FROM BREEDING TO NUTRITION: ORANGE-FLESHED SWEETPOTATOES IN FARMING AND FOOD SYSTEMS OF UGANDA, KENYA, AND BURKINA FASO

A CASE STUDY OF PROJECTS COMMISSIONED BY THE MCKNIGHT FOUNDATION'S COLLABORATIVE CROP RESEARCH PROGRAM (CCRP), 1994–2014


Photo: G. Horneber

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DEDICATION

Jean-Célestin Somda, PhD (1956–2015)

The staff of Helen Keller International (HKI) and our project partners and collaborators are deeply saddened by the death of our respected colleague Jean-Célestin Somda, PhD, nutrition adviser and VAS coordinator in Burkina Faso. Dr. Somda had significant impact on the HKI Burkina Faso program, particularly the introduction of orange-fleshed sweetpotato (OFSP) in Burkina Faso as a strategy to combat Vitamin A deficiency in children and women. He led the implementation of nutrition and food security projects, served as nutrition and research adviser, and worked closely with the Ministry of Health to support the recent strategy shift toward routine Vitamin A supplementation in the country. His integrity, commitment to high standards, sound advice, incisive insights, dry sense of humor, ability to cut straight to the point, incredible memory, and knack for saying funny things when least expected will be greatly missed by all. His efforts made an indelible mark on HKI and the entire nutrition sector in Burkina Faso.

This study is dedicated to Dr. Somda in honor of his many years as the coordinator and driving force behind the OFSP project work in Burkina Faso, which, among other projects, is described in this study.

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LIST OF ABBREVIATIONS AND ACRONYMS

A4NH	Agriculture for Nutrition and Health
AEI	Agroecological Intensification
AESA	Agro-Ecosystem Analysis
AGRA	Alliance for a Green Revolution in Africa
BMGF	Bill & Melinda Gates Foundation
CCRP	Collaborative Crop Research Program
CG	Consultative Group (see CGIAR)
CGIAR	Consultative Group for International Agricultural Research
CIP	International Potato Center
COMESA	Common Market for Eastern and Southern Africa
CoP	Community of Practice
ECOWAS	Economic Community of West African States
FAO	Food and Agriculture Organization of the United Nations
FFS	Farmer Field School
FICAH	Food Industry Campaign Against Hunger
(G×E)	Genotype by environment interaction
GIS	Geographical Information System
GTZ	Gesellschaft für Technische Zusammenarbeit (now GIZ)
HIV	Human immunodeficiency virus
HKI	Helen Keller International
IBPGR	International Board for Plant Genetic Resources
IDRC	International Development Research Center
IITA	International Institute of Tropical Agriculture
INERA	Institut de l'Environnement et des Recherches Agricoles (Burkina Faso)
IRSAT	Institut de Recherche en Sciences Appliquées et Technologies (Burkina Faso)
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
KALRO	Kenya Agricultural & Livestock Research Organization
KARI	Kenya Agricultural Research Institute
LSU	Louisiana State University
MLS	Multilateral System for Access and Benefit-Sharing
NAADS	National Agricultural Advisory Services (Uganda)
NaCRRI	National Crops Resources Research Institute (Uganda)
NGO	Non-government organization
OFSP	Orange-fleshed sweetpotatoes
PPB	Participatory Plant Breeding
PRA	Participatory Rural Appraisal
QTL	Quantitative trait locus
R&D	Research and development
SASHA	Sweetpotato Action for Security and Health in Africa
SOCADIDO	Soroti Catholic Diocese Integrated Development Organization (Uganda)
SOSSPA	Soroti Sweetpotato Producers and Processors Association (Uganda)
SPVD	Sweetpotato virus disease
SUN	Scaling Up Nutrition
UNICEF	United Nations Children's Emergency Fund
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
VEDCO	Volunteer Efforts for Development Concerns
WHO	World Health Organization

1 SUMMARY

The McKnight Foundation commissioned a series of case studies to assess the approach of its Collaborative Crop Research Program (CCRP) as evidenced by the accomplishments and contributions of selected CCRP-funded projects. The case study presented here focused on three CCRP-funded projects targeting the breeding, production, and utilization of orange-fleshed sweetpotatoes (OFSP) in Uganda, Kenya, and Burkina Faso. The projects were interrelated in that the results and practical outcomes of previous projects (e.g., OFSP germplasm and varieties) were used in new ventures and other countries. The case study covers a funding period of twenty years (1994–2014).

The objectives were to 1) introduce and describe the background issues and general context, 2) describe the project results, 3) assess CCRP contributions to the projects' accomplishments, and 4) define program recommendations for current and future CCRP support.

A desk review of publications and written documents was used to describe the general context as well as rationales and development of all three projects. Learning, collaboration, and CCRP contributions to the projects' accomplishments were assessed based on interviews and project reports. Furthermore, focus group discussions, individual interviews, and semi-quantitative participatory communication tools were applied in Uganda and Burkina Faso to study the project outcomes and impact from the perspectives of actors along the OFSP supply chain.

The results comprise the description of the general context (Section 5.1), followed by the presentation of findings for each of the three projects and countries covered (sections 5.2–5.4). Sweetpotato is introduced here as a crop of increasing importance for food and nutrition security, given its relatively high yield per area and its adaptability to poor soil fertility conditions. In Africa, its production area has increased nearly threefold over the last two decades while average yields have remained low. Enhancing resistances to sweetpotato virus disease (SPVD) and insect pests has been a focus of plant breeders working with this crop. Enhancing nutritional quality and meeting the preferences of consumers and food processing industries have also been breeding program objectives.

Vitamin A and the issue of Vitamin A deficiency and its effects on human health are briefly introduced. Vitamin A deficiency can severely affect physical and mental development, particularly in young children, including nutritional blindness in extreme cases. It also causes increased morbidity following common infectious diseases. Vitamin A deficiency has thus received increasing attention as a public health issue since the 1990s.

Vitamin A is a fat-soluble vitamin that occurs naturally in animal products such as eggs, milk, meat, and liver. One of its precursors, *ß*-carotene, occurs in certain plants and plant products, particularly in orange-fleshed fruits and dark green leafy or orange vegetables. Examples are squashes, mangoes, carrots, red palm oil, spinach, and other leafy vegetables, as well as OFSP.

Approaches to combatting Vitamin A deficiency entail food-based approaches and supplementation. Biofortification, or purposeful breeding and selection for increased micronutrient contents in staple food crops, is understood as a food-based approach that targets particularly poor rural populations of developing countries. Biofortification has been successfully applied in several staple crops, one of which is OFSP. Its effectiveness in reducing the incidence of Vitamin A deficiency in vulnerable population groups has been scientifically proven.

However, the approach is heavily criticized by some civil society organizations as reducing to a mere technical problem (e.g., breeding sweetpotatoes with higher *ß*-carotene content) the root causes of poverty and malnutrition. Dietary diversification has been proposed as an alternative; in practice, various paths are often combined. For example, OFSP is promoted as part of home and school garden projects that aim to enhance nutritional diversity and related knowledge in many African countries.

“Nutrition-sensitive agriculture” is presented as a system approach focusing on nutrition and health of individuals. One important insight gained through this type of research is that there are various interrelated pathways of how changes in farming practices or technologies can influence nutritional outcomes. Agroecological intensification (AEI), on the other hand, aims to make agricultural production more efficient (e.g., with regard to the capacity of production landscapes to provide ecological services or contribute to dietary diversity).

The CCRP-funded sweetpotato breeding project in Uganda was among the first of its kind in the country and on the African continent. Starting under primitive conditions in 1994, the project facilitated pioneering work by providing technical equipment and effectively linking researchers of Uganda’s national agricultural research system to an emerging international research community focused on this particular crop. Its funding period coincided with an era of rapid progress in plant breeding technology. The project enabled leading scientists of Uganda’s national sweetpotato breeding program to adopt the emerging technology and take part in the process, both with regard to contemporary molecular tools as well as to participatory approaches involving selection and variety testing in close cooperation with farmers.

As a result, twenty sweetpotato varieties were released in Uganda between 1995–2013, several of which were OFSP of a new variety type combining high *ß*-carotene content with a relatively dry and starchy texture, which is preferred by many consumers in African countries. Furthermore, breeding progress was achieved with regard to two major production constraints: sweetpotato weevils and SPVD, which is caused by several distinct virus types. On the way toward reaching these goals, basic research on sweetpotato genetics and metabolic pathways for relevant substances was progressively advanced, later allowing for the identification of molecular markers to facilitate characterization of germplasm and selection for related traits. Resistance in the field, however, is more complex and involves other factors (e.g., nutrient and water availability, soil structure, and the presence and behavior of virus vectors). Hence, the resistance of varieties observed in the field does not fully correspond to the resistance levels observed under controlled conditions. Farmers’ experiences with the newly developed varieties, particularly with regard to yield and levels of resistance, are thus variable and depend on specific site and climatic conditions.

The project further succeeded in enhancing the research capacities of individual researchers, including scientists of the national program as well as PhD and MSc students who later made careers in national and international research organizations. The NaCRRI in Namulonge became one of the world’s leading research institutes in the field of sweetpotato breeding and gained capacity to increasingly participate in international research networks and breeding initiatives.

Whereas the original focus of the breeding work was on developing multiple-resistant sweetpotato varieties of various types and for a range of agroecological conditions in Uganda, the focus shifted toward breeding and disseminating OFSP since biofortification started to become an attractive option for donors and research organizations alike. OFSP varieties that had been developed in Uganda were promoted or used for further breeding in other African countries via the International Potato Center (CIP). In Uganda, the dissemination of these varieties was hampered by a number of challenges, including the diversity of agroecological conditions and difficulty organizing the multiplication and distribution of virus-free planting material. For the dissemination of the OFSP varieties to farmers in Uganda, the project relied on NGO partners and HarvestPlus. As a result, the spread of these varieties has remained limited to those areas where these partners are active. The entire distribution system for OFSP planting material depends heavily on external funding as well as on the commitment and priorities of these partners and their respective donors. Any official structures for variety and seed quality testing and dissemination have remained underdeveloped. A risk at the end of the funding period is that previous achievements could again be lost since most donors tend to concentrate their efforts on large-scale dissemination activities rather than on facilitating further progress in breeding and the development of sustainable institutional structures.

The project in Kenya followed a slightly different approach in that it addressed the management of sweetpotato diversity at various levels. The project consortium included the national research organization KARO along with national institutes in the neighboring countries of Tanzania and Uganda, as well as Europe- and US-based research organizations and CIP, the latter as a partner operating at regional and international scale. The project activities entailed the collection and characterization of sweetpotato germplasm and the building of a joint database to facilitate exchange of and access to information. The project further included input from social scientists, who contributed village-level surveys using participatory methods, including on women's and men's tasks, routines, and preferences relating to farming and livelihood activities. The concept of Farmer Field School (FFS) was used to create a participatory space for variety evaluation and experimentation that pertained as well to processing methods. The project also emphasized capacity building in production and dissemination of sweetpotato vines, activities developed in partnership with CIP and various NGOs.

The project reports revealed that the project activities were successfully implemented and results achieved for its various components; however, the task of integrating knowledge from diverse activities and partners, including researchers, NGO staff, farmers, and processors, into ongoing project activities had possibly been underestimated in the proposal. Little evidence exists of mutual learning at higher levels, even though it may have occurred among those directly involved in the activities. An intended second project phase was not funded by the CCRP, stopping the project after only four years.

The CCRP-funded sweetpotato project in Burkina Faso targeted the entire OFSP delivery chain. It was based on the introduction of several OFSP varieties via CIP, including some that originated from the breeding work in Uganda. The project activities entailed variety evaluation at several locations and under a range of agroecological conditions. Various agronomic practices were tested, partly in cooperation with farmer groups. Special focus was put on product development and enhancing the content of nutritionally valuable components in processed products (e.g., the contents of *ß*-carotene and antioxidants). Project activities included large-scale awareness campaigns and promotional efforts for OFSP in general. The project could build on the long-standing experience of one of its partners, Helen Keller International (HKI) in Burkina Faso, particularly with regard to the promotion of nutritional and health-related knowledge and issues. In this project, cross-institutional learning and cooperation appear to have taken place in spite of the reported challenges and the time demanded for coordination. Participating researchers stated that together they achieved more and in less time than they would have be able to do on their own. An identified weakness was the informal involvement of farmers, their roles and responsibilities insufficiently clarified. The production and marketing of sweetpotato roots remain a challenge because of risks involved at various nodes of the delivery chain; however, in the focus region, OFSP was generally accepted by many people and grown by farmers, at least on small plots, to meet their families' requirements.

In Chapter 6, the results are discussed in relation to the projects' contributions to breeding progress achieved in sweetpotato, their potential to address Vitamin A deficiency, their ways of addressing linkages between agriculture and nutrition, and the project design.

Lessons learned (Chapter 7) addresses major problem areas for developing OFSP supply chains, one being the high seed cost in relation to the product value and risks involved in OFSP production and marketing. Value-chain development and improved nutritional outcomes for vulnerable groups through promotion of self-consumption are presented as potentially conflicting goals. Issues such as resource endowment for different groups of actors to ensure that they can benefit from such approaches require consideration. Seed system development for OFSP planting material involves several challenges, particularly the need for developing adequate infrastructure for multiplication, quality control, and marketing of vines. The present distribution system depends heavily on the priorities of external actors (e.g., NGOs and their respective donors). Long-term funding of projects can effectively help reach impact at larger scales. Assimilating expertise on the implementation of participatory multi-actor projects involving non-academic partners could help make the project activities more relevant to farmers and their market partners. Lastly, system perspectives and gender aspects could be better integrated in future projects.

Our main recommendations with regard to future CCRP funding strategies are to:

- Continue long-term funding and nonmonetary support to maximize impacts;
- Invest more time and resources in a project pre-phase to ensure that all partners needed to achieve the desired change are identified and, whenever possible, formally linked to the project and its management structures;
- Consider full budget funding in order to ensure that the projects' quality and impact are not limited by a lack of resources;
- Consider professional project coordination in order to relieve scientists from this task, particularly in the case of larger projects involving multiple actors;
- Achieve more clarity on the resources required by each partner to participate in the research;
- Place greater emphasis on the integration of diverse knowledge and co-innovation of solutions to the problem or issue addressed;
- Better address influencing macro factors to facilitate impact at larger scales;
- Make a gender perspective mandatory for all future projects (e.g., by assessing its relevance for all project objectives, activities, and outcomes when establishing the proposal and throughout the project's lifetime).

Some of the above recommendations are already practiced in current CCRP funding strategies.

2 STUDY INTRODUCTION AND BACKGROUND

The McKnight Foundation's Collaborative Crop Research Program (CCRP) supports place-based, collaborative agro-ecological systems research and knowledge-sharing that strengthen capacities of smallholder farmers, research institutions, and development organizations, the goal being to improve food and nutrition security for vulnerable populations. CCRP grantmaking and non-grant support is provided through four Communities of Practice (CoP): one in the Andes and three in Africa (Eastern Africa, Southern Africa, and West Africa). The program has evolved and refined its organizational structure and focus over its history, but has always maintained its original intention of helping farmers feed their families.

In order to assess the efficiency and effectiveness of the CCRP approach as evidenced by the accomplishments and contributions of selected CCRP-funded projects, The McKnight Foundation commissioned a series of case studies. The case study presented here focuses on the three CCRP-funded projects in Uganda, Kenya, and Burkina Faso below, although the primary emphasis is on the Uganda-based project.

1. "Development of High Yielding, Multiple Pest-Resistant Sweetpotato Germplasm" (Uganda), which was funded 1994–2014
2. "Assessment and Utilization of Eastern African Sweetpotato Germplasm" (Kenya), which was funded 2001–2005
3. "Promotion of Orange-Fleshed Sweetpotato to Control Vitamin A and Antioxidants Deficiencies" (Burkina Faso), which was funded 2005–2013

3 OBJECTIVES

The overall aim was to analyze the ways in which the CCRP's financial and non-financial support have benefited the projects' and organizations' research and development (R&D) capacity over time. The assessment sought further to review the impact of the projects' applied research and how it facilitated the development and spread of technology, food security, and improved farmer livelihoods.

The objectives covered four areas, those being to:

1. Introduce and describe the background of issues and general context,
2. Describe the project results,
3. Assess the contributions of the CCRP to the projects' accomplishments, and
4. Define program recommendations for current and future CCRP support.

4 METHODS

4.1 GENERAL METHODOLOGICAL APPROACH

The focus of the data collection for this case study was on those communities and institutions that were directly involved in project activities and their immediate surroundings. A broader assessment of impacts *beyond* the areas where project activities took place could not be provided, except by referring to data from other sources.

Information was sought 1) in communities where the projects had been active, based on voluntary participation, 2) at public places (e.g., markets, based on spontaneous and voluntary participation), 3) through cooperation with other organizations (e.g., if they were promoting OFSP varieties that had been developed by the CCRP-funded projects under study), and 4) based on publications, reports, and other written documents.

The fieldwork relating to the second objective (assessing the contribution to production and consumption of OFSP) was done in Uganda and Burkina Faso but not Kenya. The contribution to improved nutrition could only be indirectly assessed (e.g., based on interviews and existing data made available by project partners and organizations involved in the implementation). Given that we needed to organize the fieldwork independently with different teams for East and West Africa, we separated the case study into seven smaller subprojects (Figure 1).

4.2 METHODS APPLIED

A mixed methodology was applied to target the different components of the study, combining qualitative and semi-quantitative tools and building on the extensive data already available in written form, including quantitative information (e.g., on adoption and spread of OFSP varieties in various countries).

DESK REVIEW OF WRITTEN DOCUMENTS

Written documents such as project reports, scientific publications, and information from internet databases were retrieved and assessed in order to describe the general context as well as the projects' rationales, development, and outcomes.

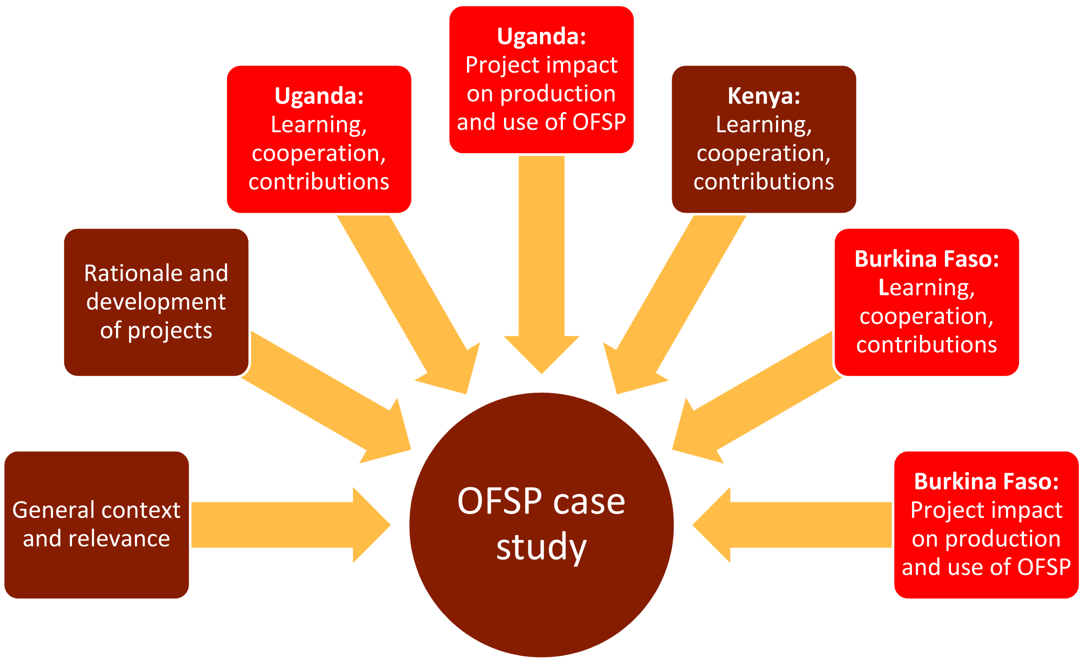

Figure 1: Overview of the different components contributing to the OFSP case study. The components in red were done on-site and based on written documents. Those in brown were based on written documents only.

INTERVIEWS AND FOCUS GROUP DISCUSSIONS

In order to explore the project partners' views on cooperation, learning, and contributions to project achievements, individual and group interviews were conducted and addressed the following:

- What has or has not been achieved relative to the original project goals?
- What have been supportive and hindering factors?
- What has been learned?

- What has been the specific contribution of the CCRP approach to the project accomplishments in terms of funding and other support provided (e.g., capacity building, networks)?
- What has been the impact of the CCRP support on the broader institutional development (e.g., networks, capacities)?

See the Annex for travel itineraries and lists of all the interviews conducted.

FOUR SQUARE ANALYSIS

The projects' impact on production and use of OFSP was assessed based on semi-quantitative assessments in villages, complemented by informal interviews with traders at vegetable markets and other actors along the supply chain (e.g., representatives of food processing companies and restaurant managers).

For the work in villages, the participatory tool Four Square or Four Cell Analysis, which is appropriate for generating semi-quantitative data on variety use and related characteristics (Sthapit et al., 2006), was used. In its participatory distribution analysis, the different sweetpotato varieties used by the farmers are listed and then allocated to one of the following four categories:

1 Used by many farmers on large area	2 Used by many farmers on small area
3 Used by few farmers on large area	4 Used by few farmers on small area

The resulting matrix was used as a starting point to explore in more detail the relative importance of OFSP varieties in the villages compared to other sweetpotato varieties used. It led to a discussion on the advantages and disadvantages of OFSP, particularly with regard to agronomic performance, production constraints, storage, processing, consumption/marketing, and income. It also revealed for which groups of people certain varieties are important and why.

GENDER ASPECTS

Gender can be expected to be an important social category for agricultural production and marketing issues as well as for consumption and nutrition patterns in African farming and food systems. The teams conducting fieldwork in Uganda and Burkina Faso were gender-mixed, with both members possessing specific expertise and experience in gender-sensitive research. The field teams took care to encourage participation of both women and men, reflected jointly on gender differences, and reported on the results. Some focus groups in Burkina Faso were held with women only since they had been identified as the main target group for project activities. Details on site and interview partner selection are presented in the next section.

4.3 SELECTION OF SITES AND INTERVIEW PARTNERS

Since the projects targeted the entire supply chain from identification of local and foreign cultivars, breeding and selection, multiplication of propagating material, agricultural production, storage and processing, marketing, and, finally, use, a first step for identifying interview partners was to identify actors along this chain who had been involved in the project work (Figure 2). Interview partners were then identified for each link of the chain.

Figure 2: Steps of the OFSP supply chain.

Moreover, partner organizations that merely facilitated activities of or cooperation among these actors were identified (e.g., NGOs that promoted consumption and use of OFSP). Staff members of such organizations were also interviewed with the aim of exploring their perspectives on supporting and hindering factors.

In Uganda, the fieldwork was conducted in the capital city of Kampala, at the National Crops Resources Research Institute (NaCRRI) at Namulonge, as well as sixteen sites in eleven districts covering three regions of Uganda (central, eastern, northern). Parts of southwestern Uganda were remotely explored via phone interviews and e-mail with researchers and project representatives working in the region but without talking directly to people at the village level.

In Burkina Faso, the fieldwork was conducted in the capital city of Ouagadougou, in the town of Léo, capital of Sissili province near the border with Ghana, and in the villages of Boura, Sagalo, and Yoro, all located in Sissili province and where the relevant project activities had been. See the Annex for maps showing the sites visited by the field teams in Uganda and Burkina Faso, along with detailed lists of interviews conducted.

Sites were identified with the help of the above-mentioned partner organizations. They were not selected randomly but followed a snowball-sampling pattern. They are not representative for the respective geographical region. The interviews conducted can help understand the results and outcomes of interventions of the partner organizations at these particular sites, but they do not allow for drawing conclusions for other places where such interventions did not take place.

In Uganda, the selection of sites and interview partners in villages was informed by the following considerations:

- Covering different agroecological zones
- Covering villages where different partner organizations had implemented the project work
- Having diverse focus groups with male and female participants

In Burkina Faso, where there was a stronger focus on nutrition aspects, an additional criterion was included:

- Conducting focus groups with identified vulnerable groups, in this case women with preschool-aged children

5 RESULTS

This chapter includes the description of the case study context (Section 5.1) and the results of country studies from Uganda (Section 5.2), Kenya (Section 5.3), and Burkina Faso (Section 5.4). The main emphasis is on the description of the context and the Uganda case study.

5.1 DESCRIPTION OF CASE STUDY CONTEXT

The case study context is described based on three subtopics: sweetpotato as a crop and sweetpotato breeding; Vitamin A deficiency, its perception as a public health issue, importance in Africa, and related strategies; and concepts that integrate agriculture and nutrition, such as nutrition-sensitive agriculture and AEI.

SWEETPOTATO AND SWEETPOTATO BREEDING

SWEETPOTATO AS A CROP

Sweetpotato is known as a food security crop, given its early maturity (three to four months in early varieties), relatively high yield per area, and adaptability to poor soil fertility conditions. Under favorable conditions, sweetpotato produces more edible energy per area and time than any other major food crop and needs a lower amount of water per amount of food produced. Both roots and leaves are edible and nutrient-rich. Even though use in processed form exists, the crop is mainly grown for fresh consumption of roots and leaves. In some countries, particularly in Asia, both are also used as animal feed.

Sweetpotato is grown on 9 million ha in 117 countries and in tropical as well as subtropical regions, mainly Asia. Trends show a decrease in area in Asia and an increase in Africa. Compared to other regions, storage root yields are lowest in sub-Saharan Africa (according to FAOSTAT data (2011) presented in Grüneberg et al., 2015). Yields are up to four times higher in such Asian countries as China, Japan, and South Korea. Large yield differences exist between the countries on which this case study focused: in Uganda < 5 t/ha, in Mali 15–20 t/ha, and in Kenya 10–14 t/ha. It is estimated that 15 t/ha can be obtained even on poor soils by using improved varieties, clean planting material, and appropriate cultivation practices (Grüneberg et al., 2015).

Sweetpotato varieties are commonly grouped according to flesh color, dry matter content, total sugar content, and taste. In some cases, the time to maturity is also considered. Originally, two general categories were distinguished: the so-called dessert type (high in *ß*-carotene, low in dry matter content (<30 percent), moist texture, sweet taste) and the staple type, which is low in *ß*-carotene and high in dry matter content (>30 percent) and thus has a dry texture and starchy taste. Consumers in most countries of sub-Saharan Africa tend to prefer the latter. Varieties with high dry matter and starch content are usually low in sugar and *ß*-carotene content and *vice versa*, so that a negative correlation exists. However, there are also genotypes that combine these characteristics. Hence, the newly developed OFSP varieties in breeding programs of sub-Saharan Africa are of a third variety type called OFSP dry and starchy (Tumwegamire, 2011, cited in Grüneberg, 2015). Purple-colored variety types also exist (Grüneberg et al., 2015).

