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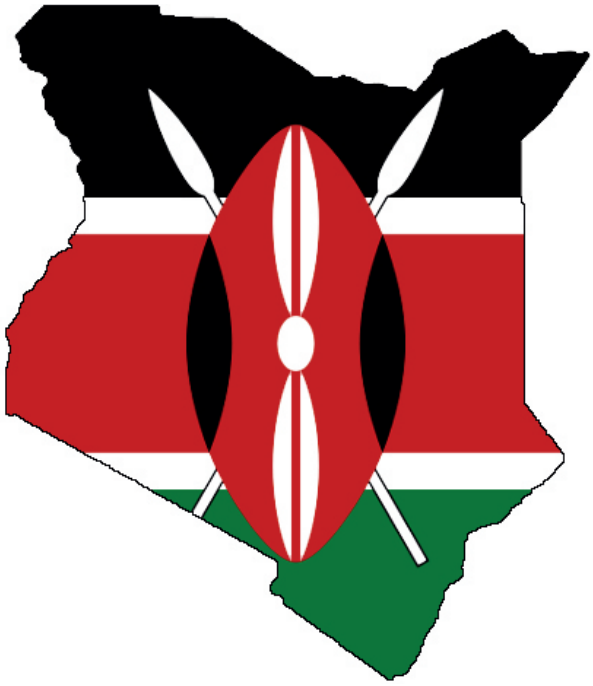
Innovation for Sustainable Agricultural Growth in Kenya



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About this study

In 12 African countries and India Green Innovation Centers (GICs) have been established under the ‘‘One World, No Hunger’’ Initiative (SEWOH) of the German government and other investors. The aim of the GICs is to promote agricultural innovation, improve food and nutrition security and build sustainable value chains in the agri-food sector of these countries. The Program of Accompanying Research for Agricultural Innovation (PARI) has been providing independent research to the SEWOH since 2015. PARI is led by the Center for Development Research (ZEF) at the University of Bonn in close collaboration with the Forum for Agricultural Research in Africa (FARA) and its network of national and regional partners in Africa, the African Growth and Development Policy Modeling Consortium (AGRODEP) facilitated by the International Food Policy Research Institute (IFPRI, Africa Office) and other partners in Germany and India. This country dossier offers a situation analysis of the current state of the agri-food sector, related policies and existing agricultural innovations. It thereby provides basic background knowledge necessary to make fruitful investments in line with the country‘s policies and its potentials, and to find promising partners for development cooperation.

Table of Contents

List of Tables

List of Figures

Acronyms/Abbreviations

AIDS	Acquired Immune Deficiency Syndrome
ASARECA	Association for Strengthening Agriculture Research in Eastern and Central Africa
ASDSP	Agricultural Sector Development Support Programme
AU	African Union
ASDS	Agricultural Sector Development Strategy
CAADP	Comprehensive Africa Agricultural Development Programme
CGIAR	Consultative Group for International Agricultural Research
CIAT	International Center for Tropical Agriculture
CIP	International Potato Center
DHS	Demographic and Health Survey
ERS	Economic Recovery Strategy
FAO	Food and Agriculture Organization of the United Nations
FARA	Forum for Agricultural Research in Africa
GDP	Gross Domestic Product
GHI	Global Hunger Index
GIC	Green Innovation Center
GNI	Gross National Income
GoK	Government of Kenya
IAR4D	Integrated Agricultural Research for Development
IFPRI	International Food Policy Research Institute
IPTA	Innovation Platform for Technology Adoption
KALRO	Kenya Agricultural and Livestock Research Organization
KARI	Kenya Agricultural Research Institute
KEMRI	Kenya Medical Research Institute
KES	Kenyan Shillings
KNBS	Kenya National Bureau of Statistics
NACC	National AIDS Control Council
NALEP	National Agriculture and Livestock Extension Programme
NARS	National Agricultural Research System
NASEP	National Agricultural Sector Extension Policy
NCPD	National Council for Population and Development
NGO	Non-governmental Organization
NMCP	National Malaria Control Programme
OFSP	Orange-fleshed sweet potato
PAHO	Pan American Health Organization
PARI	Program of Accompanying Research for Agricultural Innovation
PM	Primary Multiplication
PPP	Purchasing Power Parity
PSTAD	Promotion of Science and Technology for Agricultural Development
QPM	Quality Protein Maize
R&D	Research and Development
eRAILS2	Electronic Regional Agricultural Information and Learning Systems 2
RCA	Revealed Comparative Advantage
S3A	Science Agenda for Agriculture in Africa
SEWOH	“One World No Hunger” Initiative
SM	Secondary Multiplication
SRA	Strategy for Revitalizing Agriculture
SVCDC	Sorghum Value-Chain Development Consortium
TFP	Total Factor Productivity
TM	Tertiary Multiplication

TC	Tissue Culture
USAID	United States Agency for International Development
WHO	World Health Organization
ZEF	Zentrum für Entwicklungsforschung/ Center for Development Research

1 General background information on the agricultural and food sectors

Agriculture plays an important role in the Kenyan economy. The sector engages over 40% of the total population, over 70% of the rural population and 18% of formal employment and provides livelihood opportunities to the growing youth population. The sector has performed relatively well in recent years as it recovered from a negative growth rate of -2.1% in 2000 to a positive rate of 2.9% in 2013. However, its growth is lower compared to the other sectors of the economy. The growth experienced by the sector in the last decade (from 1.7% to 7.2%) plummeted in 2008 to -4.1% as a result of the prolonged drought and other factors. Nonetheless, the sector has resumed a positive growth and development path and has now reached 2.9%. Key to recovery has been the vibrant internal demand for major staples and pulses, livestock products and horticultural goods, and a return to growth in key export sub-sectors, such as coffee, tea, pyrethrum, fruits, vegetables and cut flowers. Horticulture contributes 27%, while coffee contributes 5%, and tea 32% according to the 2007 - 2013 average.

Opportunities for spurring growth in the agricultural sector and in the broader economy co-exist with challenges in translating such growth into greater food security for the Kenyan population. The key challenges revolve around productivity in the key sub-sectors, improvement in land and natural resource management, improvement in market access and trade, enhanced private sector participation, institutional reforms and improved coordination of the research and technology transfer components. These are all ingredients for a fully functional agricultural sector. Recent efforts by the Government of Kenya to develop the sector are well expressed in its medium-term investment plan, which is aligned to the Comprehensive Africa Agricultural Development Programme (CAADP) framework for the continental agricultural development. The plan gives adequate recognition to the diversity of agro-ecological conditions and stakeholder configuration and proposes investment in six strategic thrusts drawn from the Kenya CAADP alignment (Gerecke, 2007; Kibaara, 2009):

1. Increasing productivity, commercialization and competitiveness;
2. Promoting private sector participation;
3. Promoting sustainable land and natural resource management;
4. Reforming delivery of agricultural services;
5. Increasing market access and trade;
6. Ensuring effective coordination and implementation.

The potential for German collaboration in fostering Kenya's agricultural growth and development is enormous, ranging from research partnerships for technology generation to development of pathways and systems for translating research output into development outcomes. The need to build external collaboration on existing progressive initiatives and on the government pathways for the development of the sector is essential to ensure complementarity and synergy.

In twelve African countries, including Kenya, Green Innovation Centers (GICs) have been established in selected regions under the ''One World, No Hunger'' Initiative (SEWOH) of the German government and other investors. The aim of the GICs is to promote agricultural innovation, improve food and nutrition security, and build sustainable value chains in the agri-food sector. The selected value chains in Kenya are sweet potatoes, dairy products, and vegetables in three counties: Bungoma, Siaya, and Kakamega. The milk value chain was selected because it has been prioritized in county strategies; because of the interest expressed by stakeholders; and because of the potential for increasing productivity, refrigeration, dairy foodstuffs production, and milk processing. The sweet potato value chain was selected because sweet potatoes have high nutritional value; they are well adapted; they have low input requirements; they adds to drought resilience; and their potential for processing and marketing, especially for women.

1.1 Pan-African policies and strategies

A number of strategies and frameworks exists in Africa for agricultural development; many of these frameworks are developed at the level of the African Union (AU) and other continental bodies. The frameworks often provide political support and seek implementation at the country level to foster continental growth. A few recent frameworks are as follows:

- CAADP: It was developed by the AU Commission (implemented by the New Partnership for Africa's Development). It follows the Maputo Declaration of 2003 and represents the commitment of African countries to commit at least 10% of their budget to agriculture, with the projection that it will lead to 6% annual growth rate for the sector. Kenya embraced the CAADP compact in 2008 and started to implement the framework in 2010;
- The African Peer Review Mechanism in 2004, implemented one year after endorsement of the CAADP by AU states;
- Abuja Declaration on Fertilizer for an African Green Revolution (2006) in which the AU Member States resolved to increase fertilizer use from 8 to 50 kilograms of nutrients per hectare by 2015;
- Malabo Declaration (June 2014) on accelerated agricultural growth and transformation for shared prosperity and improved livelihoods through Harnessing Opportunities for Inclusive Growth and Sustainable Development, also marking the 10th Anniversary of the Adoption of the CAADP;
- The Science Agenda for Agriculture in Africa (S3A) was developed in 2014 by a coalition of actors under the leadership of the Forum for Agricultural Research in Africa (FARA). S3A is an African-owned and African-led process that articulates the science, technology, extension, innovations, policy, and social learning that Africa needs to apply in order to meet its agricultural and overall development goals. The strategic thrusts of S3A in the short- to medium-term are the implementation of CAADP; the increase of domestic, public, and private sector investment, creating an environment which enables the sustainable application of science for agriculture; and doubling the current level of agricultural Total Factor Productivity (TFP) by 2025 through the application of science for agriculture. In the medium- to long-term, the science agenda is to build systemic science capacity at national and regional levels, capable of addressing evolving needs for farmers, producers, entrepreneurs, and consumers, especially given strategic and foresight issues, such as climate change and urbanization.

1.2 National (and regional) policies and strategies

A number of documents exist on the progress of Kenya's national policies in agriculture. Various authors (Gitau *et al.*, 2008; Ronge *et al.*, 2005; Alila and Atieno, 2006) identify three general periods in the recent agricultural policy history of Kenya: post-independence, liberalization, and stakeholder participatory approach (post-liberalization) periods. The current regime – **the post-liberalization period** – has seen a number of reforms, for example, the Poverty Reduction Strategy Paper in 2001 and the National strategy for economic recovery in 2003. In the latter strategy, agriculture was identified as one of the three "movers" of the economy, together with trade and industry, and tourism. The Strategy for Revitalizing Agriculture (SRA), 2004-2014, was launched to implement the Economic Recovery Strategy for Wealth and Employment Creation (ERS) in the agricultural sector. In June 2008, Kenya adopted the **Kenya Vision 2030** as a new blueprint for the country's development and to give continuity to the policy achievements of the ERS. In Vision 2030, agriculture is identified as a key sector in achieving the envisaged annual economic growth rate.

The Agricultural Sector Development Strategy (ASDS) 2010-2020, was established following a revision of the SRA, 2004-2014. ASDS sets out a detailed plan to 'position' the agricultural sector as a key driver for delivering the 10% annual economic growth rate envisaged under the economic pillar of Vision 2030.

The National Climate Change Response Strategy and National Climate Change Action Plan of 2010 highlight various measures for adaptation to and mitigation of the impacts of climate change on agriculture, such as early maturing and high yielding crop varieties, drought and pest resistant crop varieties and disease-resistant livestock. The Second Medium Term Plan 2013-2017 identifies key policy actions, reforms, programs, and projects to be implemented in the 2013-2017 period, in line with government priorities.

1.3 Data on food and nutrition security in the country and GIC region

The following section includes information about important socio-economic and agricultural indicators and data on diet quantity, diet quality, and nutrition status.

1.3.1 Socio-economic and agricultural data

Table 1: Selected national economic and health-related data

Indicator	Value	Year
Population, total	45,545,980	2014
Population growth (annual %)	2.1	2014
Rural population (% of total population)	75	2014
GDP per capita, PPP (constant 2011 international $)	2,776	2014
GNI per capita, PPP (constant 2011 international $)	2,762	2014
Poverty headcount ratio at $2 a day (PPP) (% of population)	67	2005
Poverty headcount ratio at $1.25 a day (PPP) (% of population)	43	2005
Poverty headcount ratio at national poverty lines (% of population)	46	2005
Rural poverty headcount ratio at national poverty lines (% of rural population)	49	2005
Agricultural land (% of land area)	48	2012
Agricultural irrigated land (% of total agricultural land)	0.04	2009
Agriculture value added per worker (constant 2005 US$)	396	2014
Agriculture, value added (% of GDP)	30	2014
Access to electricity, rural (% of rural population)	7	2012
Employees, agriculture, female (% of female employment)	68	2005
Employees, agriculture, male (% of male employment)	55	2005
Employment in agriculture (% of total employment)	61	2005
Literacy rate, adult total (% of people ages 15 and above)	72	2007
Ratio of female to male secondary enrolment (%)	93	2012
Mortality rate, under-5 (per 1,000 live births)	71	2013
Maternal mortality ratio (modelled estimate, per 100,000 live births)	400	2013

Source: World Bank, http://data.worldbank.org/country

1.3.2 Consumption and nutrition status

Data on diet quantity, diet quality and nutrition status are relevant for assessing food and nutrition security. Overall, dietary energy supply per capita – a measure of diet quantity – is just about adequate in Kenya, closely matching the average dietary energy requirement of the population (Table 2). About one fifth of the population is unable to meet minimum dietary energy requirements and suffers from chronic undernourishment. The reduction in undernourishment since 1990-92 has been modest, amounting to only 11 percentage points, or about one third of the initial prevalence rate (Figure 1). Spikes in undernourishment in the mid-1990s and early 2000s indicate that food supply has been unstable at times. The prevalence of food over acquisition has remained low over the past 25 years:

the Food and Agriculture Organization of the United Nations (FAO) estimates that less than 10% of the population regularly acquires food in excess of their individual dietary energy needs (Table 2).

