Innovation Opportunities in Sweet Potato production in Kenya

GUIDE BOOK

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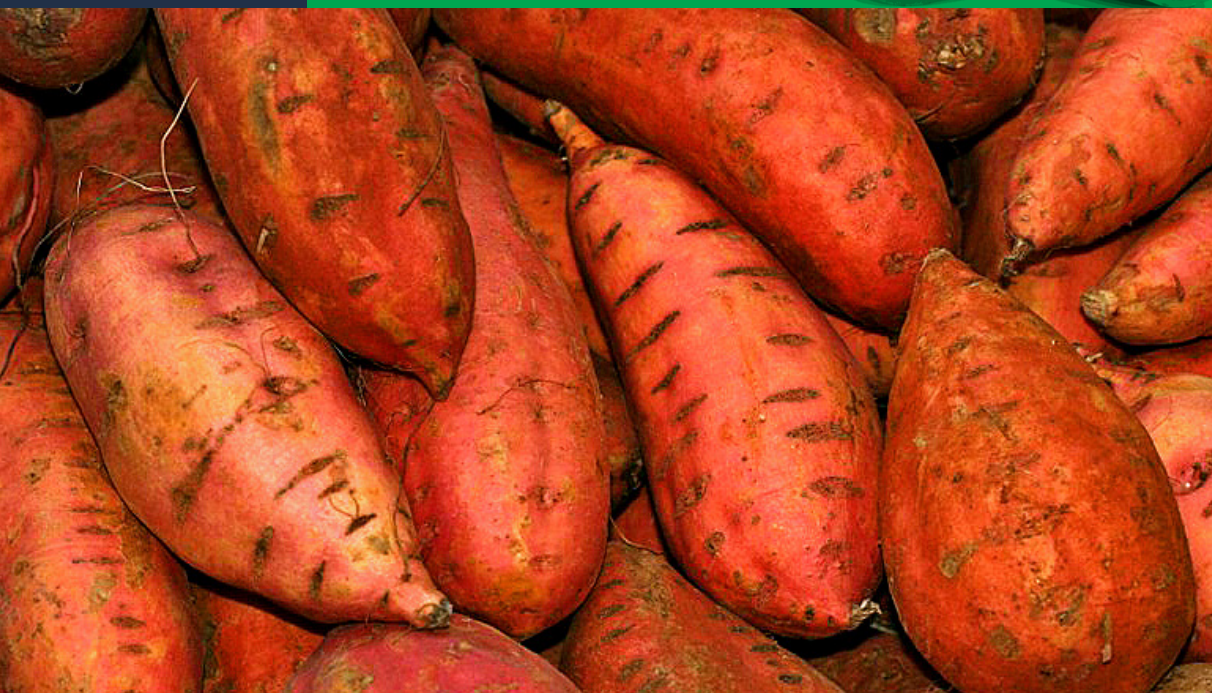
January 2018



FARA Forum for Agricultural Research in Africa
PARI
zef Center for Development Research University of Bonn
KALRO Kenya Agricultural & Livestock Research Organization

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Citation

Makini FW, Mose LO , Kamau GK, Salasya B, Mulinge WW, Ongala J Makelo MN and Fatunbi AO (2017). Innovation opportunities in Sweet potato Production in Kenya. Forum for Agricultural Research in Africa (FARA), Accra Ghana

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ISBN: 978-9988-8776-2-0

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List of Abbreviations

AGRA	Alliance for a Green Revolution in Africa
CAADP	Comprehensive African Agricultural Development Program
CBOs	Community Based Organization
CIP	International Potato Centre
CRS	Catholic Relief Services
FARA	Forum for Agricultural Research in Africa
FCI	Farm Concern International
ICT	Internet Communications Technologies
IFAD	International Fund for Agricultural Development
IFC	International Finance Cooperation
KALRO	Kenya Agricultural and Livestock Research Organization
KEPHIS	Kenya Plant Health Services
KES	Kenya Shillings
LZARDI	Lake Zone Agricultural Research and Development Institute
MOA	Ministry of Agriculture
NEPAD	New Partnership for Africa's Development
NGOs	Non-Governmental Organization
OFSP	Orange Fleshed Sweet Potato
PARI	Programme for Accompanying Research in Innovations
PO	Producer Organizations
R&D	Research and Development
RARP	Rural Access Roads Project
SACCOs	Savings and Credit Cooperative Organizations
SASHA	Sweet Potato Action for Security and Health in Africa
SME	Small and Medium size Enterprises
SpPUs	Sweet Potato Production cells or Units
SSA	Sub Saharan Africa
T& BDS	Technical and Business Development
USA	United States of America
WFP	World Food Programme

Foreword

Advances in Africa agriculture is contingent on the volume of technologies that is available for use in the sector. Apparently, the same condition was responsible for the agricultural transformation and food sufficiency in the advanced world. Every development in the history of mankind is orchestrated by technological revolutions; more specifically when technologies meets up with felt needs and social political will for change. The precarious state of Africa agriculture seems to have attain this threshold of pain more than a decade ago and triggered the action of different organization and pollical structures through the Africa Union Commission. The development of the Comprehensive Africa Agricultural Development Program (CAADP) in 1994. The CAADP ideal proposed a budgetary allocation of 10% at the country level to agricultural sector in order to yield six percent annual growth on the average. A key pillar of the earlier days of CAADP subscription by the countries was the pillar four which stood for actions around technology generation, dissemination and adoption. This was led by the Forum for Agricultural Research in Africa and its stakeholders, FARA thus took the pillar 4 action as its focus for contributing to the transformation of Africa agriculture. The efforts yielded ample attention to technology generations across board, and series of technology testing actions in several pilots. Some of the technologies have potentials and a handful also stood at bay requiring further development to yield the desired outputs.

Despite the efforts into technology generation, introduction, adaptation etc. the agricultural sector development only experiences a slight move and it seems to plateau suggesting that other actions are required to sustain the growth of the sector. A more recent effort at the continental level is the commitment of the head of state in Malabo, to sustain the CAADP momentum. The Malabo declaration came up with various targets including the doubling of the Total factor productivity by 2025 as well as eradicating hunger among others. Attaining these targets will be elusive without a firm commitment to technology generations, dissemination and adoption in a very systematic way. FARA has developed the Science Agenda for Africa Agriculture (S3A) to fast-track the broad contribution of science to deliver technologies and knowledge to ensure the delivery of agricultural growth and transformation. The S3A has four thematic focus and there cross cutting area, this is currently getting grounded at the country level with the expectation of yielding sustainable broad based socioeconomic benefit from the agricultural sector.
In addition to these efforts, the need to bring existing and upcoming technologies to scale has been highlighted broadly by policy makers and development practitioners in Africa. This felt need came along with the mantra that Africa have a lot of technologies on the shelve that are yet to be translated to socio economic benefit for the stakeholders in the sector. Whether this is factual or not, Africa agriculture requires a systematic way of bringing technologies with very high potentials to scale. This book aims to bridge this gap in knowledge, by reviewing the existing knowledge on scaling technologies and innovation. It provides a comprehensive review of knowledge and systematically propose

various strategies to ensure that agricultural technologies are scaled up and scaled out for mega social and economic benefits.

The book contains seven chapters that exhaustively covers the subject matter and make a smart proposition on the plausible pathway to ensure that agricultural technologies delivers a vibrant and economically sustainable agrarian sector.
I wish you a fruitful reading expedition.

Yemi Akinbamijo (PhD)
Executive Director, FARA

Acknowledgements

The authors wish to acknowledge the efforts and contribution of the different individuals that contributed to the technical review of this book to ascertain its peer review status. We acknowledge the efforts of Dr. Abdulrazak Ibrahim who read through the manuscript, We are also grateful to Mr. Joseph Mugha for undertaking the language editing work on this manuscript.

The studies and documentation endeavor for this book was carried out within the Program of Accompanying Research for Agricultural Innovation (PARI). The PARI project is coordinated at the global level by the Center for Development Studies (ZEF), University of Bonn in Germany and the Forum for Agricultural Research in Africa (FARA) is coordinating the action in 12 Africa countries. The funding for this work was provided by the German Federal Ministry of Economic Cooperation and Development (BMZ).

CHAPTER **01**

Introduction and Agronomy

2ND

AFRICA IS THE **SECOND LARGEST PRODUCER** OF SWEET POTATO

10.6% TOTAL WORLD PRODUCTION

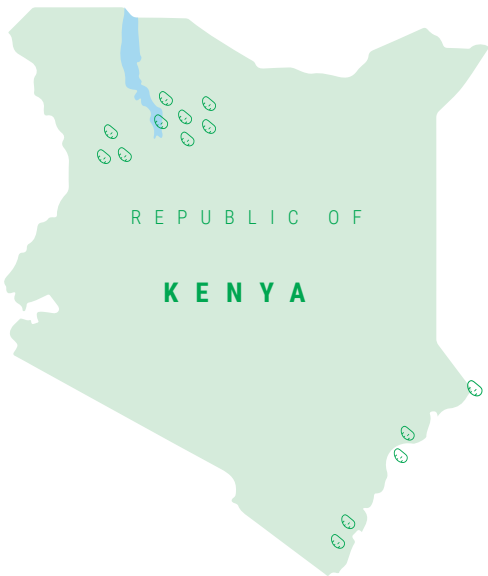
FOLLOWING **ASIA**, WHICH ACCOUNTS FOR 86.5 %

Sweet potato (Ipomoea batatas (L.) is an important food, feed and vegetable crop in most developing countries, which account for about 97 percent of the world production. They produce 131 million tonnes per year on approximately 9 million ha and obtain mean estimated yields of 13.7 tonnes ha-1 (FAOSTAT, 2009). The crop is ranked fifth economically important crop after rice, wheat, maize, and cassava, sixth in dry matter production, seventh in digestible energy production, and ninth in protein production in the developing countries (Stathers et al., 2005; Thottappilly and Loebenstein, 2009). Sweet potato is widely grown in Africa, Asia, and Latin America, with China accounting for 52 percent of the crop, grown on approximately 4.7 million ha (FAOSTAT, 2009). It is among the world's most important root crops; it originated from Latin America and was introduced into Africa by Portuguese navigators in the 16th century. Africa is the second largest producer of sweet potatoes, accounting for 10.6 percent of total production. It follows Asia, which accounts for 86.5 percent of the world's production. In sub-Saharan Africa (SSA), it is the most widely grown root crop, where about 9.9 million tonnes of storage roots are produced on an estimated 2.1 million ha (FAOSTAT, 2009; Ndamange 1987).

In Kenya, sweet potato is an important staple crop (Hagenimana et al., 2001; Irungu and Kidanemarium, 1992; Ewell, 1990). Acreage under the crop has been increasing for various reasons, notably: decreasing soil fertility in most of the agro-ecological zones of the country; removal of subsidies for fertiliser and seeds for major crops such as wheat and maize as part of trade liberalisation policies; devastating pests and diseases of major crops such as wheat and maize; a growing understanding by consumers that sweet potato is a healthy crop to consume rather than a poor man's food; and the growing shift of sweet potato from a subsistence to a commercial crop (MoALF 2015; Muli and Agili, 2013; Kwach et al., 2009; Kwach et al., 2010; Stathers et al., 2005).

Sweet potato-producing areas in Kenya

Sweet potatoes in Kenya are produced in the Lake region (Western and Nyanza), Rift Valley, Coastal and Central Kenya with the Lake Region leading in production. Various varieties are grown; varieties Kemb 10 and SPK 004 are suitable for most areas in the country; KSP 20, KSP 11, and CIP 420009 for the drier areas; SPK 013 for the Western zone including the Lake Basin; Kemb 23 and Ex-Diani for the Central and Coastal lowlands, and Mafuta for all sweet potato-producing areas for foliage production (Muli and Mwakina, 2016; Kwach et al., 2014; Odhiambo et al., 2011).



The leading sweet potato-producing area in Kenya is the Lake region, comprising and Western Kenya followed by Central and Coastal regions.

Taxonomy of sweet potato

The varieties are distinguished based on morphological traits and have a wide variability of botanical characteristics, agronomic requirements, and reaction to pests, diseases, and other stresses.

Assessments of variations in the vine, leaf, flower, and storage root characteristics have traditionally been used for identifying sweet potato cultivars (Huaman, 1991). Sweet potato is a herbaceous perennial plant in the Convolvulaceae family. It is a branching and creeping vine that bears alternate heart-shaped or palmately lobed leaves (Figure 1) and medium-sized flowers of varying colours depending on variety. The storage tuberous roots are long and tapered, with a smooth skin (Figure 2). Skin and flesh colours may be yellow, orange, red, brown, purple, and beige (Figures 2 and 3). Growth of sweet potato may be erect, semi-erect, or spreading, with vine systems that expand rapidly in a horizontal manner (Figure 1).

Figure 1 Leaf shape - (lobed, semi-palmate, palmate)

Figure 2 Tuber skin colours – (red, white, brown)

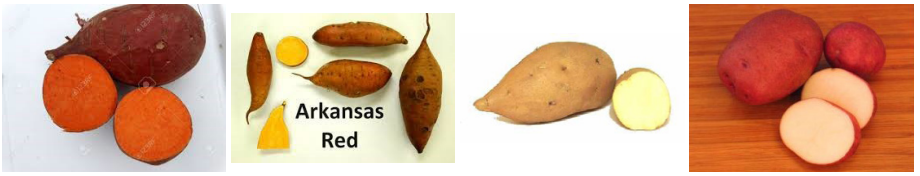


Figure 3 Flesh colours – (orange, yellow, cream, white)

Nutritional value of sweet potato

The nutritional value of sweet potato, like most crops, depends greatly on climatic and soil conditions (Aywa et al., 2013; Kidmos et. al., 2007; Woolfe, 1992). Variations are also present between and within varieties depending on the stage of maturity and growing conditions (Table 1).

Table 1 Nutritional value of sweet potato tubers

Nutrient	Amount per 100 g of raw edible portion
Protein	1.65 g
Carbohydrates	21.3 g
Fibre	3.0 g
Energy	105 Kcal
Vitamin A	2000 µg
Vitamin B1	0.07 mg
Vitamin B2	0.147 mg
Vitamin B3	1.01 mg
Vitamin B6	0.257 mg
Vitamin C	22.7 mg
Vitamin E	0.28 mg
Calcium	22.0 mg
Phosphorus	28.0 mg
Folate	13.8 µg
Magnesium	10.0 mg
Iron	0.59 mg
Potassium	204 mg
Zinc	0.28 mg

Source: Akhwale and Yegon, 2015

Sweet potato provides essential nutrients including carbohydrates, proteins, minerals, and vitamins (Stathers et al., 2005). Its storage roots comprise 25-30 percent (of its dry weight) carbohydrates and 2.5-7.5 percent protein. It also has 200-300 mg 100 g-1 of potassium (K), 0.8 mg 100 g-1 of iron (Fe), 11 mg 100 g-1 of calcium, (Ca) and 20-30 mg 100g-1 of vitamin C of its dry matter (Stathers et al., 2005; Çalifikan et al., 2007) as well as copper, zinc and manganese, vitamin B2, B6 and E; the yellow and orange fleshed storage roots provide pro-vitamin A. Sweet potato is also used in industries to produce starch, natural colorants, and fermented products such as wine, ethanol, lactic acid, acetone, and butanol (Clark, 1988; Duvernaya, et al., 2013). All its plant parts and culms are used as livestock feed (Claessens et al., 2008). Fresh storage roots are also sold in the market for income generation (Githunguri et al., 2007).