SWEETPOTATO BREEDING

Sweetpotato has long been neglected as a target crop of breeding programs. Sweetpotato breeding has, however, gained impetus since the early 1980s, with the Xushou Institute in China and Louisiana State University and North Carolina State University (both in the US) taking on leading roles, along with the NaCRRI in Uganda, since the early 1990s. With sweetpotato as one of its mandate crops, the International Potato Center (CIP) was founded in 1971. Sweetpotato breeding programs have in the past been largely driven by public funding, with private donors such as The McKnight Foundation, the Bill & Melinda Gates Foundation (BMGF), and the Rockefeller Foundation more recently having an increased presence (Gitomer, 1996; Grüneberg et al., 2015). The McKnight Foundation was among the first donors to invest heavily in sweetpotato breeding in sub-Saharan Africa. Earlier investments were limited and short-term support only.

Improved yields, quality, and resistance to various biotic and abiotic stresses have been the main breeding objectives addressed. Sweetpotatoes are known to be affected by a range of bacterial, fungal, and viral diseases as well as insects, of which five pests and diseases are known to be economically important: 1) sweetpotato virus disease (SPVD), 2) weevils, 3) nematodes, 4) Alternaria blight, and 5) Fusarium wilt and canker. The main abiotic stresses affecting the crop are drought, heat, cold, and salinity (Grüneberg et al., 2015).

SPVD often causes serious yield losses, especially in high virus-pressure zones of sub-Saharan Africa. Viruses are transmitted by sucking insects, such as white flies and aphids. Co-infections with several different viruses are frequently observed. Different virus strains may occur that make breeding for resistance even more complicated. Genetic diversity for virus resistance exists but can easily break down, and high resistance levels appear at low frequencies in breeding populations. Even though progress has been made in breeding for virus resistance, continuous efforts are required. Since sweetpotatoes are commonly propagated vegetatively by using stem cuttings, it is difficult to maintain planting materials "clean" where disease pressure and transmission rates are high. Unlike common grain crops, for examples, this fact poses particular challenges to seed system development.

In regions with pronounced dry season, sweetpotato weevils are an important constraint. The main damage is caused by the larvae, which tunnel inside roots and stems, whereas adult weevils feed on the leaves and cause less damage. Progress toward breeding weevil-resistant sweetpotato varieties has remained limited despite several decades of resistance breeding. However, certain variety types seem to be less affected, particularly starchy ones with high dry matter content, of which storage roots develop deep in the soil.

In cooler temperate and subtropical climates, or tropical highlands, fungal diseases are also important, particularly *Fusarium* and *Alternaria* sp. Developing improved sweetpotato varieties for cooler climates (e.g., tropical highlands) is also a known constraint of breeding programs. Sweetpotato typically responds to cooler climate conditions by extensive upper biomass production and reduced storage root production. Only a few national breeding programs address such conditions (Andrade et al., 2009).

Since the late 1990s, researchers from international research centers of the Consultative Group for International Agricultural Research (CGIAR), national research organizations, NGOs, and funding organizations have worked together to breed and promote new OFSP varieties rich in *ß*-carotene as a promising way to boost intake of Vitamin A and energy. These initiatives resulted from increasing awareness of Vitamin A deficiency as a public health issue (see below) and were mainly driven by donor policies.

They could at that time build on results achieved by the CCRP-funded project work in Uganda (Section 5.2). This project had a broader focus and was not initially specialized on OFSP; however, a range of OFSP varieties, besides several white- and yellow-fleshed varieties, had been developed or identified in the project and were thus used directly or as breeding material in other initiatives assumed later.

HarvestPlus, officially launched in 2004, was the first large international program focusing on OFSP (besides some other crops). Being part of the CGIAR Research Program on Agriculture for Nutrition and Health (A4NH), it has facilitated alliances and exchange of breeding materials between the CG centers and national breeding programs in sub-Saharan Africa. In 2009, the Sweetpotato Action for Security and Health in Africa (SASHA) project, funded by the BMGF, along with projects under the Alliance for a Green Revolution in Africa (AGRA), funded jointly by the Rockefeller Foundation and BMGF, helped organize comprehensive decentralized sweetpotato breeding programs (Grüneberg et al., 2009) since lack of breeding infrastructure was identified as a major challenge for unleashing the potential of sweetpotato in sub-Saharan Africa (Andrade et al., 2009). Four sweetpotato breeding platforms were established, one of which was the NaCRRI in Uganda. (The others were in Peru, Ghana, and Mozambique.) The emphasis was on providing national breeding programs in twelve countries with improved true-seed populations (Grüneberg et al., 2015). The SASHA project was closely linked to the Reaching Agents of Change (RAC) project, funded by BMGF, that had a strong component on advocacy for linking OFSP to public health programs and on promoting its use in agriculture and nutrition.

VITAMIN A DEFICIENCY AND RELATED STRATEGIES AND DISCOURSE

VITAMIN A AND VITAMIN A DEFICIENCY

Vitamin A is a fat soluble vitamin that exists in several forms in both animal foods (as retinol, retinal, or retinoic acid) and plant foods (as carotenoids). Good sources include meat, fish, poultry, and dairy. Carotenoids can also be found in dark green and yellow- or orange-colored fruits and vegetables (Annan, 2011).

For children, lack of Vitamin A causes severe visual impairment and blindness and significantly increases the risk of illness and death from common childhood infections such as diarrhea and measles (WHO, 2015a). Vitamin A deficiency can be one factor contributing to retarded growth, a phenomenon referred to as stunting (UNICEF, 2015).

For pregnant women, Vitamin A deficiency occurs especially during the last trimester, when demand by both the unborn child and mother is highest. Moreover, Vitamin A deficiency has been associated with increased rates of mother-to-child transmission of the human immunodeficiency virus (HIV) as well as increased disease progression in HIV-infected adults and immune function in general (Annan, 2011; WHO, 2015b).

Malnutrition, infection, and immune competence appear to be synergistically related, which is of particular importance in situations where malnutrition, poverty, and poor access to healthcare prevail and affect large parts of the population (WHO, 2009; Annan, 2011).

VITAMIN A DEFICIENCY AS A PUBLIC HEALTH ISSUE

Vitamin A deficiency has been conceptualized and addressed as a public health issue since it was first realized in the 1980s that children with eye symptoms of Vitamin A deficiency had a higher mortality than others in the same communities that did not have these signs (Bruins & Kraemer, 2013). This led to large-scale, community-based trials in various countries showing that Vitamin A supplementation of children and food-based interventions could significantly reduce child mortality and prevent blindness (Bruins & Kraemer, 2013).

As a result, controlling Vitamin A deficiency received more attention in national programs and initiatives of NGOs in many countries, in most cases targeting women and children. A special case is Helen Keller International (HKI), a private foundation focusing on nutrition and health and with long-standing special expertise in and a reputation for fighting causes and consequences of preventable blindness and malnutrition. HKI had since 1966 already—long before the issue attracted the attention of the global development aid community—successfully implemented programs to prevent nutritional blindness (HKI, 2014a).

The issue was also taken up by several global initiatives, including HarvestPlus[1] and Scaling Up Nutrition (SUN)[2], the latter starting in 2009, that focus on the entire delivery chain of nutritionally favorable crops such as OFSP to combat Vitamin A deficiency with a strong focus on promotion and dissemination.

IMPORTANCE OF VITAMIN A DEFICIENCY IN AFRICAN COUNTRIES

According to the World Health Organization (WHO), Vitamin A deficiency is a public health problem in more than half of all countries worldwide. A map published 1995 shows that all African countries for which data were available were mildly, moderately, or severely affected (WHO, 1995; Figure 3). According to data focusing on vulnerable groups within populations, Vitamin A deficiency[3] was found in 44 percent of preschool-aged children in Africa in the period 1995–2005 (=56, 4 million children), and in 13 percent of pregnant women (=4, 2 million women) (WHO, 2009).

Uganda, Kenya, and Burkina Faso, the three countries on which this study focused, were among the most severely affected, with Vitamin A deficiency appearing at clinical and subclinical levels when the project started. Data from Kenya (WHO, 2006a), for example, indicated that more than 80 percent of the population suffered from subclinical Vitamin A deficiency[1].

[1] www.harvestplus.org
[2] www.scalingupnutrition.org
[3] Defined as serum retinol <0.70 µmol/l.

The map shows that Vitamin A deficiency prevailed under a range of agroecological conditions, including in tropical countries, where fruits and vegetables are theoretically available throughout the year but not necessarily accessible for all parts of the population. The relation between micronutrient deficiencies and poverty has been studied in Bangladesh, where prices of nearly all other food items are high compared to rice and wheat. Because of the high prices, poor people, therefore, cannot sufficiently consume these food items even though they are aware of their nutritional value (Jaim 2002, cited in Rahman & Islam, 2013). Kennedy and Moursi (2015) found that the income of the world's poorest people would need to increase tenfold or more to enable them to meet their dietary needs through regular purchase of high-nutritional value food products. On the other hand, higher income and food expenditures do not necessarily result in more healthful diets, owing to higher consumption of processed food and changes in nutrition styles (Keding et al., 2013).

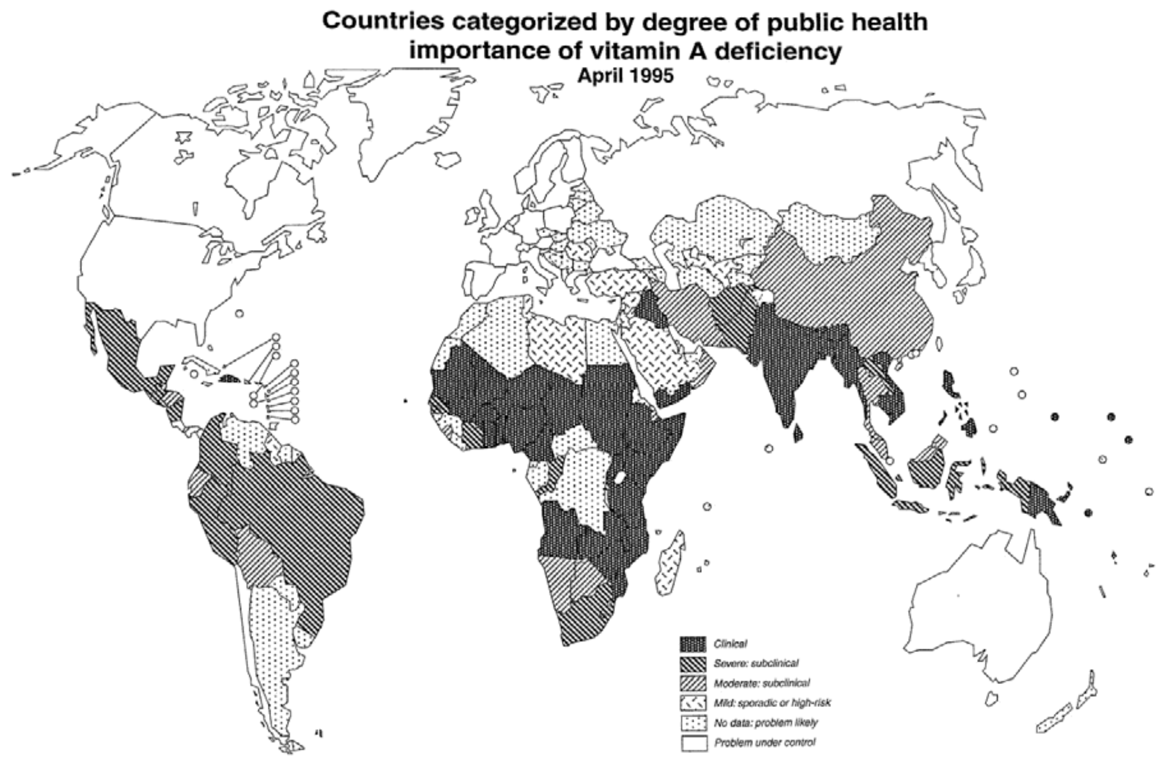

Figure 3: Global prevalence of Vitamin A deficiency 1995 (WHO, 1995).

The focus of public health programs on women and preschool-aged children should not lead to the assumption that only these groups are affected. In Kenya, for example, 42 percent of men had a low Vitamin A status compared to 51 percent of women (WHO, 2006a). In Uganda, 26 percent of women and 30 percent of men were affected (WHO, 2006b)[4], with rates of Vitamin A deficiency being higher among vulnerable population groups (36 percent of women ages 15–49 years and 38 percent of children ages 6–59 months, according to official health statistics (UBOS & ICF, 2012). In Burkina Faso, nearly 40 percent of schoolchildren (average age of 11.5 years) were found to be Vitamin A deficient in a study covering the nutritional status of children in urban and peri-urban areas of the capital city Ouagadougou (Daboné et al., 2011).

[4]No data are available for Burkina Faso in this database.

STRATEGIES TO COMBAT VITAMIN A DEFICIENCY AND RELATED DISCOURSE

Strategies to combat Vitamin A deficiency are broadly divided into supplementation and food-based strategies. Supplementation includes intermittent high-dose Vitamin A medicines given to young children (usually up to 5 years of age). It also entails lower Vitamin A doses given to women during pregnancy.

Vitamin A supplementation has proved effective in significantly reducing child mortality and, in many cases, other symptoms associated with Vitamin A deficiency, such as night blindness and incidence of diarrhea and measles (Bruins & Kraemer, 2013). Its success depends on how well healthcare services are developed in a country and how effectively they reach the vulnerable groups.

For these reasons, supplementation can be combined with food-based approaches that entail a variety of measures, including fortification of industrially processed staple foods (e.g., cooking oils) with Vitamin A or the distribution of multi-micronutrient powders to help enrich normal food. Compared to supplementation approaches, fortification of industrially processed foods is less targeted toward vulnerable individuals. Some vulnerable groups may be insufficiently reached, for example, if they do not consume industrially processed foods on a regular basis, which is mainly the case for poor people in rural areas. The issue of why large segments of the population cannot meet their dietary needs with the normal food they consume is not addressed by such approaches (Bruins & Kraemer, 2013).

Here, the concept of biofortification of staple foods comes into play. Biofortification, again, means to, through selection and breeding, increase the micronutrient density of staple foods that are regularly consumed by vulnerable groups. In order to be considered biofortified, the micronutrient content of a crop should be increased through breeding so that it reaches half of the recommended dietary allowance (RDA) (Grüneberg et al., 2015). The idea is that the diets of poor people being mainly starchy staple crops, their consumption more or less remains stable even with fluctuating food prices (Kennedy & Moursi, 2015).

Biofortification has been applied to a number of staple foods, including rice, maize, wheat, beans, sorghum, pearl millet, cassava, and sweetpotatoes, and targeted various micronutrients besides vitamin A, among them iron, selenium, and zinc. It has been demonstrated in South Africa (van Jaarsveld et al., 2005), Mozambique (Low et al., 2007), and Uganda (Hotz et al., 2012) that OFSP can improve Vitamin A status in children and women. In a very resource-poor setting in central Mozambique, significant improvements in Vitamin A intake and serum retinol concentrations (a proxy for Vitamin A status) were achieved. Depending on the preparation, between 100 and 250 grams (1/2 to 1 cup) is required to provide the daily recommended amount of Vitamin A to children.

Critics of the biofortification approach fear that by promoting biofortified crops, attention will be diverted from the deeper-lying causes of hunger and malnutrition. Severely food-insecure people, goes the thinking, may suffer from other nutritional and health problems that would persist after their Vitamin A deficiency has been "fixed." Biofortification is also seen by some as further strengthening institutional structures that are co-responsible for poverty, malnutrition, and disempowerment of rural people (Daño, 2014; Holt-Gimenez, 2016).

Home and school gardens have been proposed as an effective means to promote dietary diversity and can result in improved nutrition and health, as has been demonstrated, for example, by Helen Keller International's Homestead Food Production and School Health programs (see examples presented by Jaenicke & Virchow, 2013; Sifri et al., 2003). These same programs could also serve as examples how biofortified staple foods such as OFSP could effectively be integrated into such initiatives. In 2008, at least fifty-nine development and promotion projects in sub-Saharan Africa focused on OFSP, many of them based on home and school gardens (Low et al., 2009).

In other publications, a shift away from the biofortification *versus* dietary diversity debate can be observed in the last decade. The previous focus on nutritional *inputs* was transformed into one on nutritional *outcomes* as reflected, for example, by the research priorities published by the CGIAR Science Council Secretariat (CGIAR, 2005). The decision to focus on human impacts rather than on the nutrient-enhancement of selected crops has allowed for greater discussion of cross-cutting issues crucial to nutrition, including gender and intra-household resource control, and led to a variety of attempts at framing causal pathways between agricultural interventions and nutrition (Webb, 2013).

APPROACHES THAT ADDRESS LINKAGES BETWEEN AGRICULTURE AND NUTRITION

NUTRITION-SENSITIVE AGRICULTURE

Nutrition-sensitive agriculture is a concept that aims to explicitly incorporate nutritional objectives into agricultural research and development agendas and to address the inter linkages between human nutrition, health, and environment. As one of their stated aims of the renewed focus on agriculture, many donor initiatives encourage agricultural policies and programs to become *"nutrition-sensitive"* (e.g., USAID 2011, cited by Webb, 2013) or, more specifically, to make *"agriculture work for nutrition"* (FAO, 2012). This focus corresponds to the CCRP's overall approach, which also mentions improved nutrition as a major objective for funding agricultural research (CCRP, 2015a).

Hammond & Dubé (2012) suggest a systems framework for food and nutrition security where the nutritional outcomes of individuals are put as the central issue in between three main spheres of influence: the agri-food, environmental, and health/disease systems. The agri-food system shapes the quantity and nutritional quality of food available to individuals at a given place and time. Individual decision-making is influenced by several other aspects that relate to access and utilization of food, such as food prices and distribution pathways, advertising, or marketing. The nutritional outcomes for individuals are further influenced by environmental factors such as climate, clean air, or drinking water, and by their access to and efficiency of the existing health care system. Identifying these links helps to bring important feedback loops into view. For example, ecosystems are closely interrelated with agri-food systems in that they affect production levels, macro- and microclimatic factors, and the availability of water for irrigation. In return, the agri-food system can have positive or negative impacts on ecosystems via pollutants and soil degradation associated with intensive farming. Demand on agri-food systems, if motivating unsustainable agricultural practices, can pose challenges to the health system and the environment.

Hawkes et al. (2012) suggest a conceptual framework for assessing research contributions to nutrition-sensitive agriculture that is similar to the above approaches but explicitly consider influencing macro-factors such as policy and governance. Problems occur *"when the links in a 'chain of evidence' or 'research chain' linking an intervention and a nutritional outcome is not complete."* Too many studies relied on *"simplistic associations"* and too few *"include all the necessary aspects of the research chain"* (Hawkes et al., 2012, cited by Webb, 2013).

Webb (2013) concludes that a common factor across frameworks for nutrition-sensitive agriculture is the understanding that agriculture can influence nutrition and health through multiple pathways. Only one of these pathways includes the consumption of food produced: Many of the links *across* major pathways apparently remained poorly understood. For example, increased consumption of a particular food item (e.g., a biofortified crop) does not indicate whether the overall quality of a person's diet or health status has improved, nor does selling a particular crop indicate whether a household's total income has increased or how inputs and returns are distributed among household members.

AGROECOLOGICAL INTENSIFICATION (AEI)

The concept of AEI, which underlies the CCRP approach, means improved performance of agricultural and food systems based on agroecological principles. Depending on the context, it may entail, for example, enhanced use of local resources, maximized returns from external inputs, improved stability and/or diversity of diets, or increases in resilience and environmental service provision from farmed landscapes. It is context-specific and, as such, requires a deep and evolving understanding of biophysical, socioeconomic, cultural, and other contexts in which a particular project operates (CCRP, 2015b).

What AEI means for a specific context or project needs to be continuously developed as a project evolves. For the projects under study, the concept was introduced too late for this to be done. In general, however, there is opportunity for plant breeding projects to contribute to AEI; for example, if varieties are developed that 1) are well adapted to site-specific conditions and biotic as well as abiotic constraints, 2) produce stable yields, 3) form part of diverse and resilient farming systems, and 4) have good post-harvest and processing quality and high nutritional value. Thus, genetic enhancement of crops is in line with this concept but requires a broader perspective on other aspects of farming and food systems, including complex yield *reducing* factors that make it difficult for smallholder farmers in sub-Saharan Africa to benefit from genetic improvements. Besides natural factors, these include capital and other resource endowment that tend to be insufficiently addressed by approaches that focus on improvement of farming practices and technologies alone (Tittonell & Giller, 2013).

5.2 SWEETPOTATO BREEDING IN UGANDA

The Ugandan-based project “Development of High Yielding, Multiple Pest-Resistant Sweetpotato Germplasm” started in 1994 and received funding from the CCRP until 2014. This exceptionally long period allowed for a deeper look at experiences and results achieved.

Sweetpotatoes are an important staple crop in Uganda, the world’s third largest producer country after China and Nigeria (FAOSTAT data, 2014). Cultivation takes place mainly in subsistence-oriented farming systems and usually without application of productivity-enhancing inputs or technologies such as fertilizers, pesticides, or irrigation. Farmers produce most of the propagating materials; commercial seed enterprises are of minor importance. The average reported yield of 4.2 t/ha is low compared to optimal conditions on research stations, where yields as high as 25 t/ha can be reached (Grüneberg et al., 2015).

Sweetpotatoes are grown in all parts of Uganda but based on different local cultivars, given the country’s high diversity of agroecological conditions (see also Annex). Most of the Ugandan sweetpotato varieties are white- or pale yellow-fleshed, which are preferred by farmers because they are considered more resistant to prolonged drought and disease stress and tend to have higher dry matter content compared to most orange-fleshed varieties. The higher dry matter content is associated with post-harvest quality (e.g., storability and cooking response). This perception may be one reason for the relatively low importance of OFSP varieties (other reasons are mentioned below). The proportion of OFSP of the total area grown with sweetpotatoes is estimated at around 5 percent (Grüneberg et al., 2015).

Research on root and tuber crops was given a low priority during the colonial era that prevailed in Uganda until 1962. A breeding program for cassava, sweetpotato, and yams was developed in the early 1980s at Serere Research station with funding from the International Development Research Center (IDRC) and technical support and training from the International Institute of Tropical Agriculture (IITA). The International Board for Plant Genetic Resources (IBPGR) supported the collection of more than 450 landraces of sweetpotato in 1985. The program was then moved to NaCRRI’s Namulonge Research Station in 1987 because of civil war in the northern parts of Uganda.

Sweetpotato research was reorganized as a separate program in 1989 based on collaboration between the national program and CIP. Two donors, the German agency for technical cooperation and development (GTZ) and Food Industry Campaign Against Hunger (FICAH), a private organization, provided funding.

Since then, steady progress was made in sweetpotato research with various support (training, equipment, germplasm) from different sources. Hence, the CCRP support to the sweetpotato program in Uganda starting in 1994 built on earlier support provided by GTZ, the United States Agency for International Development (USAID), IDRC, FICAH, CIP, and the government of Uganda.

PROJECT DESIGN AND APPROACH

The project's original focus was on improving sweetpotato germplasm to enhance yield and resistance against viral diseases and pests, particularly various types of viruses and weevils that affect the crop in the field and root-knot nematodes. The focus, therefore, was initially on agronomic performance and yield in the broader context of food and nutrition security.

Four specific objectives were presented:

1. Development of insect-resistant germplasm
2. Development of virus resistance
3. Improvement of yields and agronomic traits
4. Improvement of nutritional quality and storability

Given these foci, the breeding work did not initially focus on OFSP in particular but included a range of different germplasm from various sources, including local varieties and material obtained from genebanks such as those held by CIP. However, genotypes combining the above general breeding objectives with orange and yellow flesh color were tested in 2002 and 2003 and gained importance since then.

The project built on a close cooperation between the national sweetpotato breeding program in Uganda with researchers in the United States and the United Kingdom, with increasing involvement of researchers from other African countries. In fact, the project linked the NaCRRI in Uganda directly to leading researchers and institutes in sweetpotato breeding (see above).

Technical training and capacity building of young scientists was an important component of the project and offered interesting career opportunities for young researchers, given the international cooperation framework and technical support provided (e.g., adequate laboratory equipment, which was unusual for national research institutes in sub-Saharan Africa at the time of the project's start).

In line with the strong focus on breeding for resistances to viral diseases and insects, the scientific network established through the project mainly included breeders and plant pathologists. A broader interdisciplinary focus (e.g., including agronomists, post-harvest specialists, economists, or social scientists) was subsequently not developed.

The close cooperation between scientists of the national breeding program and farmers through participatory plant breeding and on-farm variety evaluation trials was pioneering work in Uganda and formed part of the rapidly evolving Participatory Plant Breeding (PPB) community that had emerged in various countries across all continents since the early 1990s. The collaboration between farmers and researchers was not, however, institutionalized and remained rather informal.

In relation to the above-mentioned objectives, this project setup was appropriate since the focus was clearly on crop improvement and not or not explicitly on institutional development or seed systems. However, the production and delivery of seeds and planting materials to farmers is a known bottleneck of many public breeding programs (van Mele et al., 2011). Since a formal system of distributing sweetpotato planting material in Uganda was largely absent, not addressing the production and dissemination of planting materials in a targeted manner constituted a severe risk for the projects' impact on the ground. The difficulties that exist for producing virus-free vegetative planting materials on farm pose further challenges in this regard (see also below).

OVERALL PROJECT DEVELOPMENT AND ACHIEVEMENTS

Much of the work during the first years focused on developing appropriate breeding and selection methodologies (e.g., selection for weevil and virus resistance) in cooperation between the NaCRRI, the North Carolina State University (US), Clemson University (based in South Carolina), and several other research partners. Pioneering work was done with regard to genetic mapping and analysis, with the aim to develop DNA-based markers for traits associated to virus and nematode resistance. In this regard, a milestone achieved by the project was the completion of a genetic map and increased development of quantitative trait locus (QTL) analyses in 2007/2008.

Progress was also reported with regard to field level resistances against viral diseases. Highly specialized methods for characterizing chemical plant components associated with weevil resistance mechanisms were applied. At the same time, basic infrastructure, such as electricity supply or internet service, remained unreliable and were repeatedly mentioned as impediments to the work. The project work thus continued to develop under difficult conditions but at a high scientific level, which is also documented through the high number of publications that can be related to it.