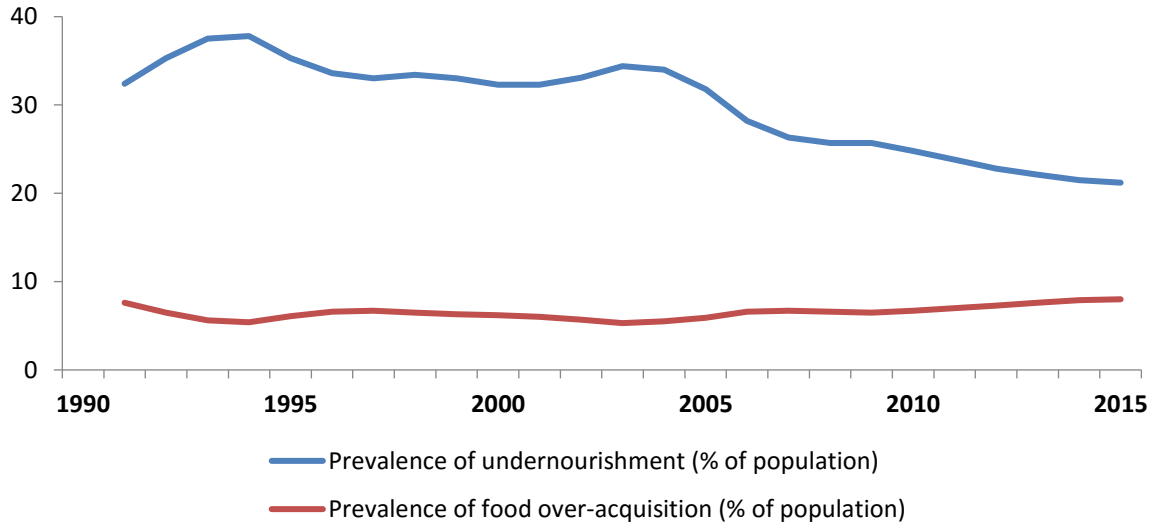
Table 2: Food and nutrition security indicators

Indicator	Value	Year
Diet quantity		
Dietary energy supply (kcal/caput/day)	2215	2014-16
Average dietary energy supply adequacy (% of average requirement)	102	2014-16
Prevalence of undernourishment (% of population)	21	2014-16
Prevalence of food over-acquisition (% of population)	8	2014-16
Diet quality		
Dietary energy supply from cereals, roots and tubers (% of total dietary energy supply)	56	2009-11
Dietary energy supply from carbohydrate (% of total dietary energy supply)	68	2009-11
Dietary energy supply from protein (% of total dietary energy supply)	11	2009-11
Dietary energy supply from fat (% of total dietary energy supply)	21	2009-11
Average protein supply (g/caput/day)	61	2009-11
Average fat supply (g/caput/day)	51	2009-11
Child feeding practices		
Minimum dietary diversity: consumption of 4+ food groups (% of children 6-23 months)	41	2014
Consumption of foods rich in vitamin A (% of children 6-23 months)	72	2014
Consumption of foods rich in iron (% of children 6-23 months)	33	2014
Nutrition status		
Child wasting (% of children under five)	4	2014
Child stunting (% of children under five)	26	2014
Child overweight (% of children under five)	4	2014
Adult overweight and obesity (% of adults 18+ years)	26	2014
Adult obesity (% of adults 18+ years)	7	2014
Vitamin A deficiency (% of children 6-59 months)	49	2013
Anemia in children (% of children 6-59 months)	36	2015
Anemia in women (% of women 15-49 years)	25	2011

Source: FAO (2016), and authors' calculations based on FAO (2016); Kenya National Bureau of Statistics, Ministry of Health, National AIDS[1] Control Council, National Council for Population and Development, Kenya Medical Research Institute, National Council for Population and Development and ICF International (2015); National Malaria Control Programme, Kenya National Bureau of Statistics, and ICF International (2016); Stevens et al. (2015), quoted in International Food Policy Research Institute (IFPRI) (2015); World Health Organization (WHO) (2015a); WHO (2015b)
Note: See Annex A for definitions of the indicators.

[1] AIDS = Acquired Immune Deficiency Syndrome

Figure 1: Prevalence of undernourishment and food over-acquisition (1990-92 to 2014-16)



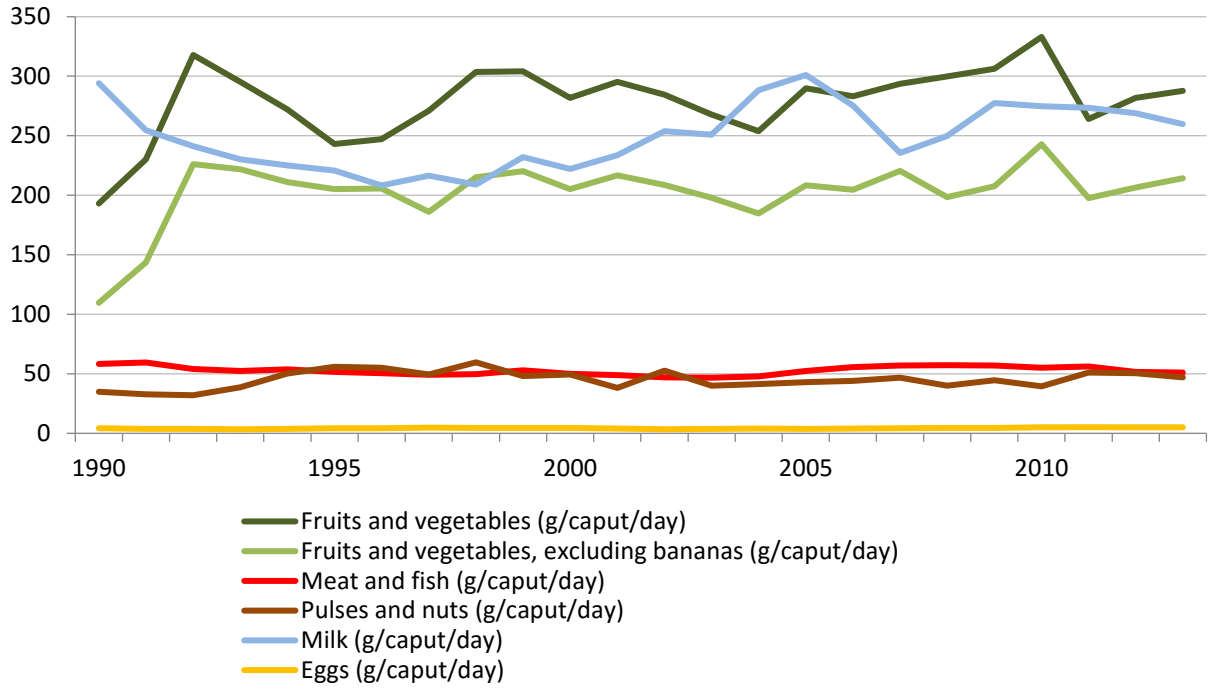
Source: Authors' presentation based on data from FAO (2016)

The main sources of dietary energy in Kenya are cereals (especially maize and wheat) and starchy roots. Since non-staple foods, such as milk, sugar, pulses, and vegetable oils, also play an important role in the Kenyan diet, starchy staples contribute only a bit more than half of overall dietary energy supply (Table 2). The shares of dietary energy supply from carbohydrates, protein, and fat are well within the recommended ranges of 55-75%, 10-15%, and 15-30%, respectively (WHO, 2003). This means that the diet is balanced in terms of its macronutrient composition. Average protein supply is sufficient to meet protein requirements (Table 2; see Annex A for further explanation).

The consumption of sufficient quantities of non-staple foods, such as fruits and vegetables and animal-source foods, is essential for a diet that provides adequate amounts of micronutrients. Meat and fish supply amounts to only about 50 g/caput/day in Kenya and has remained virtually unchanged since the early 1990s (Figure 2). Milk supply has been volatile, but overall has remained at fairly high levels by African standards, whereas the supply of eggs has continued to be low. Together with milk and meat, pulses are an important source of protein in the Kenyan diet,[2] although the supply of pulses and nuts amounts to only about 50 g/caput/day. Fruit and vegetable supply has varied between 260 and 330 g/caput/day in recent years, still falling below the recommended intake of 400 g of fruits and vegetables per day (WHO, 2003). Bananas, including green cooking bananas (matoke), which are a popular staple in some parts of Kenya, make up about one quarter of the fruit and vegetable supply (Figure 2).

[2] Source: Food balance sheet for Kenya, 2013, from FAOSTAT, accessed 9 Nov, 2016.

Figure 2: Supply of non-staple foods (1990-2013)



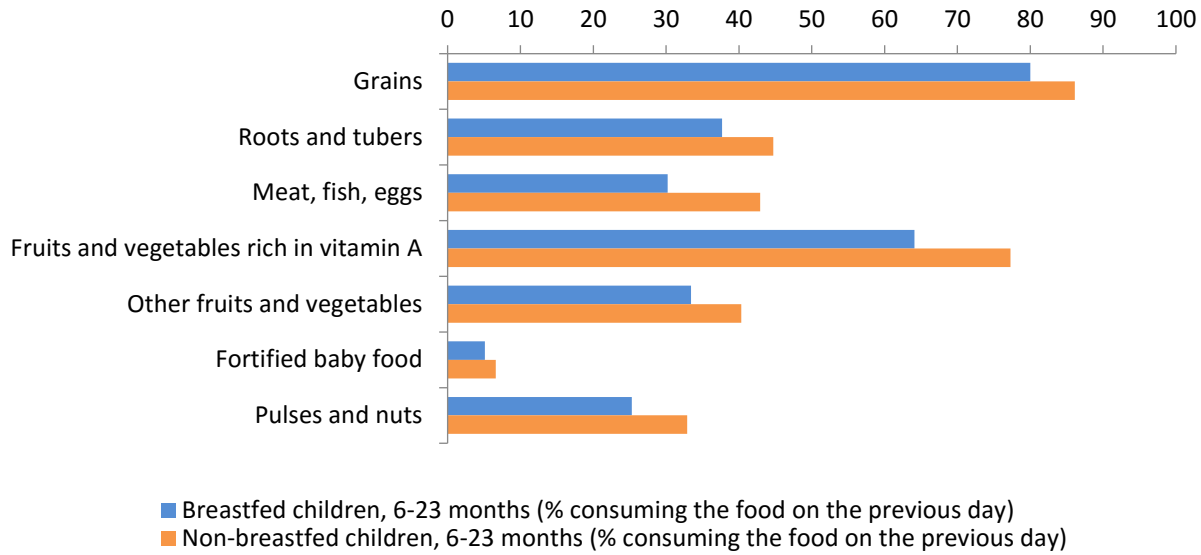
Source: Authors' presentation based on data from FAOSTAT, accessed 07 Oct 2016
Note: Based on their nutrient profiles, pulses and nuts includes groundnuts and soybeans, although these foods are classified by FAO as oilcrops. Coconuts are not included among pulses and nuts because they have low protein content.

Infant and young child feeding practices are crucial for children's nutrition and health status and long-term development. Children between 6-23 months of age should consume at least 4 out of 7 food groups (minimum dietary diversity) and receive iron-rich foods and foods rich in vitamin A daily (WHO, 2010; PAHO[3]/WHO, 2003; WHO, 2005). In Kenya, infants' and young children's diets fall short of these goals: about two fifths achieved minimum dietary diversity, roughly 70% consumed foods rich in Vitamin A, and only one third had foods rich in iron on the previous day (Table 2). Both breastfed and non-breastfed children aged 6-23 months were most frequently fed foods made from grains; other, more micronutrient-rich foods, such as meat, fish and eggs, or pulses and nuts, were not as frequently consumed, although fruits and vegetables rich in vitamin A came close (Figure 3). Fortified baby foods, which can compensate for a lack of micronutrients in locally available foods, were consumed by less than 10% of breastfed and non-breastfed children.

An analysis of infants' and young children's diets in two districts in Kenya (Vihiga in the Western region and Kitui in the Eastern region), identified iron and zinc in both sites, and calcium in Vihiga, as the main 'problem nutrients' for which solutions such as fortification are needed in order to ensure adequate intake, as it would be difficult to meet the requirements for these micronutrients solely with locally available foods (Ferguson et al., 2015).

[3] PAHO = Pan American Health Organization

Figure 3: Percentage of infants and young children consuming foods from selected food groups (2014)



Source: Authors' presentation based on Kenya National Bureau of Statistics, Ministry of Health, National AIDS Control Council, National Council for Population and Development, Kenya Medical Research Institute, National Council for Population and Development and ICF International (2015)

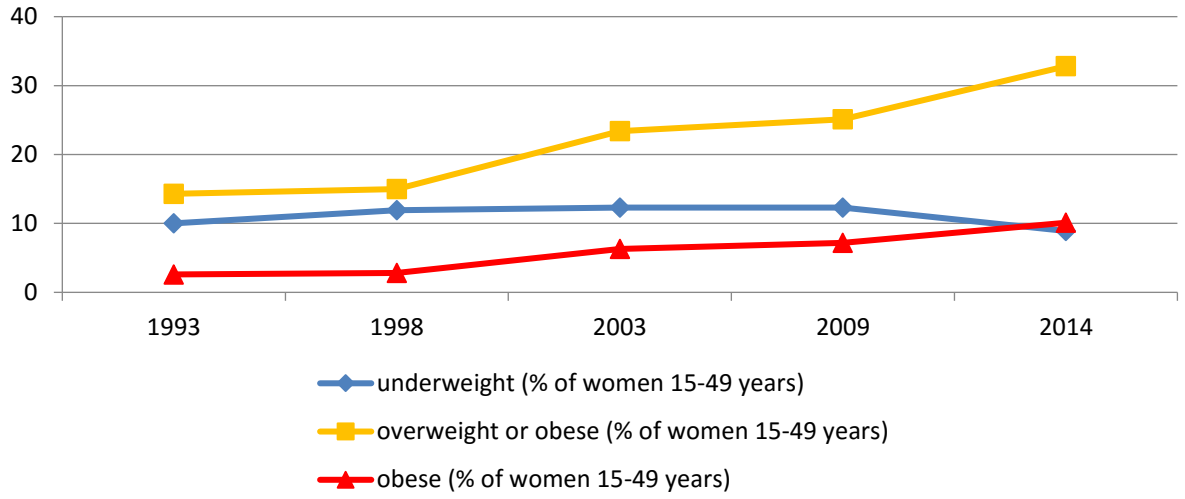
Stunting and wasting are indicators of chronic and acute child undernutrition, respectively. The prevalence rates of stunting and wasting have been reduced in Kenya in the past decade (UNICEF[4]/WHO/World Bank, 2016). Wasting is now below the threshold for mild public health significance of 5%, and stunting affects about one fourth of children under five, falling within the range of 20-29% for mild public health significance of stunting (Table 2). According to the latest available data, overweight in children stands at 4% and does not give cause for great concern.