DRIED WEIGHT POTATO ROOTS PROVIDES 25-30% **CARBOHYDRATES** 2.5-7.5% **PROTEIN**

while yellow and orange fleshed sweet potatoes provide ***pro Vitamin A.***

Agro-climatic conditions and soils suitable for sweet potato production

Sweet potato is a versatile crop that grows from sea level to 2400 masl although its growth varies with rainfall, temperatures, soil type, and pH. It is grown in medium to low altitude agro-ecological zones concentrated in drier areas. For optimal growth, the soils should be well drained, light and medium textured types with a pH range of 4.5-7.0; the crop is sensitive to aluminum toxicity. It thrives on fertile, sandy-clay soils and has high flexibility with respect to the timing of planting and harvesting. Root development is enhanced by short days with low light intensity.

Rainfall

750-1000

MILIMETERS

Temperature

24°C | 75°F

Annual rainfall of 750–1000 mm is most suitable during the growing season. The crop is sensitive to drought at the tuber initiation stage 50–60 days after planting; it is generally tolerant to drought and impoverished soils. It is intolerant to water-logging as this may cause tuber rot and reduce growth of storage roots due to poor aeration. An average temperature of 24 °C (75 °F), abundant sunshine, and warm nights are ideal conditions for sweet potato growth.

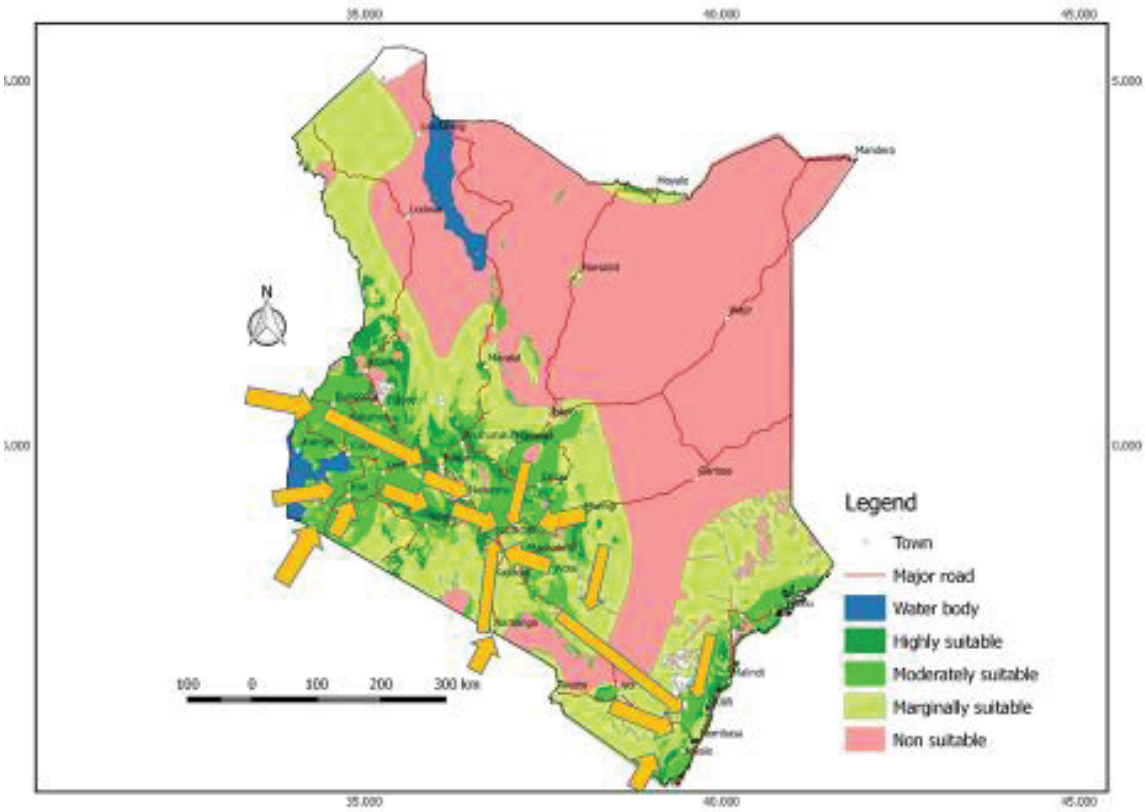


Figure 4: Sweet potato suitability map

Sweet potato varieties released and grown in Kenya

Several sweet potato varieties have been released in Kenya since 2001; some are shown in Table 2.

Table 2 Sweet potato varieties released in Kenya

No	Variety name/ code	Official release name	Year Released	Optimal altitude (masl)	Maturity (months)	Tuber yield (tha-1 y-1)	Tuber (flesh colour)
1	Jayalo	Jayalo	1998	1000 - 2000	4	10-15	White
2	SPK004	SPK004	2001	1300-2000	3-4	13-20	orange
3	Kemb 10	Kemb 10	2001	1300-2000	3-4	16-25	yellow
4	SPK013	SPK013	2001	1200-1400	4-5	21-35	white
5	Mugande	Mugande	2001	1300-2000	4-5	15-25	white
6	292-H-12	Rachar	2011	1200-1680	4-5	14.2	White
7	56682-03	Haraka	2011	1300-1600	4-5	16.3	Orange
8	K117	Lisamu-DP	2011	1200-1600	5-6	15.1	Orange
9	Kabode	Kabode	2013	1,200-1,800	4-5	16-25	Orange
10	VITAA	Vitamu	2013	1,200-1,800	4-5	15-22	Orange
11	Kenspot 013	Kenspot-1 (Nyawo)	2013	1,700-2,300	6-7	15-25	Yellow
12	Kenspot016	Kenspot-2	2013	1700-1900	6-7	15-46	White
13	Ken-spot010/6(1)	Kenspot-3	2013	1,900-23,00	6-7	10-27	Orange
14	Ken-spot06/1(2)	Kenspot-4	2013	1,700-2,300	6-7	10-26	Orange
15	Ken-spot02/16(1)	Kenspot-5	2013	1,700-2,100	6-7	10-23	Orange
16	NASPOT-1	Double -Double	2015	1,700-2,300	3-4	27	Deep yellow
17	Bungoma	Bungoma	2011	1,400 -1,600	4-5	25	Yellow
18	Mtwapa8	Mtwapa 8	2001	15-500	3-4	30	Yellow

Sweet potato production

Sweet potatoes are mostly propagated by stem cuttings or adventitious roots called "slips" that grow out from the tuberous roots during storage. Once established, the vines grow rapidly and shade out weeds. Thus, apart from the first weeding, very little weeding is required thereafter. Depending on the cultivar and conditions, tuberous roots mature in two to nine months.

Planting site

Sweet potato should be planted only on land where no sweet potato or any other tuber or root crop has been grown for the last two years. The field should also not be located next to a previous or recent root or tuber crop. This is important to minimise pest and disease carry over as well as nutrient depletion.

Preparation of planting materials

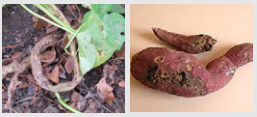
The planting vines should be from 2- to 3-month-old apical portions that are free of insects, soil, and any symptoms of viruses or fungal diseases. However, where planting material is in short supply, middle and basal vine cuttings may be used with little reduction in expected yields. To promote rooting at the nodes, vines should be stored for 1-2 days in humid conditions.

Preparation of land and planting

Sweet potato grows best in well-prepared soil that is deep ploughed, flat, or ridged, or on mounds to allow easy penetration and expansion of roots in the soil. Planting involves pushing the lower parts of the vine cuttings into the soil so that they are nearly horizontal. About 20 cm or two thirds of the cutting should lie beneath the soil surface at an angle with vine ends towards the centre of the ridge or mound. Optimum root yields are obtained when vines are planted on single rows at the middle of the ridge at 30 cm between plants within the row. The field should be kept weed free.

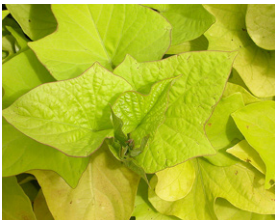
Protection of sweet potato against pests and diseases

Table 3 Important sweet potato pests and their control measures

Pests	Symptoms and damage	Control and management
Sweet potato weevil 	› Adult weevils feed on the vines, stems and roots. › Larvae make tunnels into the vines and roots. › Damaged roots become bitter. › Damaged vines and roots are rendered unmarketable. 	Integrated pest management including: › Crop rotation; › Clean planting material; › Filling soil cracks; › Early planting; › Prompt harvesting; › Field sanitation; › Avoiding previous season's crop; › Spraying with a fungicide; › Incorporating a good amount of Lantana camara before planting to repel the weevils.
Sweet potato moth (Omphisa anastomasalis) 	› Caterpillar bores into the main stem and/or directly into the roots forming tunnels. › Vines with severe tunneling show weak growth and poor foliage development; vine later yellows, wilts and dies. › Infested plants show poor storage root formation.	› Dip sweet potato cuttings in an insecticide solution before planting. › Handpick caterpillars or attacked vines and destroy them. › If seriously infested spray with a fungicide.
Aphids (e.g. Aphis gossypii) 	› Aphids suck sap from leaves and stems and are vectors of virus diseases. They cause leaf curl on the tender leaves. › Adult wingless females are oval-bodied, 1.2-2.1 mm in body length, of very variable colour. › Aphids are vectors of virus diseases.	› Aphids are attacked by a wide range of natural enemies such as wasps. › Spray with insecticide.

Rodents: *moles, field rats, squirrels* 	› *They dig through the ridges and mounds and feed on the roots.* › *They often spoil more roots than they actually eat.* › *Signs of rodent infestation are: small mounds of freshly dug soil, sweet potatoes being pulled back down into the soil, holes in the sides of ridges or mounds*	› *Keep the field and surrounding areas clean.* › *Dig a deep ditch around the field to deter rodents from digging tunnels straight into their fields.* › *Set up traps.* › *Mix cow dung and pepper and place it in the tunnels, and then burn to smoke the rodents out.* › *Plant on mounds rather than ridges*
Erinose *(hairiness)* 	› *A sweet potato field infested with mites may result into the vines reacting and forming hairiness, a defense mechanism to fight off the mites. This hairiness condition is referred to as "erinose".*	› *Removal and destruction (burning) of affected vines reduce the effects of mites.* › *Miticide spray controls the mites.*
Whiteflies *(Bemisia tabaci)* 	› *Whiteflies feed on the lower leaf surfaces.* › *High numbers of whiteflies may affect plant development, particularly during periods of water stress and drought.* › *Direct damage by adults and nymphs sucking sap from the plant is generally not economically important.* › *Aphids are also vectors of virus diseases.*	› *Conserve natural enemies (parasitic wasps and predators such as predatory mites, ladybird beetles, and lacewings are important in natural control of whiteflies)* › *Spray Neem extracts and other insecticides.*

Table 4: Important sweet potato diseases and their control/ management measures

Diseases	Symptoms	Control/Management
Sweet potato virus 	› Causal agent: Sweet potato feathery mottle virus and sweet potato chlorotic stunt virus. › It is spread by aphids, white flies, and planting infected vines. Symptoms include: › Dwarfing of plant, › Yellowing of vines and young leaves; › Excessive branching; › Dark brown to blackish corky spots in rootsreducing marketability.	› Use resistant or tolerant varieties; › Use disease-free planting material; › Control the white flies and aphids; › Carry out crop rotation; › Remove infected plants; › Isolate vine/seed fields from old fields.
Alternaria leaf spot 	› Causal agent – Alternaria spp › Blackened lesions on the stems and leaves. › Leaves become shriveled, blackened, die and fall off in severe cases	› Use resistant or tolerant varieties; › Use healthy, clean disease-free planting materials; › Destroy or burn infected crop material; › Practice crop rotation; › Use fungicides for commercial seed production;
Root knot nematodes	Meloidogyne nematodes	› Use root knot nematode-tolerant varieties

Harvesting and storage

Harvesting commences between **4 and 7 months** after planting, depending on the variety and environmental conditions. The mature tubers may be left underground and harvested piecemeal for at least two months or they may be harvested and placed in grass-lined pits.

Figure 5 Piecemeal harvesting of sweet potatoes

The role of sweet potato in the food chain and other traditional uses

Sweet potato is an important food and nutrition security crop that provides an alternative food source when the major and highly dependable food crops such as maize, rice, and potatoes fail especially due to drought (Mutuura et al., 1992). Sweet potato has also been shown to improve soil fertility through nitrogen fixation and humus. It is also a cover crop that reduces soil erosion (Woolfe, 1992). The vines are used as livestock feed for dairy cows, sheep, and goats; dairy animals fed on sweet potato usually produce more high quality milk (Kivuva et al., 2015).

Sweet potato roots, vines, and leaves are utilised in many ways. They provide cheap and nutritious food for humans and feed for livestock. They can be consumed whole--boiled, roasted, deep fried, or mixed with food products such as cooked beans and maize, mashed and consumed as a complete meal. The roots can be made into chips, crisps or dried and ground into flour. The flour can be composited with wheat flour to a make wide range of products including bread, cakes, biscuits, "mandazi", doughnuts, "chinchin", crackies and "chapatis". Sweet potato flour can also be composited with sorghum or millets and used to prepare "uji" or "ugali". Recipes for sweet potato value added products are indicated in

*Sweet Potato remains one of the most underexploited food crop with more than **133 million tons** in annual production. It is a major food security crop for rural households with a high yield potential that may be realized within a relatively short growing season*

Annex 1. Starch is produced from sweet potatoes in much the same way as from cassava, except that the solution is kept alkaline (pH 6.8) by using lime, which helps to flocculate impurities and dissolve the pigments. The orange-fleshed varieties are rich in pro-vitamin A, vitamin C, and minerals that alleviate malnutrition. They contain zinc and calcium.

Green leaves of some varieties are consumed as vegetables by humans and provide protein, vitamins, and minerals especially magnesium, iron, and calcium as well as fibre. The crop is efficient in production of carbohydrates and remains one of the most underexploited food crops with more than 133 million tons of annual production. It is a major food security crop for rural households with a high yield potential that may be realised within a relatively short growing season. In the New Partnership for Africa's Development (NEPAD), Comprehensive African Agricultural Development Program (CAADP), sweet potato is ranked among the high-priority crops for agricultural research to contribute to food security and poverty alleviation for the urban and rural poor.

CHAPTER **02**

Production constraints and identified hindrances to productivity and profitability

Sweet potato has a yield potential of **20-50 t ha-1** *of storage roots in the tropics but farmers in sub-Saharan Africa produce less than 10 t ha-1*

Despite the numerous potential uses and benefits of sweet potato, including its good performance under low soil fertility compared to other crops such as Irish potato, the production of the crop is below the potential level. It has a yield potential of 20-50 t ha-1 of storage roots in the tropics but farmers in sub-Saharan Africa produce less than 10 t ha-1 (Califikan et al., 2007; FAOSTAT, 2009). In Kenya, these low yields are due to several research, production, and marketing constraints. The major research factors affecting sweet potato include limited availability of clean planting material and inadequate technical knowhow. Production constraints include: land sizes and conditions, cultural practices, labour constraints, diseases and pests, post-harvest handling, lack of storage facilities, lack of clean seed, and poor seed distribution system (Gichuki et al., 2006; Njeru et al., 2004). Constraints related to marketing of sweet potato are market access and perishability.

Research Constraints

1 Limited availability of clean planting material

Sweet potato production is affected by inadequacy of improved and disease-free planting materials. Farmers therefore often plant vines that are infected with pests and diseases; this contributes to the low yields. Some farmers obtain seed of inferior quality and type or variety from their neighbours. Under the Crops Act 2013, sweet potato was declared a scheduled crop with breeding programmes under voluntary certification, thus giving seed production and multiplication more emphasis. Currently, there are three types of formal seed production–the formal seed (mainly by KALRO and certified by KEPHIS), also referred to as primary seed; the integrated seed, produced by NGOs, CBOs and farmer groups under the supervision of KALRO and is referred to as secondary seed; and the informal seed, where individual farmers collect clean seed either from KALRO or from the secondary seed producers and produce tertiary seed. Often, this seed is not inspected by either KEPHIS or KALRO. However, the seed produced as described above supplies less than 10 percent of the sweet potato seed required, meaning that most farmers use low quality planting material.