Between 1995 and 2013, twenty sweetpotato varieties were released in Uganda. The first set of varieties were released after thirteen years (NASPOT 7 to 10). These included the OFSP varieties Kabode (NASPOT 10 O) and Vita (NASPOT 9 O). Two other OFSP varieties, Ejumula and Kakamega, were not bred but identified from existing germplasm collections. All the varieties developed are available in the public domain. The CIP Catalogue for OFSP varieties from 2014 lists the NASPOT varieties 9 to 13 as well as Ejumula and Kakamega and several other varieties bred from these. Hence, the breeding work done at NaCRRI with CCRP support has resulted in a number of varieties that are now internationally available and used in breeding programs (Tumwegamire et al., 2014).

PhD and masters students were increasingly involved in project-related work. International relationships and also those with partners from other African countries developed as the project evolved, gaining impetus when the international R&D community discovered OFSP for integrated agriculture, nutrition, and health programs (Section 5.1).

The issue of seed system development came into focus from 2002/2003 onward, when a first set of improved and tested varieties was available for wider distribution. Farmers were trained in producing planting materials at farm level and encouraged to develop community-based seed systems. Since the project itself did not invest in the production and distribution of planting materials, the national sweetpotato breeding program linked up with partner NGOs to promote and disseminate the new varieties. The bulk of the sweetpotato planting material purchased and disseminated in 2002/2003 by NGOs was OFSP. Until present, a clear focus of the NGO partners is on disseminating only OFSP varieties based on their own program objectives. Thus, a distribution pathway for non-OFSP varieties from the national breeding program to farmers is largely absent in Uganda.

Economic gains for farmers through the selling of planting materials (vines) are mentioned in the 2004 and 2005 project reports: Farmer-to-farmer dissemination of the newly developed varieties had started to occur. However, this information was based on occasional observations rather than systematic assessments. A study on socioeconomic impacts of participatory plant breeding and adoption of improved sweetpotato varieties was mentioned in the report referring to the period 2005–2007. It indicated high adoption rates for farmers directly involved in the project activities. The report for the period 2009/2010 states that the multiplication of planting materials had concentrated on OFSP varieties.

Assessing the broader context (e.g., farming system, supply chain, and seed system analyses) as well as policy analyses focusing on nutritional and agricultural policies, right to food, gender equality, etc. in Uganda, has apparently not been the focus of the project, nor has it been considered for its further development. Rather, the increasing interest in the project outcomes (varieties) from large international donor initiatives appears to have contributed to a shift away from delivering varieties to farmers in Uganda. It is now about linking up with the international R&D community and delivering varieties and breeding materials to large international programs. Some of them (e.g., HarvestPlus and SASHA) have their own project activities in Uganda and are taking a leading role in promoting OFSP.

COOPERATION, COMMUNICATION, AND LEARNING

As mentioned, the project activities focused on the breeding work done at NaCCRI in partnership with universities and research institutes in various countries. In the project reports, the cooperation among the scientists is described as trustful and collegial. No major problems are mentioned that would have been attributable to a lack of communication or cooperation among the scientists involved. The cooperation seems to have worked well, with partner contributions being well managed and materials and information shared freely.

For the researchers and students at the national sweetpotato breeding program of Uganda, the project has clearly contributed to capacity building, learning, and career development. Several of the previous staff members and masters and PhD students later worked in international programs and research centers (e.g., CIP and IITA). The project has served as a steppingstone on their way toward achieving their professional goals.

Cooperation along the entire supply chain has not, however, been as close as among the researchers involved in the breeding work. The actor map, established based on interviews, shows which organizations in Uganda are working at various functional nodes of the OFSP supply chain, with a large number of other actors being involved (Figure 4). The project did not explicitly address facilitating cooperation, communication, and learning between these actors. The actors obviously share the goal of promoting OFSP but act on their own organizations' program objectives rather than on the basis of a shared strategy. Nor has there been a documented effort to integrate the learning experiences that may have occurred at different nodes of the supply chain. Such does not mean that this type of communication and learning has not occurred based, for example, on personal contacts, but it was not captured systematically.

CCRP CONTRIBUTIONS

The CCRP-funded project focused on the breeding work as such and not on downstream activities. As such, other actors were not found to be aware of having a role as partners of The McKnight Foundation or the CCRP; they rather considered themselves partners of NaCRRI.

Accordingly, the specific contributions of the CCRP to the project's achievements and outcomes could only be assessed based on interviews with researchers at CIP and NaCRRI. Here, the CCRP support was mentioned as having been much more than just funding of a project. Reports were read and discussed, and project activities monitored. This was helpful, particularly as it facilitated stepwise planning of the activities based on achievements and needs. The CCRP also supported the NaCRRI in establishing realistic budgets.

An important difference relative to other funding organizations was that funding was demand-driven: The researchers were asked what they needed to do their work, which is different from other funding schemes that simply define programs to which researchers may then apply. Researchers at NaCRRI subsequently felt that they were enabled to drive the agenda, facilitated and supported by the CCRP.

In sweetpotato breeding in particular, a lot of basic work had to be done since the crop biology differs from many other crops (e.g., grain crops) and had previously been neglected by donors. The CCRP partnership led to a dynamic process in which outcomes became visible and more people and organizations got involved.

Even though other funding organizations had provided grants, and in larger amounts, to the OFSP breeding work at NaCRRI, their engagement has not been as consistent as the CCRP funding. The latter was maintained for twenty years and resulted in the varieties and breeding materials now available in many countries and, via CIP, worldwide. Also important were the continuous investment in human capacities and material resources.

NaCRRI at Namulonge became a well-equipped, renowned research station connected to researchers and breeders in Africa, Europe, and America. Proactive linking to experts, universities, workshops, conferences, and ongoing studies occurred. This development was associated with growing social capital and helped establish a dynamic team of professionals working to apply innovative methods and pioneer new approaches. Such opened the way for new funding organizations and initiatives (e.g., cassava and banana breeding programs funded by BMGF).

Capacity building took place at all levels: researchers, but also PhD students, technicians, NGO staff, and farmers. Several members of the sweetpotato breeding team made important progress in their careers. Farmers were increasingly interested in cooperating with NaCRRI based on the new participatory approaches developed by the breeding team, which resulted in important mutual learning experiences. For example, breeders initially focused their attention on only three plant traits but learned that farmers considered more than fifty different plant traits in their selection decisions or assessment of varieties.

New, big actors came in to play their part in disseminating the OFSP varieties. They included HarvestPlus (established 2003), the Mama SASHA project operated by CIP (established 2009), and USAID under its Feed the Future initiative (established 2010). The growing international recognition and networking were definitely a major landmark, given the basic conditions under which the project work had started in the 1990s. It finally resulted in Robert Mwanga, PhD, being selected as one of four laureates of the World Food Prize 2016, along with colleagues from CIP and HarvestPlus, Maria Andrade, PhD, Jan Low, PhD, and Howard Bouis, PhD, for their pioneering work in OFSP breeding and dissemination.[5]

The project had already established its own international networks when the CCRP East & Horn of Africa CoP was established in 2007. However, there was no general spillover of spirit and approaches to the rest of the scientific community in Uganda, and much of the human capital left the organization with the people who were previously involved in the project as leading researchers or young scientists. The NaCRRI does not presently receive any large grants to continue the breeding work with the same intensity, and the funds presently available are often too small to produce visible progress. Most of the external

PARTNERSHIP

"Many donors have funded sweetpotato breeding but none was as consistent as McKnight. From 1994, there were funds that provided consistent research leadership in sweetpotato breeding teams. Because the funding was consistent and for a long time, it produced impact, in that twenty varieties of sweetpotatoes were released for farmers. […] Some of these released varieties have spread as far as Kenya, Rwanda, Tanzania, Ethiopia, and Ivory Coast, and are being used by NGOs within Uganda in their dissemination campaigns. Consistent, steady, and substantial support are needed for breeding programs. This is a lesson for all donors."

—Breeder

[5] https://www.worldfoodprize.org/en/laureates/2016__andrade_mwanga_low_and_bouis/

funding nowadays goes not to breeding but to dissemination activities. This, together with the shortcomings in the dissemination and marketing system, leads to a situation where there is a risk that previous achievements could be lost again.

HINDERING AND FURTHERING FACTORS FOR THE OFSP SUPPLY CHAIN IN UGANDA

For the different functional nodes of the supply chain, hindering and furthering factors were identified with the help of interview partners directly involved in the related activities.

GERMPLASM IDENTIFICATION AND BREEDING

Identifying germplasm for the breeding program was facilitated through cooperation with CG centers and genebanks held by foreign partner institutes. For the breeding work, capacity building, investment in equipment, long-term cooperation, and funding by the CCRP were mentioned as furthering factors (see also below: CCRP contributions). The local and national governments have been supportive to NaCRRI's sweetpotato breeding program, providing for the research station and paying salaries to regular staff members. Individual politicians—a member of parliament and some local government representatives—were also interested and supportive.

On the other hand, breeding for weevil resistance has turned out to be particularly difficult and no sustainable resistance has been identified so far, even after twenty years of breeding work. This may be because of a lack of expertise in that area (e.g., no biochemist involved) or because effective resistance mechanisms do not exist. Furthermore, little progress has been made for storability and cooking quality of OFSP varieties. In many cases, a negative correlation exists between high *ß*-carotene content and high dry matter content in the roots, which limits storability both in the soil and at the shelf.

Sweetpotatoes have ninety chromosomes, which is more than most other crops have. This makes the application of state-of-the art tools such as DNA sequencing more demanding and time consuming. Farmers' varietal preferences and needs vary considerably across the thirty-two officially identified agroecological regions of Uganda, where, for example, drought can occur at different stages of crop development and virus susceptibility depends, obviously, on environmental conditions. It is challenging for a breeding program to address this complexity and develop appropriate selection schemes (see also next section).

VARIETY TESTING ON STATION AND ON FARM

Given the highly diverse agroecological conditions in Uganda, the project initially pursued a participatory breeding approach. The cooperation with farmers was considered a furthering factor for the breeding program in that it helped the breeders to better understand adaptive and culinary traits the farmers were looking for. Establishing direct links between NaCRRI and farming communities in various parts of the country, often with NGO support, was new and created a pioneering spirit among those directly involved.

Longer term, the participatory breeding approach turned out to be too demanding on both farmers' and researchers' time and resources. The farmers were unable to engage in cultivating and screening a great number of early-generation crossbreeds on their farmland.

BREEDING FOR HIGHLY DIVERSE CONDITIONS

"Sometimes you take a high-yielding variety released from NaCRRI but, when you go to try it on farm, it yields so poorly that it frustrates and disappoints the farmers and you ask yourself, Why did I even come here?"

—*Breeding technician*

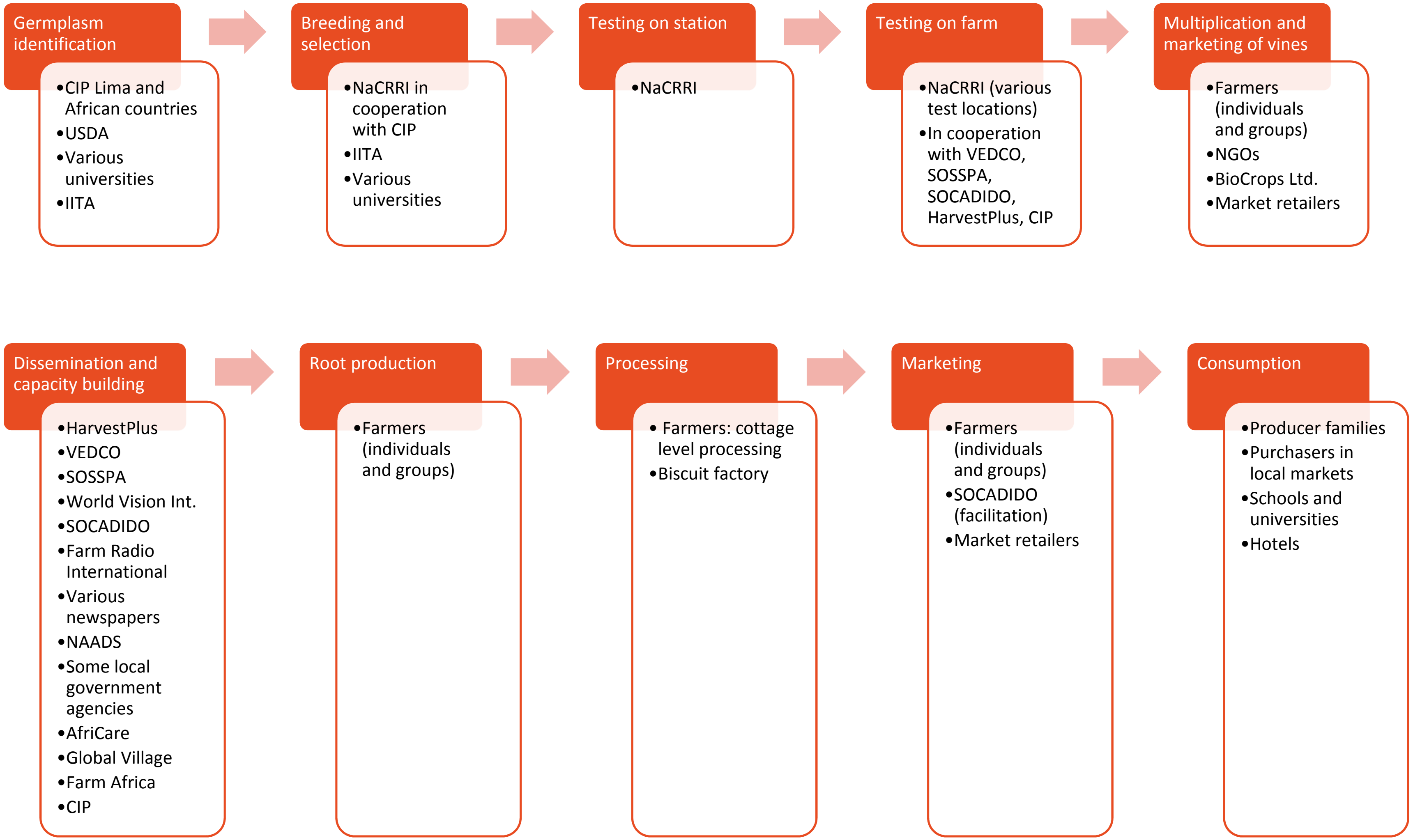

Figure 4: Actors in Uganda's OFSP supply chain (based on interviews; may not be comprehensive).

No incentives existed other than training, yet they had to provide labor and land. For the researchers it was difficult to follow up on these on-farm trials because of large distances and travel time. This is why the project shifted toward a participatory variety selection (PVS) approach, with farmers testing smaller sets of six to fourteen potential varieties that had already been pre-tested at NaCRRI.

In conclusion, a lack of resources and funding hindered continuation of the participatory on-farm selection in early generation breeding material. Breeding work was subsequently reorganized and adapted to the resources available to both farmers and researchers.

MULTIPLICATION AND MARKETING OF VINES

Sweetpotato being a vegetatively propagated crop, the multiplication of high-quality virus-free planting material is a particular challenge. Sweetpotato vines cannot be stored and distributed over large distances, as can the seed of grain crops. The vines are more susceptible to climate variability; for example, they can dry up during drought periods, potentially making it difficult for farmers to get good planting material elsewhere. Some farmer groups explained that vine production was only possible in their area where irrigation water was available (e.g., from swamps or rivers), but that there was in general a high risk of loss because of excessive heat and insect pests. Hence, in areas such as northern Uganda, where the dry season extends from November to March, the conservation of planting material is a huge challenge. In southwest Uganda, it is rather the scarcity of land that limits the farmers' possibilities of maintaining planting material in sufficient quantity.

Additionally, the production of virus-free planting material requires technical knowledge and equipment since virus-clean materials can only be obtained from tissue culture in laboratories or greenhouses. The production is expensive and results in higher prices for virus-free materials, which may be a problem for poor farmers unless they receive this material free from NGOs. In general, farmers have to renew their planting material after three to four growing cycles to avoid yield decrease from viral diseases. Hence, the biology of the crop, along with climate variability and biotic stresses, can be considered hindering factors for establishing an effective system for the multiplication and marketing of vines.

A well-organized formal seed system does not yet exist in Uganda, and particularly not for vegetatively propagated crops such as sweetpotato. The flow of planting material is shown in Figure 5. No effective system exists to control and ensure quality of planting materials (e.g., there are no certified virus-free vines of proven origin). Quality control relies mainly on informally developed and agreed-upon standards for the multiplication of vines, and some NGO field staff try to keep an eye on the application of these standards. Some multipliers received, as a gift from one of the NGOs, aphid-proof nets to protect the vines against insects, and considerable effort went into capacity building for growers to maintain clean planting materials.

Nevertheless, since selling vines is economically profitable, some multipliers lacking in responsibility are less-trained and too profit-oriented. As a result, it has happened that poor planting materials were sold and varieties were mislabeled or mixed, with losses occurring and customers losing trust. This occurred particularly in times of high demand (e.g., after drought periods). According to several NGO interviewees, without strict monitoring by their field staff, the quality of the planting material would rapidly decline. One NGO was considering establishing some sort of certification scheme to address the problem.

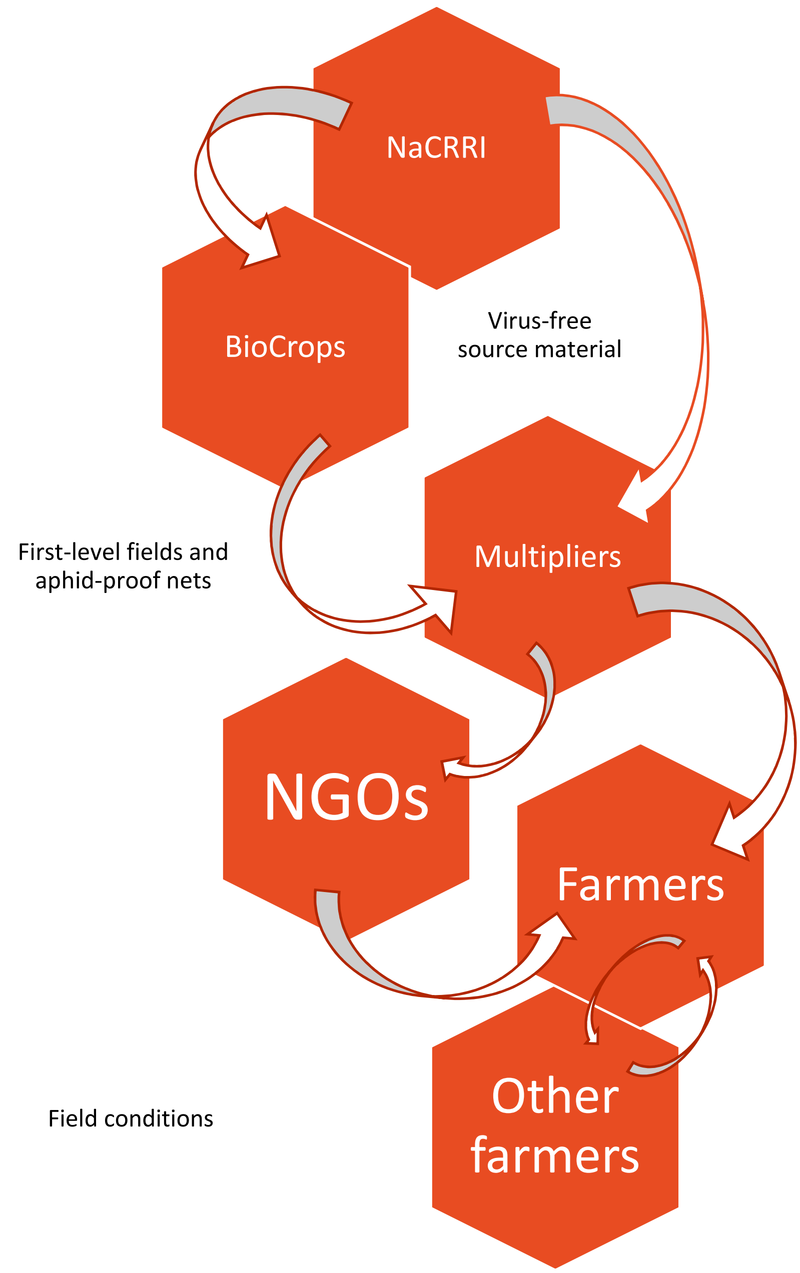

Figure 5: Flow of planting materials between different actors of the sweetpotato seed system in Uganda.

Paradoxically, the fact that the multiplication of vines is economically interesting is an incentive for people having enough land area and good relations with NGOs to engage in this type of business. One acre (=0.4 ha) can produce vines for fifty to a hundred acres (500–1,000 bags of vines); one bag can be sold at 20,000 Ugandan Shillings (US $5.65). So, from one acre, a multiplier can get returns of 10–20 million Uganda Shillings (US $2,862–5,652), and make a profit of 6–14 million Uganda Shillings (US $1,700–3,956), a very good return for farmers in Uganda.[6] On

[6] This information was provided by a farmer group.

the other hand, for planting one acre with new sweetpotato vines, a farmer has to invest about 200,000 Uganda Shillings (US $56.52).

It is nonetheless difficult to build up a functioning market for OFSP vines since many of the potential customers can get the vines free. Many different NGOs are engaged in the distribution of vines with the aim of reaching vulnerable groups and increasing the amount of OFSP produced. A policy stands that farmers who were given vines should supply two others with vines the next season, meaning that OFSP vines are more or less available for free or at much reduced rates to those targeted by NGO activities.

For private companies and multipliers, little incentive exists to engage in market development unless they sell to the NGOs who in turn distribute the material. Customers have various pathways for purchasing vines at different prices and conditions. The NGOs are big players in the seed system, which may bear risks for its sustainability since it largely depends on external funding. All told, the lack of coordination in the seed system results in a mix of hindering and furthering factors for the different actors involved.

DISSEMINATION AND CAPACITY BUILDING

A large number of NGOs engage in dissemination, demand creation, and capacity building with regard, for example, to root and vine production, marketing, and consumption. This is obviously a supporting factor since it offers possibilities to test new varieties under local conditions and gain contextual knowledge on their performance, multiplication, and use.

But hardly any official structures such as government agencies or extension services are involved. The National Agricultural Advisory Services (NAADS) was perceived by several interview partners as more or less dysfunctional. Even the quality checks for planting materials are performed by NGO staff rather than official authorities. The absence of state authorities and official institutional relationships makes the dissemination system vulnerable, since it depends on strategic decisions by the NGOs or their donors.

For example, NGOs only promote OFSP varieties; as a result, improved white- or yellow-fleshed varieties, which could have other advantages for farmers, do not reach farmers' fields at all. The dissemination and capacity building activities are narrowly focused on OFSP and nutritional impacts. A policy strategy to support OFSP breeding and dissemination activities at the national level is presently not in place.

ROOT PRODUCTION

Sweetpotato roots are mainly grown on small areas of one to three acres (equivalent to 0.4-1.2 ha). According to farmer groups, around 60 percent of sweetpotato growers are women. Yields of improved varieties can reach 15 t/ha in trials; however, the average in farmers' fields is 4-5t, according to several interview partners.

A furthering factor for root production is that the new OFSP varieties have a number of positive characteristics such as increased plant vigor (rapid soil coverage), early maturity, improved physical quality of roots (with regard to size, shape), and overall higher resistance to viral diseases. How much these advantages contribute to increased production, however, appears to vary a lot for different locations and years. In certain situations, OFSP varieties do not yield better than local varieties, even though there was agreement that in general they were higher yielding.

Given the large differences in agroecological conditions, information given by farmers on advantages or disadvantages of certain varieties varied. Drought, for example, can occur in various phases of plant development: 1) during the rainy season, reducing growth and yields, and 2) during the dry season, favoring weevil attacks because the soil cracks and the weevils easily enter the soil. Weevil infestation is still a big challenge, particularly in the semi-arid environments of northeast Uganda. Whether a variety is considered drought tolerant by farmers depends on a combination of factors, including when during the season the drought occurs, along with soil characteristics and pest incidence.

Some areas of Uganda are virus hot spots (e.g., central zone); others are less affected. This led to contradictory information regarding the assessment of virus-susceptibility of OFSP varieties. For example, the variety Kakamega was mentioned to be highly resistant in some villages and highly susceptible in others.

Local varieties can more easily be stored in the soil for up to six months, depending on the level of weevil infestation. Storability after harvest is short (one to two weeks) for both local and OFSP varieties. There has subsequently not been much progress in the newly developed varieties in this regard.

Very important for farmers is that, in order to benefit from the yield advantages of the OFSP varieties, they need to regularly renew the planting materials, at least after three to four harvests, with virus-free vines. Unless facilitated through NGOs, planting materials are not generally available. Paying for sweetpotato vines is not a custom and is a challenge for some, given the high production risks, low market value, and lack of stable demand for OFSP in markets.

The highly variable production conditions, along with persisting production risks, difficulties accessing clean planting materials, and low market value and demand are the main hindering factors for OFSP production in Uganda.

PROCESSING AND MARKETING

According to farmer groups interviewed, by far the biggest share of the OFSP produced is for self-consumption, with only the surplus being sold occasionally. The production volumes entering markets are therefore small and the supply is not stable.

OFSP are sold in local markets around those villages where they are produced. In general markets of Kampala or Mbarara, they are usually not found. In vegetable markets of Kampala, traders were aware of OFSP but did not offer them because of limited supply and unstable demand.

Since sweetpotatoes are in general not a high-value crop (but rather “poor man’s food”), the incentive to invest in improved marketing is low for farmers and traders alike. Once harvested, sweetpotatoes are quickly perishable and need to be sold quickly, producing a relatively high risk of loss. Lack of incentives stemming from low market value, unstable supply and demand, and related risks are the main hindering factors for marketing OFSP. This is why some farmer groups have contracts for delivering OFSP directly to school and university canteens. Such initiatives are facilitated by NGOs.

OFSP processing takes place mainly at cottage level. The OFSP are sliced, sun-dried, and milled into flour, which can in turn be used to prepare cakes, porridge, soup, chapatti, or juice. Processing helps the OFSP keep for longer time after the harvest period but is also labor intensive, given the rudimentary equipment used (e.g., manual graters at household level). With the exception of dried chips, most of the processed products are perishable. Juice, for example, ferments quickly if sterilization units are not available. Flour can be kept

OFSP SPREADING TO SPECIAL MARKET SEGMENTS

“I first got to know of the orange-fleshed sweetpotato when I saw a World Vision staff promoting it at this hotel during a workshop. I then asked him to supply us some of these potatoes. The OFSP was so much appreciated in this hotel because it cooks so fast [and] looks so good on a plate when serving customers. They have good taste. And because of their color, they arouse appetite and are good as garnish and in potato salad.”