Overweight and obesity are risk factors for chronic diseases such as diabetes (Must and McKeown 2012). About one fourth of adults in Kenya are overweight or obese (Table 2). Since the early 1990s, the combined prevalence of overweight and obesity has more than doubled among women of reproductive age, now affecting about one third of this population group, while the prevalence of obesity has almost quadrupled during the same period (Figure 4). The prevalence of underweight has recently fallen below 10% after a transient increase that prevailed throughout the late 1990s and early 2000s.[5]

Vitamin A deficiency is a risk factor for blindness and for mortality from measles and diarrhoea in children aged 6–59 months (Imdad et al. 2010; Imdad et al. 2011). In Kenya, about half of all children in this age group are estimated to be vitamin A deficient (Table 2). A lower proportion of children aged 6-59 months, namely, a bit more than one third, and only one fourth of all women of reproductive age suffer from anaemia (Table 2). About half of the global burden of anaemia can be attributed to iron deficiency (WHO, 2015b). Malaria is another cause of anaemia, yet a recent survey in Kenya found that malaria prevalence among children aged 6-59 months was relatively low (only 5% were infected) and that severe anaemia, which is typically associated with malaria, was rare. This suggests that the predominantly mild forms of anaemia observed among Kenyan children have diverse causes, including nutritional deficiencies (National Malaria Control Programme, Kenya National Bureau of Statistics, and ICF International, 2016).

[4] UNICEF = United Nations International Children's Emergency Fund
[5] See Annex A for definitions of overweight, obesity, and underweight.

Figure 4: Underweight, overweight, and obesity among women of reproductive age (1993-2014)



Source: Authors' presentation based on data from ICF International (2015), The Demographic and Health Survey (DHS) Program STATcompiler, funded by the United States Agency for International Development (USAID), accessed 12 Sept 2016

Regionally disaggregated data are available for indicators of nutrition status and child feeding. The diversity of infants' and young children's diets ranges from a very low level in the Northeastern region to a fairly high level in Nairobi, where three quarters of children 6-23 months achieved minimum dietary diversity (that is, they consumed 4+ food groups on the previous day [see Table 3]). Large disparities between the capital city and the Northeastern region, which borders Somalia to the east and Ethiopia to the north, are also evident with regard to the shares of children consuming foods rich in vitamin A and foods rich in iron. Anemia prevalence among children is lowest in the area with low malaria risk which includes Nairobi, whereas it is highest in the lake endemic area in which the GIC regions are situated (Table 4). Wasting among children is particularly high in the Northeastern region, whereas stunting is highest in the Rift Valley, Eastern, and Coast regions.

Overweight and obesity among women are most common in Nairobi and the adjacent Central region (Table 5). At only 3%, the prevalence of underweight in women is low in Nairobi, but about 10 times higher in the Northeastern region.

Table 3: Child feeding practices by region, 2014

Share of children 6-23 months consuming:					
4+ food groups		Foods rich in vitamin A		Foods rich in iron	
Region	**(%)**	**Region**	**(%)**	**Region**	**(%)**
Nairobi	75	Nairobi	50	Nairobi	24
Central	57	Central	40	Nyanza	21
Nyanza	46	Nyanza	37	Central	19
Rift Valley	37	Rift Valley	34	Western	16
Eastern	34	Western	33	Rift Valley	15
Western	29	Coast	31	Coast	13
Coast	28	Eastern	31	Eastern	10
Northeastern	12	Northeastern	11	Northeastern	9

Source: Kenya National Bureau of Statistics, Ministry of Health, National AIDS Control Council, National Council for Population and Development, Kenya Medical Research Institute, National Council for Population and Development and ICF International (2015)
Notes: GIC regions are highlighted in red. See Annex A for definitions of the indicators.

Table 4: Child nutrition status by region, 2014/2015

Prevalence among children under five:						Prevalence among children 6-59 months:	
Stunting		Wasting		Overweight		Anemia	
Region	**(%)**	**Region**	**(%)**	**Region**	**(%)**	**Region**	**(%)**
Nairobi	17	Western	2	Northeastern	3	Low risk	25
Central	18	Nyanza	2	Coast	3	Coast endemic	32
Nyanza	23	Central	2	Western	3	Highland epidemic	38
Northeastern	25	Nairobi	3	Rift Valley	4	Semi-arid, seasonal	39
Western	25	Eastern	4	Eastern	4	Lake endemic	48
Rift Valley	30	Coast	5	Nyanza	4		
Eastern	30	Rift Valley	6	Nairobi	5		
Coast	31	Northeastern	13	Central	6		

Source: Kenya National Bureau of Statistics, Ministry of Health, National AIDS Control Council, National Council for Population and Development, Kenya Medical Research Institute, National Council for Population and Development and ICF International (2015); National Malaria Control Programme, Kenya National Bureau of Statistics, and ICF International (2016)
Notes: GIC regions are highlighted in red. Data on wasting, stunting and overweight were collected in 2014, and data on anemia in 2015. The data on anemia among children from the Malaria Indicator Survey 2015 are presented by malaria endemic zone, not by administrative division. See Annex A for definitions of the indicators.

Table 5: Women's nutrition status by region, 2014

Prevalence among women of reproductive age (15-49 years):					
Underweight		Overweight + obesity		Obesity	
Region	**(%)**	**Region**	**(%)**	**Region**	**(%)**
Nairobi	3	Northeastern	19	Northeastern	5
Central	6	Western	24	Western	6
Nyanza	**6**	Nyanza	27	Nyanza	7
Western	9	Rift Valley	29	Rift Valley	8
Eastern	10	Eastern	30	Eastern	8
Coast	11	Coast	32	Coast	12
Rift Valley	12	Central	47	Nairobi	17
Northeastern	29	Nairobi	48	Central	18

Source: Kenya National Bureau of Statistics, Ministry of Health, National AIDS Control Council, National Council for Population and Development, Kenya Medical Research Institute, National Council for Population and Development and ICF International (2015)
Notes: GIC regions are highlighted in red; data on anemia among women at the regional level are not available from the above source and the Malaria Indicator Survey 2015. See Annex A for definitions of the indicators.

Among indicators of children's nutrition status that are available at the regional level, anaemia has the highest rates of children affected, followed by stunting (Table 4). Under the assumption that half of all anaemia is due to iron deficiency, iron deficiency anaemia among children is of mild public health significance in all malaria risk zones except for the lake endemic area, where it has moderate significance.[6] Stunting has mild public health significance in the Nyanza, North-eastern, Western, and

[6] About half of the global burden of anemia is attributable to iron deficiency (WHO, 2015b). Since the prevalence of anemia among children in Kenya by malaria risk zone is in the range of 25-48%, the prevalence of iron deficiency anemia can be estimated to be 13-24%. Only one zone therefore exceeds the threshold of 20% established to classify iron deficiency anemia as a moderate public health problem (see Annex A). However, it is

Rift Valley regions, and moderate significance in the Eastern and Coast regions. Wasting is a mild concern in the Rift Valley region, and at a moderately high level in the North-eastern region. Overweight in children has moderate public health significance in the Nairobi and Central regions, and mild significance in all other regions except for the North-eastern region, where the prevalence amounts to less than 3%.

Considering indicators of women's nutrition status that are available at the regional level, overweight and obesity have the highest prevalence rates in all regions except for the North-eastern region, where underweight is more common (Table 5). Regionally disaggregated data on anaemia in women are not available, yet the modelled estimate from the World Health Organization (WHO) and findings from the latest DHS suggest that, at the national level, anaemia is less widespread in Kenya than overweight and obesity combined (25% versus 32% prevalence).[7]

In summary, Kenya is affected by both over- and undernutrition, and micronutrient deficiencies persist. The dietary energy supply needs to be raised in disadvantaged regions and for deprived population groups, while overweight and obesity should be monitored in better-off regions. Dietary diversity can be increased and diet quality enhanced by developing value chains for vegetables, fruits, animal-source foods, pulses and nuts, and possibly also red palm oil (rich in vitamin A). Dairy, beans, and mango, for example, are micronutrient-rich foods that already play an important role in the Kenyan diet. The fortification of staple foods and the production of fortified baby foods could be addressed at the processing stage of the value chain. Promoting bio-fortified staple foods, such as iron-rich beans and vitamin A-rich orange-fleshed sweet potatoes (OFSP), yellow cassava and orange maize developed by HarvestPlus also have the potential to improve micronutrient intakes.[8]

Additionally, reducing the aflatoxin contamination of foods is critical to the improvement of food safety in Kenya. Aflatoxins are highly toxic substances that are produced by certain types of fungi and can cause acute poisoning, liver cancer, and stunted growth in children (Bhat and Vasanthi, 2003; Gong et al., 2004). In 2004, a large outbreak of acute aflatoxin poisoning in Eastern Kenya killed 125 people who had consumed improperly stored, aflatoxin-contaminated homegrown maize (Azziz-Baumgartner et al., 2005; Lewis et al.; 2005; Probst, Njapau, and Cotty, 2007). Further outbreaks occurred in 2005 and 2006 when aflatoxin concentrations exceeded the Kenyan regulatory limit in 41-51% of maize samples from two high-risk districts; extremely high concentrations of more than 50 times the regulatory limit were detected in 7-8% of the samples (Daniel et al., 2011). In addition to maize, sorghum, groundnuts, animal feed, and milk are among the products known to be contaminated with aflatoxins in Kenya (Ayalew et al., 2016).

A look at the regions reveals that nutritional deficiencies are particularly severe in the North-eastern region, which would suggest prioritizing this region for future interventions and agricultural innovations. In Nairobi, infants and young children have much better diets, and child stunting and underweight in women are comparatively low. Yet, overweight and obesity are widespread in the capital, affecting almost half of all women of reproductive age.

possible that more than half of all anemia among children in Kenya is caused by iron deficiency because malaria prevalence in children was found to be fairly low (National Malaria Control Programme, Kenya National Bureau of Statistics, and ICF International, 2016).

[7] Data sources: WHO (2015b) for anemia, quoted in Table 2, and Kenya National Bureau of Statistics, Ministry of Health, National AIDS Control Council, National Council for Population and Development, Kenya Medical Research Institute, National Council for Population and Development and ICF International (2015) for the prevalence of overweight and obesity.

[8] See www.harvestplus.org/what-we-do/crops.

Kenya is a member of the Scaling Up Nutrition network, a global movement led by 57 countries that aims to end malnutrition in all its forms[9].

1.4 Data on most relevant crops and value chains

The most relevant crops in Kenya include maize, wheat, tubers (potatoes and sweet potatoes), bananas and plantains, cassava, fruits, vegetables, and legumes (beans, cowpeas). There is also coffee and tea production and a significant livestock sector. Production and consumption data are provided below.

1.4.1 Production

Table 6 presents the top 10 crops produced in Kenya, taking into account the cultivated area, the volume produced, and the production value. Maize, beans, Sugar cane, potatoes, dairy and meat, and tea are the most important crops produced.

Table 6: Top 10 crops produced by area, volume, and value

Area harvested (ha)		Production volume (tons)		Production value*	
Top 10	% of total	Top 10	% of total	Top 10	% of total
Maize	37.3	Sugar cane	28.9	Potatoes	10.3
Beans, dry	18.6	Maize	16.5	Milk, fresh cow	10.0
Pigeon peas	4.7	Potatoes	10.3	Maize	8.5
Cow peas, dry	4.3	Bananas	6.4	Tea	8.2
Sorghum	3.9	Cassava	4.2	Meat indigenous, cattle	8.2
Tea	3.5	Sweet potatoes	3.6	Meat, cattle	8.2
Wheat	2.7	Beans, dry	3.0	Bananas	6.1
Millet	2.5	Mangoes, mangosteens, guavas	2.8	Milk, whole fresh camel	6.0
Potatoes	2.4	Cabbages and other brassicas	2.8	Beans, dry	3.5
Coffee, green	1.9	Vegetables, fresh nes	2.8	Tomatoes	2.7
Rank 14: Vegetables, fresh nes	1.3			Rank 11: Sweet potatoes	2.2
Rank 16: Sweet potatoes	1.1			Rank 12: Cabbages and other brassicas	2.1
				Rank 15: Milk, whole fresh goat	1.4

Data: average 2012-2014, FAOSTAT, accessed 18 January, 2017
* Gross Production Value (constant 2004-2006 million US$), data: average 2011-2013, FAOSTAT, accessed 18 January, 2017
Note: GIC value chains marked in red; nes refers to 'Not elsewhere specified'

[9] See scalingupnutrition.org for more information.

1.4.2 Trade

Wheat, rice, and palm oil play the most important roles in import trade. Tea is the most important export good, which accounts for more than 35% of the export volume and value. The GIC value chains (sweet potato and dairy products) cannot be found in the Top 10.