2 Inadequate technical knowhow

Inadequate knowledge and skills by farmers and entrepreneurs on good agronomic practices, disease and pest management, post-harvest handling and value addition is a constraint. More research and extension efforts need to be directed towards capacity building of farmers and entrepreneurs in improved agronomic practices, pest and disease management, storage, and processing of sweet potato. More research is also required to find ways of simplifying harvesting, particularly when terminal drought occurs, making the soil surface hard to break.

3 Equipment/machinery

Most research centres working on sweet potatoes do not have machinery to carry out research that can lead to appropriate mechanisation. For example, irrigating the field softens the soil surface and simplifies harvesting. However, no research has been carried out on appropriate ways of irrigation, including analysing its cost benefit. In addition, use of oxen and tractors could simplify harvesting and reduce root damage. But this is inappropriate for the very small plots on which sweet potato is grown.

4 Research–Extension–Farmer linkage.

Some of the innovations developed by research have not reached the farmers because of insufficient research-extension-farmer linkages. The extension staff are few, while research scientists can only reach a limited number of farmers through on-farm trials and field days.

5 Production versus consumption needs

Although improved, nutritious sweet potato varieties with high yield potential been availed, farmers still prefer local landraces because of their very high dry matter content. The highly nutritious orange fleshed sweet potato varieties being promoted for adoption have low dry matter. More research is therefore required to develop a variety that has high dry matter and is highly nutritious.

Production Constraints

1 Land sizes/condition

Land sizes are diminishing in most parts of Kenya including the main sweet potato-growing regions. As a result, sweet potato faces competition for land with maize and sugarcane especially in western Kenya. Most farmers allocate small land sizes ranging from 0.125 to 0.5 acres to sweet potato and mainly during the second season after harvesting maize. Because of small land sizes, farmers prefer short-duration, determinate potato varieties so as to release land for other crops early. However, such varieties are often not preferred by consumers, presenting a dilemma to growers. In addition, because of these diminishing land sizes as well as the adverse weather conditions, households are expanding the acreages for maize to compensate for reduced maize yields per unit land area, leaving very small acreages for other crops including sweet potato (Ajanga et al., 1992). There is however much variation on ownership of land and production of sweet potato; some farmers produce the crop for commercial purposes.

2 Cultural Practices

Farmers lack information on improved cultural practices. In addition, women perform most of the operations on sweet potato; however, due to the women's heavy workload, sometimes important operations such as weeding are not carried out on time, which leads to reduced yields. Moreover, because of the perception that sweet potato is a woman's crop, and male household heads are the owners of resources including land, it receives insufficient resources. However, once production exceeds consumption and especially when there are good market prospects, the man becomes the recipient of the proceeds from the sales.

3 Labour Constraints

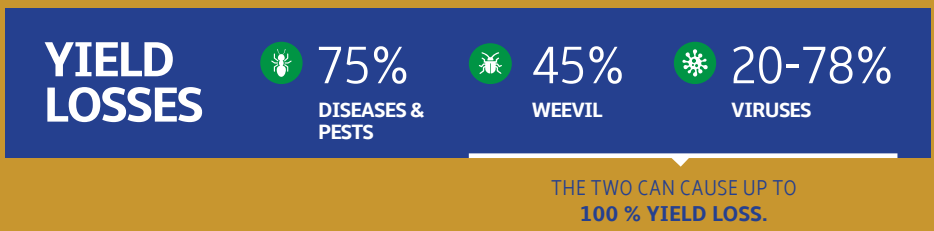
High labour costs for land preparation, making ridges, planting, weeding and harvesting are a major constraint. Sweet potato requires deep friable soils and deep plowing for root growth, expansion, and ease of harvesting. Mechanisation is constrained by low availability of machinery. Moreover, since sweet potatoes are planted on small acreages, farming is difficult to mechanise. This leads to delayed land preparation, hence late planting and reduced yields. Drought, which is associated with a hard soil pan, is a major constraint to land preparation and planting using a hoe. Thus, ways need to be devised for breaking the hard pan to ease land preparation and planting.

Similarly, drought during harvesting is also a major constraint due to the hard soil pan that leads to increased bruising of the tubers. Bruised potatoes have a low shelf life. Breeding for drought-tolerant varieties, especially the deep rooted types, may also minimise yield losses due to hard pans and weevil infestation.

There is need to devise ways of simplifying harvesting, particularly when drought occurs and makes the soil surface hard to break. Irrigating the field softens the soil surface and simplifies harvesting. Similarly, use of oxen and tractors would simplify harvesting, especially where land sizes are large. This would reduce root damage. These practices are however rarely followed as they are prohibitively costly for most farmers and the land areas cultivated are too small to allow mechanisation.

4 Diseases and pests

Diseases and pests can cause yield losses of up to 75 percent in sweet potatoes (Musembi et al., 2015). Yield losses of 20-78 percent due to viruses (Zhang et al., 2006) and 45 percent due to sweet potato weevil (Cylas formicarius) have been reported (Musana et al., 2016; Lagnaoui et al., 2000). Virus- and weevil-infected plants also become susceptible to other pests and diseases and can suffer up to100 percent yield loss (Ateka et al., 2004). Other diseases affecting sweet potato include alternaria blight, bacterial wilt, and fusarium wilt (Ames et al., 1996). Conversely, yield increases of up to 160 percent (40.8 t ha-1) can be realised by using virus-indexed planting materials (Zhang et al., 2006). In China, use of virus-indexed sweet potato seeds resulted in annual benefits worth $145 million (11.6 billion shillings) (Fuglie et al., 1999). Acquisition of insecticides is also a constraint to farmers because they are packaged in large quantities that are unsuitable for small-scale farms; their costs are also prohibitive. The problem of diseases and pests is further exacerbated by the limited availability of disease-free planting material for improved high-yielding varieties



Production constraints and identified hindrances to productivity and profitability

5 Post-harvest handling/perishability

Fresh sweet potato roots are highly perishable once harvested due to their high moisture and sugar content, and a delicate skin. They can only keep for 4 days because the roots are living material that continue to respire after harvesting and produce heat, leading to softening and hence deteriorating in quality. There are several other causes of post-harvest losses that should be controlled in order to extend the shelf life of sweet potato. These include:

- **Mechanical and other damages:** cuts, skinning, and bruises during harvesting, transportation or marketing as well as cracking due to nematodes; the cracks become entry points for germs, which shorten the shelf life of the potato.

- **Respiration:** contributes to weight loss of the roots and altered appearance; wounding can increase the respiration rate and weight loss. Varieties with high dry matter content have less weight loss following harvest. Respiration rate increases with temperature.

- **Sprouting:** if roots are stored at high temperature and humidity, sprouting occurs very quickly.

- **Pests and diseases:** the sweet potato weevil (Cylas spp.) is a serious field and post-harvest pest of sweet potato that not only causes ugly holes in the roots but also causes a bitter taste and an unpleasant smell. Similarly, fungal and bacterial rots result in soft and sunken areas developing on the roots. Often, this causes the roots to have a bitter taste. Fungal and bacterial rots often gain access through cuts and bruises on the roots at harvesting, through weevil damage or through infected planting materials..

6 Storage

Effective storage systems are central to increasing the shelf life of sweet potatoes, thus easing food insecurity while increasing incomes for households. However, storage systems for sweet potato are inadequate. Currently, most smallholder farmers practise piecemeal harvesting or in-ground storage where only the roots required for immediate sale or consumption are harvested. The rest are left in the ground to continue enlarging. Farmers who use this method are supposed to check the field regularly for cracks or exposed roots and cover them with soil to prevent root weevil damage and exposure to the sun. This is because weather, notably moisture, temperature, and air composition affect the shelf life of sweet potatoes.

The down side of the in-ground storage system is that it limits the use of the land for other purposes. As a result, farmers are sometimes forced to harvest the entire planted crop at once so as to plant another crop on the same piece of land. In such cases, farmers are forced to sell the tubers cheaply. The alternative is for farmers to harvest all the roots, dry them and store them as dry chips to be used when required. Other methods for storing fresh sweet potato for longer periods include clamp and pit storage.

7 Over-reliance on rainfall

Potato farmers in Kenya over-rely on rainfall; this exposes them to the dangers of unreliable rainfall, a key feature of climate change. Rainfall and temperature fluctuations lead to both increased incidences and emergence of new pests and diseases, which in turn lead to low crop yields and high post-harvest losses. There is need for investment in irrigation to sustain crop production. However, irrigation facilities are not available except in irrigation schemes.

Distribution and marketing of sweet potato in Kenya

Distribution and marketing of potatoes are hampered by poor infrastructure, notably bad roads. Most roads in the sweet potato-growing areas are earth roads that become impassable during the rainy season; this raises transaction costs and lowers profit margins. The county governments are however trying to ensure that the roads remain passable during the rainy season. Other marketing and distribution constraints are discussed below.

1 Market access

Poor market access is partly due to poor infrastructure and poor access to accurate and timely market information. The bulky and perishable nature of sweet potatoes limits the distance over which they can be economically transported and marketed.

2 Storage facilities

Storage facilities are inadequate and inappropriate, limiting the volume of sweet potatoes that can be aggregated at a time. Inadequacy of appropriate transportation facilities makes it difficult for farmers to utilise favourable market periods. This means that most sweet potatoes are marketed close to the point of production, often leading to a glut and low prices. Alternatively, the tubers are bought by middle men, who later sell them in secondary and tertiary markets at prices five to six times of what they paid the farmers. This exploitation is exacerbated by lack of commercial processing of sweet potato.

3 Limited market information services

Limited market information services lead to exploitation of farmers by individual traders. Bargaining power by individual producers is weak, due to weak collective action on marketing.

4 Seasonal fluctuation

The supply of sweet potato is seasonal, with the peak being in August to December in Eastern Kenya and November to February in Western Kenya. The supply decreases during the dry season because the ground becomes too hard to allow harvesting of the roots. This, together with reduced availability of staple foods--mainly maize--result in a higher demand for sweet potato than the supply; this leads to higher prices during the

dry season. On the contrary, prices are lower during the main harvesting seasons. This seasonal fluctuation is worsened by the lack of storage facilities. Proper (cold) storage facilities are necessary to reduce post-harvest losses and price fluctuations.

Policy and legislation challenges

There are no specific policies on sweet potatoes although potatoes are adversely affected by policies of other crops. Existing agricultural policies favour crops such as maize at the expense of traditional crops. The general policies/legislation that pose challenges to promotion of sweet potatoes include high taxation when the farmers take the tubers to the market, and cess when the traders transport the potatoes from the county. This double taxation is reflected at the farm gate price offered to the farmer.

CHAPTER 02

Innovation opportunities in sweet potato

Introduction

Innovation may be defined as the process of application of new or existing knowledge in new ways and contexts to do something better for socioeconomic benefits. It involves changing an established product, process or service by introducing something new either incrementally or radically; this may occur at various levels of the value chain. Radical innovations result from advances in knowledge, whereas incremental innovation refers to the continual process of improvement of techniques. The innovation may be a product, a service, or a process that is managerial, organisational, or evolutional. Five key attributes characterise an innovation: relative advantage, compatibility, complexity, trialabilty and observability (Rogers, 2003). In all cases, it is important to note that change cannot qualify as an innovation unless it is applied.

Policy innovation

Sweet potato is one of the crops that have been grown by farmers as subsistence crops for many years and until recently, were classified under 'orphan crops' or a poor man's crop. Consequently, there has not been much attention given to it by policy makers. However, due to its multiple uses, the crop has gained renewed attention at the county, national, continental, and global levels. But little has been done to mainstream it in the policy narratives to obtain policy support from the relevant government arms.

There is therefore a need to formulate policies that support the sweet potato value chain, including by creating platforms such as a sweet potato producers' association. Such a platform could be created and strengthened to articulate pertinent issues that would spur the production and marketing of sweet potato. The policy will need to be formulated to motivate the involvement of the private sector in supporting the value chain in areas such as standardisation of products, provision of credit, and entrepreneurship.

Production innovation

Production innovation could be at different levels starting from production and distribution of planting material; field management; and post-harvest management.

1 Planting material

The sweet potato planting material system is predominantly farmer based and vines are often regarded as "common property". The planting materials cannot be stored and so farmers require a live crop from which vines can be sourced for propagation. Farmers use diverse methods of preserving planting materials during the dry season. A popular method is to wait for roots that are deliberately or accidentally left in the ground (ground-keepers) to sprout after the first rains. It takes 6-8 weeks after the start of the rains for roots to sprout. Limited quantities of vines are then obtained from the sprouted roots (Figure 6). The material obtained often gets infected by pests and pathogens from the previous crop. However, because that is what is available, the farmers use it instead of looking for clean planting material.

Figure 6 Sweet potato sprouts

An opportunity exists to develop mechanisms of strengthening and increasing availability of clean planting material through multiplication systems using proven planting material that have been successfully tried. The systems include formal, integrated, and to a lesser extent informal systems.

The formal system involves development of improved sweet potato varieties but production, marketing and distribution of planting material are the responsibility of different organisations as specialised activities following seed rules and regulations. Examples of actors within this system include Kenya Agricultural and Livestock Research Organisation (KALRO), Kenya Plant Health Inspectorate Services (KEPHIS), and Farmers and Community-Based Organisations (CBOs).

ACTORS IN VEW

The integrated system is where production and distribution as well as marketing of improved materials are done under the local system where rules and regulations are not strictly adhered to as in the formal case but still leads to clean planting material. Here, farmer groups, Non-Governmental Organisations (NGOs), CBOs, and some individual farmers get seed from KALRO and produce secondary seed for sale or distribution to other farmers. Producers of secondary seed are trained by KALRO and the Ministry of Agriculture, Livestock and Fisheries (MoALF) on seed production. The seed is then distributed for planting.

The informal system is where individual farmers collect clean seed either from KALRO or the secondary seed producers and produce tertiary seed. Most of these are not registered and the planting material is not inspected for cleanliness.

Individual farmers can also use rapid multiplication techniques to quickly produce seed when planting material is in short supply. This can be done in nurseries planted on beds or in gunny bags filled with fertile soil as illustrated in Figure 7 below. There is an opportunity for counties to establish such nurseries so that they are in close proximity to the farmers, and to increase the amount of planting materials.

Figure 7 Stages of rapid multiplication of sweet potato vines

Establishment of full-time planting material producers similar to the tissue culture banana producers could also be explored. Propagation or micro-propagation of sweet potato tissue culture could be developed to produce disease-free materials and the plantlets given to CBOs for hardening in before distribution to the producers. This is a promising technology; however, it is costly as it involves the transfer of in vitro plantlets to field conditions for further multiplication. Utilisation of this method is restricted by the high percentage plant loss at rooting and acclimatisation stages (Chabukswar and Deodhar, 2005; Pospíšilová et al., 1992)

An attempt to operationalise such an approach was tried by the International Potato Center (CIP) between 2010 and 2012 under the Sweet-potato Action for Security and Health in Africa (SASHA) project (Namanda et al., 2015). This was in partnership with the Lake Zone Agricultural Research and Development Institute (LZARDI), Tanzania, the Kenya Plant Health and Inspectorate Service (KEPHIS), Catholic Relief Services (c) and CRS-affiliated community development organisations. The aim was to promote timely dissemination of quality planting material; it involved successful cross border transfer of 35,000 sweet potato tissue culture plantlets from Nairobi to Bukoba in Tanzania, a distance of 1,500 km by road and the subsequent hardening process.