—Hotel food and beverage manager

LACK OF AWARENESS

“Ugandans in general are not food conscious.”

—Director of radio program

for up to six months and fried chips for up to two years. Vitamin A content is reduced if OFSP are directly exposed to sunlight.

Food processing industries have expressed some interest, but amounts processed are very low. To increase the Vitamin A content, processed OFSP flour can be mixed with flours such as cassava, wheat, sorghum, or millet. Such fortified flour is used in school canteens and for malnourished HIV/AIDS patients in hospitals and nutrition clinics.

According to interview partners who represent food processing industries, the sweet taste of OFSP (compared to Irish potatoes) limits its usability. In terms of production and processing, the outlook improves by removing the sugars and making Vitamin A-fortified starch and anti-cancer starch from the purple sweetpotato, which has been documented to have anti-cancer anthocyanins. Currently, these options are only explored occasionally based on partnerships and are not yet valid for business ventures. A coordinated initiative to build up value chains for OFSP products in Uganda is not in place.

Awareness building by NGOs, including such media initiatives as "farm radio," are furthering factors, but the fact remains that minimal demand and awareness among the general population, coupled with OFSP products' low economic value, are hindering factors. Lack of policy support was also repeatedly mentioned in this context.

CONSUMPTION

Interview partners expressed positive and negative statements about the quality, taste, and nutritional value of OFSP.

Overall, the nutritional value was highlighted and sometimes underlined with examples: children being more healthy, growing more quickly (absence of stunting), and having fewer infectious diseases, particularly measles. With meals prepared from OFSP, small children take in enough food at once, making the time until they get hungry longer compared to other food preparations. Furthermore, OFSP need up to 50 percent less cooking time compared to other sweetpotato varieties.

OFSP consumption was associated by interview partners with better skin and eyesight as well as improved performance at school. That said, it was not always possible in the interview situations to clearly distinguish between the interviewees' own observations and the messages conveyed by NGO staff.

Negative statements concerning consumer perception included soft and watery texture, not tasty in general, and strange odor of the cooked meal. Market traders reported that some customers fear that OFSP is a genetically modified (GMO) crop with unknown potential side effects.

Children generally seem to like OFSP, given their sweet taste, attractive color, and soft texture. A university caterer reported that college students preferred fried OFSP chips. Adults, particularly men, tend to prefer traditional varieties, even though it was acknowledged that some OFSP varieties have high dry matter content that is not soft and moist as is often assumed.

The reputation of OFSP as a health food is a furthering factor for consumption, whereas deviant cooking characteristics and taste, as well as unknown properties, are rather hindering factors. The hindering and furthering factors identified for the various nodes of the OFSP supply chain in Uganda are summarized in Figure 6.

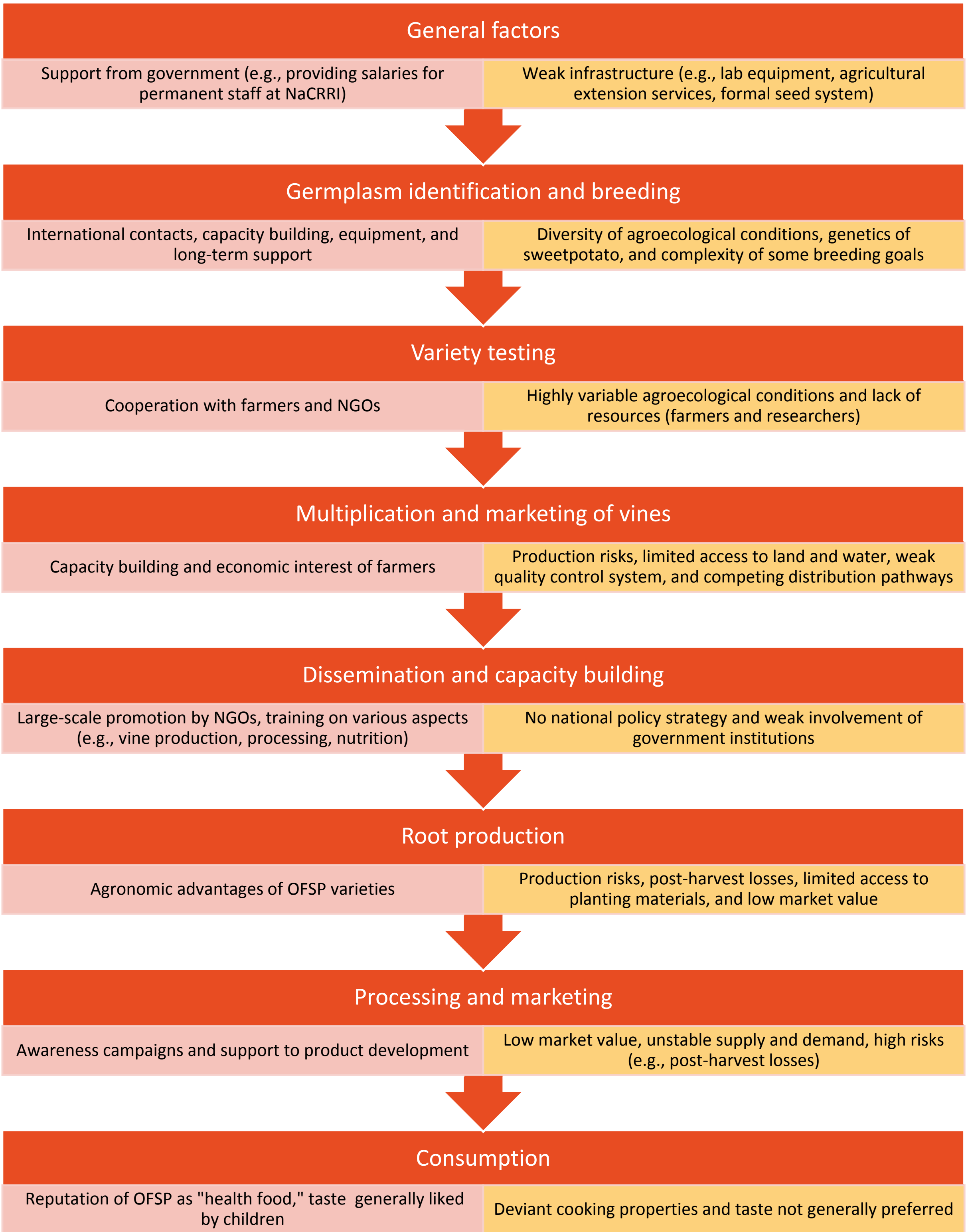

Figure 6: Summary of hindering and furthering factors at various nodes of the OFSP supply chain in Uganda; furthering factors are listed at left in pink, hindering factors at right in orange.

IMPACT ON PRODUCTION AND USE OF OFSP

The project's impact on production and use of OFSP was assessed in six selected villages based on the participatory distribution analysis tool (Four Cell Analysis) and interviews with farmers, market traders, and food processors.

PRESENCE OF OFSP IN FARMERS' FIELDS

A list of sweetpotato varieties grown in six villages of Uganda, categorized into local and introduced varieties, is presented in the Annex (Table A). None of the local varieties grown by the farmers is orange-fleshed, whereas all of the newly introduced varieties are OFSP. With fifteen to twenty-two cultivated varieties per village (six to fifteen local varieties plus six to nine introduced varieties), the varietal diversity in farmers' fields continues to be very high, even in villages where OFSP have been intensively promoted.

However, the participatory variety distribution analysis (Figures C1–6 in the Annex) revealed that the newly introduced OFSP varieties were overtaking the traditional varieties, so that the above-mentioned varietal diversity may be reduced over time. In Kakibu (Eastern region), four of the initially listed varieties (Okobo, Bunduguza, Arakaraka, and Abukokin) had disappeared from farmers' fields when the group discussed which varieties to assign to each of the four cells. Similarly, in Barr village (Northern region) the local varieties Oleke, Abututenge, Kakondo, and Anam oyito had nearly disappeared, even though other local varieties were still grown by many households on large areas.

In two villages Koro Bobi (Northern region) and Katente (Central region), only OFSP were grown on large areas, whereas local varieties were grown either by few (Katente) or many (Koro Bobi) households on small areas. In Kakibu (Eastern region), the only varieties being grown by many households on large areas were the newly introduces OFPS varieties.

Interviews with researchers and NGO staff supported the trend observed in the study villages: OFSP are increasingly taking over the local varieties in acreage and production volumes, but to varying degrees in the country's different regions, where the situation varies from village to village. OFSP are less common in southwest Uganda, due in part to the cooler climate to which the varieties seem to be less adapted. Land is particularly scarce in this region, limiting the possibilities to engage in the multiplication of vines.

A general trend seems to be that local varieties are still widely grown alongside OFSP in central Uganda, while OFSP varieties tend to replace the local varieties in Northern and Eastern regions, especially for their higher yield, early maturity, and provision of additional household income through the sale of vines. The adoption process for OFSP varieties depends strongly on NGO activities that promote and support OFSP multiplication, cultivation, and utilization.

Most varieties grown were used by women and men alike, while some were preferably grown by either women or men. Positive and negative features of OFSP versus local sweetpotato varieties stated by farmers, including production- as well as consumption-related aspects, are summarized in Table 1.

PRESENCE OF OFSP IN MARKETS

As described above, OFSP were not found to be present in general urban vegetable markets of Kampala and Mbarara. NGO staff conveyed that their focus had been on reaching rural populations and markets.

Table 1: Positive and negative aspects of OFSP versus traditional sweetpotato varieties as stated in interviews with farmer groups in Uganda.

	OFSP Varieties	Local Varieties
Positive aspects	• Higher yields (not always) • Virus resistance (some varieties) • Short (three to four months) growing cycle • Leaves edible for humans and livestock • Income generation for some farmers from selling vines • Nutritious value (Vitamin A)	• Particular features of each variety are known • Preferred taste and cooking characteristics • Better drought tolerance • Can be conserved in the soil longer
Negative aspects	• Storability in the soil inferior to local varieties • Taste not generally preferred • Taste of cooked meals deteriorates quickly • Vines costly; would not buy them if not provided by NGOs • Neighbors and passersby steal vines from multipliers' fields	• Lower yield (not always) • Smaller roots • Longer (four to five months) growing cycle

However, the production volume reaching markets, even in rural areas, seems to be low and variable, with individual farmers delivering only their surplus to markets during a certain period of the year. Unstable demand and supply make it more risky for market retailers to engage in OFSP compared to common sweetpotato varieties.

Individual farmers or market retailers did not report being able to sell OFSP at prices higher than local varieties. The advantages regarding nutritional quality are not particularly valued by market partners at present, except where direct marketing to school and university canteens and collective marketing initiatives could be established based on facilitation by NGOs.

Hence, selling OFSP roots does not presently seem to be a particularly lucrative business option in Uganda. Whereas the focus of the NGO activities is on vulnerable rural population groups, common supply chains lack coordination and incentives. General market and value-chain development are, however, not the focus of those actors presently involved in OFSP promotion and dissemination.

5.3 ASSESSMENT AND UTILIZATION OF SWEETPOTATO GENETIC DIVERSITY IN KENYA

The project "Assessment of Genetic Diversity, Farmer Participatory Breeding, and Sustainable Conservation of Eastern African Sweetpotato Germplasm" started in 2002 and was funded for a period of four years. The project consortium included the Kenya Agricultural Research Institute (KARI), the Lake Zone Agriculture Research and Development Institute of Tanzania, CIP, Louisiana State University (LSU), the Austrian Research Center (now Austrian Institute of Technology), a R&D company owned by the government of Austria, and private investors. Several other institutions collaborated with the project *inter alia* the national sweetpotato breeding program of Uganda.

The majority of project activities took place in Kenya. The case study thus focuses mainly on activities and achievements described for Kenya. Similar activities were, to a smaller extent, conducted in the Lake Zone of Tanzania. The national sweetpotato breeding program of Uganda and CIP were predominantly involved in the exchange and evaluation of germplasm. CIP also engaged in awareness building activities, whereas LSU and the Austrian Research Center were mainly involved in molecular germplasm characterization. LSU also contributed to the work on Geographical Information Systems (GIS). The project was implemented prior to the establishment of the East & Horn of Africa CoP in 2007.

PROJECT DESIGN AND APPROACH

The project aimed at improving regional sweetpotato productivity and sustainability through collaborative and participatory research on germplasm conservation, crop improvement, and development of technology for planting material production. It was meant to address these issues in the wider context of food security, disaster/drought preparedness, and agrobiodiversity loss.

The project's overall approach was to link local knowledge and user perspectives associated with sweetpotato germplasm with up-to-date breeding technologies in order to produce relevant germplasm and ensure that breeding progress takes a direction that is useful to farmers.

The project was built around three specific objectives: 1) participatory germplasm conservation, management, and utilization, 2) farmer participatory breeding, and 3) farmer participatory planting material production, management, and conservation.

Each objective was subdivided and addressed through detailed activities. For example, the first objective included assessments of genetic diversity and related local knowledge; development of a GIS database and identification of target agroecologies; germplasm collection, characterization, and participatory evaluation, and establishment of a regional germplasm bank and conservation networks, as well as awareness building and development of research capacities.

The second objective entailed assessment of farmers' variety choices and trait preferences, breeding activities to combine farmer-preferred traits with high *ß*-carotene content, and agronomic performance with farmer participation in selection and variety evaluation. Additionally, national breeding programs for root and tuber crops were to be strengthened through multidisciplinary collaboration and research capacity development.

The third objective focused on identifying opportunities and constraints in the conservation and production of planting materials, developing and testing strategies to overcome problems and constraints, and developing sustainable seed production schemes. All activities were planned based on participatory approaches, including for participatory technology development (e.g., Farmer Field School, or FFS). FFS was developed around twenty-five years ago by the Food and Agriculture Organization of the United Nations (FAO) and partner institutions to provide a risk-free setting in which farmers, guided by a trained facilitator, discuss, modify, and experiment with new agricultural management practices (FAO, 2015).

Overall, the project approach was ambitious and beyond the state-of-the-art. It assimilated new knowledge on interdisciplinary and participatory collaboration that had been developed in other projects and regions. Particularly, it addressed plant breeding and conservation and utilization of agricultural biodiversity in an integrated way, which could be considered a rather novel concept for plant breeding programs at the time of the project's start.

OVERALL DEVELOPMENT AND ACHIEVEMENTS

Given its focus on local knowledge and user perspectives, the project initially emphasized diagnostic work. For example, participatory rural appraisal (PRA) assessments were conducted in twenty communities of five sweetpotato production regions of Kenya and Tanzania, namely the Machakos district of Eastern Kenya, the Nyeri district situated in the central highlands, Migori and Rachuonyo districts in Southwest Kenya, and the Lake Zone of Tanzania.

These participatory surveys covered such issues as the importance of sweetpotatoes in local diets, the varieties grown in the past and present, and the main production constraints facing farmers. Information was collected on the on-farm, off-farm, and household responsibilities of men and women. The PRAs aimed at understanding the farming system as a whole and included aspects of social difference such as gender and age. Detailed information was compiled regarding resource endowment. Production costs, price-setting criteria, and price fluctuations were assessed for sweetpotato crops in various villages of Kenya and Tanzania. These data were documented in a detailed manner.

The main constraints identified relating to sweetpotato cultivation across locations were weevil damage, lack of planting materials, and marketing constraints. Decreasing yields and farm size, as well as reduction of water volumes in rivers and streams, were repeatedly mentioned as general problems farmers faced.

Participatory surveys were also used to compile information on popular varieties used and their characteristics. Based on this information, a sweetpotato germplasm collection was established by combining two different approaches: 1) collecting samples from roadsides every 5 km, and 2) collecting samples of all varieties listed by farmers during the PRA exercises. The sweetpotato varieties used by farmers included white-, yellow-, and orange-fleshed variety types with various skin colors, indicating that a high level of variety diversity existed in farmers' fields.

This germplasm collection, including more than 500 accessions from Kenya alone, was characterized morphologically. It was further used to study genetic diversity and distribution of traits by using molecular markers, with the aim of establishing a core collection for easier management of these genetic resources in the future. Collection sites were then linked to a GIS database that allowed for spatial display of accession data, thereby facilitating access and utilization based on a built-in ecological niche-modeling tool (see Villordon et al., 2005).

Through the breeding activities, high-dry matter and high *ß*-carotene sweetpotato clones were introduced from CIP for evaluation in regional trials. The G×E interaction was found to be high, which emphasized the need to develop varieties that were adapted to specific agroecological niches.

Research on virus susceptibility underlined the complexity of the issue and difficulties to transfer to the field the results obtained in laboratory trials. For example, some cultivars tended to tolerate virus infection under favorable conditions; symptoms were only expressed if conditions become stressful. The extent of symptoms expressed further depended on the presence of other viruses in the same plant. Furthermore, plants may escape infections, even if they are not resistant, because they are not preferred by the virus vectors in certain situations.

The breeding work further included isolation of main genes and development of a marker system to identify alleles and genetically map some of the main enzymes of the *ß*-carotene pathway. As a result, three genes (FPP synthase, phytoene synthase, and lycopene cyclase) of the *ß*-carotene pathway genes were identified and partial sequences isolated.

With regard to the production of virus-clean planting materials, the project did research on the degeneration of planting materials and the movement of viruses through plant tissue. Tissue-culture derived planting materials were produced and propagated by KARI (now KALRO) and nurseries established at various sites.

For the FFS, a curriculum was developed that included land preparation, planting material selection, planting, and variety characteristics. A further focus of the FFS was on collecting data for the agro-ecosystem analysis (AESA) system, an approach to systematic field observation of plants, their environment, and the interactions. Data collected included plant establishment, growth rate, and yield. Four improved sweetpotato clones and a local variety as check were evaluated by two groups of farmers, with an attendance of fifteen to twenty farmers per session every two weeks. Similar evaluations were conducted by individual farmers in other areas of the country. The number of participants was limited, but it was expected that participants would be able to act as trainers to other farmers later on. In spite of sweetpotatoes being predominantly grown by women in the project areas, the majority of participants in FFS activities were men. Two other FFS with a total of fifty-one participants focused on processing, product development, and evaluation of sweetpotato products.

A second phase of the project focusing on research addressing challenges at various nodes of the sweetpotato supply chain was intended but not funded. This project phase could have built on the established spaces for cooperation (e.g., the FFS). On the other hand, the approach taken in the first phase and proposed for the second is highly ambitious in that research is done in many different fields, starting from developing molecular markers to evaluate germplasm and further including participatory variety evaluation with farmers and value-chain activities. Without a clear concept of managing the flow of information gained and integrating it into the various ongoing activities, parts of these efforts are at risk of remaining ineffective.

COOPERATION, COMMUNICATION, AND LEARNING

With its focus on participatory research and technology development, the project facilitated cooperation, communication, and learning through many of its activities and at various levels. For example, the participatory surveys offered opportunities of communication and learning among researchers and farmers and delivered comprehensive data sets on farming systems and livelihood activities of women and men farmers. The FFS created a space for farmer-to-farmer learning, at the same time generating data supporting the research component. Awareness building activities addressed the general public through radio and video programs, newspaper articles, and printed materials. Cooperation with development aid organizations was sought to reach particular target groups (e.g., with “Send a Cow,” a church-based initiative working with people having very limited access to land).

The project further offered an educational tour for farmers and extension officers from central and eastern Kenya to visit the sweetpotato production systems in western and southwestern Kenya. A particular highlight was an international exposure visit to Italy for sweetpotato farmers, traders, and processors from Kenya, Uganda, and Tanzania during which they learned from others’ experiences and established business contacts.

Exchange visits and conferences addressing sweetpotato breeders were organized with the aim to discuss and harmonize approaches, methods, and protocols for sweetpotato breeding and to acquaint partners with available statistical and biometric tools emphasizing participatory research methodologies. The project scientists presented their work at scientific workshops and conferences. Furthermore, the project provided opportunities to PhD and masters students to conduct field and laboratory studies for their theses, partly in cooperation with the Louisiana State University, and to participate in project activities.

Challenges mentioned in project reports included difficulties maintaining regular communication across institutions, in some cases because of technical problems (e.g., erratic internet connections) and lack of transport for village activities. The project reports do not provide much information as to what degree the insights gained (e.g., through the participatory surveys) were integrated systematically to inform the ongoing research activities or how the farmers’ contributions influenced the planning and implementation of project activities.

The reports provided tend to present information on project activities and outcomes at a high level of detail but separately for its various components. They do not provide the necessary information to assess whether the project produced tangible impacts among poor rural communities in the region or to what extent outcomes were successfully institutionalized into the national breeding programs and CIP.

CCRP CONTRIBUTIONS

Project reports or other written documents did not offer explicit reflections on CCRP contributions. Meetings of the project team as well as those with other CCRP grantees were repeatedly mentioned in the annual reports, but without providing details on the agenda or outcomes or achievements of such meetings.

Still, the project provided urgently needed basic technical equipment (e.g., office and lab equipment) to the national research institutes to fulfill their respective project roles. The entire setup of the project, with national research institutes of neighboring countries, supported by CIP and foreign research institutes for specific tasks, taking on a central role, is a major contribution in itself. The project offered good opportunities for exchanging ideas, building a joint database, advancing and harmonizing methods, addressing hindering factors such as intellectual property issues, and building networks across institutions. This form of cooperation also provided excellent possibilities for young scientists to learn and improve their skills in an international setting. However, the funding period of four years was rather short, so it is uncertain if the efforts led to lasting results.

5.4 PROMOTING THE USE OF OFSP IN BURKINA FASO

Burkina Faso is classified as one of the countries most severely affected by Vitamin A deficiencies (see Section 5.1). Even though the level of Vitamin A deficiency has not been determined by a national survey, studies conducted by HKI in ten villages of the Sanmatenga province (central-northern region) showed that 85 percent of children aged 12–36 months had low concentrations of serum retinol, as did 62 percent of their lactating mothers. Likewise, in the Sissili province (central-western region), 52 percent of children had low serum retinol concentrations (HKI, 2014b).

Similar to other West African countries, Burkina Faso has a long-standing tradition in sweetpotato cultivation, and its importance is growing: Over the past decade (2001–2011), the area under cultivation increased about fivefold. This dynamic may stem from the crop's ability to produce high yields per area even under poor soil fertility conditions. Food made from sweetpotatoes is also popular among consumers in Burkina Faso (CGIAR, 2013). The morphological and genetic diversity of sweetpotato germplasm from Burkina Faso is moderate to high, but most of the varieties are white- or pale yellow-fleshed types (Somé et al., 2014). Since 2001, OFSP from East African and Asian origin have been introduced via CIP and are promoted with a view toward fighting Vitamin A deficiency. A number of projects has since been implemented, focusing on different parts of the country and with funding from various sources (Table 2).

The McKnight Foundation was among the first donors to address the issue in Burkina Faso, with the first project ("Sweetpotato and Nutrition in Burkina Faso") starting from 2005 and its second phase ("Promotion of Orange-Fleshed Sweetpotato to Control Vitamin A and Antioxidants Deficiencies in Burkina Faso") from 2010. Both projects were implemented under the West Africa CoP established in 2007. Several partners who participated in these projects were/are also involved in some of the other initiatives, particularly HKI for the nutrition and health components and Burkina Faso's national agricultural research institute (INERA) for agronomic components.

PROJECT DESIGN AND APPROACH

The first project phase aimed at improving Vitamin A intakes among women and children via the promotion of OFSP production and consumption. The project focused on two regions of Burkina Faso: Sissili province in the central-western region and Gourma, Gnagna, and Komondjari provinces in the eastern region. For multi-locational trials, experimental sites in two more provinces were included later.

Table 2: OFSP projects in Burkina Faso and respective donors[7] (2001–2016); Source: HKI (2014).

Project Name	Region	Period	Donor
School and community gardening project	Gourma province	2001–2004	United Nations International Children's Emergency Fund (UNICEF)
Sweetpotato and Nutrition in Burkina Faso	Gnagna, Gourma, Komondjari, Kourittenga, Sissili, and Tapoa provinces	2005–2009	McKnight Foundation
Promotion of OFSP to Control Vitamin A and Antioxidants Deficiencies in Burkina Faso	Sissili province	2010–2014	McKnight Foundation
Enhanced Homestead Food Production (EHFP)	Gourma province	2009–2012	United States Agency International Development (USAID) and Office of US Foreign Disaster Assistance (OFDA)
Improving the health of mothers and children (PASME)	Koudougou	2012–2015	Canadian government
Reaching Agents of Change	countrywide	2013–2015	Bill & Melinda Gates Foundation (BMGF)
Families Achieving Sustainable Outcomes (FASO)	Boulsa, Manni, and Gayéri districts	2013–2015	United States Agency International Development (USAID)
Mobilizing the radio and ICTs in the fight against Vitamin A deficiency by improving the production and consumption of OFSP	Kénédougou, Banwa, and Boulkiemdé provinces	2013–2015	Bill & Melinda Gates Foundation (BMGF)
Promoting OFSP in West Africa through diversified markets	Kénédougou and Houet provinces	2014–2016	Bill & Melinda Gates Foundation (BMGF)
Participatory breeding of OFSP adapted to Savannah and Sahelian environment of Burkina Faso	West, Central East, Central South, and Central West regions	2014–2016	Alliance for a Green Revolution in Africa (AGRA)

The project pursued six specific objectives: 1) to promote the production and consumption of OFSP starting from organized school and village structures and teaching the technical and nutritional practices both at the national and

[7] This list may not be comprehensive.

local levels, 2) to promote solar drying of OFSP with women's groups and NGOs, 3) to increase the financial resources of recipients, 4) to adopt a participative approach in the promotion, followup, and evaluation of OFSP, 5) to develop and apply a more accurate evaluation system of the production and consumption of sweetpotatoes in collaboration with the national agricultural statistics division, and 6) to present, evaluate, and disseminate OFSP varieties with high yield and high content of dry matter.

Project partners of the first phase were HKI and INERA. The project was initially meant to complement a second phase of the UNICEF project (Table 2), which was not implemented. For this reason, project activities focused on agronomic evaluation, sensitization, and popularization of OFSP production and consumption (see also below). Not all of the above objectives were fully addressed.