Table 7: Kenya's imports

Import volume (tons)		Import value (US$)	
Top 10	**Share of Total**	**Top 10**	**Share of Total**
Wheat	36.5	Wheat	18.1
Rice – total (Rice milled equivalent)	12.9	Oil, palm	16.5
Oil, palm	9.8	Rice – total (Rice milled equivalent)	10.3
Maize	6.0	Tea	6.7
Sugar refined	4.1	Sugar refined	5.3
Sorghum	2.9	Food prep nes	3.3
Sugar Raw Centrifugal	2.3	Sugar Raw Centrifugal	3.3
Flour, wheat	2.2	Tobacco, unmanufactured	3.1
Tea	2.0	Maize	3.1
Beans, dry	1.5	Flour, wheat	2.0
Rank 31: Milk, whole fresh cow	0.3	Rank 16: Milk, whole dried	1.0
Rank 34: Onions, dry	0.2	Rank 39: Milk, whole fresh cow	0.3
		Rank 74: Vegetables, frozen	0.1

Data: average 2011-2013, FAOSTAT, accessed 18 January, 2017
Note: GIC value chains marked in red; nes refers to 'Not elsewhere specified'

Table 8: Kenya's exports

Export volume (tons)		Export value (US$)	
Top 10	**Share of Total**	**Top 10**	**Share of Total**
Tea	36.1	Tea	35.6
Beer of barley	6.2	Crude materials	25.0
Coffee, green	5.0	Coffee, green	9.4
Sugar confectionery	4.3	Beans, green	4.8
Beans, green	4.0	Cigarettes	3.1
Pineapples canned	3.7	Pineapples canned	1.8
Bran, wheat	2.9	Sugar confectionery	1.5
Avocados	2.7	Nuts, nes	1.3
Beverages, non-alcoholic	2.7	Avocados	1.2
Oil, palm	2.4	Oil, palm	1.1
Rank 13: Vegetables, preserved nes	1.9	Rank 11: Vegetables, preserved nes	1.1
Rank 27: Milk, whole fresh cow	0.6	Rank 21: Vegetables, frozen	0.3
Rank 131: Sweet potatoes	0.0	Rank 22: Vegetables, fresh nes	0.3
		Rank 26: Milk, whole fresh cow	0.3
		Rank 141: Sweet potatoes	0.0

Data: average 2011-2013, FAOSTAT, accessed 18 January, 2017
Note: GIC value chains marked in red; nes refers to 'Not elsewhere specified'

1.5 National (and regional) innovation system

1.5.1 Research system and organizations

Kenya, like other nations, is directly dependent on agriculture and has established National Agricultural Research System (NARS) units, such as Kenya Agricultural and Livestock Research Organization (KALRO) (formerly Kenya Agricultural Research Institute - KARI), Kenya Forestry Research Institute, universities, etc.

KALRO is the coordinator for agricultural research in Kenya with long standing partnerships with international, regional and sub regional organizations (FARA & Association for Strengthening Agriculture Research in Eastern and Central Africa (ASARECA)), Consultative Group for International Agricultural Research (CGIAR), other Association of International Research and Development Centers for Agriculture members[10]; advanced research institutes, universities, local and international Non-governmental Organizations (NGO), and the private sector among others. These partnerships provide a wealth of expertise for advancing agriculture.

Innovation efforts and outcomes also stem from interventions of the regional and international agricultural Research and development (R&D) centers that are based in Kenya, the civil society organizations, including NGOs, Faith Based Organizations, etc. The contributions of these bodies include the implementation of different projects and programs that are funded both locally and internationally. About 10 out of 15 CGIAR centers have ongoing initiatives in Kenya.

International and Regional

A large number of international organizations actively conduct agricultural research in Kenya as part of larger economic development agendas, including:

- The Food and Agriculture Organization;
- The United Nations Development Program;
- National entities such as the United Kingdom, the United States of America, and the European Union have risen to particular prominence, wielding influence and exerting impacts on what research is to be conducted beyond their national interests;
- CGIAR:
  - Biodiversity International;
  - Center for International Forestry Research;
  - International Center for Tropical Agriculture;
  - International Food Policy Research Institute;
  - International Institute of Tropical Agriculture;
  - International Livestock Research Institute;
  - International Maize and Wheat Improvement Center;
  - International Potato Center;
  - International Crops Research Institute for the Semi-Arid Tropics;
  - World Agroforestry Centre;
- The Biosciences eastern and central Africa – International Livestock Research Institute Hub.

A number of regional organizations have also contributed to agricultural development in the country, including:

- World Vegetable Center;
- Alliance for Green Revolution in Africa;
- African Agricultural Technology Foundation;
- Forum for Agricultural Research in Africa;
- Association for Strengthening Agriculture Research in Eastern and Central Africa.

[10] www.airca.org/index.php

National

NARS in Kenya has undergone reform. More recently, in 2013, the sector was reformed through the formation of KALRO, in line with the second medium term plan. KALRO is a corporate body created under the Kenya Agricultural and Livestock Research Act of 2013 and is mandated to establish a suitable legal and institutional framework for the coordination of agricultural research in Kenya[11]. The formation of KALRO was aimed at restructuring agricultural and livestock research into a dynamic, innovative, responsive and well-coordinated system driven by a common vision and goal. KALRO has several institutes each dealing with a particular crop or combination of thereof or livestock research activities.

1.5.2 Innovation platforms

An Innovation Platform for Technology Adoption (IPTA) is a forum for partners with a common objective to improve agricultural production and services through the analysis of constraints and by planning interventions using a value chain approach. Platform membership generally comprises of representatives of farmers and farmers' organizations, extension services, agro processors, marketers, agribusiness, transporters, and research (ASARECA, 2014). IPTAs aim to address the challenge of difficulties in the adoption of new agricultural technologies as a strategy for improving agricultural production, yields, and commercialization. The strategy is geared towards making the technologies accessible, adoptable, and impactful to most small-holder farmers. Under this approach, each technology is moved through a rigorous multi-phase trial process to assess its success rates, after which, if found suitable, it is then scaled across the farmers' networks (One Acre Fund, 2013).

FARA has participated in the process of setting up different innovation platforms in Kenya, indicated in Table 9. The innovation platforms focused on three main value chains: sorghum, Orange-fleshed sweet potato (OFSP), and quality protein maize (QPM). The selection of the crops to be put into the IPTA was mainly based on their food security potential and nutritional advantages.

Table 9: List of innovation platforms in Kenya

IP Name	Location	Commodity of interest
Sorghum Value-Chain Development Consortium (SVCDC)	Nairobi	Sorghum
Electronic Regional Agricultural Information and Learning Systems 2 (eRAILS2)	Nairobi	various
Busia IPTA	Busia County (W. Kenya)	OFSP
Bungoma IPTA	Bungoma County (W. Kenya)	OFSP
Mumias IPTA	Kakamega County (W. Kenya)	OFSP
Ugunja IPTA	Siaya County (W. Kenya	OFSP
Kirinyaga	Central Kenya, Kirinyaga County	QPM
Maragua	Central Kenya, Murang'a County	QPM
Embu	Eastern Kenya, Embu County	QPM
Karurumo	Eastern Kenya, Embu County	QPM
Kathonzweni	Eastern Kenya, Makueni County	QPM
Kilifi	Coastal Kenya, Kilifi County	QPM

Source: Makini et al. (2016)
NB: This list is not exhaustive; a comprehensive assessment is ongoing.

[11] www.kalro.org

- **Sorghum Value Chain Development Consortium (SVCDC)** – SVCDC was started in 2012 as an incubation project aimed at catalyzing growth of sustainable agribusinesses in specific value chains and improve agribusiness education and training. Its focus was to support development of sustainable enterprises along the sorghum value chain with major products being food, feed, fuel, fibre and seeds from the sorghum value chain. To support technology adoption in the value chain, SVCDC provides the farmers with business services (such as registration, licenses, quality management, technology transfer, accounting, strategy development, marketing, and export/import facilitation among others); financial brokerage services and/or through financial services such as credit, equity, and guarantees; capacity building and networking to enhance market linkages; and support through infrastructure, such as labs and production facilities, office space, meeting rooms, electricity, phone, internet, etc.
- **Electronic Regional Agricultural Information and Learning Systems 2 (eRAILS2)** – This is a component of the project for the Promotion of Science and Technology for Agricultural Development (PSTAD) in Africa aimed at contributing to the development of strong African agricultural information systems. PSTAD is a project initiated and coordinated by FARA, managed by sub-regional Organizations, and implemented by NARS in 34 countries in Sub-Saharan Africa with funding from the African Development Bank. FARA also implements Regional Agricultural Information and Learning Systems (RAILS). eRAILS2 was developed to give farmers a voice by establishing a constructive dialogue in a bottom-up approach between the farming community, the national agricultural research system, and the other stakeholders of the agricultural sector. It was also intended to enhance the knowledge management capacity of the RAILS Learning Teams (RAILS-LTs) in mediating between the farming communities and the national agricultural research system and improve sharing of information on agricultural research between the countries in the region (Makini *et al*., 2016).
- **Orange Fleshed Sweet Potato** – Actors under this IPTA were drawn along the sweet potato value chain (farmers/farmers associations, processors, researchers, NGOs/public extension, Business Development Services, etc.). Four IPTAs for OFSP were established in Bungoma county – 2008, Busia county (Mumias) - 2011, Kakamega county – 2011, and Siaya county (Ugunja) in Western Kenya. In each platform, a partner was nominated by the members to coordinate the IPTA. Technical backstopping for the IPTAs was provided by the International potato Center (CIP) up to 2010 and later by ASARECA. Initial activities of the IPTAs were to promote OFSP variety called Ejumula, because it has higher beta-carotene content compared to SPK004 (Kakamega 4), which farmers had been used to. The project supported farmers in the region in accessing clean planting materials (vines) and with technical capacity on production and processing of OFSP, as well as conservation of the planting materials. All the platforms started with production of planting material using a three-tier system: Primary Multiplication (PM), Secondary Multiplication (SM) and Tertiary Multiplication (TM). The PM sites were established at KARI-Kakamega, Alupe sub-centre, and Yala swamp and managed by KARI-Kakamega scientists. Materials from the PM sites were used to establish SM sites, which were managed by the Busia and Bungoma IPTAs. Two different seed multiplication approaches were used by the IPTAs.
- **Quality Protein Maize (QPM)** - QPM contains nearly twice as much usable protein as other maize grown in Kenya. It produces 70-100% more protein than the most modern varieties of maize. The protein helps the body to eliminate wet malnutrition. The aim of the QPM IPTA has been to support the increased adoption of the maize by farmers so as to enhance food and nutrition security. KALRO has developed two seed varieties, KH600-31Q for medium to late maturing areas and KH500Q for medium maturing areas, each with a yield potential of 35 to 40 bags per acre. The maize variety is good for both human consumption and animal feed. A total of six IPTAs for the QPM have been established in Eastern, Central and Coastal regions of Kenya, i.e. Kirinyaga, Maragua, Embu, Karurumo, Kathonzweni and Kilifi respectively.

1.5.3 Extension system and organizations

i. The National Agriculture and Livestock Extension Programme (NALEP)

This program was formulated in 2000 in partnership with SIDA, the Swedish International Development Cooperation Agency. NALEP became the implementation framework for the National Agricultural Extension Program. NALEP was implemented as follows:

- NALEP I (2000–2006) – this program was positively evaluated in 2006 as an innovative approach to demand-responsive and holistic extension.
- NALEP II (2007–2011) – this is the follow up program to NALEP I and was implemented between 2007 and 2011 (Cuellar *et al.,* 2006).

ii. The National Agricultural Sector Extension Policy (NASEP)

NASEP is the extension program for the Agricultural Sector Development Support Programme (ASDSP) (Government of Kenya (GoK), 2005). It has been developed to guide and harmonize management and delivery of agricultural extension under the ASDSP. ASDSP was established to provide support services at a variety of levels within the framework and other institutional actors. ASDSP's overall objective is to support the transformation of Kenya's agricultural sector into an innovative, commercially oriented, competitive, and modern industry that will contribute to poverty reduction and improved food security in rural and urban Kenya.

The objectives of NASEP are to:

- Facilitate the development of pluralism in service delivery;
- Improve the efficiency and effectiveness of extension service provision from public and private sectors;
- Establish a regulatory system to guide service providers and modalities for setting operational standards, quality, and norms (GoK, 2005).

1.5.4 Private research and development activities

1.5.4.1 Private sector and private philanthropic groups

The current private sector players dominating agricultural innovation ecosystems in Kenya are large multinational companies, including:

- Monsanto;
- Badische Anilin- und Soda-Fabrik;
- Bayer Crop Science;
- Syngenta;
- Dow AgroSciences;
- Land O'lakes (for dairy technology).

Private philanthropic groups have also played significant roles in research, including:

- The Rockefeller Foundation;
- Bill & Melinda Gates Foundation;
- Ford Foundation

While the number of institutions supporting agricultural research has expanded over time, public expenditure and investments in agricultural innovation have not been sufficient to maintain the levels of annual growth in crop yields nor to conduct research in climate resilience agriculture. Government has significantly scaled back support for agriculture R&D at a time when innovation was most needed in crop and livestock production systems. Increased private funding has helped to pick up some of the slack and has led to the commercialization of higher yielding varieties of a handful of major crops. Industry research is aimed, for the most part, not at basic science, but rather at adding recoverable value to seeds by imparting them with the ability to overcome specific problems like disease, pests, or

weeds. It is primarily focused on major crop species (maize, cotton and potatoes) whose seeds are sold in sufficient quantity to give industry the opportunity to recoup significant R&D costs through sales.

1.6 Key challenges, emerging needs and potentials in the agricultural sector

The key areas of policy concern are:

- Increasing agricultural productivity and incomes, especially for small-holder farmers;
- Emphasis on irrigation to reduce over-reliance on rain-fed agriculture in the face of limited high potential agricultural land;
- Encouraging diversification into non-traditional agricultural commodities and value addition to reduce vulnerability;
- Enhancing the food security and reducing the number of those suffering from hunger, hence supporting the achievement of Millennium Development Goals;
- Encouraging private-sector-led development of the sector;
- Ensuring environmental sustainability.

