4.pdf.

White, H. 2009. *Theory-based Impact Evaluation: Principles and Practice.* Working Paper 3: International Initiative for Impact Evaluation (3ie). Accessed January 22, 2015. http://www.3ieimpact.org/en/evaluation/working-papers/working-paper-3/.

Zulu, B., T. S. Jayne, and M. Beaver. 2007. *Smallholder Household Maize Production and Marketing Behavior in Zambia: Implications for Policy.* Policy Synthesis Food Security Research Project—Zambia. Lusaka, Zambia: Ministry of Agriculture & Cooperatives, Agricultural Consultative Forum, Michigan State University, and Market Access, Trade and Enabling Policies (MATEP).

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