To consolidate the achievements of the first phase and address remaining challenges, a second phase of the project was funded by The McKnight Foundation ("Promotion of Orange-Fleshed Sweetpotato to Control Vitamin A and Antioxidants Deficiencies in Burkina Faso"). Project goals shifted toward nutritional outcomes and income generation, the overall aim being *"To contribute to the improvement of the nutritional status of the population in targeted women and in children under 5, to reinforce food security at the household level, and to increase the incomes of OFSP producers and those that create and sell other OFSP products."*

Consequently, the second project took into account the whole OFSP value chain and involved a consortium of four organizations, each responsible for implementing one component: 1) HKI for promotion of OFSP production and consumption, 2) INERA for the agronomic component, 3) the Applied Sciences and Technology Research Institute (IRSAT)/Food Technology Department (DTA) for OFSP valorization and processing, and 4) the University of Ouagadougou (UO/LCOPA) for an antioxidant component aiming to optimize antioxidant levels in OFSP-based recipes.

Second phase project activities focused on villages in the Sissili province in the central-western region of Burkina Faso, one of the provinces where on-farm evaluation trials of the first project phase had been implemented (see above). The nine specific objectives included 1) to provide farmers with the identified best-performing varieties for the respective agroecological zones, 2) to better control production constraints and technical routes, 3) to improve post-harvest treatment (also in view of conserving nutritional components, such as antioxidants), 4) to develop processing techniques to better valorize OFSP in order to diversify consumption modes and frequency, 5) to develop capacities of project stakeholders through trainings and supervision, 6) to determine the level of antioxidants in OFSP leaves and roots and optimize cooking and transformation processes to preserve antioxidant levels, 7) to facilitate the development of marketing networks for OFSP-based products, 8) to design and develop a social marketing strategy and increase awareness, and 9) to improve food security at the household level through increased OFSP production and consumption.

Interestingly, the specific objectives were phrased more precisely in later reports. Objective No. 9 (improve food security at household level), for example, was phrased *"improve the Vitamin A status of children aged 6–59 months and women of child-bearing age in OFSP production zones"* from the third year of project implementation onwards. Objective No. 7 (facilitate marketing networks) was phrased *"improve the income of OFSP producers and processors."*

The project further aimed to improve collaboration among researchers of various institutions and NGO partners to strengthen the infrastructure of the institutions involved (e.g., by providing equipment), and build capacities of researchers and producer groups. Monitoring and evaluation played a strong role in the project to ensure that the planned activities for each component were in line with project objectives and were timely implemented.

The project was highly ambitious in that it aimed to integrate production and consumption aspects and to facilitate the development of marketing networks and related strategies. Furthermore, it emphasized post-harvest processing, product development, and nutritional quality.

OVERALL DEVELOPMENT AND ACHIEVEMENTS

The main activities of the first project phase focused on performing agronomic trials at the research station and multi-locational on-farm testing in collaboration with experienced producers identified in each province. Following these adaptation tests, three OFSP varieties were identified for each area based on their agronomic performance and sensory tests. A further focus was on establishing a network of OFSP seed producers and popularizing the newly introduced varieties.

Among the first activities implemented were baseline surveys in the target regions and agronomic evaluation trials, including a set of seventeen newly introduced OFSP varieties received as seed from CIP in Uganda. Observations were taken during the dry and rainy seasons and included *inter alia* yield parameters, pest/disease incidence, and dry matter content. Generally, the OFSP varieties from Uganda adapted well to the conditions of the test sites in Burkina Faso. The number of varieties included in the evaluation trials was reduced to the ten best performing varieties of previous trials.

As the project evolved, the agronomic evaluation trials were extended to more experimental sites and the on-farm evaluation schemes were developed at four locations: Pittenga in the Gourma province, Léo in the Sissili province, Koupéla in the Kouritenga province, and Gayéri the Komondjari province. Five to ten producers at each site managed the trials by basically applying their normal farming and management practices.

On-farm sensory evaluation tests revealed some variation with regard to sweetness and firmness. Results from agronomic and sensory evaluation tests were integrated with data from nutritional quality tests focusing on *ß*-carotene content to identify the best performing varieties with regard to the overall project goal and to link agricultural and nutritional aspects more effectively.

The promotion of production and consumption started with three varieties, namely Taining, Jewel, and Caromex that had been introduced since 2002 at a limited scale as part of the UNICEF-funded project (Table 2). The activities included sensitization campaigns as well as practical training and distribution of OFSP cuttings to schools and village communities in the Komondjari province. The promotion activities resulted in higher production and consumption of OFSP year after year.

Further activities entailed knowledge exchange workshops and advocacy at the national, regional, and local levels for the promotion of OFSP production and consumption increasingly linked up with other initiatives (e.g., HarvestPlus), and several staff members participated in national, regional, and international meetings.

An important outcome of the first project phase was the considerable variability of variety performance depending on environmental conditions: The annual climate variations had more important impact than the location effects. This was addressed by changing the trial data evaluation methods but not systematically enough: The problem was repeatedly mentioned in later reports, too. All varieties tested were acceptable with regard to sensory quality.

At the end of the first phase, nearly all producers in the villages where project activities had taken place had adopted OFSP varieties and 96 percent consumed OFSP products. About 83 percent of surveyed participants had a site for conserving cuttings for the next season, and the majority of women were aware of the benefit of consuming OFSP during pregnancy. Project activities were thus successful in that the target groups were reached.

As stated, the activities of the second project phase concentrated on villages of the Sissili province. Throughout its duration, the project received technical support from the Provincial Directorate of Agriculture (DPA) based at Léo, the capital of Sissili province. With the help of the DPA, three villages were identified initially as intervention villages (Sagalo, Yelbouga, and Yoro) and three others as control villages (Tabou, Yallé, and Bouara).

The OFSP promotion and production component conducted baseline surveys for the selected villages in the project's initial stage, including anthropometric measurements of children and mothers, taking blood samples for determining hemoglobin and serum retinol levels, and questionnaires on mother and child nutrition. A complementary survey was also conducted on OFSP production.

In each intervention village, nurseries were established for the preservation and multiplication of planting material to meet the growing demand for the production of OFSP varieties being disseminated through the project. Seed nurseries were also established later in Boura and Bihéa, or in five villages altogether. Nursery management was entrusted to four voluntary groups of seed producers, the project facilitating the formation of these groups and providing technical support for establishing the seed nurseries. Each seed producer group was provided with planting material of Caromex 440136, Kandee 440140, and Tiébélé 2, the three best performing OFSP varieties in the project area, according to results of the first project phase. Basic equipment (fences, buckets, watering cans, etc.) was supplied based on a previous assessment of needs. The technical support to seed producer groups, including for off-season production of planting materials to speed up and secure the production, remained an important activity throughout the project cycle.

A sensitization campaign, including guided tours for farmers, market stands in local markets of the project zone (Biéha, Boura, Léo, Yelbouga, and Yoro), quiz games, and musical shows, was implemented from 2011 onwards. It further entailed radio programs on OFSP consumption in four local languages and promotional events at various occasions, some of them linked to international initiatives such as "World Food Day," which is promoted by FAO.

The project's agronomic component included germplasm collection and evaluation trials, soil fertility management, and crop rotation trials, as well as the development of a pest and disease control system targeting weevils and viral diseases. The soil fertility management trials assessed the effects of various levels of organic and mineral fertilizer application on yield. Assessing a variety of factors that influence weevil infestation was a further important issue addressed.

The antioxidant component invested in the development of methodologies in the project's initial phase. From 2011 onwards, it contributed data on antioxidant contents in fresh OFSP roots and finished products such as biscuits. A main focus initially was on assessing differences between OFSP varieties. As the project evolved, the influence of fertilization, weevil damage, and processing practices on the levels of antioxidants, polyphenols, and carotenoids in OFSP roots and finished products was studied.

The value addition and transformation component developed products such as OFSP chips, flour, biscuits, and cakes that were analyzed for antioxidant content and presented at exhibitions and tasting events organized as part of the sensitization campaign (see above). Women members of root processing groups in the area of Léo and agricultural extension workers of the DPA of Léo were trained to prepare OFSP-based varieties of local dishes. Local storage techniques for storing fresh sweetpotato roots were also assessed. Another important activity was the identification of potential OFSP value-chain stakeholders in areas with high production of sweetpotato.

As a result of the project, the constraints faced by producers and other actors were more clearly understood. For example, producers from all five villages cited as the main constraints the highly perishable nature of OFSP roots, its planting period coinciding with the time they were very busy with other crops, and low remuneration for OFSP on the local markets.

The research on nutritional components gave tangible results; for example, the variety Jewel was outstanding with regard to its *ß*-carotene and antioxidant contents. Mixed fertilization with organic and mineral fertilizers (NPK) contributed to increasing the levels of total polyphenols, antioxidants, and carotenoids in harvested OFSP roots. A particularly striking result was the high level of losses in nutritionally relevant contents during post-harvest processing (e.g., up to 82 percent of carotenoids are lost through air drying of OFSP chips and more than 60 percent when OFSP flour is processed into cakes). Losses in processed products can be reduced, however, by adding ingredients such as oil or eggs to biscuit dough.

At the end of the second project phase, OFSP was included in the production system of 73 percent of participating households. The project resulted in an increase in OFSP production of nearly 250 percent. Surveys conducted by the project team further indicate a moderate increase in yield per area, and the availability of OFSP planting materials had considerably improved. However, the area planted with OFSP per producer was still small compared to areas allocated to white sweetpotato varieties, with areas of about 0.5 ha on average per producer.

Surveys and reports suggest that the project partners have to a large extend achieved their goals and that adoption rates among participating farmers were high. The remaining challenges, particularly the sustainable development of OFSP value chains, would have required a new project phase with special emphasis on market development.

COOPERATION, COMMUNICATION, AND LEARNING

Cooperation among the project partners seems to have worked well most of the time. Nonetheless, it was repeatedly mentioned in reports that coordination of activities required a lot of time and effort, that the sharing of results (e.g., research reports) among the partners was too slow, and that activities had to be postponed. Staff turnover seems to have been a difficulty with regard to some of the project activities.

In interviews with our research team, the project partners stated that the project had created a new type of identity beyond institutional boundaries, particularly since the institutions were partners in a nonhierarchical setting but with clear responsibilities assigned to each. This led to synergies and the achievement of better results in less time.

Highlighted was the fact that formal meetings and procedures were established for taking decisions and priority setting; however, it was challenging at times to bring people together for meetings. The joint supervision missions provided essential information about the activities implemented by the project's other components and reinforced knowledge sharing and collaboration among the different partners.

All project partners worked on improving and evaluating methodologies in the respective components for which they were responsible (e.g., with regard to experimental designs,

CCRP CONTRIBUTION

"OFSP in Burkina: This is The McKnight Foundation's 'baby.' It was through their projects that OFSP became more and more visible since 2005."

—*Researcher*

survey methods, and descriptors used). Nevertheless, a project report states a lack of interest of some partners in the planning process, which led to incomplete managing and monitoring tools.

The lessons learned communicated in project reports address practical issues such as the need to establish seedbeds near permanent water collection points. Enhancing marketing opportunities (in addition to popularizing consumption) is clearly understood as a precondition for the wider adoption of OFSP varieties by farmers. The project partners learned that off-season OFSP production could ensure more stable supply with roots and vines. Improving storage methods for harvested roots would be a priority, both in view of nutritional outcomes and marketing.

For the farmers who participated in interviews, an important learning outcome was that they were now able to manage OFSP production and multiplication and were aware of the nutritional value and specific characteristics of several varieties. The guided tours to other villages with OFSP production were of particular interest to them.

The farmers, however, were not involved in project management and decision-making. As a result, locally known constraints were sometimes insufficiently addressed. One example mentioned was the amount of water required for the irrigation of the seedbeds (see box).

CCRP CONTRIBUTIONS

Interview partners expressed appreciation for an approach that implements projects as networks of various institutions. Nowadays, HKI, IRSAT, and INERA constitute a sustainable network and continue their cooperation in other projects, for example in a new three-year project funded by the private food company Cargill, whose US $600,000 in annual funding covers sixty villages and about ten schools in the eastern region of Burkina Faso. CCRP support on the way to bringing OFSP varieties to scale in Burkina Faso is clearly acknowledged.

A further contribution was the strengthening of the research component (e.g., by financing surveys, including in control villages, to better monitor the progress made). The investments made in methodology development and infrastructure (e.g., technical equipment) were highly appreciated, particularly by the research partners.

An effect of capacity building for participating staff and young scientists through the project was reported. Several people could develop their careers, and partnerships with other projects and institutions have increased. As a result, some new projects were initiated (e.g., for processing OFSP together with other ingredients to develop health products and special dietary products for people who are ill).

The project has facilitated international exchange, particularly with people from Uganda, Ghana, and institutions such as CIP and Farm Radio International. New contacts between researcher and companies (e.g., seed companies) have emerged, and there is considerable demand for OFSP planting materials from government and aid organizations. The reputations of people who were involved in the project have increased (e.g., they are asked to act as trainers or present at conferences), and state institutions display increased interest in various matters concerning OFSP. The OFSP varieties evaluated and produced in Burkina Faso have passed the borders to other countries of the region, with some varieties being officially released in Senegal, Mali, and Ivory Coast.

However, the project partners also mentioned some weaknesses of the CCRP strategy concerning project funding and support. In some institutions, policies have changed, making full budget funding mandatory. In those cases, funding that requires mobilization of resources from elsewhere to run a project could no longer be accepted.

Several partners stated a lack of flexibility with regard to adapting project plans to needs or opportunities identified during the course of the project. An important criticism was that the project was weakly grounded in local institutional structures, since no funding existed for local community workers *("animateurs")* and the funding for field staff who could effectively link the partner institutions with local actors was insufficient. Given the abrupt end of the CCRP funding, confidence was lost between the implementing institutions and local farmers, making it impossible to plan further activities with these village communities in future projects.

IMPACT ON PRODUCTION AND USE OF OFSP

The project's impact on production and use of OFSP was studied based on interviews and participatory distribution analysis exercises in the three villages of Boura, Sagalo, and Yoro, all located in the Sissili province, as well as on interviews with women's groups, market retailers, and food processing companies.

PRESENCE OF OFSP IN FARMERS' FIELDS

Farmers in the three selected villages grew six to eight different sweetpotato varieties per village. Approximately half were OFSP varieties that had been introduced through the project, namely Jewel, Tiébélé 2, and Caromex. The participatory distribution analysis (Figures E1-3 in the Annex) shows that sweetpotatoes are generally grown on small areas only, with the exception of some traditional varieties in the village of Sagalo. Three local varieties are yellow-fleshed (Table B in the Annex).

Most people in these villages had tested the OFSP varieties when the project was active and adopted them for their own households' needs. All of these varieties are grown on small areas of land and are nearly exclusively for self-consumption.

In Boura and Yoro, the large majority of farmers grow OFSP on small plots. Fewer farmers in Sagalo grow OFSP compared to the other villages. Here, farmers maintain six local varieties compared to three in Boura and Yoro. This is attributed to the perceived constraints of OFSP varieties, particularly with regard to pest incidence, storability, and limited marketing opportunities (Table 3 and below).

In all three villages, the area under OFSP increased initially when the project was implemented and then dropped gradually because the marketing opportunities were not improved as expected.

On the other hand, the production and selling of vines is a good business opportunity for those who have enough land, water, and labor resources. Particularly in the village of Boura, multiplication and selling of OFSP vines has become an important income-generating activity, since a dam provides parts of the village with sufficient water for irrigation. The number of OFSP vine producers increased about threefold (from about thirty to around a hundred) after the project ended. Customers come from neighboring villages, other Burkina Faso provinces, and even neighboring countries such as Niger and Ghana.

Hence, the production of OFSP vines is economically much more interesting than the production of roots, which is mainly limited to the amount needed for family.

BUYING FOOD

"The OFSP we consume are from our own harvest. Nobody here buys food; everybody's priority is to produce for the needs of their own family. This is why there is no local market for OFSP."

—*Women's group from Sagalo*

COLOR OF FOOD

"If you offer orange and white sweetpotato fries, the orange ones are always finished first. This is because they look much more attractive and the taste is also better."

—*Women's group from Sagalo*

MARKETING

"Some traders do not want to take the OFSP because they fear that they spoil before they are sold at Ouagadougou and that they would also infect other sweetpotatoes they have in their stock. It is necessary to find a solution for controlling the weevils. This is, in fact, the main constraint."

—*Men's group from Sagalo*

Table 3: Positive and negative aspects of OFSP versus traditional sweetpotato varieties as stated in interviews with farmer groups in Burkina Faso.

	OFSP Varieties	Local Varieties
Positive aspects	• Higher yields • Short (three-month) growing cycle • Good taste • Not too filling • Good for health in general, particularly for children • Nutritious value (Vitamin A) • Income generation for some farmers from selling vines	• Storability of roots in the soil and after harvest better compared to OFSP varieties • Marketing easier compared to OFSP • Less labor requirements for weeding • Particular traits of some varieties are valued depending on the situation
Negative aspects	• Higher labor requirements for weeding (particularly the variety Jewel because of its weak ability to cover the soil) • Susceptible to pests in the field and during storage • Storability in the soil and after harvest inferior to local varieties • Marketing constraints	• Lower yield (some, not all varieties) • Longer (usually four-month) growing cycle (exception is a local variety called "Two Months") • Less appealing and tasty than OFSP

PRESENCE OF OFSP IN MARKETS

According to the farmers interviewed, a local market for OFSP roots is practically nonexistent. Traders do not pay more for OFSP varieties compared to white- or yellow-fleshed local varieties. Some traders are even reluctant to buy OFSP varieties because they fear losses resulting from damaged roots.

This does not, however, seem to be the whole story, since traders at the Léo market reported that today, with the increased production and demand for sweetpotato in the country, traders come to buy sweetpotatoes in large quantities. These traders are thought to sell the OFSP at higher prices in Ouagadougou, but they are reluctant to pay higher prices to farmers and local traders (who themselves are usually farmers selling sweetpotatoes from their own production). One reason may be that the OFSP varieties need more attention. In order not to spoil, the roots need to be covered directly after harvest, during transport, and even at the market stall. Some of these large-scale traders seem to avoid the Léo market, buying even more cheaply direct from farmers in surrounding villages.

The price fluctuations at the Léo market are in general notably high–120 percent or more–depending on the season, but also on a daily basis. The highest price is usually paid at the beginning of the harvest season. Transport from the field to the market, including paying people to fill bags, load the trailer, and drive the tractor, is expensive for the local traders. This is why they accept even low prices, since taking the sweetpotatoes back to the village and to the market again another day is usually not feasible. So there is a lot of risk involved for the traders also.

USE OF OFSP IN PROCESSED PRODUCTS

Various stakeholders engage in the OFSP processing, including associations of small processors (mostly women) and food processing companies. Companies have a number of opportunities relating to OFSP. One important supporting factor is the large-scale promotion and sensitization in various African countries, including initiatives such as the World Food Day, that reach many stakeholders, including schools and universities. Also, the partnership with the university and IRSAT initiated through the CCRP-funded project has supported experimental product development. Yet the work on developing OFSP-based processed products practically stopped since 2012 because of limited availability of the raw material (OFSP roots) and the limited size of the potential market. In Burkina Faso, the vulnerable groups most affected by Vitamin A deficiencies have very limited access to processed food products. The number of people who are aware of the health benefits and are willing to pay for such products is estimated to be very small, even in cities. Plans nonetheless exist to produce canned baby food and flour enriched with OFSP in the near future.

Members of an association of small-scale food processors based at Léo see the situation more positively. They are using different drying equipment, including solar and gas driers, to produce OFSP flour. The drying process is not simple since the product easily starts fermenting if not dried quickly enough. The solar dryers are therefore more risky than gas dryers. It takes 7 kg of fresh OFSP roots to make 1 kg of processed flour, which can then be used for many different purposes, including soups, various types of cakes and biscuits, and *dégué*, a traditional dish made from flour and milk or yogurt. For certain recipes, OFSP flour is mixed with wheat or cassava flour. Additionally, women process fresh roots for a large variety of products, including chips, couscous, cakes, *brochettes* (grilled vegetable skewers, also mixed with meat), and salads.

According to the association members, the project benefited them and they became food processing experts. Demand similarly exists for training from other projects and for employment by the regional state agency. However, fluctuating prices and unreliable availability of OFSP at the Léo market are difficulties. The prices are such that the processed products are hardly accessible for rural households. It is customers in food shops and markets of Léo and Ouagadougou who purchase such products.

USE OF OFSP IN RURAL HOUSEHOLDS

To learn more about OFSP consumption in rural households, group interviews were conducted with women who had small children when the project was active. The women are mainly interested in OFSP for its nutritional quality, thinking it supports their children's healthy development by making them less susceptible to disease. They observe a form of malnutrition in children caused by repeated illness and reduced appetite, which they feel has reduced.

They use OFSP at least once a week when they are available, mainly in the form of *ragout* (sauce) for family meals. They serve OFSP grilled, fried, and boiled at various occasions. They prepare special meals from cooked and mashed OFSP for young children. The women also use homemade flour from sliced, sun-dried, and ground OFSP to prepare food for their babies.

The number of known preparations increased through the project. Previously, the OFSP were mainly consumed in boiled form and as raw snacks. The women learned how to adapt their cooking practices for some OFSP varieties such as Jewel that are very soft and need less preparation time and heat.

The main constraint is the limited storability of the roots after harvest. This is why they cannot be kept for more than two weeks after harvesting. Drying is a possibility, but it is labor intensive. Further complicating matters, the drying process is not easy if there is insufficient sunlight.

HINDERING AND FURTHERING FACTORS FOR THE OFSP SUPPLY CHAIN IN BURKINA FASO

The hindering and furthering factors identified for various nodes of the OFSP supply chain in Burkina Faso are summarized in Figure 7.

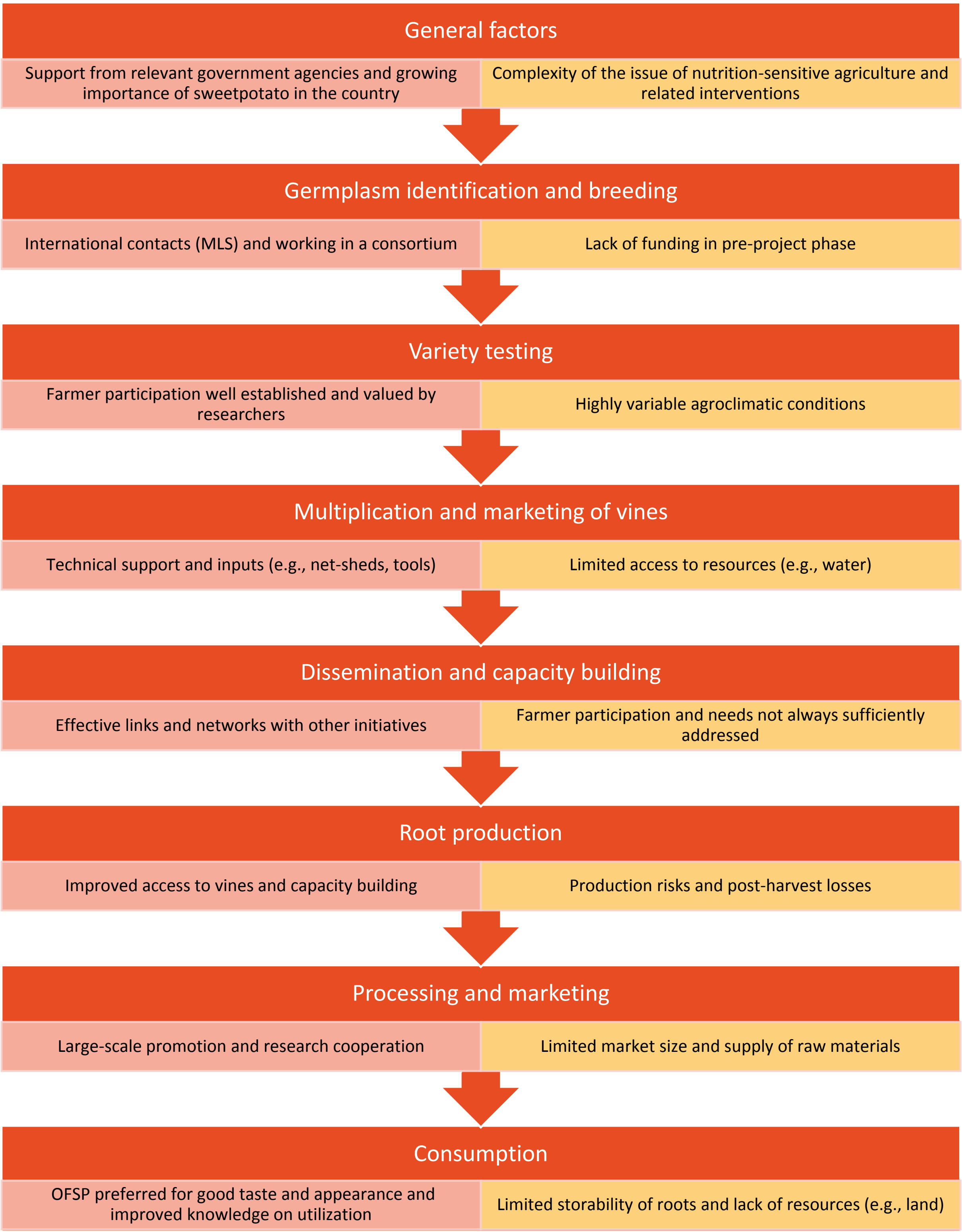

Figure 7: Summary of hindering and furthering factors at various nodes of the OFSP supply chain in Burkina Faso; furthering factors are listed at left in pink, hindering factors at right in orange.

6 DISCUSSION OF RESULTS

In this chapter, we discuss the study findings in relation to progress made in sweetpotato breeding (Section 6.1), the projects' potential to address Vitamin A deficiency (Section 6.2), and the ways linkages between agriculture and nutrition are addressed (Section 6.3). A final passage deals with project design (Section 6.4).

6.1 PROGRESS MADE IN SWEETPOTATO BREEDING

CCRP support to Uganda's national sweetpotato breeding program has been successful in developing more virus- and weevil-resistant sweetpotato germplasm and varieties with higher yield potential and improved nutritional value. Moreover, it contributed substantially to the scientific understanding of these issues. The project's initial goals were maintained without any major reorientations. The progress made in breeding methods during the funding period, including molecular marker assisted germplasm characterization and selection, for example, led to the adoption of innovative methods and approaches and their successful application. In this regard, the project has delivered pioneering work at the scientific (e.g., publications, methods) and practical (variety development, PPB) levels.