Figure 8 Sweet potato tissue culture process (Source, Namanda et al., 2015)

Sweet potato vines could also be produced outside potato-growing areas where there are no pests and diseases and the clean material is transported and sold to farmers in conventional growing regions. Conversely, planting material could also be produced under irrigation during the dry season to avail vines at the onset of the rains.

Field Management

The low yields of sweet potato could be attributed to several challenges that require both conventional and other innovative field management practices. In some cases, the challenges experienced are brought about by the farmers' endowment level while others have to do with the biological potential. It is therefore imperative to identify context-specific solutions.

Figure 9 Sweet potato vines and planting on ridges

Mechanisation of land preparation, ridges, and harvesting

A major problem that is faced by sweet potato farmers is the high labour cost that is incurred in various production activities such as land preparation, ridging or making mounds, planting, weeding and crop management up to harvesting. To minimise labour at all these stages, appropriate mechanisation is required. Machines such as ridgers, planters, and harvesters are available and could be utilised but in a collective

Figure 10 Ridger

way since land sizes are small. Such machinery could be fabricated into small sizes and drawn using motor bikes and other suitable means

Small-scale irrigation/water harvesting strategies

Reliance on rains for sweet potato production often leads to either overproduction or very low production. Small-scale irrigation systems to produce sweet potatoes throughout the year and especially targeted production can be explored although such systems would require a water source that is adequate and reliable.

Climate-smart agricultural practices (for water)

Sweet potato has the advantage of being drought tolerant after establishment and its yield potential is generally greater than that of popular staple food crops in Kenya. The crop has also been shown to be among those whose yields will not be seriously affected by climate change. In addition to yield advantage, the higher nutritional value of sweet potato is beneficial to farmers producing under conditions that are susceptible to drought stress. The crop can therefore be used together with others in climate-smart agricultural practices. In the meantime, more studies are required to explore possibilities of enhancing the crop's drought tolerance to increase its contribution towards food security in Africa and especially in Kenya.

Teaching of agronomic practices

There is need to create more awareness amongst smallholder farmers on the value of sweet potato as a major crop for subsistence and rural economic development. Farmers should also be sensitised on the minimal purchased inputs required for its production; this is an advantage to the majority of poor smallholder farmers. This is possible through innovative ways such as village social activities, religious gatherings, and other fora. Training on utilisation and value addition is also necessary to avoid consumption in the traditional 'boil and consume' approach. Storage practices could also be encouraged to prolong shelf life for sale when there are better prices or for consumption during periods of scarcity.

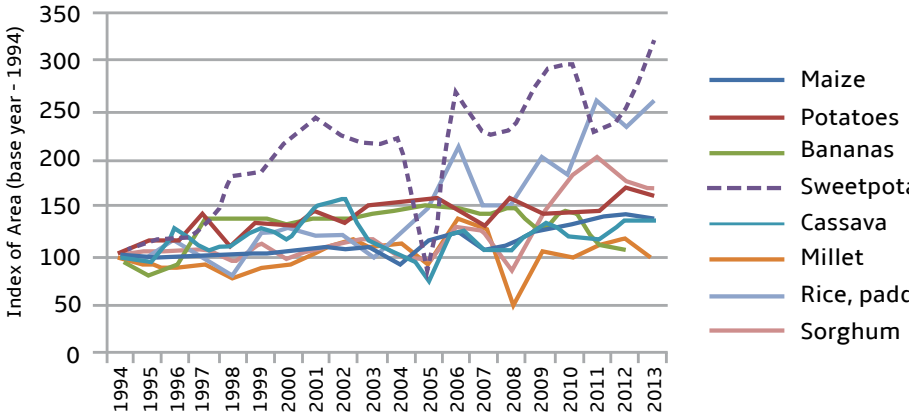


Figure 11: Proportional growth in areas of different staple crops in Kenya from 1994 to 2013 (Source: FAOSTAT)

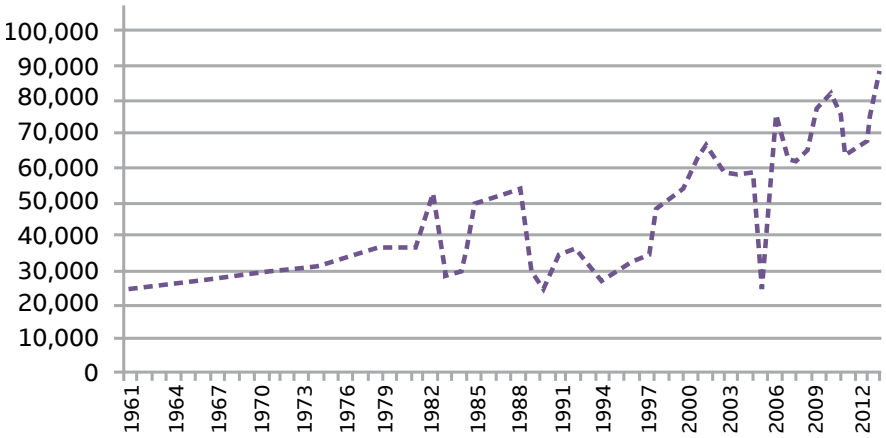


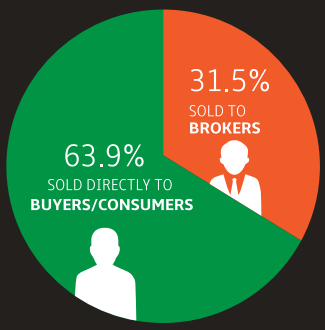
Figure 12: Area planted with sweet potato in Kenya – 1961-2013. (Source: Tedesco and Stathers, 2015)

Marketing innovation

While smallholder farmers are concerned about agricultural productivity and household food consumption, they are also increasingly concerned about better market access. Various studies have demonstrated the challenge of markets for sweet potato due to many factors that contribute to poor marketing systems. Various innovations that could address this constraint exist. Collective production and aggregation of tubers can address the fragmented nature of production, where each farmer produces small quantities that make sweet potato marketing un-economical.

FARMERS ARE BEING EXPLOITED

ACCORDING TO 2016 STUDY



In a 2016 study, it was found that 31.5 percent of farmers sold their potatoes to brokers while 63.9 percent sold directly to buyers/consumers. This led to exploitation of farmers. Farmers could be organised into sweet potato production cells or units (SpPUs) of 20–30 farmers, each growing potatoes on a minimum of one acre. Every village could have five or ten of such groupas similar to the ones formed for production of Gaddam sorghum or the commercial villages (Kilelu et al., 2013; Kavoi et al., 2013; Farm Concern International, 2010). Arrangements could also be made to source planting material collectively as well as learn production techniques together. Planting could also be synchronised to produce and supply large quantities that could support processing of products such as puree or any other industrial product. The idea is to shift from approaching sweet potato production from a subsistence to a commercial enterprise.

Such farmer clusters could also give the farmers bargaining power due to market information asymmetries as well as improve linkages with other services such as credit, weather information, insurance, and access to market information. They could also allow farmers to be paid upfront upon delivery of produce.

Standardised measurement

The sweet potato seed system is mostly farmer based, with very limited private sector involvement. As indicated above, farmers require a live crop for production of planting material, which could be available for free (Gibson and Aritua, 2002). The vines are usually not packed in units that would allow a farmer to determine how much area they would be able to plant. A unit of measure could be introduced to guide farmers on the quantity required to establish a known area of land. The package could be labelled to give variety, area, and suitable environments.

The harvested produce is sold using various volumes or weight measures that vary greatly by trader, season, and market. Through volume measures, avenues for exploitation of consumers are often common. The buyers also come up with their own requirements and thus there is need to develop a documented grading system that is accepted by the producers, traders, and consumers. Once such a system is in place, marketing of sweet potatoes can be undertaken beyond particular physical markets. Convenient, well labeled packages of sweet potatoes that meet various consumer markets will boost demand and consumption of sweet potatoes, thereby indirectly enhancing production.

Figure 13 Extended sweet potato bag and heaped sweet potatoes

Root supply variation:

Owing to the production of sweet potato based on rains, there is often a challenge of glut as well as shortages. This is unfavourable to processors who require a constant supply of raw materials. There is a peak fresh root supply in Busia, Kabondo, and Kericho in January to March after the short rains. The supply increases again after the long rains in June to July. In Busia and Kericho, the supply increases again in July to August. The peak supply in Migori and Siaya is normally in March to May (Tedesco and Stathers, 2015).

To stabilise the supply of potato roots, storage structures are required. Alternatively, planting can be staggered in areas where rainfall is well distributed as in Nyanza and Western Kenya. An example is Kabondo Sweet Potato Cooperative that organises its producer members to ensure that farmers do not harvest until the processing centre confirms they are expecting the roots (Tedesco and Stathers, 2015)

Table 5: Varying supply of fresh sweet potato roots in Busia, HomaBay, Migori, Siaya and Kericho Counties

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Busia	***	***	***	*	*	***	***	**	**	*	*	**
Kabondo	***	***	***	**	*	**	**	**	**	*	*	*
Migori	**	**	***	***	***	*	*	***	***	**	**	**
Siaya	**	**	***	***	***	***	*	*	***	***	***	*
Kericho	***	***	***	*	*	*	***	***	*	**	***	***
Key***=Peak supply;**=Medium supply;*=Low supply												

(Source: Tedesco and Stathers, 2015)

Information system

Potato farmers are dispersed and often far removed from main urban consumption areas. They do not have adequate market information with respect to prices and required consumption volumes. Individually, the farmers do not have adequate analytical capacity for market trends to enable them predict future prices so that they make appropriate production decisions.

Actors in some value chains in Kenya such as dairy and horticultural export commodities are linked to specific ICT platforms. A similar platform for sweet potato stakeholders would benefit them in many ways, including accessing information on prevailing and expected prices, existing and new markets, and networking with other value chain actors. Currently, the only information available is from some radio and TV stations on the market prices in different parts of the country.

Transportation innovation

Lack of transport for goods and people is identified as a major constraint to agricultural and rural development. The rural roads are mostly unpaved and severely degraded due to poor maintenance. Kenya has a road density of 2.3 km/100 persons, which is lower than the 3.0 km/1000 persons average for Africa (Table 6). Ex-post evaluation on rural access roads project (RARP) in SSA indicated a strong positive correlation between feeder roads and agricultural productivity. The RARP minor roads project showed a 29 percent increase in crop production from the baseline condition one year after project completion. Over the same period, sales of farm produce rose by 51 percent, farm income by 275 percent, non-farm income by 11 percent and total household earnings by 20 percent (Njenga 2003; MoITC, 1984). In Nyandarua, Kenya, poor road infrastructure discouraged adoption of high-value horticultural crops through which farmers could easily improve their income (Dijkistra and Magori, 1992). In Siaya District, Omamo (1998) established that cropping patterns were influenced by access to market centres from the farms, with physical distances to market centres being a function of means of transport. Obare (2000) in a study in Nakuru, showed a Kesh14,000 savings on production costs through a 10 percent increase in access costs.

Table 6 Road to transport ratio in km per 1000 persons

	km per 1000 persons		
	1980	1990	1995
Sub Saharan Africa	3.3	2.6	2.9
Sub Saharan Africa (excluding SA)	3.1	2.2	2.5
Uganda	2.1	1.8	-
Kenya	3.1	2.6	2.3
Ghana	3.0	2.3	3.0
All Africa	3.1	2.3	3.0

(Source: World Bank, 2000)

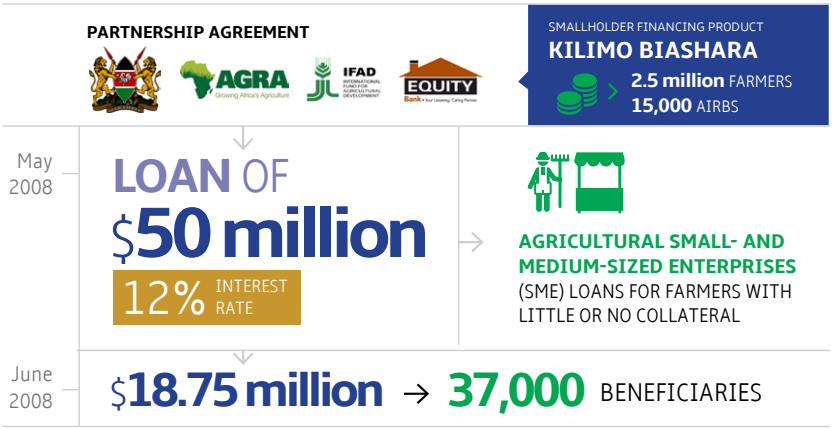
It is clear from the above information that market access for sweet potato should be improved through improvement of the road infrastructure. The current trend in some counties to improve rural access roads should be enhanced, especially in the sweet potato-producing areas such as in Western and Eastern Kenya.

Financing innovation

The need for agricultural commodities grows as populations grow but the growth is often challenged by farmers' inability to access appropriate financial services for their farming activities and overall household expenses. Three major challenges face lenders who want to engage in the agricultural sector. These are: high transaction costs, sub-optimal policies, and inadequate regulatory environments. Lenders face irregular payments of invested capital. Lending in the agriculture sector also involves systemic, covariate risks; farmer diversification does little to divert risk from those systemic risks that affect all of the creditor's activities and potentially the entire agricultural finance portfolio (IFC, 2012). Financing agriculture is more effective when it is part of a broader package combining both financial and non-financial services to the farmers. The objective of the non-financial services is to improve yields and quality through access to better inputs and extension, and ensure access to markets. An emerging trend is to provide insurance to protect farmers and financial institutions from severe losses. Since this industry is still evolving, partner interventions can play a critical role in accelerating its development and deployment in emerging markets. There is also a need to strengthen producer organisations as important aggregators for delivering financial and non-financial services to smallholder farmers. This can involve capacity building for financial and managerial skills as well as improved corporate governance. There are already a number of NGOs and initiatives that work to strengthen producer organisations, but more efforts and a bigger scale are needed.

Innovative financial interventions that could be deployed to finance sweet potato production are similar to the Kilimo Biashara product by Equity Bank among others as indicated in the text box below.

TEXT BOX 1 Equity Bank - Kilimo Biashara Package



Equity Bank's approach to agricultural financing is based on direct smallholder lending integrated into a larger supply chain partnership and supported by a first loss guarantee provided by donors. Equity Bank signed a partnership with AGRA, IFAD, and the Government of Kenya in May 2008. The agreement includes a loan project of USD 50 million in agricultural small- and medium-sized enterprises (SME) loans for farmers with little or no collateral. AGRA and IFAD provide a 10 percent first loss guarantee. Under this partnership, Equity Bank developed the smallholder financing product "Kilimo Biashara," which is designed to make financing available for 2.5 million farmers and 15,000 agricultural input retail businesses in rural areas. Equity Bank enhances security by (i) capping loan exposure at USD 17,000 per farmer, (ii) applying group lending terms, whereby six farmers act as co-guarantors, and (iii) reducing the cash amounts in farmers' hands (farmers can pay agro-dealers out of their Kilimo Biashara credit). By June, 2008, USD18.75 million in loans had been disbursed, reaching 37,000 beneficiaries. The loans carry a 12 percent interest rate applied when the loans fall due, a rate below Equity Bank's standard lending rate of 18 percent. According to Equity Bank, the project is a success because it has changed the position of smallholders from food insecure to semi-commercial producers. One of the success factors is the technical assistance on financial literacy and farm management provided by the government extension service bureau to the farmers. The repayment risk of the individual farmers is mitigated by their integration into supply chains, including World Food Programme (WFP) P4P programme. (Source: IFC, 2012)

Postharvest handling

Sweet potato is a highly perishable crop and requires proper post-harvest handling starting from the field where injuries to the skin drastically reduce the shelf life. Harvesting therefore has to be done carefully to avoid bruising and damaging the remaining roots during piecemeal harvesting. Currently, over 95 percent of sweet potatoes produced in Kenya are consumed without being processed. The implication is that the commodity gives low returns to farmers yet it can be processed into several products through value addition. There is an opportunity for farmers to establish village cottage industries that can produce products like puree, crisps, and other high-value products. The peels could be used to feed livestock and vines ensiled for dry season feeding.