Key policy concerns include:

- Declining agricultural performance;
- Limited high potential agricultural land and over-reliance on rain fed agriculture;
- Limited diversification of agricultural production;
- Poor and inadequate rural infrastructure;
- Inadequate and declining research in agriculture;
- Lack of agricultural sector financing and related activities;
- Limited development and exploitation of the livestock sector;
- Lack of a comprehensive land use policy.

1.7 Potential areas for investment in Kenya

Based on the general approach presented in chapter 4 of Husmann et al (2015) and in pursuit of efficiency and effectiveness, investment by Germany into the agricultural and food sector are suggested in those African countries which:

- Show actual progress in sustainable agricultural productivity driven by related innovations, as indicated by comprehensive productivity measurement and innovation actions on the ground;
- Have a track record of political commitment to foster sustainable agricultural growth, as indicated by performance under CAADP;
- Prioritize actions for hunger and malnutrition reduction and show progress where agricultural and rural development and nutrition interventions are likely to make a significant difference, as indicated by public policy and civil society actions.

Results of the assessment for Kenya[12]:

Expected agricultural growth performance:

- Kenya has significantly increased its agricultural growth – with seven years showing at least 6% annual agricultural growth target defined by CAADP between 2005 and 2014 (www.resakss.org).

[12] Details on the data sources and methodology used in the assessment can be found in Husmann et al. (2015)

- Agricultural total factor productivity in Kenya has improved by 24% between 2001 and 2008 (Fuglie and Rada, 2011), indicating that Kenya´s commitment to R&D into the agricultural and food sector is significant.

Government commitment:

- Kenya has a track record of political commitment to foster sustainable agricultural growth by being active in the CAADP process and having completed six out of the eight steps in the CAADP process (www.resakss.org).
- Kenya spends 1.1% of its agricultural GDP on agricultural R&D, which is higher than the CAADP target value of 1% (www.asti.cgiar.org). This indicates that Kenya´s investment on agricultural innovation is high.
- However, the Kenyan government has not shown a strong willingness to invest in the agricultural sector. In no single year between 2005 and 2014 has Kenya achieved the CAADP 10% agricultural expenditure target (www.resakss.org).

Food and nutrition security progress and need:

- Kenya is only modestly prioritizing actions for hunger and malnutrition reduction and shows less than 9% improvement in undernourishment between 2001 and 2011 (FAO, 2014).
- In addition, Kenya has a Global Hunger Index (GHI) score value of 16.5, reflecting a serious level of hunger (von Grebmer *et al.,* 2014)[13]. This makes the need for investment into the agricultural and food sector in Kenya very urgent in order to fight the high rate of food insecurity. In light of to the economic, political, and social/nutrition framework in Kenya, accelerated investment into the agricultural and food sector of the country is recommended.

Table 10: Kenya performance indicators

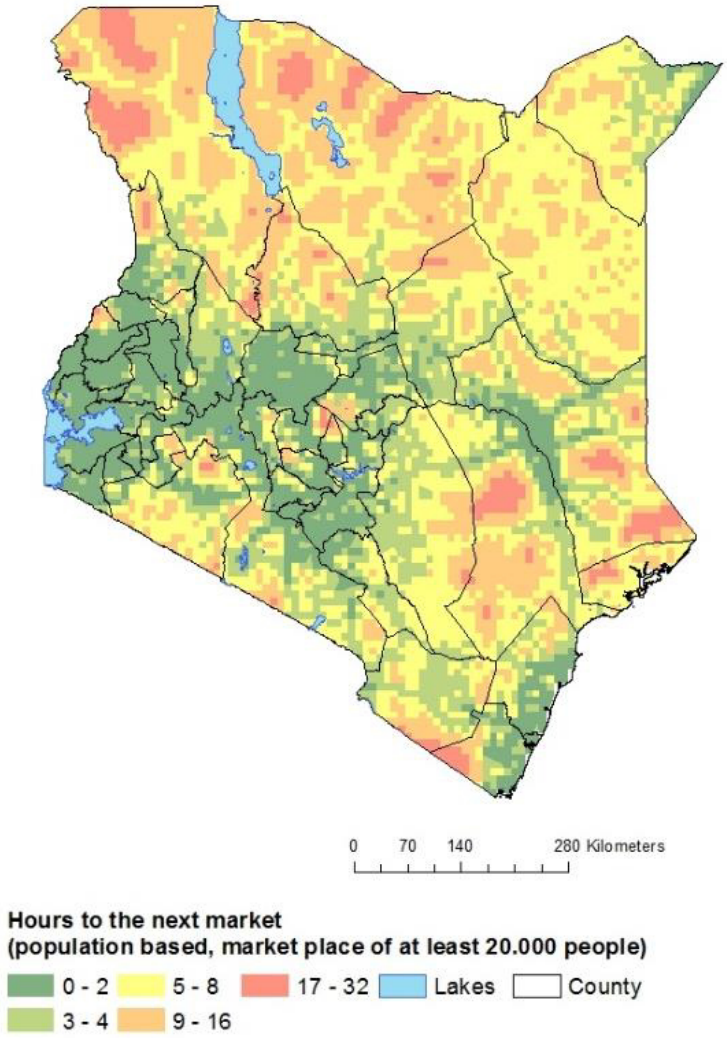
Indicators	Indicator score	Overall score
1. Number of years with more than 6% agricultural growth (2005 to 2014)	7	70
2. Percentage point change in TFP index between 2001 and 2008	24	100
3. Number of years with more than 10% government expenditure (2005 to 2014)	0	0
4. Average share of agricultural GDP spent on R&D (2005 to 2011) in %	1.1	100
5. Steps in CAADP completed	6	75
6. Percentage point improvement in undernourishment between 2001 and 2011	8.5	60
7. Global Hunger Index (2014)	16.5	60
Total score (weighted)		68

Data source: Husmann et al (2015)

The selection of the value chains on which to focus is also determined by market access, i.e. transport intensive products should be promoted in areas that are well connected to markets, whereas remote areas should focus on low volume and livestock value chain segments. Figure 5 presents the average time (number of hours) it takes to reach the nearest market place of at least 20,000 people in Kenya.

[13] GHI score Values less than 5.0 reflect low hunger, values from 5.0 to 9.9 reflect "moderate" hunger, values from 10.0 to 19.9 indicate a "serious" level of hunger, values from 20.0 to 29.9 are "alarming," and values of 30.0 or greater are "extremely alarming" (von Grebmer *et al.,* 2014).

Figure 5: Distance to market



Data sources: Hours to next market - HarvestChoice, 2015;
Administrative areas: http://www.gadm.org/, accessed 20.9.2015
Inland water bodies: http://www.diva-gis.org/gData (water bodies), accessed 20.9.2015

2 Most relevant value chains in Kenya

The relevant value chains beyond those selected for the GICs are discussed in this subsection. The relevance in this case is based on, among other things, the extensive review of available literature on the crop, the importance of the crop in relation to share of area cultivated (harvested), production volume, and trade importance (import and export).

2.1 GIC value chains

The value chains that were chosen for the GIC include sweet potatoes, dairy, and vegetables.

2.1.1 Sweet potato

In Kenya, sweet potato is considered a subsistence or famine relief crop by many households. When there is shortage in maize, sweet potato and other indigenous tubers, such as cassava, become very important in the diet of many rural households. Demand for sweet potato is also growing rapidly

among the urban population as a result of changing consumption patterns and population growth. Generally, production of sweet potato in Kenya has steadily increased over the years. According to the Ministry of Agriculture (2011), sweet potato production increased by 89% between 2004 and 2009, a development mainly due to the availability and use of improved cultivars and farming methods that have helped increase yield per unit area (Kenyon *et al.,* 2006). In the recent past, there have been renewed efforts by the government and other players in the agriculture sector to promote production of traditional high value crops including sweet potato. For example, the government distributes improved planting materials for crops to farmers as one of the activities in the effort to promote their production through the Traditional High Value Crops Programme. These efforts are a result of the recognition of the important role that these crops play in contributing to food security through increasing food supply to both the producers and consumers and generating income for the producers.

Sweet potato is produced mainly in the Nyanza and Western provinces. Some cultivation of the crop is also carried out in parts of Eastern, Central and Coast provinces. Nyanza province accounts for over 50% of national sweet potato production. The Homa-Bay and Migori counties in the province are the main production areas. Sweet potato production in these areas is primarily rain-fed, with few farmers practicing irrigation along rivers. The sector is dominated by smallholder farmers who practice semi-subsistence mixed farming, engaging in both livestock-rearing and in the production of a range of crop enterprises, but not on a fully commercialized basis. The small-scale production system usually translates into scattered small quantities of output, which, combined with the bulkiness and perishability of the crop, makes marketing the sweet potato a major challenge. It is estimated that over 80% of sweet potatoes in Kenya are sold fresh and the market for the commodity is not well-organized. Post-harvest losses and low producer prices are a challenge.

2.1.2 Dairy

The dairy sector is relatively well organized with a strong domestic processing presence, dominated by the cooperative sector. Competitive dairy requires significant capital investment, but allows producers to significantly leverage profitability of a relatively small plot of land. The processors tend to have quite good control over the supply chain and a ready and stable off-take market in terms of local supermarkets and groceries. As a result, financiers are more interested in opportunities in the dairy sub-sector. The dairy value chain in Kenya is extensive. It is estimated to include 5.7% of Kenya's households and contributes to about 3.5% of the national GDP; the annual income per producer is about US$ 600 (Pelrine, 2009). Further, both production volume and prices have increased by around 19% between 2006 and 2008 (ibid).

The main challenges facing the dairy sector include:

- lack of/poor feed (major factor contributing to about 70% of costs of production);
- breeds/genetics;
- pest and diseases;
- improper care management;
- poor milk storage and marketing;
- sanitation;
- lack of value addition.

2.1.3 Vegetables

Vegetable production in Kenya is broadly divided into two categories: subsistence household production with minimal sales and medium to large commercial farming/out-grower production, focusing on exports and urban supermarkets (Wiersinga and Jager, 2007; Mausch *et al.,* 2006) ''approximately 22% of the vegetables produced with a free-on-board value of 6.8 billion Kenyan Shillings (KES) are exported. The total market value of vegetables in Kenya is about US$ 188 million. While it is estimated that 3 million Kenyans grow vegetables for cash sales, only about 220,000 are

engaged in vegetable production on a commercial basis and these are clustered close to major urban centers where consumers and exporters are located" (Pelrine, 2009). The sector is faced with low to no value addition, lack of (certified) seeds, and perishability.

2.2 Other relevant value chains

The other relevant value chains besides those selected for the GICs are discussed in this subsection. The relevance in this case is based on, among other things, the extensive review of available literature on the crop, the importance of the crop in relation to share of area cultivated (harvested), production volume, and trade importance (import and export).

2.2.1 Maize

Maize is the main staple food in Kenya, accounting for 65% of total staple food calorific intake and 36% of total food calorific intake (FAO, 2009). The average person consumes 88 kg of maize products per year (Ariga *et al.*, 2010). A more recent study shows that households in the first and second quintiles spend the greatest proportion of 'staple budget' on maize and maize products, 37% and 29% respectively (Kamau *et al.,* 2011). The Kenyan maize sector has many actors, including farmers, input suppliers (seed companies, fertilizer and pesticide suppliers), traders, millers, retailers, and consumers.

The maize value chain has been considered a success because of the widespread use of hybrid seeds, a well-structured seed system. Some of the biggest challenges are low soil fertility – which translate to low productivity, monoculture production, pests and diseases (e.g. Maize Lethal Necrosis), post-harvest losses, price fluctuations, etc.

2.2.2 Wheat

Wheat is the second most important staple in Kenya. It accounts for about 17% of staple food consumption and its share in household food expenditure has overtaken that of maize among urban households (Muyanga *et al.,* 2005). Wheat production in Kenya is largely dominated by large-scale producers. However, demand for wheat outpaces supply from both large-scale and small-scale production and thus 60% of national wheat consumption is imported (Pelrine, 2009; Ariga *et al.*, 2010). Pest and diseases (rust), climate variability, and low prices are some of the key challenges in the wheat farming in Kenya.

2.2.3 Beans

Beans are the third most important staple food nationally, accounting for 9% of staple food calories and 5% of total food calories in the national diet (Ariga *et al.*, 2010).

Beans are widely consumed in Kenya and are considered a major source of protein and micronutrients. The cross border trade with neighboring countries is huge (in large part informal and not systematically documented). Beans are widely grown, especially in mixed systems, and are therefore a major contributor to household food and nutrition security. Climber beans have been developed with potential for system intensification.

The major challenges of bean farming include: low productivity due to poor soil fertility, poorly developed seed systems, recycling of seed resulting in low yields, low adoption of improved varieties, pest and diseases, climate impact, and post-harvest losses.

The International Center for Tropical Agriculture (CIAT) and KALRO have developed varieties with wide potential for markets and production across varied agro-ecological zones. Currently CIAT and KALRO are supporting private sector investments in these crop- seed systems, marketing and value addition.[14]

2.2.4 Mango

The mango sub-sector is characterized by a large number of small-scale producers producing low quality mangos for domestic consumption. There is limited processing, export, and value addition in the value chain. Indeed, waste in the mango value chain is relatively high with much of the crop spoiling before it reaches consumers. Another problem typical with tree fruit crops is the relatively long payback period required before the crop becomes economically viable. There is little financing available in the mango sub-sector.