Major landmarks identified were the release of varieties in Uganda and growing recognition by and interaction with regional and international partners. The OFSP varieties developed by the project are now popular varieties that complement farmers' variety portfolios or replace local cultivars in some regions of Uganda. Several varieties that originated from NaCRRI's sweetpotato breeding program (e.g., the NASPOT varieties) have been successfully introduced to other countries or are used as breeding parents (Tumwegamire et al., 2014). The Multilateral System for Access and Benefit Sharing (MLS), established as a key instrument under the International Treaty on Plant Genetic Resources for Food and Agriculture (ITBGRFA) since 2004, has greatly facilitated access to plant genetic resources and related information for national breeding programs of African countries. Toward this end, the genebanks held by CIP and IITA play an important role in facilitating the spread of varieties to other countries. Uganda's national sweetpotato breeding program has become one of the leading institutions worldwide: an impressive success story.

The project developed varieties with higher levels of virus resistance compared to other varieties previously available. However, breeding for virus resistence is complex: The degree of SPVD expression depends on the presence and behavior of insects as virus vectors as well as on the presence of other viruses and stress factors. In this regard, the project delivered important basic and applied research results (Gibson et al., 2004; Kokkinos et al., 2006; Clark et al., 2012).

Reducing susceptibility to insect pests and improving post-harvest traits (e.g., storability) have not been as successful and would require a new effort. A broader approach not focused on breeding alone would possibly be more promising to address the diverse constraints in an integrated manner. For example, soil fertility and soil moisture management, general agronomic practices such as crop rotations and planting distance, integrated or biological pest control, and/or locally adapted post-harvest technologies could all contribute to integrated and site-specific strategies for mitigating the problems of weevil damage and post-harvest loss. Andrade et al. (2009) suggest that *"a set of interrelated approaches addressing specific constraints and groups of constraints"* was required.

The highly variable agroclimatic conditions were a challenge for the sweetpotato breeding program in Uganda and elsewhere. In Burkina Faso, for example, the evaluation of agronomic trials was challenging methodologically, given the high annual variation of relative yields among the varieties tested. In Uganda, farmers were found to cultivate fifteen to twenty-two varieties per village and even where OFSP varieties had been widely promoted. Relying on a range of crops and varieties is a known strategy of farmers to adapt to highly unpredictable agroecological conditions that cannot be controlled (Kaufmann et al., 2013). By promoting only OFSP, chances were missed to enhance farmers' access to a broader range of improved sweetpotato varieties. The breeding progress achieved through the

CCRP-funded project in Uganda has thus only partly been delivered to the country's farmers, with an estimated share of OFSP varieties of around 5 percent countrywide (Grünewald et al., 2015).

Hence, the success of the OFSP varieties is partly credited to the fact that they are the only improved varieties available. Making newly bred varieties available to farmers is a known bottleneck of public breeding programs and could be considered an original task of national agricultural research systems. However, since this part of the process was not funded, a lack of resources limited the possibilities to establish a decentralized system of variety evaluation trials and multiplication facilities.

Instead, the project relied on a network of partner organizations, mostly NGOs, whose program objectives resulted in a narrower focus on promoting OFSP. Improving livelihoods, nutrition, and health of rural populations, and strengthening their socioeconomic development in several ways, are the main goals of these NGO partners (see for example VEDCO Uganda, 2014; SOCADIDO, 2015). Making OFSP varieties with higher nutritional value available to farmers fits well with this agenda, even though the organizations' general focus may not necessarily be on agriculture. On the other hand, HarvestPlus as an international initiative concentrates only on promoting a range of biofortified crops, including OFSP. By filling the gaps between the national breeding program and farmers, they facilitate farmers' access to improved and virus-free sweetpotato vines in at least some regions of the country. The question could be raised: Would it not be more sustainable to support government institutions to build up effective seed supply and quality control systems in cooperation with farmers?

A major challenge for developing sweetpotato seed supply systems is the discrepancy between the high production costs of virus-free planting material and the low market value of the roots produced. Hence, purchasing expensive planting materials on a regular basis is uneconomic for many farmers, particularly in view of prevailing production and marketing risks. As a result, high-value planting material is mainly accessed from NGOs, which represent the real customers in the seed market, whereas farmers get the vines for free or at much reduced costs. Hence, the market for OFSP planting materials in Uganda heavily depends on external funds provided by NGOs or their donors.

This system will possibly need to be reorganized to enhance its sustainability in the longer term. Uganda, as a member country of the Common Market for Eastern and Southern Africa (COMESA), is bound to a strategy for the implementation of COMESA's seed trade regulations. These include registration of varieties through a formal variety release system and permitting sale, exchange, and bartering of only registered and certified seed. Farmer-to-farmer distribution of sweetpotato planting materials could thus require formal certification in the near future. Kenya is also a member of COMESA, and similar regulations are underway for the Economic Community of West African States (ECOWAS), to which Burkina Faso is a state party.

Hence, the approach to seed system development taken by the projects in all three countries may not comply with future legal requirements. Formalization of existing farmer seed-producer groups, effective cooperation with national breeding programs, capacity building for compliance with official certification requirements, value-chain development, and reduction of post-harvest losses may become important needs for future action. Even though some ongoing activities support, for example, selected private sector companies in meeting certification requirements, this is probably not enough to solve the above-described problems in the seed system. Rather, the need exists to build up a decentralized system for the production of OFSP vines involving various types of actors operating in a coordinated manner at different scales.

Furthermore, the idea of promoting to farmers certain varieties or agricultural practices somehow opposes the basic principles of participatory research, which include joint learning about possible improvements and the freedom to choose from a range of available options. Creating low-risk spaces for joint experimentation, feedback, and learning was a common feature of many other initiatives that were established since the 1990s with the aim to institutionalize linkages between publicly funded breeding programs and farmers (Braun et al., 2000; Christinck et al., 2014). Yet the approach taken by the Kenya project went more clearly this direction. In the FFS, farmers were exposed to a broad range of germplasm, local as well as improved, from which they could make their own choices.

6.2 POTENTIAL TO ADDRESS VITAMIN A DEFICIENCY

Promoting OFSP as part of a food-based approach to combat Vitamin A deficiency played an important role in Uganda, mainly for the associated partners involved in its dissemination. In Kenya, making OFSP varieties available was a key issue addressed by the project but without directly targeting nutritional outcomes. In contrast, the work in Burkina Faso focused explicitly on improving the Vitamin A status of clearly defined target groups.

Our findings suggest that OFSP varieties have several advantages for a food-based approach to addressing Vitamin A deficiency in rural areas: 1) sweetpotatoes are not a completely new crop and many farmers have experience with their cultivation, 2) they are widely consumed, 3) they are available at relatively low cost, 4) only small amounts are needed to improve the Vitamin A status, particularly of children, and 5) OFSP are generally liked by children and to varying degree by adult consumers.

A number of disadvantages are similarly in play, namely 1) OFSP are not available throughout the year, 2) they cannot be stored for longer periods in the soil or after harvest, 3) processed products are either expensive or, in the case of home-processed OFSP flour, contain much lower amounts of *ß*-carotenoids than the fresh product, 4) their cultivation requires resources (e.g., land, water, labor) not easily available to all people having Vitamin A deficiency, and 5) not all people like the taste and texture of OFSP.

De Brauw et al. (2015) found that OFSP promotion by HarvestPlus led to improved Vitamin A status of young children in Mozambique and Uganda, in spite of the above-mentioned limitations. In Uganda, the study included data of eighty-four farmer groups in Bukedea, Kamuli ,and Mukono districts that had received training and OFSP planting materials. After two years, about 60 percent of participating households had adopted OFSP and both the intake of *ß*-carotene-rich food as well as the serum retinol concentration of young children significantly increased. However, the cost of the intervention was relatively high at US $132 per household.

A focus on promoting only OFSP may be effective but too narrow for reaching all relevant population groups. Combining OFSP with a broader approach to dietary diversification, income generation, and enhancing nutritional knowledge could help overcome some of the limitations mentioned. Although we understand that many proponents of OFSP would agree that it should be part of a broader approach, we observed a clear focus on OFSP promotion in practice. However, which measure or combination of measures are most appropriate to improve the nutritional status of vulnerable people depends on their land, labor, and capital endowment, among other factors. For example, it may be easier, require less land and labor, or involve lower risk for some people to keep a few hens, to plant a mango tree near their house, or to generate some off-farm income in order to purchase nutritious food. Yet in practice we observed that various alternative options were neither assessed nor offered by projects focusing on OFSP promotion.

6.3 WAYS OF ADDRESSING LINKAGES BETWEEN AGRICULTURE AND NUTRITION

Looking at the impact pathways of CCRP-funded OFSP projects from a broader perspective, we find that the projects targeted several impact pathways, including consumption of food produced and developing options for processing and marketing OFSP. A mere side effect seems to be income generation through the marketing of OFSP vines, which was stated to be much more profitable than selling OFSP roots.

Referring back to the concept of nutrition-sensitive agriculture (Section 5.1) we found that the impact pathway "consumption of food produced" had the clearest outcomes. In the areas where projects were actively promoting OFSP and organized access to planting materials, many farmers adopted the OFSP varieties and cultivated them at least at small scale for their own family's requirements. Processing and marketing activities were hampered by the distance to relevant markets, fluctuations in supply and demand, low volumes, the risks involved for farmers as well as traders, lack of coordination, and the low economic value of OFSP roots. Small-scale food processors in Burkina Faso could obviously better cope with these conditions than larger food processing enterprises, even though a role may exist for them if markets become more developed. Direct marketing to school and university canteens as well as restaurants and hotels is also promising. The possibilities to develop a sustainable production and supply system could be much supported by linking up with government initiatives (e.g., for nutritional education and school meals).

The lack of linkage research covering all the necessary aspects of the research chain for nutrition-sensitive agriculture stated by Hawkes et al. (2012) is also relevant for the projects studied here. The CCRP-funded projects in Uganda and Kenya targeted relatively small (albeit important) parts of the OFSP delivery chain: mainly plant breeding and variety utilization. In Burkina Faso, an attempt was made to integrate more downstream activities and to directly address nutritional outcomes as part of the project. In Uganda, these activities were implemented by loosely associated partner organizations and were thus not part of the research.

Connections between the agri-food system and the environment (e.g., the diversity of agroecological conditions and resource availability), on the one hand, and the relations between the agri-food system and the medical/health system on the other, were addressed in each of the projects but with different foci. The Kenya project addressed environmental variability by taking a decentralized and participatory approach to variety diffusion: Nutritional and health issues were indirectly targeted. The Burkina Faso project was more focused on the linkages between agriculture, food, and human health than on environmental issues of relevance for food and nutrition security, such as coping with climate variability and water resources management.

The concept of AEI is context-specific by definition and can include improved resource-use efficiency at various levels, including landscape or farm levels, or outcomes for households or individuals. We found no evidence in project reports or publications that the concept was used in practice in the projects under study since it was not used by the CCRP at the time the studied projects were designed. That does not mean these projects did not contribute to AEI. To become more relevant for the practical orientation of project work, it would possibly require increasing inclusion in accompanying studies, as well as in monitoring and evaluation activities.

6.4 PROJECT DESIGN

Comparing the three country cases, we observed that the general setup of the projects developed from researcher-researcher cooperation (Uganda) linking up informally with other actors toward institutional cooperation (Kenya/Tanzania) and multi-actor projects targeting the entire value chain (Burkina Faso).

All projects studied included farmer participation (e.g., in variety evaluation and multiplication of planting materials). In many cases, the farmers' knowledge was valued by scientists and stated to have significantly contributed to the research. However, there is no evidence from the reports that a systematic approach to integrating farmers' and other practitioners' knowledge has been taken that would go beyond informal consultations and occasional village or project meetings. Even for the Kenya project, where FFS were established to facilitate farmer learning, we do not find any clear pathway ensuring that the knowledge generated in the FFS was effectively connected with the research done in the project's other components.

During the decades on which our case study focuses, scientific progress has not only been achieved in plant breeding methodologies but also with regard to the scientific foundation of farmer-researcher collaboration (Hoffmann et al., 2007) or multi-stakeholder cooperation (Lelea et al., 2014; Brouwer & Woodhill, 2015). These newer approaches conceptualize farming and food systems as human activity systems that are established and managed by human actors based on their objectives and understanding of the system's components and their functioning (Restrepo et al., 2014). Deeper insight *of scientists* into existing problems does not necessarily increase the likelihood that proposed solutions will be adopted or that problematic practices will be changed. Rather, changes in these systems can occur if the research process is implemented in a way that allows *the actors* to take a vital role in the co-creation and integration of new knowledge (Restrepo et al., 2014). Overall, farmers and other non-academic actors had limited power and roles in the projects, which suppressed their possibilities to contribute to and learn from the research process and to put the results into practice.

Women are important actors in sweetpotato production and processing in all of the countries covered by this study and they were also identified as the main target group with regard to the nutritional aims. Yet none of the projects clearly conceptualized a gender perspective (e.g., by assessing planned activities with regard to resource requirements, contributions, or benefits).

In Kenya, for example, gender-disaggregated data was collected but it remained unclear from the project reports how this information was used and integrated to influence, for example, germplasm choices or selection decisions made by plant breeders. In Southwest Uganda, neither interest nor nutritional needs were decisive factors for a person to participate in project activities; rather, it was access to sufficient area of land. Particularly poor rural women, the project's main target group, tend to have restricted access to land in this region, so their participation was limited. In Burkina Faso, access to water for the irrigation of seedbeds and household needs was mentioned to cause conflicts between women and men. Obviously not assessed were resource requirements for planned project activities (e.g., concerning irrigation water, labor, and land, and how and by whom they would be provided).

Gender differences are more commonly considered when it comes to assessing consumer preferences. For example, the acceptability of biofortified food has been studied in various African countries, including Uganda (see Birol et al., 2015 for an overview). Yet sensory evaluation and preference tests do not provide clear information on the complex linkages between production and consumption in rural households that result in nutritional outcomes for individuals.

"JUST ADD WOMEN AND STIR"

Since the 1990s, women have increasingly been discovered as a target group for development activities due to growing awareness of their marginalized position in local, national, and global economies.

However, interventions in which women were included in development programs, meetings, and participatory activities to fill gender quotas without considering the causes of gender differences or mechanisms of continuing exclusion led Charlotte Bunch, a US-American feminist, to criticize the concept being "just add women and stir."

—*Bitzan et al. (2016)*

7 LESSONS LEARNED AND CONCLUSIONS

The lessons and conclusions we draw from this case study refer to three major problem areas relating to OFSP production and use: 1) seed cost and production risks, 2) value-chain development and nutritional outcomes, and 3) seed multiplication and distribution systems for OFSP. Furthermore, we will take up issues that concern project design and funding strategies more generally: 4) long-term funding and support to projects, 5) research as a collaborative learning endeavor, 6) system perspectives and change, and 7) gender issues in crop improvement projects.

7.1 SEED COST AND PRODUCTION RISK

It can be difficult for small-scale farmers to spend cash money on agricultural inputs such as seeds or fertilizers in cases where the product is not sold but self-consumed. Most farmers have to borrow money to afford agricultural inputs. If the product is not sold, it is difficult or impossible to pay back the loan unless the farmer has other sources of sufficient cash income.

Even if the product is sold, entirely or in part, the relation between seed cost and sales revenue is important: The farmer needs to recover at least the cash money spent for production and marketing. Given the low price for OFSP roots in local markets, this may not generally be the case.

Production risks remain high with even the improved OFSP varieties. Potentially large losses can occur during the growing cycle and after harvest. Even the success of processing the harvested roots at cottage level depends on weather conditions and bears risks (e.g., that the products start fermenting before being dried). Price fluctuations at local market—even on a daily basis–make it risky for farmers and traders to bring larger quantities of sweet-potato roots to the market.

Conclusion: Risks that occur during the growing cycle, after harvest, or at the processing/marketing stage could result in livelihood-threatening risks if OFSP vines were purchased based on loans and at regular prices. Future research could focus on further reducing such risks. Also needed are economic studies that include risk and vulnerability assessments to better understand the situations in which farmers would use OFSP varieties if they had to pay for the vines at a regular price.

7.2 VALUE-CHAIN DEVELOPMENT, POVERTY, AND NUTRITION

The objectives to improve the nutritional status of vulnerable groups by promoting self-consumption and to develop value chains may target different groups of farmers or may even be conflicting goals. On the one hand, limited marketing opportunities were reported as being a major factor limiting the production of OFSP. Hence, developing value chains including various (also processed) products could be an important incentive for farmers to grow OFSP on larger areas. A certain minimum of available resources and assets is usually required for farmers to benefit from such approaches (Stoian et al., 2012).

On the other hand and even more for people with limited resource endowments, increasing the area under OFSP production competes with alternative uses of the required productive

FARMERS AS RESEARCH PARTNERS

"We would prefer a more participatory approach, considering the village as a partner, with an activity plan and a budget that are known to all villagers for transparent management."

—Farmer from Boura village, Burkina Faso

resources and assets. The relative advantages of various alternative uses with regard to poverty reduction and food and nutrition security of vulnerable populations may vary according to many factors (Hawkes & Ruel, 2012; Stoian et al., 2012; Sheck et al., 2013). Hence, the benefits and trade-offs involved with OFSP production for self-consumption or marketing, particularly for vulnerable groups, have so far not been assessed in much detail (e.g., considering various alternatives).

If value-chain development was successful and resulted in a higher market value of OFSP, this could actually be a disincentive for self-consumption by vulnerable groups, a problem that has been described for high value food products such as quinoa (Richardson, 2014). Future projects targeting value-chain development should thus consider value for nutrition along with economic value, and focus on creating benefits for the value-chain actors in their roles as producers and consumers (Hawkes & Ruel, 2012).

Conclusion: Value-chain development activities do not automatically reduce poverty or lead to positive nutritional outcomes for vulnerable groups. The fact that people with better resource endowment tend to benefit more from such activities than others should be considered if any future activities for value-chain development are planned. To allow vulnerable population groups and resource-poor farmers to benefit from such activities, they should be based on thorough assessments and impact evaluation frameworks that take into account the specific needs and constraints of these groups.

7.3 SEED MULTIPLICATION AND DISTRIBUTION SYSTEMS FOR OFSP VINES

Establishing sustainable seed systems for virus-free sweetpotato vines is more challenging than with grain crops since it requires technological knowledge as well as capital investments (e.g., tissue culture equipment, aphid-proof nets). Once cut, the vines are perishable and cannot be stored for longer periods. This requires decentralized multiplication and marketing systems plus well-planned logistics.

Hence, the production of virus-free OFSP vines is expensive compared to seed of many other crops. The seed cost cannot easily be recovered unless markets and value chains are developed to increase the value of OFSP roots and to reduce losses and risks.

At present, NGOs and international donor-driven initiatives are the largest players in the market for OFSP vines. This is problematic in view of sustainable seed system development, since the OFSP vines are given to farmers for free or below production cost. This is a potential disincentive for private companies or even farmer-managed cooperatives to engage in commercial production of OFSP vines.

Additionally, organizing the distribution of seed and planting materials from publicly funded breeding programs is an original task of the respective organizations. Important steps such as quality control and certification of vines need to be under the control of state agencies. If these institutional structures are absent or weak, solutions need to be found. We understood that such initiatives involving *inter alia* CIP, HarvestPlus, private sector multipliers, and the Ministry of Agriculture were "in the pipeline."

This could be an important new step since disseminating OFSP vines only based on informal partnerships with farmer groups and NGOs bears high risks for the sustainability of seed supply in the longer term. Recent developments regarding regional harmonization of African seed laws pose new challenges to seed system development in many countries. The common practice of farmer-to-farmer exchange of seed and planting materials may become illegal or subject to legal uncertainty. To avoid setbacks, certified or quality-declared (formal) systems may be required in the near future. Farmers could be encouraged and trained to participate in such activities as, for example, members of farmer-managed seed enterprises.

Conclusion: Seed system and value-chain development are closely interrelated; hence, a seed system where farmers pay for OFSP vines cannot be developed without considering the interrelations with the entire OFSP supply chain. NGOs targeting nutritionally vulnerable groups should clarify the pathways and modalities for distribution of OFSP vines in view of ensuring sustainable seed system development in the longer term. Furthermore, formal pathways of OFSP vine production, quality control, and dissemination are required to respond to current developments of seed legislation in East and West Africa. Vulnerable people's access to OFSP vines could also be ensured by taking alternative options into consideration (e.g., voucher systems) instead of distributing the vines for free or below production costs.

7.4 LONG-TERM FUNDING AND SUPPORT TO PROJECTS

This case study demonstrates how long-term funding and other support provided by the CCRP resulted in impacts at a relatively large scale. Strengthening Uganda's national sweetpotato breeding program has contributed to the dissemination of OFSP varieties in many other countries. Furthermore, national breeding programs of other countries were also strengthened indirectly (e.g., via germplasm exchange or partnership in regional collaborative projects such as HarvestPlus and SASHA).

PhD and masters students were trained in advanced breeding methods and related skills, which helped them develop their individual careers but also to strengthen institutions in their own or other countries through their capacities and networks.

Conclusion: Long-term funding and support to projects focusing on one topic or issue can contribute to large-scale impact and strengthen research capacities beyond the initially funded project.

7.5 RESEARCH AS A COLLABORATIVE LEARNING ENDEAVOR

The CCRP-funded OFSP projects were all designed as a cooperation of research institutes, with NGOs being involved mainly for facilitating the delivery of research results to farmers or other target groups. Farmers were involved in all three country case studies in the on-farm evaluation of varieties; however, in none of the case studies were farmers or their market partners directly part of the project consortium or otherwise formally involved.

In future projects, it could be considered to take advantage of the rapidly evolving knowledge and expertise on implementing multi-stakeholder cooperation in research on farming and food systems and to involve farmers or farmer organizations (and, depending on the problem or issue addressed, other relevant actors) more formally and directly in the research process. This more formal involvement could also help develop and maintain trust among the project partners (see box).

More emphasis could be placed on developing a joint understanding of the problem or issue addressed before activities are planned. The integration of knowledge from various sources, including non-academic, could facilitate co-innovation and make the outcomes more relevant to farmers and other actors.

It could be better clarified in advance which resources are needed for each partner to participate in the research project and which part of these contributions will be funded by the project or not. Particularly for farmers, it should not be taken for granted that they contribute land, labor, and other resources without compensation and over longer periods.

Conclusion: Involving farmers and other relevant actors more directly and formally in future research projects, not only indirectly via NGOs, could improve the relevance and impact of the research and help create and maintain trust among the partners.It would possibly require a funded project pre-phase, allowing for developing a joint understanding of the problem or issue addressed, for establishing a participatory system of cooperation, and for joint planning of project activities and outcomes.

7.6 SYSTEM PERSPECTIVES AND CHANGE

Crop improvement for improved food and nutrition security is complex and requires a system perspective to assess the outcomes and set priorities. Most projects cannot target the complex interrelations between agri-food systems, environment, and medical/health systems in a comprehensive manner that were described as principal components of nutrition-sensitive agriculture frameworks (see Section 5.1)

The case studies show that it requires constant effort to relate activities and outcomes of individual projects to system perspectives. For example, large-scale promotion of OFSP led to loss of other sweetpotato varieties from farming systems of Uganda, at least in some regions. Impact assessments focus on Vitamin A status of target groups, which has improved. However, this does not necessarily mean that food and nutrition security of these target groups or all villagers has also improved. If other aspects such as availability of food throughout the year, income, stability, and resilience are not considered.

For the AEI concept to become applicable in practice, it would be necessary to constantly relate project activities to a context-specific and evolving AEI framework, for example as part of a Participatory Monitoring and Evaluation system (PM&E). To avoid that, long lists of indicators have to be processed during project meetings. PM&E systems could also be implemented in a more active manner, e.g. by denominating local observer teams whose responsibility is to visit ongoing project activities, reflect on their relevance for reaching the agreed upon goals, and share their observations at meetings (Restrepo et al., 2015).

When it comes to facilitating change at larger scales, influencing macro-factors gain importance. Such factors were not assessed in any of the projects studied. For example, policy, stakeholder, and resource distribution analyses are research issues that go beyond what is normally considered to fall under crop research but could help achieve impact at scale.

Conclusion: To ensure that system perspectives are considered in the development and implementation of project activities, it would be helpful to integrate system frameworks into Monitoring & Evaluation (M&E) activities and reflect on the outcomes on a regular basis and on various levels. Influencing macro-factors should not be left out of consideration if it comes to facilitating change at larger scales.

7.7 GENDER ISSUES IN CROP IMPROVEMENT PROJECTS

If gender issues are not adequately considered, a part of a project's impact can easily be lost. Taking a gender perspective requires more than just addressing women as a target group for project activities. Gender-specific differences and constraints need to be assessed

PARTICIPATION

"Future projects should be implemented and managed in a more participatory manner in order to avoid confidence crises that may have negative effects on the activities. For example, it should be avoided to talk to one farmer alone who is supposed to organize activities with other villagers. Because the others will believe that he was paid or that he is anticipating [being] paid for the successful implementation of certain activities for which others contribute the labor without any compensation."

—Farmer from Boura village, Burkina Faso

BUDGET FOR VILLAGE ACTIVITIES

"A budget should be planned for certain activities at village level, [including] construction of seedbeds, renting a place, and buying food such as rice and sauce for project meetings, or renting loudspeakers locally for presentations at markets and fairs."

—Farmer from Boura village, Burkina Faso

for each objective, activity, and outcome planned and then addressed by specifically designed interventions targeting both women and men. For example, both can contribute to improving the nutritional status of their children, perhaps more effectively if both are aware of their respective contributions. Certain constraints, such as women's limited access to land, can only be solved if men are asked to cooperate in finding solutions. Curricula for trainings and FFS should take the interests and needs of both genders into account equally.

Conclusion: Considering gender issues more systematically in the design of project objectives, activities, and assessment of outcomes could improve the efficiency and impact of research funding in any projects targeting improvements in food and farming systems. Even though gender may not be relevant to certain research questions (e.g., biochemical pathways in crops), an effort should be made to assess how such highly specific research questions are related to broader project goals that may in turn be gender-sensitive.