Sweet potato production in Kenya is almost wholly on small-scale. The roots are highly perishable and bulky, and the crop is considered a famine crop rather than a staple food crop. Cultivation is rain-fed and therefore production is seasonal. A communal storage facility could be an innovative approach in upgrading the value chain. The facility could use solar energy as a source of energy for refrigeration and other potato processing activities. A mix of communal storage facility and a warehouse receipt system could be established with several advantages including

1	being an aggregation centre for sweet potato;	3	being a source of employment for the community;
2	being a one-stop shop for communal cottage industry;	4	bringing better prices and returns for value chain actors such as farmers, transporters, and processors.

Timely harvesting and proper handling

Considerable root abrasion and skinning occurs after harvest during loading, transporting, and unloading due to rubbing of the delicate skin against the inside surface of the containers such as sacks, and against adjacent roots. Containers should preferably be made of smooth wood or durable rigid plastic and should be ventilated on the sides and bottom; a good example is bread crates. These containers are stackable and easily cleaned and sanitised. Their smooth inner surfaces result in minimal root damage. Field containers should not be overfilled with roots above the upper rim, as stacking will cause injury to the top layer of roots. If the fresh roots are cut during harvesting and do not reach the market

within 1 or 2 days, they start rotting. This high perishability forces farmers to sell the fresh roots immediately after harvest. As a result, they often accept low prices from brokers. Transporting the roots in sacks on donkeys' sides can also damage the roots due to the poor state of the roads. They eventually rot and are rejected by buyers. Orange-fleshed sweet potatoes (OFSP), which are grown by many farmers in Kenya, are reported to have a short shelf-life and are poor in-ground storage. They are heavily damaged by weevils and mole rats once mature. There is therefore need for further studies of the shelf-life and in-ground storage ability of the different OFSP to aid their production, marketing, and processing.

Figure 14: Harvested sweet potato, potato in sacks, and recommended plastic packing tray

Research Innovation

While there is a whole array of sweet potato varieties being produced in Kenya, the genetic potential of locally bred varieties has not yet been fully utilised as it has in the case of other crops such as maize and wheat. There is therefore an opportunity to develop local crosses to combine attributes that would address the diverse challenges experienced. Some unique areas such as Shimba Hills in Coastal Kenya and others where sweet potatoes produce viable seeds could be identified and used for breeding. Viable seed-producing conditions could also be simulated in green houses and utilised to multiply planting materials.

Another area of research innovation could be on pests such as the sweet potato weevils (Cyclas spp) and the white fly, which cause 10 to 20 percent of fresh root losses (Tedesco and Stathers, 2015). The potato tuber moth and root knot nematode (Meloidogyne spp) also pose a challenge to production (Karuri etal., 2016). The current control measures in use are chemical and cultural control methods. A study by Karuri et al. (2016) identified Kenyan sweet potato varieties that were resistant to root knot nematodes and less susceptible to root cracking, thus enhancing marketability. Such tolerant varieties could be crossed with the high-yielding varieties, which may be susceptible, to reduce yield losses. There is need to screen sweet potato varieties for resistance to the major pests and diseases.

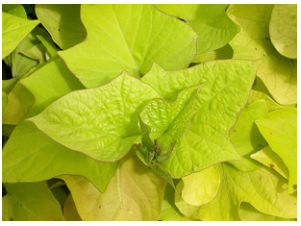
Natural enemies could be identified and introduced as in the USA. The natural enemies include wasp species, entomophagous nematodes and disease pathogens (Jansson et al., 1993; Mullen 1985). The natural enemies of the common pests and diseases should be identified in Kenya to develop the most effective for a biological control programme.

Sweet potato weevil

Weevil damaged vines

Weevil damaged roots

Figure 15 Sweet potato weevil (Cyclass spp) and damage symptoms



Sweet potato virus

Altenaria leaf spot

Figure 16: Sweet potato virus and alternaria leaf spot

CHAPTER 04

Value Chain Analysis

The aim of the value chain analysis was to deepen understanding of the entire flow of the sweet potato value chain activities, from production to final consumption. The analysis describes the actors and activities involved in all aspects of ensuring sweet potato is with the final consumer. Figure 17 is a mapping of sweet potato core value chain process in selected counties of Kenya.

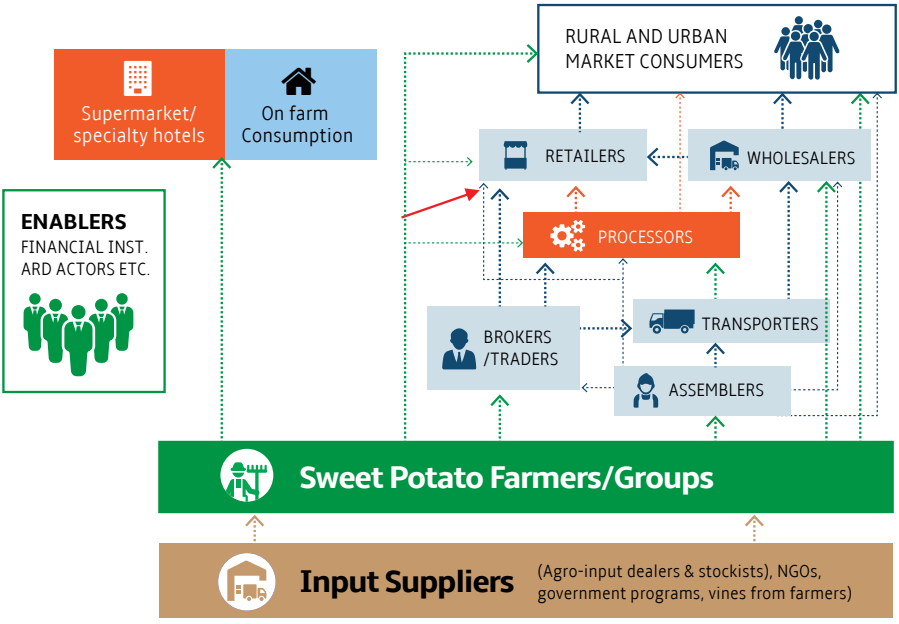


Figure 17 Sweet potato value chain core processes map 1

Interactions exist among various actors in the value chain. The main operators in the sweet potato value chain are: input suppliers, producers, processors, assemblers, retailers (urban and rural), wholesalers (urban and rural), transporters who also double as traders, exporters, and importers. A description of the key processes and their relationships that enable fresh and processed sweet potato products to reach the final consumer is provided in the following subsections.

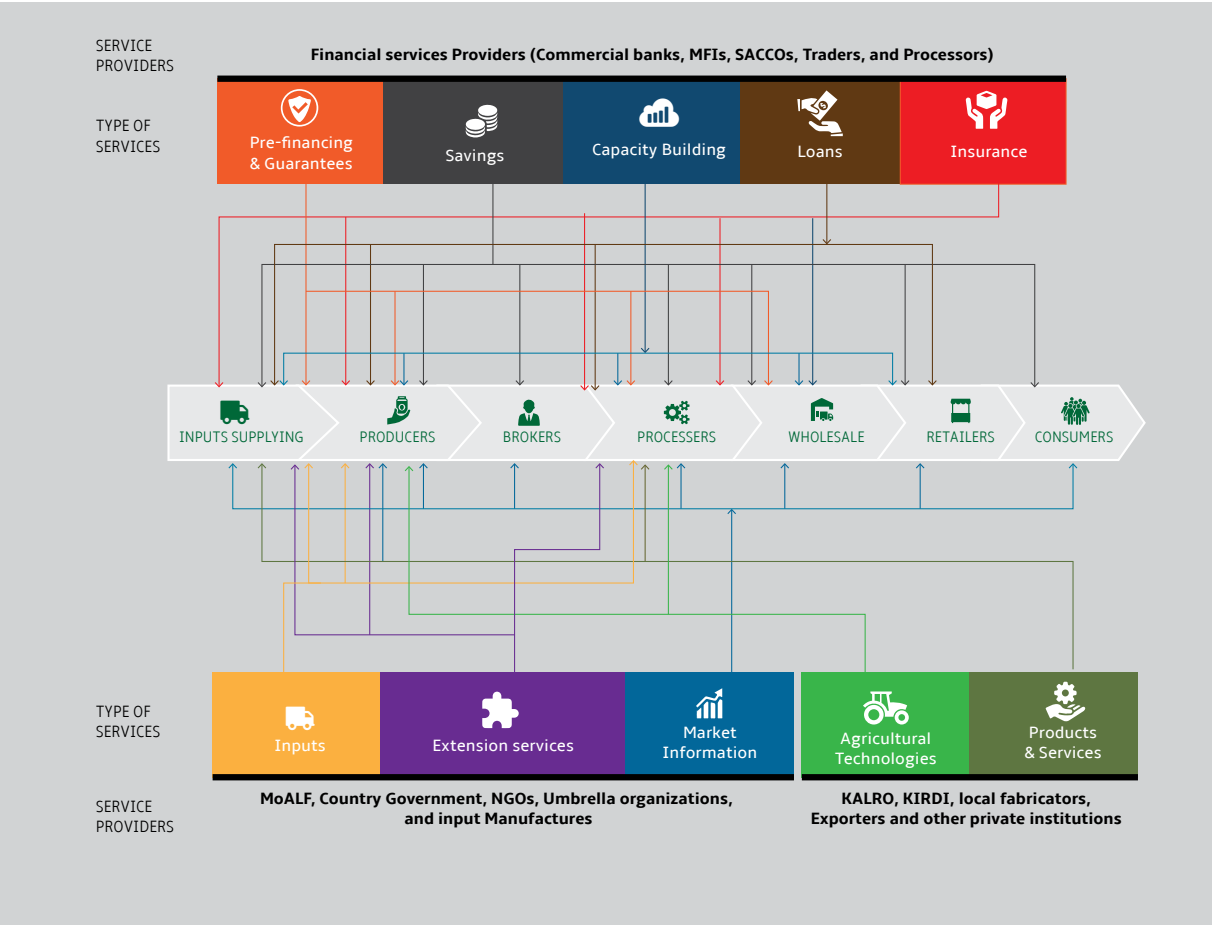


Figure 18 Sweet potato value chain core processes map 2

Input suppliers and service providers

1 Inputs

Vines or sweet potato planting materials are the main inputs procured by farmers from suppliers. The sweet potato vine system consists of both improved and indigenous variety supplies with the latter having the greater market share. Producers are a key source of vines of the traditional varieties with some of them supplying to their fellow producers. There are a few formal suppliers of vines of improved sweet potato varieties. They consist of KALRO Centres (Kisii, Embu, Kakamega, Katumani) and farmer groups who are contracted by the National and County Governments as well as NGO service providers. A survey conducted in selected counties revealed that most potato farmers source their planting materials from either their own farms (48 percent) or their neighbours (38 percent).

Table 7: Source of planting material

		Source of planting material		
		Own	Neighbour	Purchased
Region	Kakamega	53.8	42.3	3.8
	Bungoma	46.3	27.8	25.9
	Homa Bay	47.6	38.1	14.3
	Kirinyaga	26.4	56.6	17.0
	Kwale	39.3	42.9	17.9
	Siaya	88.2	11.8	-
	Busia	44.4	22.2	33.3
	Kisii	44.8	48.3	6.9
	wMigori	46.4	42.9	10.7
Overall	47.8	37.8	14.4	

The same study shows that traditional varieties (73 percent) form the main common type of planting materials (Figure 19). The practice is most prevalent in Siaya, Kisii, Kakamega, Homa Bay and Kwale Counties.

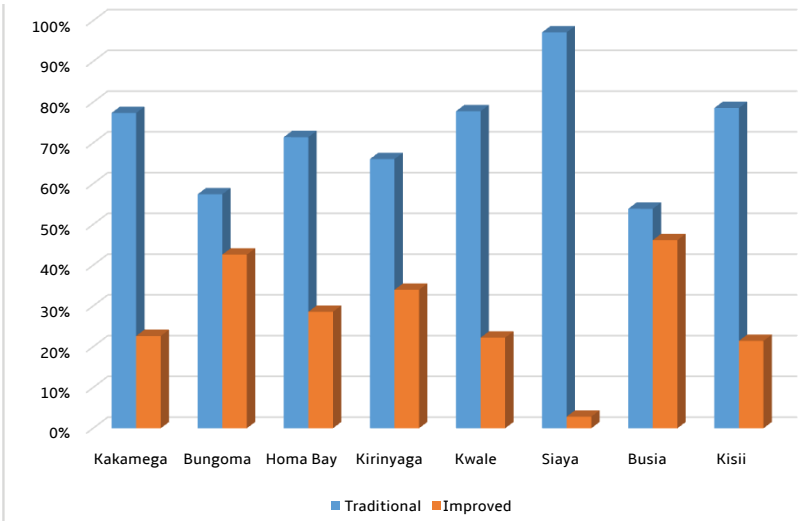


Figure 19: Type of planting material

Other inputs procured include fertilisers at planting, gunny bags and tarpaulins during harvesting, milling machines, and packing materials during processing.

2 Service provision

Service provision is provided by financial institutions, agro dealers, government extension service providers, NGOs, and input manufacturers among others.

i Financial service providers

Commercial banks, SACCOs, microfinance institutions and insurance companies provide financial services to agriculture stakeholders including sweet potato farmers. Farmers find it easier to deal with small- and medium-size institutions and other value chain operators that are located in the rural production areas. Other sources of finance include crop financing from traders to producers either in cash or in kind. Such financing arrangements are embedded in the cost of produce supplied by the producer to trader (buyer). The main products and services offered include: i) loans categorised as agricultural, asset, business, microfinance, group, land title processing, and animal traction loans; ii) savings accounts; iii) commodity financing and working capital; and iv) financing towards agricultural production enhancement, input supplies, and training in agriculture.

ii Technical and business development service (T&BDS) providers

The focus of services provided by the T& BDS actors were Research and Development (R&D), technological advice, capacity building in financial management, and extension services on good agricultural practices. Most of the services are provided by governments and the private sector. Figure 20 shows that this service was most common in Bungoma and Busia Counties but least common in Migori County.

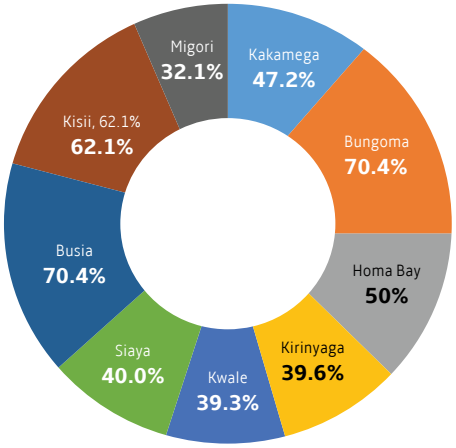


Figure 20: Proportion of farmers who receive extension services (Source: Survey, 2016)

Overall, most of the potato farmers received extension services from fellow farmers (Table 8). Farmers were especially important in providing unscheduled visits. Government institutions provided mainly scheduled and upon request services (72 percent). NGOs provided scheduled extension services (63 percent).