The mango value chain clearly meets a strong domestic demand and has a potential for international markets. However, like the value chains for other tree fruit, it is also constrained by:

- Poor quality local production unsuitable for export or juicing;
- Slow return on investment for replanting;
- Relatively weak agri-processing;
- Exposure to strong international competition;
- Poor logistics and post-harvest handling**.**

2.3 Promising agricultural products and value chains

In addition to assessing the returns on investments into institutional innovations in Kenya, analyses are also undertaken in order to choose the most promising value chains in the country. This analysis is important because it provides an objective indicator for priority value chains that would have the highest returns on investments into technological and institutional innovations. The trio objectives of PARI (to promote and support the scaling of proven innovations in the agri-food sector; to support and enhance investments in the GICs through research; and to contribute to the development of the agri-food sector in Africa and India through the identification, assessment and up-scaling of innovations) guide the selection of indicators. The indicators should thus focus on improving the food and nutrition security, reducing poverty and improving the market participation of the small holder farmers. Taking into account the availability of data and the purpose of the study, four indicators that focus on poverty and market potential are used to select the five most promising agricultural products from the long list of agricultural products that the country produces and sells. These indicators are:

1. Trade potential (Revealed Comparative Advantage (RCA) index): computed to identify value chains over which the country has revealed, albeit may not necessarily potential, comparative advantage in the export market. The revealed comparative advantage is an index used in international economics for calculating the relative advantage or disadvantage of a certain country in the production and export of a certain class of goods or services as evidenced by trade flows. It is based on the Ricardian comparative advantage concept. We use Balassa's measure of RCA to determine the competitiveness of selected agricultural products in overseas export markets. In the present case, the RCA index compares the share of a given agricultural product in the country's export basket with that of the same product in total world exports.
2. Yield gap: used to assess the expected return of the envisaged investment on the given country value chains. The yield gap of a crop grown in a certain location and cropping system is defined as the difference between the yield under optimum management and the average yield achieved by farmers. A standard protocol for assessing yield potential and yield gaps is applied for some crops

[14] Further reading: www.researchjournali.com/view.php?id=2457, www.cta.int/images/1832_PDF.pdf, vegetables.wsu.edu/Hort-503/Seed-Syst-paper.pdf

based on best available data, robust crop simulation models. It is a powerful method to reveal and understand the biophysical opportunities to meet the projected increase in demand for agricultural products.

3. Average yield growth: used to examine the potential of the product for poverty reduction. The most widely used indicator of crop productivity is production per unit of land (also referred to as crop yield). Average yield growth may reduce poverty in the following ways: (1) higher yield implies higher surplus product that could be sold in the market and thereby increase farmers income, (2) higher surplus product mean large quantity of food supplied to urban and rural market at a relatively lower price which in turn reduces urban and rural food poverty, (3) higher agricultural productivity will stimulate growth in the non-agricultural sector through its strong backward and forward linkage. For example, it boosts growth in the industry sector by freeing agricultural labor and reducing urban wage pressure (Lewis, 1962), and (4) agriculture's fundamental role in stimulating and sustaining economic transition, as countries (and poor people's livelihoods) shift away from being primarily agricultural towards a broader base of manufacturing and services (DFID, 2004).
4. Total production of the crop as a share of total supply (production + imports) is also used to assess the relevance of investing on that crop .Because it signals whether the agro-ecological system is suitable for the production of that crop in meeting the global demand for that particular crop. The ratio of production to total supply also illuminates the degree of integration of the producers that particular crop, small holder farmers in most African countries cases, into markets. The extent to which small holder farmers are able to participate in both input and output markets, and the functionality of those markets, are key determinants of their willingness and ability to increase marketable surpluses (Arias, 2013). Across the developing world, smallholders farm in diverse agro-climatic systems which together with their assets and skills, shape their economic lives. Markets and the extent to which they are functioning well, also play a determining role.

Note: The share of production of that particular crop over the total crop production is another key indicator considered in this study while assessing the relevance of investing on a particular crop in a country. This indicator is used as an eliminating criteria. If the share of a given crop out of total crop production is less than 0.5 %, we consider it as less relevant and exclude from the list of most promising value chains.

The summary of the five most promising value chains based on the RCA index, average yield growth and relevance of crop is reported in Table 11 below. The production share, RCA index, actual yield growth and relative yield gap for the GIC value chain(s) is also reported at the bottom of the table, when they are not included in the list of the first five most promising value chains.

Table 11: Selection of promising agricultural products /value chains

	Rank by RCA		Rank by Yield progress***		Rank by yield gap		Rank by relevance of crop	
Rank	**Name of agricultural product**	**RCA index (2012)**	**Name of the crop**	**Average annual yield growth (2005-2012)**	**Name of Stable crop (rain fed)**	**Relative yield gap (%)****	**Name of agricultural product**	**Production share of supply (2012)***
1	Beans, green	11,516	Cassava	18	Maize	87	Cloves	200
2	Tea	5,231	Wheat	12	Millet	86	Pineapples and products	125
3	Peas, green	4,370	Rice, paddy	12	Sorghum	86	Pulses, Other and products	106
4	Nuts, nes	1,211	Bananas	8	Wheat	86	Cream	105
5	Crude materials	663	Beans, dry	8			Coffee and products	102
GIC Selected	Milk, whole fresh cow	79	Papaya	8			Sweet potatoes	100
	Sweet potatoes	24	Sweet potatoes	-3			Butter, Ghee	100

Source: * Own computation based on FAO 2015 data, ** from Van Bussel *et al.* (2015)
Note: *** a minimum of 0.5% production (volume) share threshold is used as a screening (crop relevance) criteria.

Results of assessment (Table 11):

- The trade potential (RCA index) is very high for green beans, tea, green peas, nuts, and crude materials. This indicates that Kenya has a comparative advantage (in the export) of these commodities. The RCA value for the two GIC value chains, namely dairy and sweet potatoes, is also very high, indicating that Kenya still performs better than the world average in the exports of these products;
- The yield performance indicating progress suggests that over the CAADP period (2005 to 2012), cassava, wheat, paddy rice, bananas and dry beans are the five most promising crops. Other horticulture crops, such as papayas and avocados, are also among the top ten promising crops, according to the yield progress indicator. However, the yield growth of the other selected value chain, sweet potatoes, was negative over the CAADP period;
- Yield gaps indicate potential from another angle, and are observed to be high for rain fed maize, sorghum, millet, and wheat, indicating the high potential return of investing on these value chains;
- In terms of relevance (production share of supply) the leading value chains are cloves, pineapples and products, pulses, cream and coffee value. The total production of these commodities exceeds the total market supply. The result also indicates that total market supply of the two value chains selected by the GIC is domestically produced.

2.4 Summary on selection of agricultural products and value chains

This chapter has presented different relevant value chains in Kenya based on different criteria. In summary, the three top value chains – GIC-selected value chains, other relevant value chains, and those identified by analysis of promising agricultural products and value chains – are presented in Table 12. The summary table shows that none of the GIC-selected value chains is identified as promising by analysis of promising agricultural products and value chains. However, a number of overlaps in the

value chains is shown between the analysis of promising agricultural products and value chains and the review of the literature. These products/value chains are maize, wheat, and beans.

Table 12: Summary of all value chains

GIC value chains	Other value chains	Promising agricultural products and value chains (top 3)			
		RCA	Yield progress	Yield gap	Relevance of crop
Sweet potato	Maize	Beans, green	Cassava	Maize	Cloves
Dairy	Wheat	Tea	Wheat	Millet	Pineapples & products
Vegetables	Beans	Peas, green	Rice, paddy	Sorghum, wheat	Pulses, Other and products
	Mango				

Source: Authors' compilation

3 Innovations in value chains in the past 20 years

3.1 Main limiting factors

The agricultural sector in Kenya has had a relatively steady growth in recent years, but more is required in order to ensure that the sector can respond to the national needs in a sustainable manner. Opportunities for spurring growth in the agricultural sector and in the broader economy co-exist with challenges in translating such growth into greater food security for the Kenyan populace. The key challenges revolve around productivity in the key sub-sectors, improvement in land and natural resource management, improvement in market access and trade, enhanced private sector participation, institutional reforms, and improved coordination of the research and technology transfer components.

The government of Kenya aims to achieve success on these strategic thrusts through the use of holistic approaches, which include a consistent increase in funding for agriculture from the current 5% of GDP to the 10% as stated in the Maputo declaration. The government intends to increase the budgetary allocation by 30% which translates to KES 36.04 billion in 2015. The government will further adjust the existing programs and projects and will develop new projects to respond to emerging needs in the sector. These include the adverse effects of climate change and the increasing use of smart technologies and green energy, as well as a shift from mechanical hoes to more efficient and environmentally friendly options. The issue of broad based capacity development is also projected as an area of interest. Towards this end, staff has already been trained to various levels through long and short term courses in order to ensure the availability of skills commensurate with the demands of the sector stakeholders.

A key reform in the agricultural sector was that of the research bodies, in which KALRO was reorganized in 2013 and given a two-pronged focus. The first is to promote, streamline, co-ordinate, and regulate research in crops, livestock, genetic resources, and biotechnology in Kenya and the second to expedite equitable access to research information, resources, and technology and to promote the application of research findings and technology in the field of agriculture. Through its 14 research institutes that are commodity based, KALRO has generated a lot of technologies that have been translated into innovations that have contributed to economic and environmental benefits in the country. The selected technologies include Tissue Culture (TC) bananas, improved indigenous chicken, etc.

3.2 Important value-chain related and cross-cutting innovations

In this section, we describe some of the key innovations that have been initiated in selected value chains in Kenya in the last 20 years. The described innovations are considered significant or beneficial because of widespread adoption, proven positive impact on increasing productivity, increasing incomes, adapting to the environmental challenges (such as drought), creating employment etc.

According to IFPRI, innovations can be deemed to be successful if they have met four criteria: (i) they have contributed to productivity growth; (ii) they have resulted in enhanced efficiency and increased farmer incomes; (iii) they have addressed equity concerns; and (iv) they are sustainable (NGI, 2009). Innovation activities and strategies related to the crops sub-sector include: use of crop varieties suited for the changes in moisture and temperature; switching to farming practices that conserve soil moisture and nutrients; controlling soil erosion and improving water uptake by crops; use of seasonal forecasts; forestry and agroforestry; small-scale irrigation; disease and pest control; and conservation agriculture and micro-dosing. Among the important interventions identified for the animal sub-sector are participatory breeding of the local breeds, establishment of fodder banks, replanting rangelands, and diversification of livestock enterprises.

3.3 GIC value chains

3.3.1 Swet potato

OFSP is a cheap source of beta-carotene important in control of vitamin A-deficiency, a major nutritional problem in Kenya. KARI (now KALRO)-Kakamega in collaboration with CIP and farmers carried the following activities in this value chain:

- Develop several of sweet potato technologies to increase the benefits from OFSP varieties,
- Develop planting material production techniques,
- Train on agronomic practices,
- Carried out integrated pest and disease management,
- Trained on post-harvest handling, storage, product development and marketing.

These activities were carried out in Busia and Bungoma districts. This has led to shifting of sweet-potato from subsistence to commercial crop status. Some 17 new superior varieties have been released from 2008 to 2013. Multiplication of planting material for the OFSP varieties was done at the primary, secondary and tertiary levels. The PM sites were established at KARI-Kakamega (0.48 ha), Alupe sub centre (0.48 ha), Yala Swamp (0.2 ha), the Kenya Sugar Research Foundation (0.36 ha), and Muhande farm in Bungoma district. A total of 200 bags of cuttings were obtained from the PM sites. This material was then used to establish the SM sites which later generated 600 bags of planting material. This was then multiplied further in the TM sites in the Busia and Bungoma districts.

Reasons for the innovation's success: the innovation is considered a success based on the three-fold root yield increase from 10 t/ha to 30 t/ha, and because high quality tubers are a boon to food and nutritional security in terms of calories and vitamin A content.

Drivers of success: The multi-stakeholder nature of the process led to the success of the innovation. These actors were comprised of key players in the sweet potato product value chain, including farmers, seed multipliers, market traders, extension agents/training of trainers (TOT), processors, the media, and community based organizations.

Ways of up/outscaling the innovation: Formulating policies that would motivate marketing of sweet potatoes and establishing value addition centers, such as drying and flour-making, would enhance the uptake of this innovation. Involvement of human health actors would play a significant role in promoting OFSP as a health product.

3.3.2 Milk

Dairy farming is a major source of income and livelihoods for majority of Kenyan smallholder farmers who keep between one and two dairy cows. However, daily milk production per cow among these farmers is low and averages 5.46 litres per day (Mutua, 2015). The main reason for this low dairy production is the poor animal husbandry and feeding practices, characterized by reliance on rain-fed pastures and green fodder grasses. Seasonal deficiencies of forage, caused by drought-related challenges and inadequate feed and nutrient intake by cows, results in low milk productivity. To address the challenge, an innovation to improve milk productivity by smallholder farmers was introduced with support from the United States Agency for International Development (USAID). The innovation entailed supporting farmers in the implementation of a number of practices aimed at increasing fodder crop production and conservation using high-nutrient indigenous grasses, introducing improved grass varieties, making better use of existing crop residues from maize and sweet potato vines, and increasing adoption of protein-rich legumes such as leucaena. These solutions were found to increase per cow productivity, resulting in higher incomes and increased milk consumption by the communities.

Reasons for the innovation's success: Adoption of the dairy feed improvement practices by the farmers led to a two-fold increase in productivity to an average of 9-12 litres per cow per day at low production cost. Smallholder farmers supported through the innovation program are realizing incomes of $2.50 per day per cow, up from a baseline of $1, and household milk consumption has doubled from 1.5 to 3 liters per household. This has raised the demand for quality forage by smallholders. As a result, a corollary fodder crop market has emerged with more than 5,000 farmers planting 12,500 acres of fodder resulting in 5,600 bales of improved grasses and legumes valued at KES 1.23 billion, or $125,400. As a result of the increased milk production, dairy producer groups in selected project areas have been able to increase total sales of milk by 90 percent.