8 RECOMMENDATIONS

Our main recommendations with regard to the future funding strategies of the CCRP are to:

- Continue long-term funding and support to maximize impacts.
- Invest more time and resources in a project pre-phase where diagnostic surveys can be conducted, a project consortium can be built, and a joint development of the problem or issue in question can be developed before objectives and activities are fixed in a proposal.
- Take care that all partners needed to achieve the aimed-at change are identified in the pre-phase and, whenever possible, formally linked to the project and its management structures. This includes researchers as well as non-academic stakeholders such as NGOs, government bodies, farmers, and actors in supply chains.
- Achieve more clarity on the resources required by each partner to participate in the research.
- Consider full budget funding since it is mandatorily required by many organizations and helps avoid underfinanced projects, thereby limiting their success. This would include considering how farmers and other non-academic partners could be compensated, fully or in part, for the time and resources they invest.
- Put more emphasis on the integration of diverse knowledge and co-innovation of solutions to the problem or issue addressed.
- Develop a clearer focus on and assimilate methodologies for effective participation of farmers and other non-academic partners, starting from the project design phase, in order to increase the relevance of project activities and outcomes.
- Make a gender perspective mandatory for all future projects funded by the CCRP (e.g., by assessing its relevance for all project objectives, activities, and outcomes when establishing the proposal and throughout the project's lifetime).
- Address influencing macro-factors to facilitate impact at larger scales. Go beyond what has traditionally been understood as crop research (or cooperate with other institutions to include a perspective on influencing macro-factors).
- Relate M&E plans for individual projects more clearly to systems frameworks such as nutrition-sensitive agriculture and AEI. Work with such frameworks during project meetings at various levels and CoP meetings to make them practical for the project partners. Facilitate so they can relate their own work more clearly to the bigger picture.
- Consider funding professional project coordinators who are not simultaneously involved as researchers to improve coordination in multi-stakeholder projects and to demand less time from researchers for coordination activities.

- In case funding is not continued, a post-project phase could help jointly secure achievements to avoid the abrupt cutoff of activities and, particularly, the loss of trust among the partners.

We are aware that some of these recommendations are already practiced in current CCRP funding strategies and that the approach has continuously been reviewed during the two decades on which this case study focuses.

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ANNEX

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OVERVIEW MAP

Figure A: Countries in which project activities and outcomes were studied.

Project activities and outcomes were studied in Burkina Faso (West Africa) and in Uganda and Kenya (East Africa). The fieldwork in Uganda took place June 4–19, 2015. The project in Kenya was explored only remotely based on project reports. The fieldwork in Burkina Faso was conducted August 17–26, 2015. Detailed information regarding case study sites and results of fieldwork is presented in the following sections.

MAP OF SITES SELECTED FOR THE FIELDWORK IN UGANDA

Figure B: Sites selected for fieldwork in Uganda. The capital city of Kampala and Namulonge, where the National Agricultural Research center is located, are in blue. The capitals of districts where field sites were selected are in red. Remotely explored field sites in south-west Uganda are in orange.

TRAVEL ITINERARY AND LIST OF FIELD ACTIVITIES IN UGANDA, JUNE 4–19, 2015

Date	Time	Place	Persons/Organization	Commentary
Thursday, June 4	05.20 09.45 21.45 23.20 18.00	Guggenhausen Stuttgart Entebbe Metropole Hotel, Kampala	Gottfried Grace	Departure Guggenhausen Flight Stuttgart-Amsterdam-Entebbe Arrival in Entebbe, transfer to hotel Arrival at hotel
Friday, June 5	08.00 11.00 15.30 19.00	Hotel FRI Office Hotel	Gottfried + Grace Askebir Gebru and Pascal, Farm Radio International Sam Sakwa, consultant, World Bank	Team organization, TORs, methodology, program Phone calls Interview Background interview Team wrap-up
Saturday, June 6	09.00-13.30 15.00	Kampala markets: Nakawa, Nakasero, Kalerwe	Women and men retailers, wholesale traders, farm worker Team	Observations and chats Analysis of findings; planning
Sunday, June 7	09.00 15.20-17.00 19.30	Hotel	Team Ronald Kitanda, former 'Bread for the World' consultant Team	Internet research and document reading Background information on research and donor policies Wrap-up
Monday, June 8	08.45 12.45 16.15 19.00	CIP office VEDCO office HarvestPlus office Hotel	Dr. Robert Mwanga, sweetpotato breeder, program director Grace Babirye, program director Sylvia Magezi, program director Team	Interview Interview Interview Wrap-up
Tuesday, June 9	09.00 10.20 12.15 14.00 15.00 16.20 17.30 20.00	NaCRRI, Namulonge Bombo (Luweero district) Mukono	Sweetpotato department: Dr. Gorrettie Ssemakula, director, breeder Dr. Bernard Yada, breeder Joeria Namakula, technician Joeria Sekiyaga, multiplier Team	Travel to Namulonge Interview Interview Interview Travel to Bombo Interview and field visit, screen house Travel to Mukono, Ridar Hotel Wrap-up

Date	Time	Place	Persons/Organization	Commentary
Wednesday, June 10	09.00	Mukono	Crespo Mubbalya, VEDCO field coordinator	Interview
	10.00	Kiiko market	Retailers, wholesale traders	Observations and chats
	11.00	Uganda Christian University	Robert, chief caterer, and David, kitchen chef	Interview and kitchen visit
	12.30	Restaurant	Team	OFSP dish
	13.00			Travel to Katente
	13.45-	Katente	Luselubi farmers group	Interview and 4 Square
	16.00	(Mukono District)	Team	Travel to Kamuli, Guesthouse
	19.30	Kamuli		Wrap-up
Thursday, June 11	08.00	Kamuli, VEDCO field office	Emmanuel Kasulubadhe and Peter, VEDCO/HarvestPlus field staff	Interview
	09.15			Travel to Bukokoma
	10.15–	Bukokoma	Bukose farmers group	Interview and 4 Square
	12.30	(Buyende district)		Travel to Kamuli
	13.00			
	13.30–	Kamuli	Wilber Naika, head of school and also sweetpotato farmer and trader	Interview
	14.15			
				Travel to Itukulu
	16.30	Itukulu		Interview and 4 Square
		(Kamuli district)	Kyebala farmers group	Travel to Mbale, Green Gardens Hotel
	19.30			Team wrap-up
	20.00	Mbale	Team	Background discussion
			Dr. Michael Wandukwa	
Friday, June 12	08.00	Mbale	Dr. Michael Wandukwa	Continue background discussion
	09.00		Team	Travel to Bukedea
	10.00	Bukedea	Kakibu farmers group	Interview and 4Square
				Field visit, greenhouse
	13.00			Travel to Soroti
	16.30	Soroti SOCADIDO office	Georg Oruka, program manager, SOCADIDO	Interview
	18.30		Soroti Hotel	Check-in
	19.30		Team	Wrap-up
Saturday, June 13	09.00	Soroti	Team	Travel to Abuket
	10.00	Abuket (Serere district)	Managing committee and members of SOSPPA	Meeting
			Coordinator of SOSPPA	Field visit (on farm trials)
	13.30	Odoo	Three women farmers in Odoo	Chat
	14.30	Kyere	SOSPPA Office in Kyere with	Visit and discussion
	15.30	(Serere district)	committee members	
	16.00		Five women farmers in Kyere (non-members)	Chat

Date	Time	Place	Persons/Organization	Commentary
	16.30 18.00	 Soroti	Team Team	Travel back to Soroti Hotel Wrap-up
Sunday, June 14	10.00 12.00 13.00 14.30 17.00 18.30	 Lira	Team Gracious Palace Hotel Mr. Tom, food manager, Gracious Palace Hotel	Travel to Lira Arrival in Lira Team data analysis Individual analysis Continue team analysis Interview on OFSP features and markets
Monday, June 15	09.00 10.00 10.30 11.30 14.30 15.00 18.00 19.00	Lira Aber (Otuke district) Lira Gulu	Ms. Stella Aber, World Vision Team + Ms. Stella Aber (transl.) BOWW Cooperative Soc. Chairman and Assets Manager Aber famers group Team and Ms. Stella Aber Team Hotel Team	Interview Travel to Barr sub-county Chat and field visit Interview and 4 Square Travel back to Lira Feedback Travel to Gulu Arrival in Gulu Wrap-up
Tuesday, June 16	09.00 11.15 11.45 12.45 14.15 15.30 19.00	Gulu Koro-Bobi (Gulu district) Gulu	Harriet, program manager, and Geoffrey, field worker, World Vision Team and Geoffrey Farmer plus multiplier group Team Market women Team	Interview Travel to Koro-Bobi Field visit: greenhouse and multiplication fields Meeting and 4 Square Travel back to Gulu Visit of markets (roots + vines) Wrap-up
Wednesday, June 17	8.00 15.00 17.00 19.00	Gulu Kampala	Team David Talengera, technical director, and Geoffrey, financial director, BioCrops Ltd. Team Team and Yvonne Papendorf, BftW Berlin	Travel to Kampala Interview and visit of the company Check-in at Shangri-La Hotel Dinner

Date	Time	Place	Persons/Organization	Commentary
Thursday, June 18	08.00	Kampala	Team	Final wrap-up
	9.45–12.00		Stella Lutelo, country director, and Joshua Aijuka, program manager, PELUM Uganda	Background interview on seed systems and agroecological issues
	13.00		Grace	Departure to Mbarara
	17.00	Kampala	Ronald Kitende	Discussion on seed system
	19.00		Gottfried	Transfer to Entebbe Airport
	23.35	Entebbe		Departure to Amsterdam/Stuttgart/ Guggenhausen
Friday, June 19	09.10	Stuttgart		Arrival Stuttgart
	12.30	Guggenhausen		Arrival Guggenhausen

LIST OF INTERVIEW PARTNERS IN UGANDA

City/Town	Category	Organization/Function	Name of Contact Person	Female	Male
Kampala	Breeder	International Potato Center (CIP)	Dr. Robert Mwanga		1
	Breeder	National Crop Resources Research Institute (NaCCRI)	Dr. Gorrettie Ssemakula	1	
	Breeder	NaCRRI	Bernard Yada		1
	Technician	NaCRRI	Joweria Namakula	1	
	Biotechnologists/ Multiplier Company	BioCrops Ltd.	Dr. David Talengera Dr. Geofrey Mwesigye		2
	NGO/Disseminator	Volunteer Efforts for Development Concerns (VEDCO)	Grace Babirye	1	
	NGO/Disseminator	Farm Radio International	Mr. Askebir Gebru Mr. Pascal		2
	NGO/Disseminator	HarvestPlus	Dr Sylvia Magezi	1	
	Markets: Nakawa	Retailer	One man		1
		Retailers	Four women	4	
		Farm worker	Joseph Ocen		1
		Wholesale trader	Tom Oonyu		1
	Nakasero	Retailers	Group of three women	3	
	Kalerwe	Retailer	One man		1

City/Town	Category	Organization/Function	Name of Contact Person	Female	Male
Kampala	Kalerwe	Retailers	Three groups of three women	9	
	Resource people	World Bank consultant	Sam Sakwa		1
		Bread for the World, Germany	Yvonne Papendorf	1	
		Process consultant	Ronald Kitanda		1
	NGO	Participatory Ecological land use management, Uganda (PELUM)	Ms. Stella Grace Lutalo Mr. Joshua Aijuka	1	1
Bombo	Farmers group	Bagya Basaaga farmers group, Nyimbwa Village	Joeria Sekiyaga	1	1
Mukono	NGO	VEDCO field coordinator	Crespo Mubbalya		1
	Markets	Kiiko market	Two women traders	2	
		Roadside wholesaler	Wholesale trader		1
	Uganda Christian University	University caterer	Mr. Robert		1
		Kitchen chef	Mr. David		1
	Farmers group	Luselubi farmers group, Katente village, Nakisunga sub-county		7	1
Buyende	NGO	VEDCO field coordinator Field worker	Emmanuel Kasulubadhe Mr. Peter		2

City/Town	Category	Organization/Function	Name of Contact Person	Female	Male
	Farmers group	Bukose abanda abangi rural producing organization, Bukokoma village, Bugaya sub-county		10	8
	Canaan Junior School	Head teacher, trader, farmer	Mr. Wilber Naika		1
Kamuli	Farmers group	Kyebaja Tobona Farmers group, Itukulu Village, Nawanyago sub-county		6	4
Mbale	Resource person	Government consultant	Dr. Michael Wandukwa		1
Bukedea	Farmers group	Kakibu seed security and marketing systems farmers group, Kachulu villlage, Koena parish, Kidongole sub-county	Mr. Charles Otuda	2	6
Soroti	CBO/NGO	Soroti Catholic Diocese Integrated Development Organisation (SOCADIDO)	Mr. George Oruka		1
Serere	Farmers groups union	Soroti Sweetpotato Processing Association (SOSSPA)	Mrs. Christine Ekunyu Mr. Joseph Okalebo	7	5
	Farmers (not members)		Three farmers in Odoo Five farmers in Kyere	8	
Lira	NGO/Disseminator	World Vision field extension worker	Ms. Stella Aber	1	
	Farmers group	Cam Ingeyo Banya farmers group	George Alele, chairman	13	2
	Hotel	Food and beverage manager	Mr. Tom		1
Gulu	NGO/Disseminator	World Vision program manager	Ms. Harriet Alonyo Nyeko	1	

City/Town	Category	Organization/Function	Name of Contact Person	Female	Male
Gulu		World Vision extension field worker	Mr. Geoffrey		1
	Farmers group	Koro-Bobi OFSP Producers organization		3	6
	Market	Retailers Sweetpotato vine (white) retailers		9	
Kabale	NGO/Disseminator	HarvestPlus field coordinator	Mr. Wilberforce Serwanga (phone interview)		1
			Total	**92**	**57**

INFORMATION ON SELECTED STUDY LOCATIONS

Namulonge is located in Kyaddondo County, Wakiso district in Central Uganda, approximately 10 km north of Gayaza and 30 km northeast of Kampala. The National Crops Resources Research Institute (NACRRI) is located at Namulonge.

Luweero-Mukono is located in Central Uganda. Characterizing this zone are higher temperatures and more intense rainfall plus heavier textured soils of silt and clay. Population density is lower compared to other parts of the country, though still relatively high at around 83 persons per square kilometer. A wide variety of crops are grown. Unlike other areas, sweetpotato is often cultivated in furrows. Sweetpotato is usually established in July. This region is also known as the hot spot for virus infections.

Bukedea-Kamuli-Buyende is located in Eastern Uganda around the Kyoga plains. Average rainfall range of 1,215 – 1,328 mm. Two rainy seasons in the southern part, with the main season from March to May and peak in April, and secondary season from August to November with a peak in October/November. Main dry season December to February; secondary dry season is June and July. Evaporation exceeds rainfall by a factor of about three during the dry months of December to February. During the main rainy season, rainfall is greater and/or about equal to evaporation. With a very high population density (more than 520 people per square kilometer), agricultural land holdings are usually small. Sweetpotato can be cultivated to some extent throughout the year, but the main season is March through August, often following a groundnut harvest. Other crops of local importance include sugar cane, soybean, yam, and rice cultivated in swampy areas. Most popular sweetpotato varieties are those of white or yellow flesh.

Serere-Soroti is located in the central-eastern region of Uganda. Virtually one rainy season in the northern part from March to November, with the main peak in April/May and a secondary peak in August/September. One dry season December to about mid-March. Evaporation exceeds rainfall by a factor of about eight during the dry months December to February. During the main rainy season, rainfall is greater and/or about equal to evaporation. Temperature ranges from 15 – 32.5 °C. Altitude ranges from 914 – 1,800 m asl. Sweetpotato often planted in early August is available for harvest around late October, generally following previous harvests of other crops such as groundnut (also called peanut), maize, millet, and sorghum. Soil preparation is usually undertaken by hand, often by women. Two to four cuttings are planted in small mounds typically 0.5 meters apart. Other crops of importance during this season include cassava. Sweet potato is often harvested piecemeal, or gradually as needed, so that foliage continues to re-seed and roots remain viable until lost to pest infections or rot.

Lira-Gulu-Otuke is located in the Northwestern savanna grasslands. Average rainfall range of 1,340 – 1,371mm with moderate variability, from about 1,200 over northwestern and western parts to about 1,500 mm over the southern parts. One rainy season, about seven and a half months from April to about mid-November, with the main peak in August to mid-October and a secondary peak in April/May. One long dry season of about four months from mid-November to late March causes loss of planting material since all crops dry out. In the months of April to June, more than half of households experience food insecurity. Driest months are December to February. Evaporation exceeds rainfall by a factor of up to ten during the driest months from December to February. During the rainy months of May, August, and September, rainfall exceeds evaporation. Temperature ranges from 15 – 25°C. Mainly smallholder food and cash crop farming with subsistence done in most areas. This zone has largely poor incomes due to high levels of strife. Land is abundant in this zone and, hence, there is high potential for increased production.

Kabale, Mbarara is located in Uganda's southwest. Bimodal rainfall, hilly terrain, and relatively productive soils; interactions with human activities resulted into varied agricultural systems and land-use practices. This region is characterized by some areas of higher altitude and cooler temperatures compared to others above. Population density is also high, at around 273 persons per square kilometer, making land a scarce resource. Farmers own small pieces of land. Predominant crops include grains, mainly maize, sorghum, millet, and Irish potatoes.

LIST OF VARIETIES GROWN

Table A: List of local and introduced varieties grown in six villages of Uganda (June 2015). OFSP varieties are in orange. Varieties predominantly grown by women or men are marked with (w) or (m), respectively.

Village	Local varieties	Introduced varieties
Katente Mukono district Central region	Bundiguza Sukali Kifoko Bijodolo Mwolanfunzi (m) Kyebandula (w)	Ejumula (w) Vita Kabode Kakamega NASPOT 12 O NASPOT 13 O NASPOT 1 NASPOT? Kawogo
Bukokoma Buyende district Eastern region	Muwulu aduduma Sula oluti Bunduguza Namukoma Nakasooma Kampala Acholi Siiliki Nabagereka Kibirikyambidi Nyindoyamularo Bulili bwampube Museveni Mpa efumbiro Sukali	Ejumula Kakamega Kabode Vita 1136 Nase14
Itukulu Kamuli district Eastern region	Nyindoyamularo Bunduguza Sula oluti Nakaima Muwulu aduduma Mpa efumbiro Kyebandule Kawogo Kibirikyambidi Mukatinduma (=Acholi) Nakasoma Tanzania Klagabolige Lilawo	Kagamega Vita Ejumula Kabode NASPOT 12 O NASPOT 13 O NASPOT 8

See next page for continuation.

Village	Local varieties	Introduced varieties
Kakibu Bukedea district Eastern region	Boy Kasim Epuramajog Akejeyikapa Betty (w) Susan (w) Tanzania Okobo Osuat Abarakere (m) Bunduguza Opapali (m) Arakaraka Abukokin Kampala (m)	Kakamega Ejumula Kabode Vita NASPOT 8 NASPOT 12 O NASPOT 13 O Gibson
Koro Bobi Gulu district Northern region	Cwaraopak Kampala tara Kinyala Lim ka dong Pokinyeki Dorcus Alero Labardege Lailon	Ejumula Kakamega Kabode Vita NASPOT 1 NASPOT 8 NASPOT 12 O NASPOT 13 O
Barr Lira district Northern region	Oleke Abututeng Penina Kakondo Rakaraka-Atar Rakaraka-Arema Okonyoneto Anamoyita Betty (=Otacla, Lira lira) Kenya (=Mbale) Inyang Beri-Majar	Vita Kabode Kakamega Ejumula NASPOT 4 NASPOT 8

RESULTS OF PARTICIPATORY DISTRIBUTION ANALYSIS CONCERNING VARIETY USE IN UGANDA

The below (Figures C1–6) show sweetpotato varieties used by farmers, distributed according to 1) the relative number of farms growing the variety, and 2) the relative area grown per farm. OFSP varieties are in orange. Varieties predominantly grown by women or men are marked with (w) or (m), respectively. The village name is in the center.

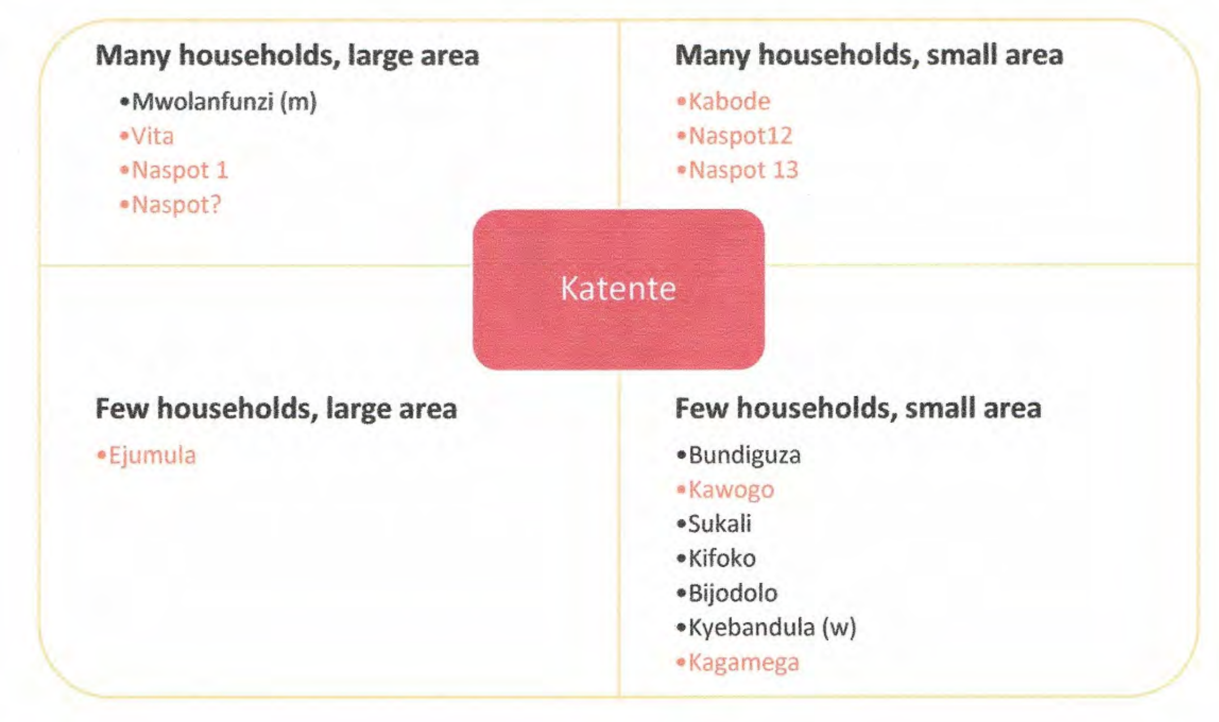

Figure C1: Distribution of sweetpotato varieties in the village of Katente, Mukono district, Central region. Variety names are as stated by the participants.

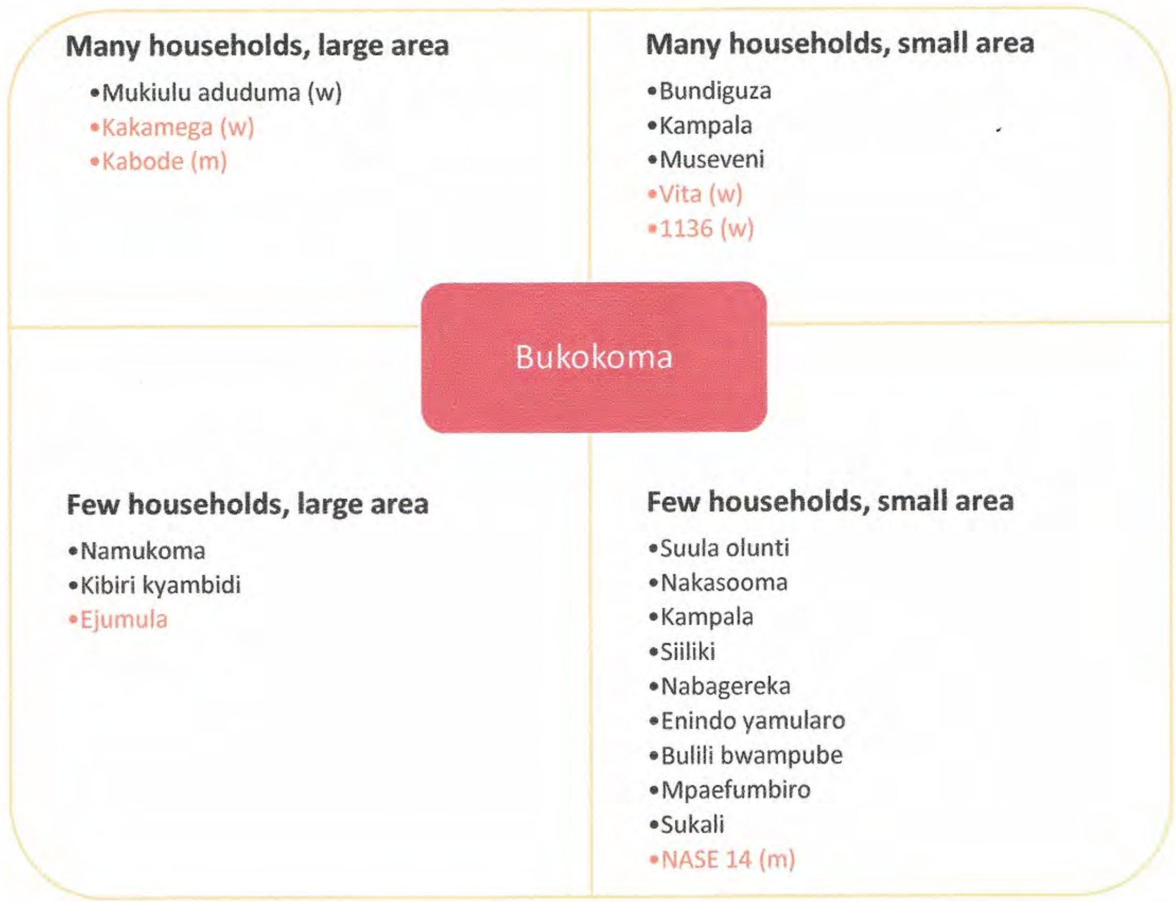

Figure C2: Distribution of sweetpotato varieties in the village of Bukokoma, Buyende district, Eastern region. Variety names are as stated by the participants.