Table 8 Extension service providers and their frequency in delivering the service

		Percentage of farmers receiving extension service		
Source of Extension services	N	Scheduled	unscheduled (pop in)	upon request
Fellow farmer	69	41	43	16
NGO	49	63	27	10
Gov. Institution	58	41	28	31

Producers

The function of production is undertaken by small and medium individual producers.
1. Land availability and utilisation: Land is a key determinant in production. Its availability and utilisation is key to agricultural development. The ownership of land as an asset has in the past been used by farmers to access financial services and it is a good indicator to farmers' wealth. Most farmers in Kenya do not own the land(s) they use for agricultural activities. In the case of potato farmers, 61 percent owned land with title deeds. A higher percentage of potato farmers who owned title deeds for their land was in Kirinyaga County (83 percent) while in Kwale County, only 28.6 percent owned title deeds. Figure 21 shows the distribution of land ownership in selected counties and its utilisation for sweet potato

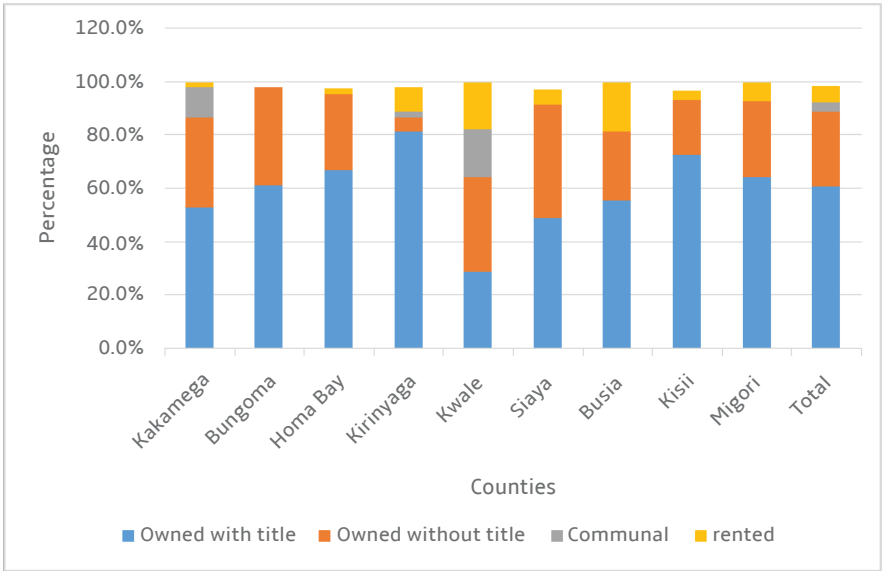


Figure 21 Land Ownership

Land utilisation among potato farmers stands at 36 percent (on average, a proportion of 0.36 of the total land owned was used to grow potato). In Kisii County, the proportion is highest (76 percent) followed by Busia (46 percent) and Siaya (44 percent) Counties.

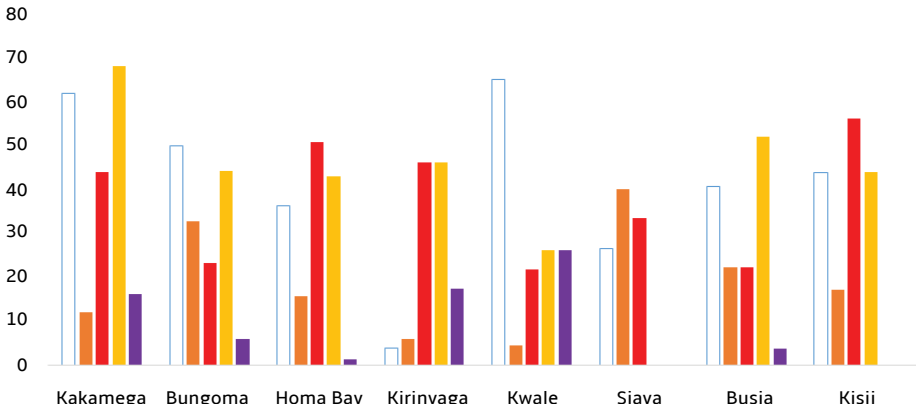


Figure 23 Tuber flesh characteristics (Color)

Itinerant gatherers/assemblers/traders

Sweet potatoes are a non-traded commodity except for low cross-border informal trade with Tanzania and Uganda. Often, farmers sell fresh sweet potato roots to neighbours or in local and urban markets. Some sell to middle men who in turn sell to urban wholesalers or retail markets, consuming institutions such as hospitals, hotels, and schools. In a few instances, sweet potatoes are sold to process products including: flour, puree, bread, chips, and cakes in processing plants such as the one in Homa Bay County. Figure 24 shows a map of the flow of potato from areas of production to major consumption areas. The potatoes are transported to the markets using several modes of transport: human porter, bicycle, motorcycle, pick-ups, and lorries, depending on the volume involved and distance from the producer to the market.

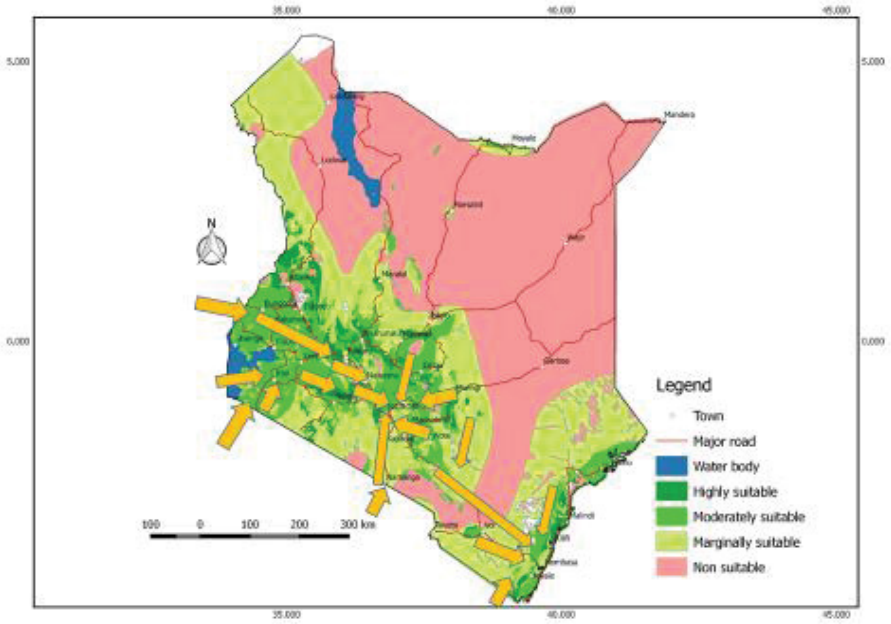


Figure 24: Sweet potato flow map

The main players along the marketing node of the sweet potato value chain are the smallholder farmers, village assemblers (bulk- buyers), retailers (both market based and roadside), middlemen, wholesalers, and processors. These traders are mostly based in the main terminal markets in Nairobi and Mombasa and in the secondary markets in the main towns in the producing areas. The wholesalers and retailers are supplied with sweet potatoes by assemblers; they then sell to final consumers such as individuals and institutions. In some areas, traders assemble and transport roots to the market.

There was very limited collective action in marketing, although economies of scale could be useful in bulking and transporting the sweet potato to distant terminal markets for the benefit of farmers and traders. Traders based in urban markets have better market information and stronger linkages with suppliers. However, bulking is a challenge because of the scattered smallholder farmers who produce limited amounts of sweet potatoes.

1 Actors who carry out marketing functions

Smallholder farmers: Small-scale producers are scattered over a wide area and are often inaccessible due to poor roads. The production system is mainly rain-fed and not synchronised with periods of surplus production after the rain season. Most smallholder farmers grow sweet potatoes for their own consumption. They do not have adequate information about and poor access to 'deep' and profitable markets: a scenario that discourages production. A few farmers near irrigation schemes are however able to synchronise their production to target niche markets and time when there is scarcity of sweet potatoes in the market. During periods of scarcity, some of the smallholder farmers take up roles such as bulking/assembling, acting as brokers, and even marketing and selling along the roadside.

Village assemblers: Village assemblers exist in collection centres but in most cases, they are informal areas identified on the basis of the most central point to bulk for transportation. Village assemblers perform the brokerage function between farmers and traders and are a vital source of information to actors on either side of the chain. They also provide gunny bags to the farmers for packing the sweet potatoes and advise the processors or larger traders on when sufficient stocks have been bulked in order to arrange for transportation. During the low season, some of the assemblers switch and act as brokers and transporters when produce is low to increase their profit margins.

Figure 25 Sweet potato assembling points

Brokers: Brokers are local people that have a link to the traders. Some of the brokers buy all the potatoes in a farmer's field before harvesting and then sell it to the trader. There is not much direct linkage between farmers and traders. A broker charges transporters and wholesalers about Kes1,500 as intermediation fee. Further, during the low season, brokers switch to be wholesalers and retailers where instead of selling to brokers, move to end markets in order to increase their earnings.

Transporters: Provide transport services to both secondary and terminal markets in Nairobi and other urban centres. To cover costs of the return trip (backhaul), transporters often carry manufactured goods such as cement, groceries, iron sheets, and other products. A small-scale transporter is able to ferry between 5,000 and 10,000 bags of sweet potato annually.

Wholesalers: There are three different types of wholesalers: secondary market wholesalers, terminal market wholesalers, and exporters. Wholesale markets exist in all secondary and terminal markets in Kenya. A wholesaler buys from either village assemblers or traders in the producing areas. The wholesaler in turn sells to retailers, other wholesalers, processors, and exporters.

Supermarkets and specialty hotels: These are new entrants into the value chain market of sweet potato that reflect the emerging demand among the middle and upper income class.

Market information service providers: The most common types of market information provided include prices, quality requirements/consumer preferences, and areas of demand both locally and regionally. The main beneficiaries are producer groups, individual farmers, and traders in that order.

To enhance market value and marketability including shelf life for fresh sweet potato, roots should be free of surface wounds and bruises, pest or disease damage, have uniform size, and not be deformed. The roots should be dry, devoid of dust, mud, or any other foreign material and should have been kept under shade after harvesting to avoid the turning of skin colour. To prepare the fresh sweet potato roots meant for immediate marketing or processing, the roots have to be washed gently without scrubbing to avoid bruising the skin. However, roots for storage should not be washed until when needed for use. After washing, the roots are sorted into different uniform sizes depending on the market requirements and to remove any rotten, damaged, or otherwise unmarketable roots. This improves the value of the produce in the market. The produce is graded according to size and packed in polythene bags or spread out in heaps on gunny bags. The sorted potatoes are taken through a process of curing whereby sweet potato roots are exposed to conditions that heal any wounds that may have been caused during harvesting. Curing also toughens the skin to protect roots from further damage. This reduces the risk of post-harvest disease infection. Curing is done at normal room temperatures by covering freshly harvested roots with a polythene sheet raised approximately 15-20 cm above the layer of roots. The polythene sheet is removed each night; this process takes 2-3 days.

Both volume and weight measures are used to determine prices of fresh sweet potatoes. The price per unit of measure (volume or weight) is often determined by forces of supply (seasonality) and demand, including supply of other substitute goods. Regional and market price variations were also observed. For instance, when retail price is Kes50 in the open air market, it can be Kes100 in supermarkets. Middlemen prefer to buy potatoes from the producers (farm-gate) using volume measures but sell to retailers using weight measures.

Volume measures

Weight measures

Figure 26 Sweet potato measures

Processing

There are a few sweet potato processors in the country; most of the sweet potatoes are eaten whole after boiling and peeling. Processors wash, chip, and dry sweet potato roots, and then mill the chips into flour. The flour is then sold and blended to produce loaves of bread, scones (bread rolls), using 10 percent sweet potato flour, and a composite flour of OFSP, sorghum and soybean for making porridge.

Income generation/profitability

Most value chain actors generate income as they undertake specific functions. Farmers reap from production, traders reap from buying and selling while transporters reap from performing the transportation function. Figure 27 presents average gross margins for functions performed during different seasons.

The average farm-gate price for local varieties is Kesh1500 per bag filled with medium- to big- size roots. In February/March, high production of sweet potato brings the price down to Kes1,300/1,400 per bag; occasionally, the price drops to as low as Kes1,000 per bag. When the root supply is lower, the price increases to Kes2,500 per bag. When the farmers bring the local varieties to the collection centre (paying the transportation costs), they can sell to brokers, big wholesalers and retailers at a higher price of Kes1,800-2,000 per bag. The Orange fleshed sweet potato is guaranteed a fixed price of Kes14 /kg at the Cooperative.

Note that the share that goes to the retail is almost 65 percent of the price. This is probably contributed by differences in measure where they buy large bags and sell in bundles and thus make huge profits; bread loaves (400g loaf sells at Kesh40, 200g loaf at Kesh20), scones (bread rolls) (12 scones sold at Kesh50), using 10 percent OFSP flour, and a composite flour of OFSP, sorghum, and soya bean for making porridge.

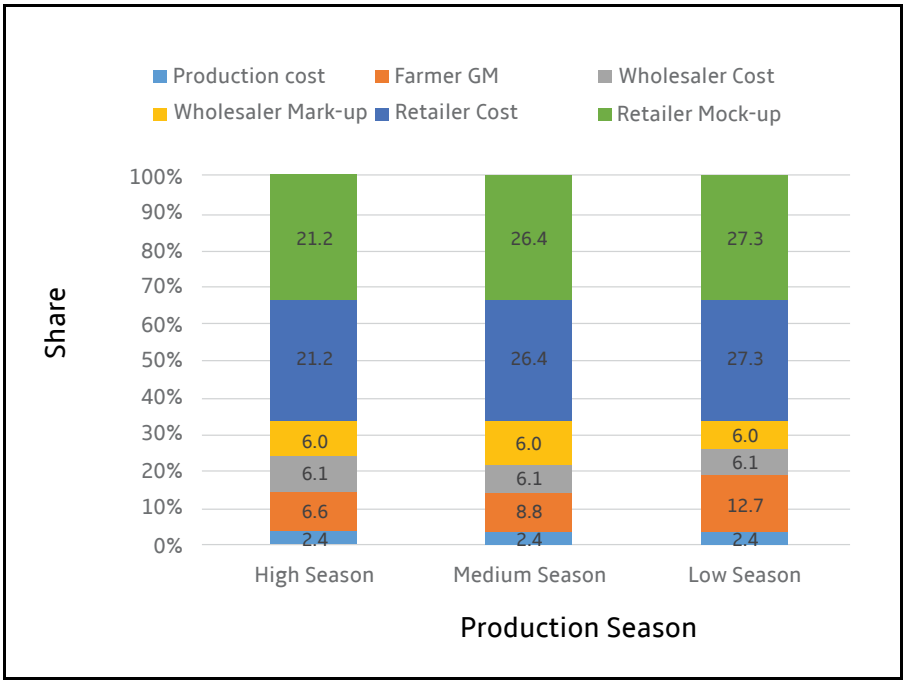


Figure 27 Value capture along the non-processed sweet potato value chain

1 Storage

As already stated, fresh sweet potato roots are highly perishable once harvested due to their high moisture and sugar content, and a delicate skin; they will keep for only 5 days. Because the roots are living material, they continue to respire after harvesting and produce heat, leading to softening of the roots. Several causes of post-harvest losses should be controlled to extend the shelf life of sweet potato.