Drivers of success: The main driver of success for the innovation can be attributed to the financial and technical backing by USAID through the Kenya Agricultural Value-Chain Enterprises project. In addition, the nature of dairy farming as a mainstay of the household and local economies in the counties necessitates open learning among farmers of better production practices; hence adoption of the innovation practices by one farmer in an area contributes to increased adoption by other dairy farmers in the vicinity.

Ways of up/outscaling the innovation: The innovation can be upscaled and outscaled by encouraging and supporting farmer groups, individual farmers, and institutions having large tracts of unused land to venture into commercial dairy feed production as an interlinked dairy value chain activity. New technologies and production systems, like the Total Mixed Rations method aimed at improving productivity of crops and milk, which reduce labour costs as well as improve yields and product quality, should be explored in coordination with extension and dairy cooperatives agents. In addition, partnerships among dairy farmers groups, development partners, and county governments should be strengthened for commercialization of low-cost high-nutrient fodder.

3.4 Other value chains

3.4.1 Banana

Bananas in Kenya are a major fruit produced by small holder farmers in many parts of Kenya, where different banana varieties are grown for different uses. The source of planting material has always been obtained from old orchards. This practice has phyto-sanitary implications since infected suckers transfer harmful pests and diseases to new sites. In response to declining banana production caused by disease-pest complexes, banana TC innovation was introduced in 1997 through a collaborative project between the Kenya government, NGOs and the private sector, and the farmers. TC banana is a product of biotechnology. The cultivars include the Cavendish group, Williams Hybrid, Goldfinger,

Lacatan, Valgy and Paz. Funding was from the Rockefeller Foundation and the International Development Research Centre of Canada. Implementation was by the International Service for the Acquisition of Agri-biotech Applications, with KARI (KALRO) as the host institute, working closely with other strategic partners, including the Genetic Technology Laboratory for production of TC banana plantlets and the Institute for Tropical and Subtropical Crops of South Africa (ARC-ITSC) in the provision of technical backstopping services. This process included the preparation of TC bananas in private and government laboratories, hardening in community owned hardening nurseries, and technical backstopping by NGOs, public institutions, and private companies. The farmers were advanced 80 banana plantlets each — the economical banana orchard unit — which they were to pay at harvest time. This micro-credit scheme worked very well, and at the end of the first season, farmers were willing to expand their banana orchards after having paid off their credit. The farmers replaced their orchards and established new ones in various banana-growing regions of Kenya. The acceptance of the TC banana propagation and the upscaling model used was favourably received by farmers beyond the *ex-ante* skepticism of its viability.

Reasons for the innovation's success: The TC banana innovation led to an increase in the quality and yields of bananas (from 10 kg per bunch to over 80 kg) and there was uniformity in maturity, which facilitated bulk marketing. Over 500,000 small-scale banana producers benefited from the innovation and banana production has been rejuvenated.

Drivers of success: The success of the innovation was largely thanks to the involvement of private and public actors at an early stage, and particularly to that of the end users, as well as other key players. The innovation was also introduced at a time when it was most needed and solved the challenge that was at hand.

Ways of up/outscaling the innovation: End-user capacity-building is critical in order to enhance their banana production skills. It is also important to accommodate user feedback, since production contexts vary from site to site. Furthermore, streamlining markets through appropriate policies would go a long way in motivating the producers

3.4.2 Cassava

A survey conducted during the late 1990s showed that cassava production in the coastal lowlands of Kenya was declining in acreage and yield per unit area. The low yields were attributed to the use of local cassava varieties susceptible to Cassava Mosaic Virus and Cassava Brown Streak Disease. The declining acreage was due to inadequate planting materials at farm level.

To address the challenge, a breeding program was initiated at KARI (KALRO) Mtwapa with the objective of developing high yielding and disease tolerant cassava varieties, and in July 2008, six high yielding cassava varieties were released. The new varieties yielded between 50 and 70 t/ha, compared to 3 to 9 t/ha by the local varieties grown by farmers. The new cassava varieties were given local descriptive names such as: Karembo, Tajirika, Shibe, Karibuni, Siri and Nzalauka. Each of the names portrayed a characteristic of the variety. For example Karembo has shiny beautiful leaves, Tajirika roots are straight and preferred in the market, Karibuni can accommodate other crops and is therefore good for intercropping, while Nzalauka is first maturing and is the first one to 'send hunger away' —the literal translation of the name. To enhance uptake, twenty four farmers were selected in six districts to undertake the planting material multiplication. These farmers were trained on clean cassava planting material production and entrepreneurship and were encouraged to plant at least one acre of the new cassava variety which would in turn produce enough material for 12 to 24 acres depending on the spacing used.

Reasons for the innovation's success: Approximately 1.2 million cuttings of various cassava varieties were produced by the 20 entrepreneurs by the end of January 2011. In general, the entrepreneurs realized KES 597,000 from the sale of cassava planting materials and roots. One major drawback voiced by some farmers was inadequate marketing outlets for fresh cassava roots. This tended to slow down

the anticipated cassava planting material business, since some farmers felt they did not want to grow a crop that had no market.

Drivers of success: Development of high yielding varieties, capacity-building of the farmers, and availability of clean and high yielding cassava led to initial uptake. However, the bulkiness of the roots, as well as the long transportation distances to the markets, led to a slowing down of the uptake.

Ways of up/outscaling the innovation: There is need for setting up small-scale processing plants at the community level and educate rural communities on the use of cassava and maize or wheat flour blends which are used to make common meals (porridge, ugali, mahamri and chapati)

3.4.3 Indigenous chicken:

Kenya has approximately 29 million indigenous chickens, which are kept by over 80% of households. Mortality rates for indigenous chicken are high because of poor production practices, especially in feeding, housing, disease control and a lack of commercial orientation. A few farmers produce indigenous chicken intensively or through semi-intensive systems (flock sizes of 20 to over 100 chicken), which has proved profitable. The local chicken market is poorly developed and mostly informal despite significant demand. A broody indigenous hen can only hatch a maximum of 10-12 chicks, which take 7-8 months to attain a 2 kg live weight, and produce about 100 eggs per year.

KALRO embarked on a program to improve performance of local chickens through selection and production/multiplication of the improved indigenous chicken with varied plumage coloration. These chickens are suitable for extensive, organic and rural production systems. The improved KALRO breeds lay between 180-220 eggs per year and reach slaughter weight (2kg live-weight) in 4 months. Sale of improved day-old chicks from KALRO Naivasha has increased from 500 to 250,000 in the last five years through the use of automated hatcheries.

Reasons for the innovation's success: The improved hens start laying at 5 months compared to 7 months for the unimproved hens. They lay between 180 and 220 eggs in a year compared with 100 for unimproved hens and attain slaughter weight at 4-5 months compared to 7 months in unimproved hens. The KARLO Kienyenji hen innovation has been rapidly adopted by farmers in different parts of the country. The poultry unit at KALRO Naivasha increased day old chick production from 74,830 to over 240,000 chicks valued at KES 24 million in 2014 as a result of this demand. In 2013 the National Gross value of the KALRO improved chicken was estimated at KES 670 million. Many resource poor farmers including Internally Displaced Persons (IDPs) have adopted the technology and are now able to take their children to school and pay for other services from their eggs and birds sales.

Drivers of success: The project took a value chain approach in the development and dissemination of the technology. Beyond developing the improved breed, disease control, feeds and feeding, good husbandry, housing and marketing were also addressed. The available research facilities in Naivasha were improved and expanded to produce day old and 4-week old chicks for farmers, hence making the improved breed available to farmers. This technology is popular with farmers in different parts of the country and has been used for emergency restocking programs in arid and semi-arid lands after droughts because of its relatively low input requirement.

The project took a business orientation, and successful businesses have been started at the Coast, Eastern, Western and Rift Valley regions, thus sustainably contributing to food security. Public-private partnerships were created to upscale indigenous chicken technologies in order to meet the existing and growing demand. A total of 330 indigenous chicken service providers, mainly from NGOs, faith based organizations, and farmer groups, have been trained and provide services at the local level. Another factor is the rapid increase in chicken consumption over the last decade (by over 8% p.a.), providing a market for the farmers' production. A robust indigenous chicken industry will generate incomes for smallholder farmers who dominate its production, support the processing industry, and increase supply to consumers, while improving the living standards of all value chain actors.

In addition, the use of multiple information channels (especially use of information and communication technologies, such as, mobile phones) has raised awareness. The project has a documentary on YouTube, and a total of 36,200 hits have been recorded. Other channels include participation in breeders' show, field days, World egg day, county showcases etc.

Ways of up/outscaling the innovation: KALRO has a hatching capacity of about 200,000 day-old chicks and a goal to sell 200,000 fertile eggs per year against an estimated national demand of 1.5 million annually. There is therefore a need to expand the capacity at KALRO Naivasha and Kakamega Centres to improve accessibility. Currently farmers have to wait for up to 6 months to access day-old chicks. There is also a need to develop a Purchasing Power Parity (PPP) strategy in the hatching of chicks from the KALRO breed. This will allow the private sector to multiply the chicks, under the supervision of KALRO in order to avoid unscrupulous people defrauding the farmers. Finally, capacity-building for farmers owning small incubators is required to improve hatching percentage. Currently many of the farmers are attaining less than a 10% hatch rate.

3.5 Cross-cutting innovations#

Hermetic grain storage bags for post-harvest loss reduction:

Hermetic storage, one of the oldest forms of food preservation in the world, provides an airtight, safe and pesticide-free means of storing dry food commodities by avoiding grain damage by insects and pests during storage. The hermetic storage bag is made up of a triple-layer plastic bag. The technology essentially consists of filling a plastic bag with grain, tying the mouth of the bag shut, enclosing this bag completely within a second one, which is in turn tightly secured, then repeating the procedure using a third bag. The third bag is added as an insurance measure. The method is simple, uses readily available materials, and is low cost. The mechanism by which triple bagging works involves oxygen depletion and elevation of carbon dioxide levels. The respiration of insects living in seeds stored in a closed space, together with the respiration of the grain itself, reduces the oxygen levels to a point where insects are unable to carry out their life processes normally and therefore die, given the limited oxygen available.

Reasons for the innovation's success: The hermetic grain storage bag was considered a success based on the number of direct benefits it provides to the farmers. First, the bags avoid the direct loss of damaged grain that results from attack by weevils and other insects. A conservative estimate of the physical quantity of harvest lost resulting from weevil attack is 25% of the total. Second, the farmers benefit by not having to sell at harvest, when prices are generally lowest, but can hold their produce for later sale, when the prices have increased. Third, farmers avoid another source of financial loss arising from the discounted price for grain that is damaged by weevils. Damage discount estimates range from 0.17% to 2.3% of the average price for each weevil hole in a sample of 100 grains. Overall, it is estimated that with 50% of grains produced, such as cowpeas, which are stored using the triple bag technology, an income increase in the magnitude of US$150 would be realized per household.

Ways of up/out scaling the innovation: The farm level triple bag hermetic storage technique can be tested in the storage of other farm produce like cereals (rice, wheat, barley, millet, and sorghum) and other pulses (groundnuts, shelled beans, kola nut and Bambara groundnut), all of which suffer from storage pests. In addition to potentially wider use at farm level, other forms of modern hermetic storage that appear applicable to bulk storage (e.g., village or regional-level storage) or higher value commodities are evolving. These include the use of large, flexible, plastic envelopes — called cocoons, or super grain bags, manufactured by GrainPro — to create a sealed environment where any pests present die from lack of oxygen. GrainPro uses an oxygen impermeable plastic that increases the costs and reduces potential for manufacturing the bags in Africa. The technology can be locally adapted to suit the needs of different countries.

Strengthening linkages between research and extension

Numerous value chain innovations have been developed through research, yet their overall impact on increasing productivity and efficiency of agricultural services often remains low or takes much longer than necessary to be achieved. This is mainly attributable to apparently weak linkage between research and extension, although extension services are meant to disseminate information about the developed and tested value chain innovations to the end users – the farmers – for adoption and implementation. Enhancing the research-extension linkages at national and county levels of government through appropriate policy, legal and institutional frameworks, buttressed by increased funding for research and extension, is therefore a critical intervention that requires more support. Additional support should be channeled to innovative approaches like e-extension through the Information and Communication Technology for Africa platform, Information and Communications Technologies for agriculture that embrace use of youth-friendly, cost-effective and efficient digital solutions, such as social media, blogs, podcasts, electronic media and web streams, in order to increase the dissemination of value chain information and promote innovations. The number of adaptive research projects should also be increased with a focus on the transfer of locally adapted value chain innovations to the farmers for implementation. The extension system is facing a myriad of challenges, such as limited investment in government led extension and declining extension-to-farmer ratios. Thus, info-pluralistic extension approaches (with the help of information and communications technologies is needed.

Training farmers on sustainable agricultural practices

Concerns continue to be raised about the need for increased adoption of ecological farming practices for agricultural sustainability. Such practices embrace innovations in land use, crop management, use biological best practices, soil fertility management/sustainable land management, conservation agriculture, and integrated pest management among others. To implement these agricultural practices, farmers need to be competently trained and benefit from knowledge-transfer approaches, such as farmer-to-farmer liaison and exchange programs. These require increased funding from the government and like-minded partners. Studies have established that increasing government expenditure on training small-scale farmers in sustainable agriculture could result in a 10-12% overall positive increase in socio-economic and environmental indicators in the medium- to long-term (Millennium Institute & Biovision Foundation, 2016).

Support for value chain incubation services

Incubation services are known to increase success rates and chances of adoption of new innovations in different sectors across the globe by allowing innovators to access a host of support services that they would not have access to under a conventional set-up. Such services may include market access for the innovations, linkage to investors for enhanced funding support, access to specialized training on implementation of innovative value chain approaches, documentation of value chain innovations for publicity and showcasing, as well as support in carrying out market research. In this regard, development of value chain innovation incubation facilities is a strategic approach that can contribute immensely to the successful development, piloting, roll out, and adoption of emerging value chain innovations. Value chain incubation centres should therefore be developed within the frameworks of existing national agricultural research system and private sector partnerships to give farmers and small business access to these services. The successes and experiences of FARA initiatives under the Sub-Saharan Africa Challenge Programme should help in facilitating the development of innovation platforms.