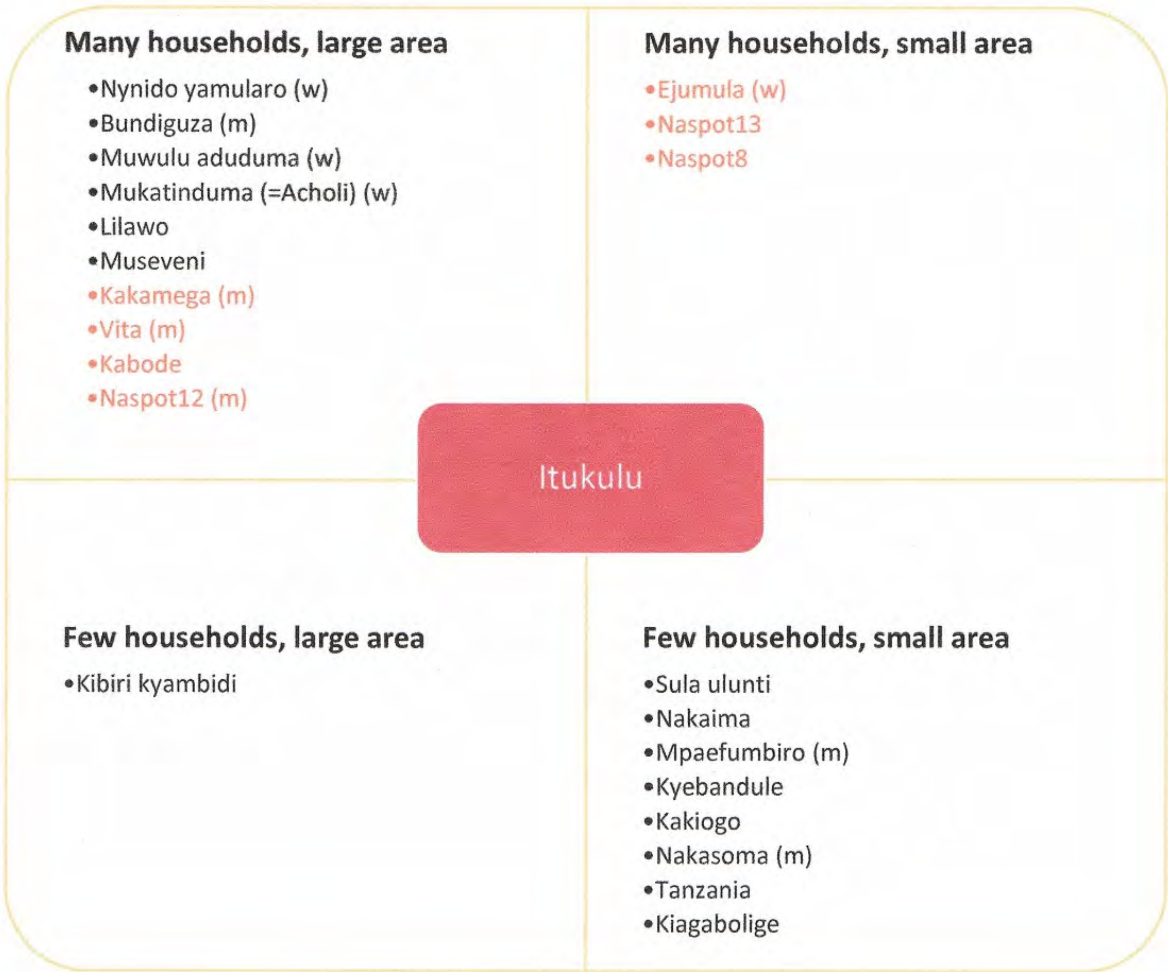

Figure C3: Distribution of sweetpotato varieties in the village of Itukulu, Kamuli district, Eastern region. Variety names are as stated by the participants.

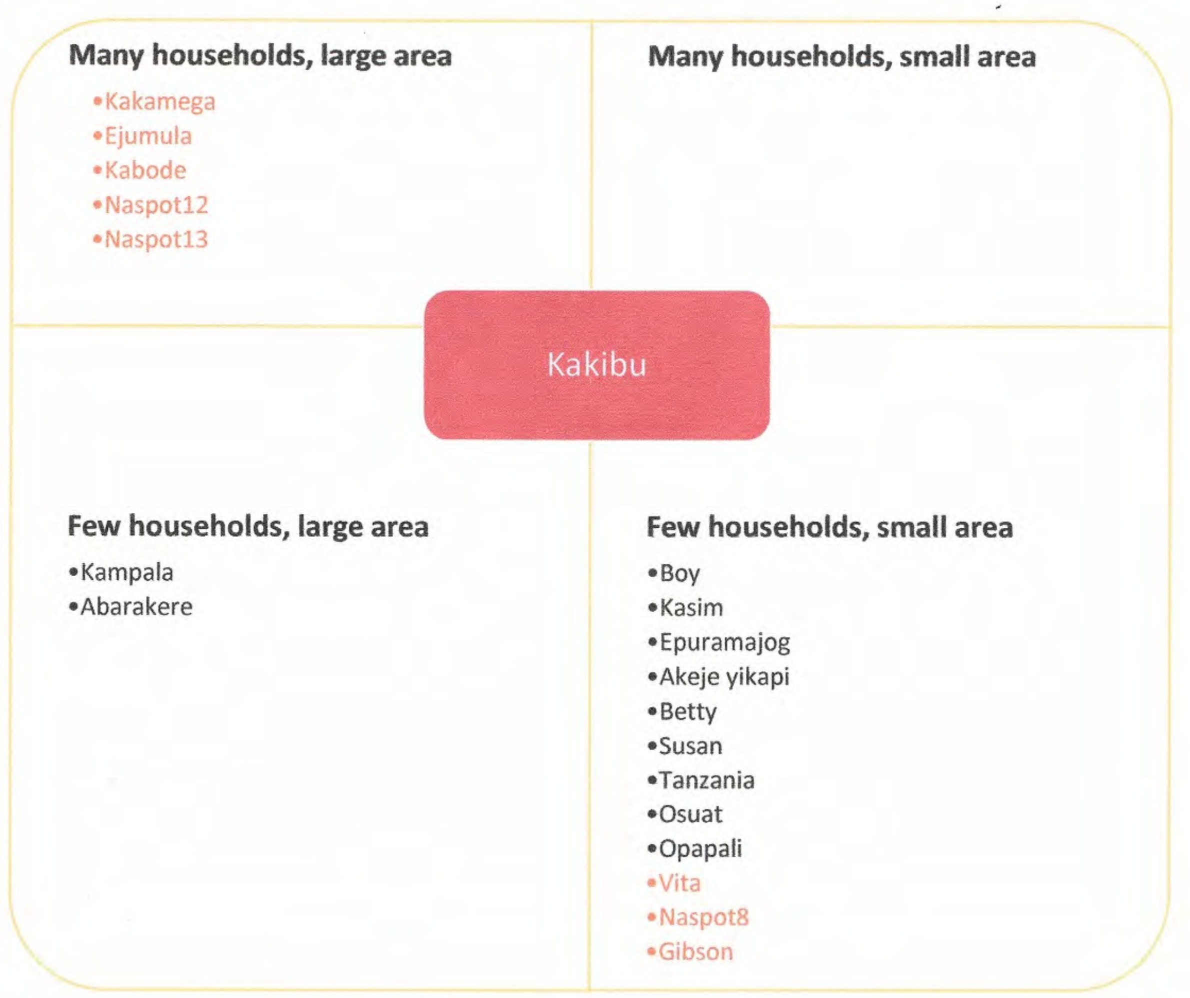

Figure C4: Distribution of sweetpotato varieties in the village of Kakibu, Bukedea district, Eastern region. Variety names are as stated by the participants.

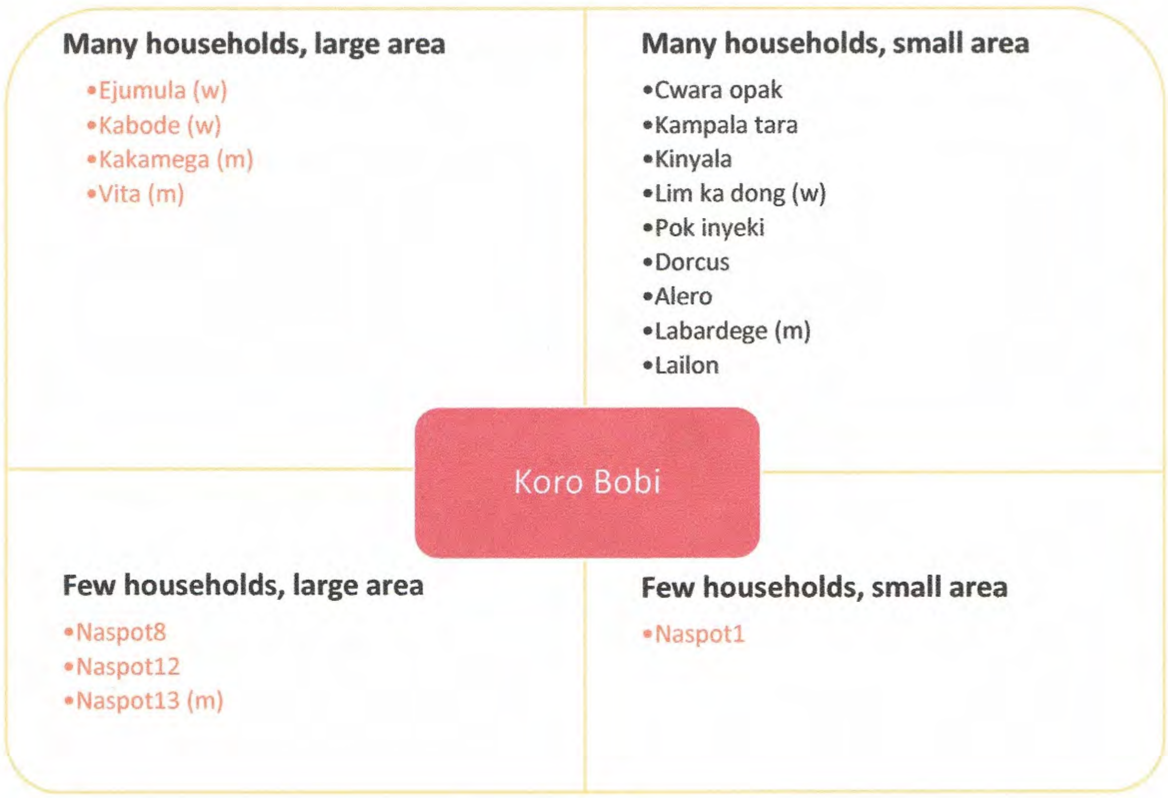

Figure C5: Distribution of sweetpotato varieties in the village of Koro Bobi, Gulu district, Northern region. Variety names are as stated by the participants.

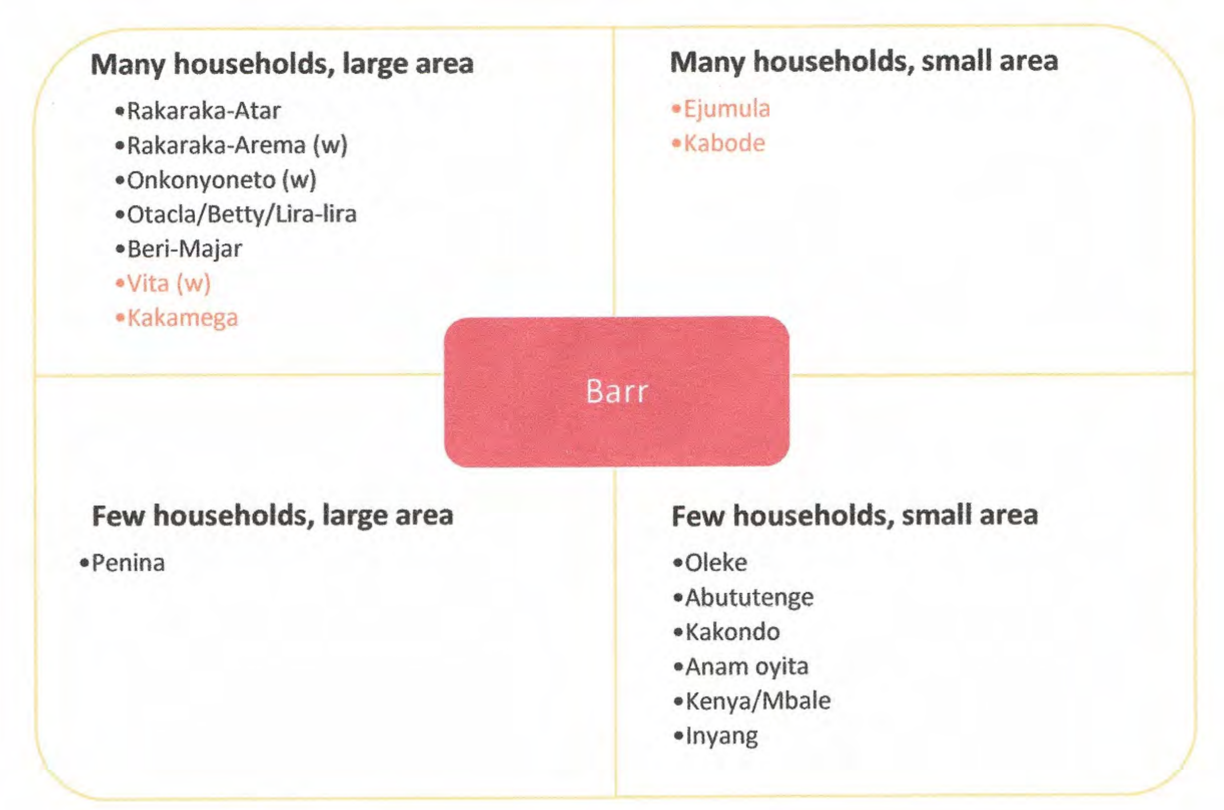

Figure C6: Distribution of sweetpotato varieties in the village of Barr, Lira district, Northern region. Variety names are as stated by the participants.

MAP OF SITES SELECTED FOR THE FIELDWORK IN BURKINA FASO

Figure D: Sites selected for fieldwork in Burkina Faso. The capital city of Ouagadougou and the capital of Sissili province, Léo, are in blue. The selected study villages of Boura, Yoro, and Sagalo are in red.

TRAVEL ITINERARY AND LIST OF FIELD ACTIVITIES IN BURKINA FASO, AUGUST 17–26, 2015

Date	Time	Place	Persons /Organization	Commentary
Monday, August 17	Morning		Grégoire and Marthe	Travel to Ouagadougou
	19.00	Hotel Ouagadougou	Grégoire and Marthe	Team formation
Tuesday, August 18	10.00–11.20	Helen Keller International, Office	Mme. Fanny Yago-Wienne, country director, and Dr. Regina Khassanova Traoré, head of nutrition programs	Overview of activities conducted in the framework of the CCRP-funded OFSP project
	11.30–14.45	Restaurant	Grégoire and Marthe	Reflection on facts learned from HKI and observations
	15.00–17.20	IRSAT/DTA	Dr. Konkobo Charlotte and Dr. Leguet Ganou	Conversation on lessons learned from the project, including constraints and suggestions
	18.10–19.00	Hotel	Grégoire and Marthe	Reflection on conversation at IRSAT and preparing for next day
	19.00–19.30	Hotel	Said General Services	Contract for car rental (to prepare fieldwork in rural areas)
Wednesday, August 19	08.30-09.30	SODEPAL	Simone ZOUNDI	Conversation on the context for processing and consumption of OFSP in Ouagadougou
	10.00	Université de Ouagadougou Département de Chimie/LCOPA	Prof. Mouhoussine Nacro Dr. Adama Hema Dr. Moumouni Koala Dr. Oumar Toé Dr Abdoulaye Sérémé	Interview on project development and outcomes, difficulties faced, lessons learnt, suggestions
	16.00	INERA	Dr. Koussao SOME, sweet potato breeder, and Mr. Souleymane, KOUSSOUBI	Interview on project activities, strengths and weaknesses, lessons learned and contributions
	18.00–19.00	Hotel	Grégoire and Marthe	Team reflection
Thursday, August 20	09.00–12.00	Ouagadougou	Grégoire and Marthe	Travel to Léo, Sissili province
	12.00	Léo	Grégoire and Marthe	Arrival at Léo
	14.00–18.00	Léo and Yoro	Grégoire	Organization of fieldwork in villages, meeting with contact people

Date	Time	Place	Persons /Organization	Commentary
Thursday, August 20	14.00–18.00	Hotel	Marthe	Synthesis of interviews with IRSAT and SODEPAL
Friday, August 21	08.00–12.00	Yelpouga	Mr. Niebé Nouhoun, president, Yelpouga farmer group	Meeting and interview with a pilot OFSP farmer (group meeting envisioned for August 25)
	14.00–17.00	Hotel at Léo	Mrs. Yago Josiane, president, group of OFSP processors at Léo	Conversation on OFSP products and processing, consumption, opportunities and constraints
Saturday, August 22	08.30–14.30	Yoro village	Yoro farmer group Benon Sylvain, president Group of women farmers Paul Zopoula, individual farmer Passielo Bassinda, individual farmer	Participatory distribution analysis; two group interviews with women and men who had been involved in project activities; three interviews with individual farmers
	17.00–19.00	Hotel at Léo	Grégoire and Marthe	Team reflection on interviews and planning for next day
Sunday, August 23	09.00–13.00	Sagalo village	Group interview (men) Group interview (women) Nignan Roger, president of farmer group	Similar to work at Yoro on August 22
	15.00–17.00	Léo	Napon Clément, OFSP producer and trader	Conversation on OFSP transactions, strengths and weaknesses, problems and opportunities
	18.00–19.00	Hotel at Léo	Grégoire and Marthe	Team reflection and documentation
Monday, August 24	All day	Boura village	-Mixed group (women and men) -Jean Sawadogo (president) -Women group	Similar to work at Yoro and Sagalo
Tuesday, August 25	08.00–12.00	Léo	Grégoire and Marthe	Team reflection, documentation of results
	12.30–14.00	Yelpouga	Nébié Nouhoun	Interview; back to Ouagadougou
	17.00	Ouagadougou	Arrival at hotel	Documentation of results

Date	Time	Place	Persons /Organization	Commentary
Wednesday, August 26	08.00–10.00	Hotel	Grégoire and Marthe	Documentation of results from fieldwork and handing over all documents to Marthe
	10.00	Hotel	Grègoire	Departure to Koudougou
	10.00–12.00	Hotel	Marthe	Continuation with documentation of results
	16.00	INERA	Dr. Jérome Belem	Conversation on project development and achievements phases 1 and 2; lessons learned, contributions, suggestions
	18.30–19.00	Hotel	Marthe	Reflection and documentation
Thursday, August 27	08.00–10.00	Hotel	Marthe	Completing documentation of fieldwork
	11.00–14.55	Ouagadougou airport	Marthe	Departure to Niamey (arrival at Niamey 14.55)

LIST OF VARIETIES GROWN

Table B: List of local and introduced varieties grown in three villages of Burkina Faso (August 2015). OFSP varieties are in orange. Yellow-fleshed local varieties are in light orange.

Village	Local Varieties	Introduced Varieties
Boura Sissili province Central-western region	Nayou rondo (=Américain) Nayou pelga Nayou zinga	Caromex Tiébélé Jewel (= Joel)
Sagalo Sissili province Central-western region	Nayou pon Nayou sion Nayou tchachalé (= Américain) Nayou minan Tchanibalanayiri (= Two Months) Locale	Tiébélé Jewel (= Joel)
Yoro Sissili province Central-western region	Nayou soumou Nayou pômon Nayou fiamon	Tiébélé (= Orange) Caromex (= Caromète) Jewel (= Joel)

RESULTS OF PARTICIPATORY DISTRIBUTION ANALYSIS CONCERNING VARIETY USE IN BURKINA FASO

The below (Figures E1–3) show sweetpotato varieties used by farmers, distributed according to 1) the relative number of farms growing the variety, and 2) the relative area grown per farm. OFSP varieties are in orange. The village name is in the center. Variety names are as they were stated by the farmers during the exercise. Refer to Table B for explanation of variety names.

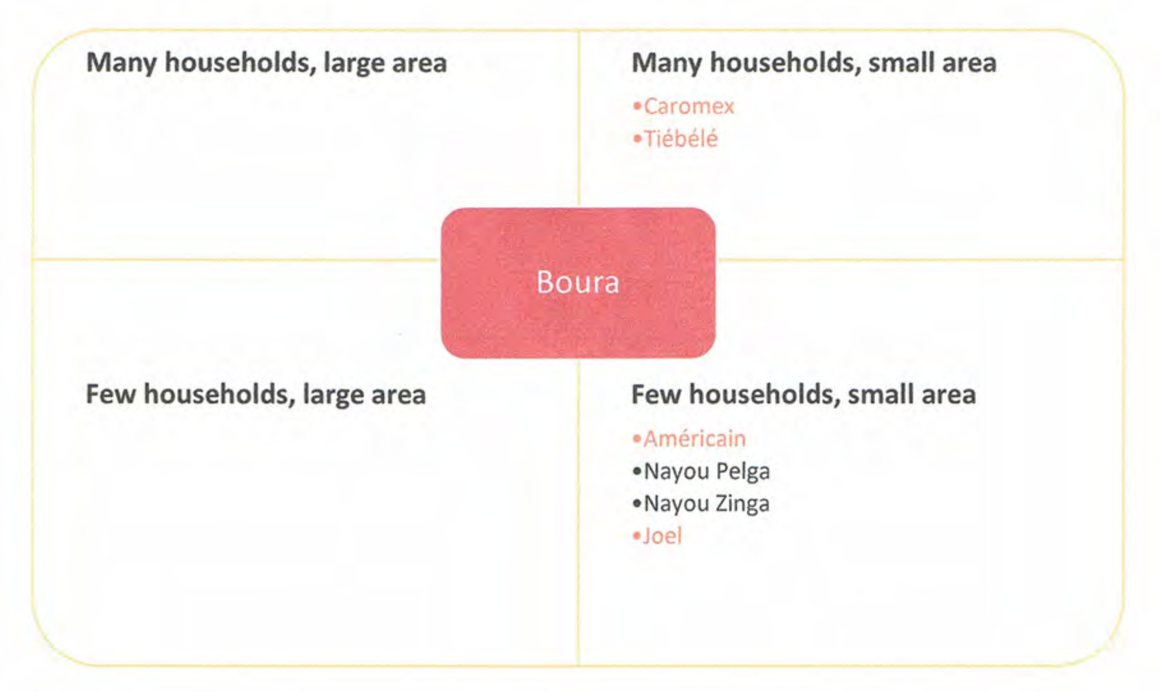

Figure E1: Distribution of sweetpotato varieties in the village of Boura, Sissili province, West-central region. Variety names are as stated by the participants.

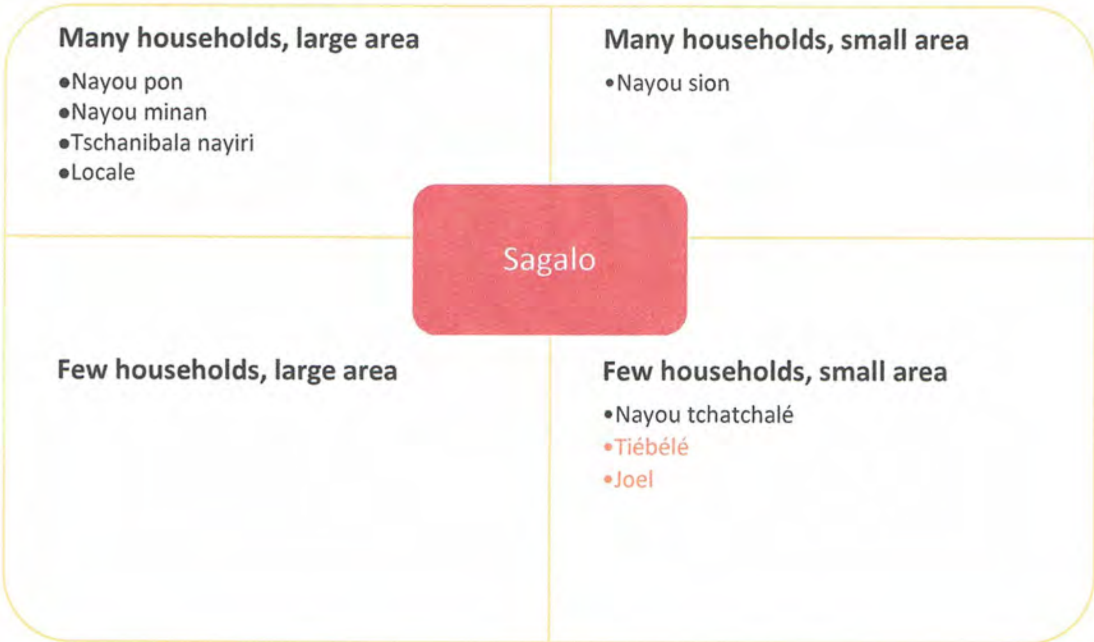

Figure E2: Distribution of sweetpotato varieties in the village of Sagalo, Sissili province, West-central region. Variety names are as stated by the participants.

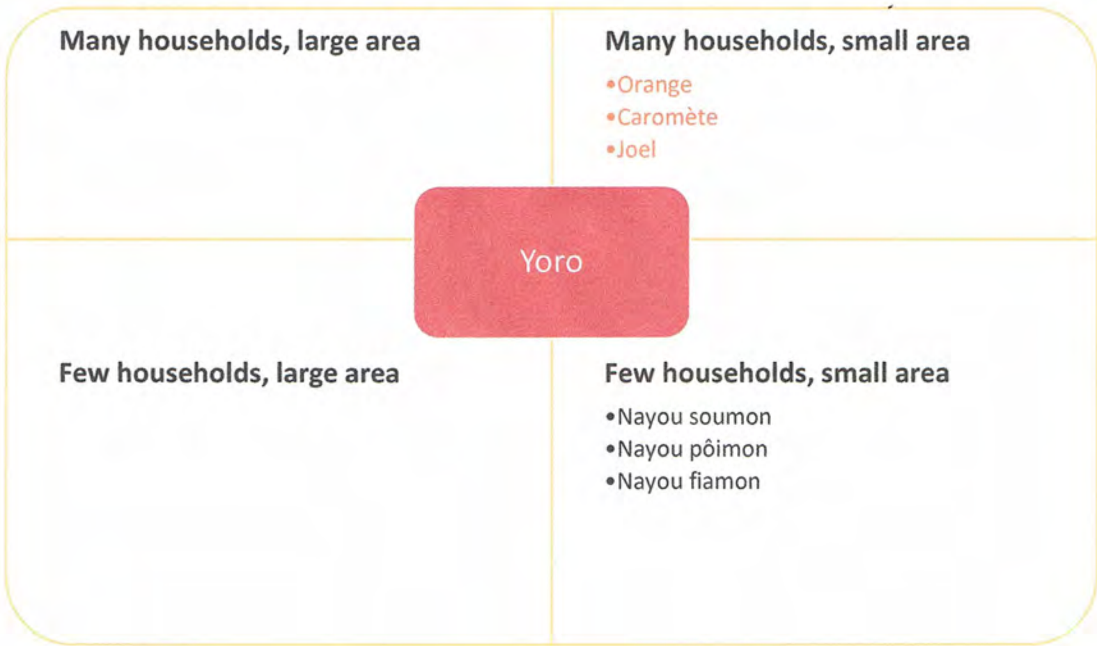

Figure E3: Distribution of sweetpotato varieties in the village of Yoro, Sissili province, West-central region. Variety names are as stated by the participants.

Photo: G. Palé

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