Storage is therefore central to increasing shelf life of sweet potatoes and also for smoothing food consumption and incomes for some households. Methods of storing fresh sweet potato for longer periods have been recommended to farmers. These include clamp and pit storage. Alternatively, farmers can harvest all the roots, dry them, and store them as dry chips to be used later when required to prepare a wide variety of products. Dry chips are prepared by washing, peeling, chipping, and drying the chips in the sun or in a solar drier (Fig. 28). The chips take one to two days to dry depending on the weather conditions. The dry chips are stored in hermetic storage bags to protect them from picking up moisture and from attack by storage pests.

Figure 28: Drying sweet potato chips in a mobile small scale solar drier

2 Value addition

Value addition provides opportunities for income generation and employment. It improves food security by reducing losses and making food available throughout the year. Value addition makes use of farm surpluses, waste, and damaged roots unsuitable for sale as fresh produce. It also reduces bulkiness, thus reducing transport and storage costs. It provides a wide range of products, thus increasing market opportunities. Finally, value addition improves quality (taste, colour, flavour and nutritional value) and consumer acceptability.

Although there are factories, they are few and isolated (e.g. Ringa factory in Homa Bay County). This means that value addition/processing for sweet potato is minimal in Kenya. At farm level, farmers blend sweet potato with wheat flour and make some confectionaries in addition to chapatis. The marketed sweet potatoes are also processed into crisps. It is also common to find sweet potatoes being roasted and sold in the streets of the coastal towns.

Value chain institutions and horizontal and vertical linkages

The sweet potato value chain consists of both horizontal and vertical linkages. The linkages begin at the input supply level, which involves three streams: the farmers themselves, agro-input dealers, and NGOs/public sector extension service. The smallholder producers stream is shaped by established but weak linkages. These are between producers, assemblers, and traders. Some of the producers are organised in groups that also carry out processing and sell the sweet potatoes straight to the traders. These two linkages are well established because of the good relationship between the producers and assemblers. There are weak linkages among smallholder producers around bulking at producer organisations (POs) level for collective marketing. The linkages are weak because they are usually unreliable and unsustainable, with such groups being organised through external forces such as NGOs or government programmes (Figure 29).

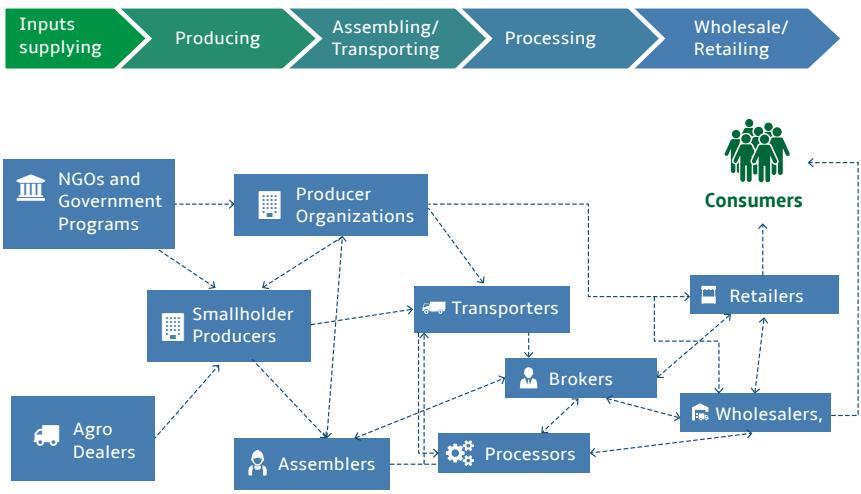


Figure 29 Linkages in the sweet potato value chain

CHAPTER 05

Conclusions and Recommendations

As the world population continues to increase and physical arable land remains largely fixed, there is increasing dependence on technological innovations to ward off world hunger and malnutrition. Among the few staple food crops the world relies on for food is the sweet potato, which is a priority crop for food security and poverty alleviation both in the rural and urban areas. The area under the crop has shown an increasing trend, and so has the estimated production increased from 88000 tonnes in 2008 to 1.2 million tonnes in 2015 (FAOSTAT 2015). Over 80 percent of the sweet potato is utilised as human food and the remaining 20 percent is sold in local and urban markets.

A major benefit of this crop is its diverse utilization: roots for food, vine for fodder, and the leaves for both food and fodder. Another benefit is its wide adaptation from sea level up to over 2000 masl. The tolerance to conditions unsuitable for other crops makes sweet potato a very versatile crop that fits into crop rotations very favourably. An additional benefit is its short maturation period, which ranges from two to nine months. The crop is therefore ideal as a hunger crop that can be available during the various periods of food shortage. Investment into sweet potato research has been made in various regions of this country; the investment has resulted in many early-maturing, high-yielding, and pest-tolerant varieties selected, bred, and disseminated to farmers.

Our analysis reveals that most of the research work has mainly been focused on the high root and dry matter yields, high beta-carotene and virus-tolerant materials. Pest and post-harvest handling themes have not been given prominence. This is despite the high

levels of yield loss incurred from the sweet potato weevil, which range between 50 and 90 percent in Kenya. By feeding on leaves, adult weevils reduce the photosynthetic area of leaves. Root injuries caused by adult and larval stages reduce root yield and quality due to terpenoid production (Musana et al., 2016). A potential area of research could be the introgression of sweet potato weevil resistance/tolerance into the high root, dry matter and carotene varieties, which could perhaps make a significant improvement on the potato productivity. Alongside this varietal development, practices such as weevil trapping using both locally produced products such as plant extracts and synthetic pheromones could also contribute towards addressing the weevil menace. This could be in addition to good management practices such as ridging, hilling, application of organic pesticides such as Neem oil as well as phytosanitary measures to prevent weevil transfers.

Another area of research is on high carotene or orange-fleshed varieties that are known to have a precursor of vitamin A and are hence good for fighting the deficiency of this important vitamin in the Kenyan populace. The varieties that exhibit this attribute are second to the high-yielding cluster. The carotene-rich varieties have potential to make a major contribution towards the health of local populations, especially the children under five years of age. This is a research thrust that should be pursued further in order to spread the health benefits to a broader population.

These varietal developments are accompanied by management practices. For instance, preparation and treatment of planting material ensure that the farmer starts with clean vines that are not infested, to avoid disease and pest build up. Observing a closed season is also an important practice where potato is not grown in former potato fields to avoid cross infection. Proper management of the vegetative phase is also useful in reducing weevil damage. Such management includes hilling and ridging as well as use of tolerant varieties to minimise weevil effects.

A crucial area of research is post-harvest handling and value addition including storage, processing, and industrial use. This is a research area that would improve on the shelf life of the potato as well as increase the income of the growers. As reported in this book, there are various post-harvest handling practices that increase the value of the harvested crop. Preparation of sweet potato flour is an important aspect that would extend the consumption period of the crop. The flour could be blended into various products including pastries and confectionary. Blending the flour with baby food formulae and maize meal is another area that needs to be explored further. Such blending is especially advantageous when the orange-fleshed flour is used. As indicated earlier, there are many health benefits in the use of sweet potato.

The sweet potato value chain can easily be upgraded using innovative ways: research, organisation and even marketing, that would lead to increased production, marketing, diversified product development, utilisation, income generation, and employment.

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Annex 1:

Recipes for Sweet potato value added products

Boiling

- Wash sweet potato roots using clean water.
- Peel the roots (optional); the peel has lots of dietary fibre.
- Boil the sweet potato roots until they are soft.
- Serve or mash to be used to prepare other products.
- Boiled sweet potato can be added to githeri and other stews.

Steaming

- Wash the sweet potato roots using clean water.
- Peel the roots (optional).
- Wrap them in banana leaves.
- Steam them over boiling water until they are soft.

Roasting

- Wash the sweet potato roots with clean water and then wipe them with a clean piece of cloth.
- Roast them on hot charcoal.
- Sweet potato roots can also be roasted in an oven.

Making high quality dried sweet potato and flour

1. Carefully select healthy fresh sweet potato roots.
2. Wash and peel the roots.
3. Wash the peeled roots in clean water and pre-dry them on a clean surface in the sun for 10 minutes.
4. Cut the roots into thin slices about 5 mm thick with a sharp knife, hand grater or motorised chipper.
5. Sun dry the slices on raised beds. Spread about 4 kg/m2 of the drying surface. Turn the chips every 2 hours so that they do not over dry on one side.
6. Dry the chips for 1-2 days so that the flour will be free from undesirable flavours.
7. Store the dry chips in clean opaque polythene bags or mill the chips into flour and store in clean opaque polythene bags, hermetic bags or airtight containers

Tantalising, easy to prepare sweet potato recipes

Sweet potato porridge

INGREDIENTS:

- 1 heaped tablespoon of sweet potato flour
- 4 heaped tablespoons of millet, sorghum, cassava or maize flour
- 1 heaped tablespoon of soya flour
- 1 small lemon
- 2 tablespoons sugar
- 6 cups water

METHOD

1. Bring five cups of water to boil.
2. Mix the cereal/root crop flours with the soya flour and make a paste with the remaining one cup of water.
3. Pour the paste into the boiling water and keep stirring to prevent lumps.
4. Squeeze the lemon juice into a cup while the pot continues to boil for 20 minutes.
5. The cooked product should jell.
6. Remove from fire; add the lemon juice and sugar.
7. Cool, then serve warm. Milk can be added if desired.

Other popular formulations of composite flours for making

Sweet potato "mukimo"

INGREDIENTS:

- 10 medium-sized sweet potato roots
- 2 cups green maize
- 4 cups beans, cowpeas and peas
- Salt to taste

METHODS

1. Sort maize and beans and pre-soak for 6-8 hours.
2. Boil the maize and beans till almost cooked.
3. Remove any soil from the sweet potato roots and peel them.
4. Wash and slice the sweet potato roots.
5. Add the sliced sweet potato roots to the maize and beans and let cook.
6. When sweet potato roots are soft and maize and beans are well cooked, mash them.
7. Add salt to taste and serve as balls or a mound heaped on a plate.

Sweet potato "mshenye"

INGREDIENTS:

- 10 medium sized sweet potato roots
- 4 cups beans, cowpeas and peas
- Salt to taste

METHODS

1. Sort the beans and pre-soak for 6-8 hours.
2. Boil the beans till almost cooked.
3. Wash, peel and chop sweet potato roots.
4. Add the chopped sweet potato roots to the beans and let cook.
5. When sweet potato roots are soft and beans are well cooked, add salt to taste and mash.
6. Serve with stew or tea.

Sweet potato "mshenye"

INGREDIENTS

- 10 medium sized sweet potato roots
- 4 cups beans, cowpeas and peas
- Salt to taste

METHODS

1. Sort the beans and pre-soak for 6-8 hours.
2. Boil the beans till almost cooked.
3. Wash, peel and chop sweet potato roots.
4. Add the chopped sweet potato roots to the beans and let cook.
5. When sweet potato roots are soft and beans are well cooked, add salt to taste and mash.
6. Serve with stew or tea.

Sweet potato crisps

INGREDIENTS

- 6 medium-sized sweet potato roots
- 2 cups oil
- Salt and red pepper to taste
- 2 containers water for preparing the roots

PROCEDURE

1. Remove soil from roots and then peel and place the roots in clean water.
2. Slice roots into very thin pieces using a knife or the larger blade of a grater.
3. Drain off the water.
4. Heat the oil and deep fry till the crisps start to turn golden brown.
5. When golden brown remove and drain.
6. Add salt and red pepper to taste, serve warm or cold.

Sweet potato crackies

INGREDIENTS

- 1 cup sweet potato flour or 1½ cups sweet potato mash
- 12 cups wheat flour
- 3 teaspoons salt
- 5 small pieces garlic
- 12-15 pieces local green hot pepper local or 3 pieces exotic green hot pepper
- 0.8 litres sunflower oil
- Lukewarm water

METHOD 1

1. Sift all dry ingredients in a mixing bowl.
2. Add sunflower oil.
3. Knead to form a smooth dough, till it leaves the bowl clean.

4. Add a little lukewarm water and keep mixing until hard and smooth. Cover it immediately with a clean cotton cloth.
5. Cut and make into small balls, roll them till flat and transparent. Add juice from crushed green hot peppers depending on the consumer's preference.
6. Heat oil and fry the flat crackies in it, when lightly brown remove them from the oil, drain the oil and let cool in a covered container.

METHOD 2

1. Sift all dry ingredients in a mixing bowl. Add mash if using mashed sweet potatoes.
2. Add margarine/oil and rub in.
3. Whisk the eggs and add to the contents in the bowl (skip this step if not using eggs)
4. Knead to a smooth dough, if hard add a little warm water.
5. Pack dough in noodle/ghantia machine.
6. Heat oil and drop contents in machine by turning the handle round.
7. Let cook till light brown.
8. Remove and drain oil and let cool. Break

Sweet potato pancakes

INGREDIENTS

- 1 ½ cups sweet potato mash
- 1 ½ cups wheat flour
- 3 ½ teaspoons baking powder
- 1 tablespoon
- Pinch of salt
- ½ teaspoon ground nutmeg
- 2 eggs, beaten
- 1 ½ cups milk
- ¼ cup butter or margarine

METHOD

1. Sieve all the dry ingredients into a mixing bowl.
2. Combine the remaining ingredients, and then add them to the flour mixture to form a batter.
3. Melt a small knob of butter in a frying pan and add to the batter.
4. Drop tablespoons of the batter into the hot frying pan.
5. Fry, turning the pancakes over once, until browned on both sides.

Sweet potato doughnuts


INGREDIENTS

- 2 cups wheat flour
- 1 cup mashed sweet potato
- 1/4 cup sugar
- 1 table spoonful Margarine
- I egg
- 2 level teaspoons baking powder or instant dry yeast
- ½ teaspoonspices (cinnamone/nutmeg etc.)

METHOD

1. Cook and mash sweet potato
2. Mix together the mashed sweet potato flours, sugar, margarine, baking powder and nutmeg until mixture resembles breadcrumbs
3. Whisk eggs until light, add into mixture. Keep adding water and mix into a stiff dough, which leaves the bowl clean.
4. Mould into doughnut shapes and deep fry until golden brown.
5. Drain and serve hot.

Note: The doughnut may also be baked. Brush with beaten egg to give a good crust.

Sweet potato fritters



INGREDIENTS

- 450 g (2 cups) grated Sweet potato
- 1 small grated onion
- 3 bulbs garlic
- 2 table spoons dhania
- 1 teaspoon ginger
- 2 teaspoon salt
- ½ cup wheat flour
- 2 eggs
- 480 ml (2 cups) cooking oil

METHOD

1. Mix grated Sweet potato, onion, ginger, dhania,
   garlic and eggs thoroughly
2. Salt to taste
3. Fry in oil until golden
4. Serve when hot

Sweet potato chapatti


INGREDIENTS

- 2 cups wheat flour
- ½ cup boiled and mashed sweet potato
- 1 level teaspoon salt
- 2 tablespoons cooking oil
- Enough water to mix

METHOD

1. Mix dry ingredients in a bowl
2. Rub in boiled mashed sweet potatoes
3. Add water little by little to make a soft dough
4. Let it rest for about 20 minutes
5. Roll out to a large circle on lightly floured surface
6. Oil, fold, cut and shape into small balls

7. Roll out the small ball to a large circle
8. Shallow fry in a little oil, turning until it is ready

Sweet potato soya chapatti

INGREDIENTS

- 1½ cup grated/flour/ mashed sweet potato
- 2 cups Wheat flour
- ½ cup Soya flour
- 1 teaspoon Salt

- adequate Lukewarm water
- ½ cup Oil

PROCEDURE

1. Mix dry ingredients together in a bowl.
2. Add the grated /mashed sweet potato and mix.
3. Add 1 tablespoon of oil to the flour and mix well.
4. Add the water to the mixture in the bowl and knead till stiff smooth paste is formed.
5. Divide the dough into 8-10 equal balls.
6. On a floured surface roll one ball at a time.
7. Fold each ball at a time to form a strip.
8. Coil each strip to form a circle and put aside for 20 minutes.
9. On a floured surface, roll out each coil into circular sheet
10. Fry each circular sheet on both sides till golden brown.
11. Ensure to grease both sides.
12. The product is the chapatti and can be served with stew or sauce or tea.

Sweet potato buns

INGREDIENTS

- ½ tea cup cooked and mashed sweet potatoes
- 2 cups wheat flour
- 2 teaspoons baking powder
- ½ cup sugar
- 2 tablespoons margarine
- 1 egg (optional)
- About ½-cup milk or water
- Pinch of salt

METHOD

1. Mix the flour and baking powder by sieving them together.
2. Rub in the margarine and s/p mash
3. Add in beaten egg and milk/ water then mix quickly to a soft dough

4. Turn onto a floured board and knead lightly. Roll out to ¼ inch thickness.
5. Cut into round shapes and place them onto a greased baking sheet
6. Glace them on top using a beaten egg
7. Bake in a pre- heated oven (250º C –350º C) for 15-20 minutes

Sweet potato cake

INGREDIENTS

- 2 cups wheat flour
- 1 cup sweet potato flour
- 2 teaspoons baking powder
- 1 cup sugar
- 1 cup margarine
- 3 eggs

Flavouring essence (optional)-lemon rind and juice, vanilla pineapple etc.

METHOD 1 (CREAMING METHOD)

1. Cream margarine and sugar together until light or creamy
2. Sieve flour and baking powder together
3. Add eggs to creamed mixture one at a time
4. Fold in flour little at a time until a smooth batter is obtained
5. Add flavouring if desired
6. Pour the mixture into a greased and dusted baking pan
7. Bake in a medium hot oven (180º C-200º C) or over a jiko.

Open –fire baking

1. Pre heat the charcoal stove/jiko
2. Grease a heavy pan with lid
3. Pour mixed dough contents into pan
4. Cover the pan with lid preferably heavy chapatti pan
5. Remove fire from stove and place on the lid evenly
6. Leave very little fire in the fire-box and cover with ash
7. Place covered pan with fire on the ash covered stove
8. Keep fire on lid burning by adding twigs for two minutes
9. Let cook for 30-40 minutes depending on type of charcoal used
10. Remove lid with fire, test cake with knife by piercing in the middle
11. If done, knife should be dry. If not, knife will be wet with uncooked contents
12. If done remove and cool cake on rack
13. If not done, replace lid with fire for a while then remove

Sweet potato chips


INGREDIENTS

- Four medium size sweet potatoes
- Deep frying oil

METHOD

1. Wash, peel and chip sweet potatoes thinly.
2. Soak in salty water for 10 minutes to remove excess starch
3. Remove and dry off the water with a paper towel
4. Deep fry in hot oil for 2-3 minutes or until cooked
5. Sprinkle with salt to taste and serve hot

Sweet potato Mandazi


INGREDIENTS

- ½ cup sweet potato mash
- 2 cups wheat flour
- 4 tablespoons sugar
- 3 tablespoons baking powder
- 1cup water or milk
- Oil for deep-frying

METHOD

1. Sieve flour and baking powder together
2. Add sugar and rub in s/p mash
3. Add milk/water and mix all ingredients to form dough
4. Roll onto a lightly floured surface to ½ inch
5. Cut into desired shapes and deep fry in hot oil until golden brown

Sweet potato biscuits

INGREDIENTS

- 4 cups cake flour
- ¼ cup s/p mash
- ¾ cup soft margarine
- 1 egg
- ¾ cup sugar
- 2 teaspoons baking powder
- ¼ teaspoon salt

METHOD

1. Sieve flour and baking powder together, add sugar and salt
2. Rub in margarine
3. Beat egg and mix with sweet potato mash
4. Mix everything together and roll out to a thin sheet on a floured surface
5. Cut into round shapes using a biscuit cutter
6. Place on a well-greased baking sheet and press down with a fork
7. Bake in pre-heated oven at 250º Cfor 15-20 minutes or until golden brown.

Sweet potato juice

INGREDIENTS

- 4 cups raw orange fleshed sweet potato mash
- 5 cups water
- 5 tablespoons lemon juice
- ½ cup sugar

METHOD 1

1. Grate the sweet potato into a fine mash
2. Add boiled and cooled water
3. Sieve and add lemon juice and sugar
4. Serve

METHOD 2

1. Grate the sweet potato into a fine mash
2. Add boiled and cooled water
3. Sieve, add sugar and boil while stirring until it thickens
4. Cool and add lemon juice
5. Serve

Sweet potato jam

INGREDIENTS

- 3 cups of boiled and mashed sweet potato
- 1½-cup water
- 5 cups sugar
- 3 teaspoons lemon juice

METHOD

1. Mix all ingredients together in a pot
2. Heat until all sugar melts, then bring to boil. Stir frequently
3. Add 3 teaspoons lemon juice just before completion of cooking.
4. Cook in low heat until jam is set (when it falls in drops from a ladle)
5. Put in pre-sterilized bottles and close properly with lid.

Baked spicy sweet potato

INGREDIENTS

- 4 sweet potatoes
- 2 tbs margarine
- 2½ tsp curry powder
- 2½ teaspoon jam
- 2½ teaspoons lemon juice
- 2 onions
- ¼ tsp salt
- 2 tbs sugar
- 1 cup water

METHOD

1. Peel sweet potatoes and wash
2. Boil until soft and chop into round 1 inch slices
3. Place the slices in an oven tin.
4. Chop onions and fry in margarine until soft. Add curry and fry for another few minutes.
5. Mix jam, lemon juice, salt, water and sugar.
6. Add to the curry and onion mixture.
7. Spread the mixture over sweet potato slices and bake in oven at 1200C for 20 minutes.

Sweet potato scones

INGREDIENTS

- ½ tea cup cooked and mashed sweet potatoes
- 2 cups wheat flour
- 3 teaspoons baking powder
- ½ cup sugar
- 2 tablespoons margarine
- 1 egg (optional)
- About ½-cup milk or water
- Pinch of salt

METHOD

1. Mix the flour and baking powder by sieving them together.
2. Rub in the margarine and Sweet potato mash
3. Add in beaten egg and milk/ water then mix quickly to a soft dough
4. Turn onto a floured board and knead lightly. Roll out to ¼ inch thickness.
5. Cut into round shapes and place them onto a greased baking sheet
6. Glace them on top using a beaten egg
7. Bake in a pre- heated oven (250° C –350° C) for 15-20 minutes

Fresh homemade noodles

INGREDIENTS

4 Eggs
2 cups Wheat flour
1 cup Sweet potato flour/mash
Water (optional)

METHOD

1. Mix wheat flour and Sweet potato flour/mash well
2. Pour the mixed flour into a mixing bowl and make a hole in the centre.
3. Break the eggs and place in the hole
4. With fork slowly combine the eggs and flour until well blended
5. If the dough mixture is too wet, add a small amount of flour, if it is too dry add water gradually and mix
6. Lightly flour table top and knead dough with palms of your hands until you have a uniform texture and colour
7. Form a ball with the dough, wrap in a towel and let it rest for 10 minutes
8. Cut the dough into slices, about ¼" thick
9. Re-wrap the rest of the dough so that it does not get dry
10. Roll out the slice of dough as thin as possible on a floured surface, making sure that it does not stick to the surface, then leave to dry for 15 minutes
11. Loosely roll it and cut across the rolls with a knife OR
12. Using the pasta machine, process the dough into pasta sheet and cut the dough sheet into desired pasta- spaghetti, noodles etc.
13. Dry strips on tea cloth in a warm dry place for 15 minutes before cooking
14. If for storage, dry completely and put in airtight container in a cool dry place.

Sweet potato vegetables

INGREDIENTS

1. Sweet potato leaves
2. Onions
3. Tomatoes
4. Flavor
5. Oil/ Fat
6. Salt
7. Warm water

METHODS

1. Clean leaves by removing dirt and very old ones.
2. Slice onions and tomatoes in separate dishes. Cut the leaves.
3. Wash twice in warm water to remove the anti- nutrients.
4. Heat the oil and fry onions till they start to brown. Add tomatoes and let cook for a while untill tender
5. Add the vegetable and let cook for 5 minutes. Add the flavor and stir the contents and let cook till done.
6. Serve with bananas/ugali or rice.

The flavor can be: milk, ground nut paste, coconut milk, soya flour, spices e.g. Roiko etc.

Sweet potato spicy balls

INGREDIENTS

4 cups mashed sweet potatoes
½ cup wheat flour for binding
2 eggs
1 cup bread crumbs
Cooking oil

METHOD

1 Cook and mash sweet potatoes
2 Roll mashed Sweet potato into balls
3 Coat the balls with wheat flour, then with beaten eggs and lastly with bread crumbs.
4 Deep fry till golden brown and serve

Sweet potato duchesse



INGREDIENTS

4 cups sweet potato mash
2 eggs
2 tablespoons butter or margarine
Dhania to garnish

METHOD

1 Mix the eggs and butter with mashed potatoes
2 Squeeze the mixture to a greased baking tin and baked

Leek and sweet potato soup

Ingredients

2 cup fresh diced sweet potato roots
2 Leeks (diced)
1 teaspoon margarine
1 medium onion (diced)
2 cups water
Salt to taste

Method

1. Fry the onions with margarine for a short while (avoid browning)
2. Mix leeks and Sweet potato well
3. Add to the fried onions and cook for staring continuously
4. Add water, bring to boil and simmer till the potatoes are tender
5. Sieve the mixture, add salt and summer for 2 minutes
6. Garnish with dhania and serve

Sweet potato vegetable salad

INGREDIENTS

- Grated Sweet potato
- Grated pilipilihoho
- Diced cabbage
- Diced onions
- Dhania
- Lemon
- Pinch of salt
- Mayonnaise (Optional)

METHOD

1 Wash vegetables separately and rinse with clean drinking
2 Drain the vegetables and cut separately
3 Mix the vegetables together, add lemon juice and a little salt
4 Add mayonnaise and mix well
5 Serve

How to make mayonnaise

INGREDIENTS

Egg yolk
Lemon/vinegar
Mustard (2 drops)
Pinch of salt
Cooking oil

METHOD

1. Put the mustard in a bowl.
2. Separate the egg yolk from the white.
3. Add the egg yolk to the mustard in the bowl and whisk until it turns creamy white.
4. Add oil little by little as you continue whisking to avoid cuddling.
5. Whisk until the mixture thickens. Add a little salt to taste and lemon juice.

About FARA

The Forum for Agricultural Research in Africa (FARA) is the apex continental organization responsible for coordinating agricultural research for development (AR4D) in Africa so as to increase its efficiency and effectiveness. It serves as the entry point for agricultural research initiatives designed to have a continental reach or a sub-continental reach spanning more than one sub-region.

FARA serves as the technical arm of the African Union Commission (AUC) on matters concerning agricultural science, technology and innovation. It provides a continental forum for stakeholders in AR4D to shape the vision and agenda for the sector and to mobilize them to respond to key continent-wide development frameworks, notably the Comprehensive Africa Agriculture Development Program (CAADP) of the African Union (AU) and the New Partnership for Africa's Development (NEPAD).

FARA's vision:
Reduced poverty in Africa as a result of sustainable broad-based agricultural growth and improved livelihoods, particularly of smallholder and pastoral enterprises

FARA's mission:
Creation of broad-based improvements in agricultural productivity, competitiveness and markets through strengthening of the capacity for agricultural innovation across the continent

FARA's value proposition:
Strengthening Africa's capacity for innovation and transformation by visioning its strategic direction, integrating its capacities for change and creating an enabling policy environment

FARA's strategic direction is derived from and aligned with the Science Agenda for Agriculture in Africa (S3A), which is, in turn, designed to support the realization of the CAADP vision of shared prosperity and improved livelihoods.

FARA's programme is organized around three strategic priorities (SPs), namely:

Visioning Africa's agricultural transformation through foresight, strategic analysis and partnerships to enable Africa to determine the future of its agriculture, using proactive approaches to exploit opportunities in agribusiness, trade and markets, taking the best advantage of emerging sciences, technologies and risk mitigation practices and approaches, and harnessing the combined strengths of public and private stakeholders.

Integrating capacities for change by making different actors aware of each other's capacities and contributions, connecting institutions and matching capacity supply to

demand, so as to create consolidated, high-capacity and effective African agricultural innovation systems that can use institutional comparative advantages to mutual benefit while strengthening individual and institutional capacities.

Enabling environment for implementation, initially through evidence-based advocacy, communication and widespread stakeholder awareness and engagement to generate enabling policies and institutions, then by ensuring the stakeholder support required for the sustainable implementation of program for African agricultural innovation.

Key to these outcomes is the delivery of three important results, which respond to the strategic priorities expressed by FARA's clients. These are:

Key Result 1: Stakeholders empowered to determine how the sector should be transformed and to undertake collective actions in a gender-sensitive manner

Key Result 2: Strengthened and integrated continental capacity that responds to stakeholder demands in a gender-sensitive manner

Key Result 3: Enabling environment for increased AR4D investment and implementation of agricultural innovation systems in a gender-sensitive manner.

FARA's development partners are the African Development Bank (AfDB), the Canadian Department of Foreign Affairs, Trade and Development (DFATD), CGIAR, the Danish International Development Agency (DANIDA), the UK's Department for International Development (DFID), the European Commission (EC), the governments of the Netherlands and Italy, the Norwegian Agency for Develop-ment Cooperation (NORAD), the Australian Agency for International Development (AusAiD) and the World Bank.

FARA
Forum for Agricultural Research in Africa

Innovating for Africa's Wellbeing

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About PARI

The Program of Accompanying Research for Innovation (PARI) brings together partners from Africa, India and Germany to contribute to sustainable agricultural growth and food and nutrition security in Africa and India. PARI offers independent scientific advice to the special initiative of the German Government "One world without hunger" (SEWOH) which, among other activities, supports the improvement of food and nutrition security and sustainable agricultural value chains by setting up Green Innovation Centers (GICs) in 12 African countries and India.

Specific goals of PARI are to promote and support the scaling of proven innovations in the agri-food sector in collaboration and partnership with all relevant actors; to support and enhance investments in the GICs through research; and thereby to contribute to the development of the agri-food sector in Africa and India through the identification, assessment and up-scaling of innovations. The core topics and thematic research priorities of the Program have been identified in accordance with the African Union's CAADP as part of the New Partnership for Africa's Development (NEPAD).

PARI's collaborative work includes:

1 Innovation research with future-oriented impact analyses, such as:

- → modelling and mapping direct and indirect impacts of potentially promising innovations
- → developing methodologies and concepts for strategic analysis of potentials and prospects
- → institutional analysis of the GICs in the context of their national agricultural innovation systems

2 Identifying and stimulating technological and institutional innovations, such as:

- → screening for promising innovations from research and innovation systems ("top-down" approach)
- → soliciting innovations generated by farmers and other actors in the value chains ("bottom-up" approach)
- → scaling of innovations

3 Engaging with food and agriculture policy making to enhance approaches for innovation that improve food and nutrition security.

The Program is being implemented by an international, interdisciplinary consortium of three universities (ZEF / University of Bonn, University of Hohenheim, Technical University Munich), the Forum for Agricultural Research in Africa (FARA) and its network of national and regional partners in Africa, and the African Growth and Development Policy Modeling Consortium (AGRODEP) facilitated by the International Food Policy Research Institute (IFPRI, Africa Office) and research collaborators in India.

ISBN:978-9988-8776-2-0

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