Supporting adoption of small-scale irrigation practices in light of climate change

Agricultural production has become irregular due to climate-change related changes in weather patterns. This, in particular, is as a result of water stress, namely depressed and erratic rainfall as well

as increased temperatures, and is affecting livestock and crop performance. Irrigation practices offer an immediate, sustainable solution by ensuring continuity in crop and livestock production cycles. This will aid in long-term adoption of different value chains and in enhancing farmer-led innovations.

Supporting Farmer organization into value chain interest groups

Organizing farmers into specific value chain interest groups improves adoption rates of sustainable value chain innovations and practices. Through collective action, members of the interest groups are able to enhance their technical and knowledge capacities and can therefore better identify, prioritize, and implement of value chain innovations geared at increasing production and the productivity of their commodities. As a result, small businesses emerge and transform into viable business entities that are better placed to pilot and support value chain-specific innovations.

Enhancing Gender and Social inclusion

Gender and social inclusion is paramount for equity and equality in value chain development. Marginalized groups, such as youth and women, often have socio-economic vulnerabilities that inhibit their full participation in the adoption and implementation of value chain innovations as well as their potential ventures into small businesses in the agricultural realm. Helping these groups to overcome such constraints calls for strategic gender and social inclusion measures and interventions informed by research.

4 Suggestions for Collaboration

There is long standing collaboration between the organizations in Germany and Kenya on agricultural R&D. The different partnerships revolved around various research themes for technology generation. However, there is new thinking among the African agricultural stakeholders that tends to give more attention to research activities and the process of translating research outputs into development outcomes and into impact on the country's economy.

This approach has led to the use of the innovation systems approach, and it has also led to the development of the innovation platforms that constitute the implementation framework for technology generation, dissemination, adoption, and use. The innovation systems' approach also pays attention to the complementary process that will translate research output into development outcomes, and encourages demand-driven research process among other benefits.

FARA has developed the Integrated Agricultural Research for Development (IAR4D) concept, which has provided the guidelines that aid the generation of measurable impact from research endeavors. In the last eight years, it has conducted trials towards the proof of the IAR4D concept and this precedes the scaling-up and scaling-out of the concept across the continent. There is major scope for partnership between German stakeholders in scaling up the innovation platforms in the different countries. The priority and strategic commodities and themes in the different countries should also guide the selection of the important value chains.

A good partnership framework is essential to bring the Germany-Kenya collaboration to fruition. Prospective partners with Germany in Kenya will include the Apex research institution in Kenya; KALRO; the Ministry of Agriculture, Livestock and Fisheries; Consultative Group of International Agricultural Research (CGIAR) and other international research centres; universities, and civil society organizations, viz., farmers' associations, NGOs and the relevant private sector actors.

The Kenyan government's agricultural development plans and the strategic priorities of the national agricultural research systems have highlighted a number of key commodities and value chains deserving of further attention, as indicated in the last chapter. Collaboration in technology generation research for these specific commodities will be vital in creating an impact.

Successful implementation hinges on research that systematically analyses the prioritized commodities from a value-chain perspective and addresses multiple sets of issues concerning technology adoption. Areas of focus will include, among others:

- The socio-economic effect of adoption of the technologies by different value chain actors;
- Direct and indirect environmental impacts and land-use changes associated with adoption of the value chain technologies;
- Impact on food and nutrition security at the household, county, and national levels;
- Constraints to adoption of the technologies by the respective value chain actors;
- Cost-benefit analyses of the value chain technologies;
- Research gaps that should be addressed through subsequent project interventions.

The findings of these researches will be used to inform the strategic policy interventions that should be put in place to support agricultural technology adoption in Kenya. In effect, this will contribute to better investment and cooperation among local and international stakeholders, such as the German Cooperation for International Development, on issues of agricultural research and technology dissemination in Kenya.

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Annex A: Background Information on Nutrition

This annex provides background information on diet quantity and quality, child feeding practices and nutrition status (including micronutrient deficiencies) and definitions of the food and nutrition security indicators presented in Chapter 1.4.2.

Background on food and nutrition security

Diet quantity: Dietary energy supply per capita is an indicator of diet quantity that can be gauged against a population's average dietary energy requirement. The data are based on FAO's food balance sheets that estimate the quantity of each food item available for human consumption at the national level. It has to be emphasized that supply does not equal intake: Supply includes food that households feed to domestic animals or pets and food that they waste. Also, a sufficient average supply of dietary energy (or a nutrient such as protein) may leave those parts of the population deprived that have greater-than-average requirements or lower-than-average intakes. Indicators of undernourishment and food over-acquisition seek to consider the distribution of dietary energy consumption in the population and the minimum/maximum requirements of the average individual in a country (Cafiero, 2014).

Diet quality: Assessing diet quality requires a look at the composition of the diet. In the absence of national food consumption surveys for most countries, data from FAO's food balance sheets are used. The percentage of dietary energy supply from starchy staples (cereals, roots and tubers) is a rough indicator of diet quality: generally, the higher this percentage, the lower the micronutrient density of the diet; starchy staples are rich in carbohydrate and good sources of dietary energy, but they are usually not very micronutrient-rich. Non-staple foods are important for micronutrient and protein supply: Foods of animal origin are good sources of high-quality protein and vitamin A as well as highly bioavailable iron and zinc (meat, fish) and calcium (milk, small fish eaten whole with bones). Pulses and nuts are also good sources of protein and micronutrients. Fruits and vegetables provide a range of micronutrients while generally contributing little dietary energy (USDA, 2016).

The shares of dietary energy supply from carbohydrate, protein, and fat roughly indicate whether the diet is balanced in terms of its macronutrient composition. The recommended shares of dietary energy are 55-75% for carbohydrate, 10-15% for protein, and 15-30% for fat (WHO, 2003). It should be noted that these shares do not reveal whether dietary energy supply per capita and average protein supply are insufficient, sufficient, or excessive in absolute terms. A diet that meets the average dietary energy requirement for Africa as a whole (2200 kcal/day according to FAO, 2016) and provides 55-82.5 g protein per day and 36-73 g fat per day contains the recommended shares of 10-15% of dietary energy from protein and 15-30% of dietary energy from fat. For an adult weighing 60 kg, a protein intake of 50 g/day is considered sufficient, and 60 g/day for an adult weighing 75 kg. No safe upper limit of protein intake has been established, but it is unlikely that intakes of twice the recommended level pose any risk (WHO/FAO/UNU, 2007).

Child feeding practices: Feeding practices are determined by local food availability and household access to food, but also by maternal knowledge and care. Breastfed and non-breastfed children aged 6-23 months should eat foods rich in iron (meat, fish, or eggs) and fruits and vegetables rich in vitamin A daily, and consume at least 4 out of 7 food groups every day (PAHO/WHO, 2003; WHO, 2005; WHO, 2010).

Nutrition status: Household food security, the health environment, and mothers' caring capacity influence children's dietary intakes and the risk of infection, and thereby their nutrition and health status (UNICEF, 2013). Wasting, or acute undernutrition, is the result of recent rapid weight loss or the failure to gain weight that is caused by inadequate diets or infection. Stunting is the failure to grow adequately and results from chronic or recurrent undernutrition or infection (UNICEF/WHO/World Bank, 2016). Stunting in early childhood can have irreversible consequences, such as impaired motor and cognitive development, shorter adult height, lower attained schooling, and reduced adult income, whereas wasting carries a higher mortality risk (Victora et al. 2008; Black et al. 2013; Olofin et al. 2013). Overweight in children and overweight and obesity in adults occur when dietary energy intakes exceed

dietary energy requirements. Overweight and obesity increase the risk of noncommunicable diseases (UNICEF/WHO/World Bank, 2016).

Micronutrient deficiencies arise from insufficient intakes or absorption of essential vitamins and minerals. Major causes are poor diets, diseases, and increased requirements during life stages such as early childhood, pregnancy, and lactation. Micronutrient deficiencies are not limited to poor populations with inadequate dietary energy intakes, but may coexist with overweight and obesity in individuals and communities. Measuring micronutrient deficiencies poses challenges: There is often a need to resort to proxy indicators and large data gaps persist. Anemia, for example, is used as a proxy indicator for iron deficiency, although only about half of the global burden of anemia can be attributed to iron deficiency. Iron deficiency anemia impairs cognitive and motor development, causes fatigue and low productivity, and may result in low birth weight and increased maternal and perinatal mortality if pregnant women are affected (WHO 2015b). Whenever survey data on anemia prevalence are not available, modeled estimates from WHO (2015b) are used. Vitamin A deficiency increases the risk of vision problems, infectious diseases, and death among children (Imdad et al., 2010). Without exception, the data on vitamin A deficiency that are presented in this dossier are modeled estimates (Stevens et al., 2015, quoted in IFPRI, 2015).[15]

Table A1: Cutoffs to identify nutrition problems of public health significance in children

Category of public health significance	Stunting	Wasting	Overweight	Iron deficiency anemia
Severe	≥40	≥15	≥10	≥40
Moderate	30-39	10-14	5-9	20-39
Mild	20-29	5-9	3-4	5-19

Source: Adapted from World Bank (2006) and based on data from WHO (1995) and WHO (2000)

Notes: The cutoffs for public health significance were applied to prevalence rates of stunting, wasting, overweight and iron deficiency anemia (estimated from anemia prevalence) that were rounded to the first decimal. In the tables in Chapter 1.4.2, the data have been rounded to integers, which may lead to seeming contradictions: In a region where 29.8% of children under five were stunted (30% if rounded), stunting would be considered a mild public health problem, and in a region where 30.3% of children under five were stunted (also 30% if rounded), stunting would be considered a moderate public health problem.

Indicator definitions

Dietary energy supply: National average energy supply, expressed in kcal/caput/day (FAO, 2016).

Average dietary energy supply adequacy: Dietary energy supply expressed as a percentage of the average dietary energy requirement. Each country's average supply of calories for food consumption is divided by the average dietary energy requirement estimated for its population to provide an index of adequacy of the food supply in terms of calories (FAO, 2016).

Prevalence of undernourishment: Probability that a randomly selected individual from the population consumes an amount of calories that is insufficient to cover her/his energy requirement for an active and healthy life (FAO, 2016). This indicator seeks to estimate of the percentage of individuals in the population who are chronically undernourished because they fail to meet their minimum dietary energy requirements on a consistent basis.

Prevalence of food over-acquisition: Percentage of individuals in a population who tend, on a regular basis, to acquire food in excess of their maximum dietary energy requirements (FAO, 2016).

Dietary energy supply from cereals, roots and tubers: Percentage of dietary energy supply provided by cereals, roots and tubers (FAO, 2016). A higher share of dietary energy supply from cereals, roots and tubers is generally associated with a lower micronutrient density of the diet.

[15] Iodine deficiency disorders are an important public health problem in many countries. They are not discussed here because salt iodization, the main prevention and control strategy, is not related to agricultural value chains.

Dietary energy supply from carbohydrate: Percentage of dietary energy supply provided by carbohydrates, calculated by subtracting dietary energy supply from protein and dietary energy supply from fat from 100%.

Dietary energy supply from protein: Percentage of dietary energy supply provided by protein, calculated as average protein supply times 4 kcal/g divided by total dietary energy supply.

Dietary energy supply from fat: Percentage of dietary energy supply provided by fat, calculated as average fat supply times 9 kcal/g divided by total dietary energy supply.

Average protein/fat supply: National average protein/fat supply, expressed in g/caput/day (FAO, 2016).

Minimum dietary diversity: consumption of 4+ food groups: Percentage of children aged 6-23 months fed four or more food groups in the 24 hours preceding the survey. The food groups are 1) infant formula, milk other than breast milk, cheese or yogurt or other milk products; 2) foods made from grains, roots, and tubers, including porridge and fortified baby food from grains; 3) vitamin A-rich fruits and vegetables (and red palm oil); 4) other fruits and vegetables; 5) eggs; 6) meat, poultry, fish, and shellfish (and organ meats); 7) legumes and nuts (ICF International, 2015, The DHS Program STATcompiler).

Consumption of foods rich in vitamin A: Percentage of children aged 6-23 months who consumed foods rich in vitamin A in the 24 hours preceding the survey. Foods rich in vitamin A include meat (and organ meat), fish, poultry, eggs, pumpkin, red or yellow yams or squash, carrots, red sweet potatoes, dark green leafy vegetables (for example, cassava leaves, pumpkin leaves, kale or spinach), mango, papaya, and other locally grown fruits and vegetables that are rich in vitamin A (ICF International, 2015, The DHS Program STATcompiler).

Consumption of foods rich in iron: Percentage of children aged 6-23 months who consumed foods rich in iron in the 24 hours preceding the survey. Foods rich in iron include meat (and organ meat), fish, poultry, and eggs (ICF International, 2015, The DHS Program STATcompiler).

Child wasting: Percentage of children under five who are wasted, that is, have weight-for-height below minus 2 standard deviations of the median of the WHO Child Growth Standards. This means that they are too thin for their height (UNICEF/WHO/World Bank, 2016).

Child stunting: Percentage of children under five who are stunted, that is, have height-for-age below minus 2 standard deviations of the median of the WHO Child Growth Standards. This means that they are too short for their age (UNICEF/WHO/World Bank, 2016).

Child overweight: Percentage of children under five who are overweight, that is, have weight-for-height above 2 standard deviations of the median of the WHO Child Growth Standards. This means that they are too heavy for their height (UNICEF/WHO/World Bank, 2016).

Adult overweight and obesity/overweight and obesity among women of reproductive age: Percentage of adults aged 18 years or older/percentage of women of reproductive aged 15-49 years whose body mass index (BMI) is equal to or greater than 25 kg/m2 (WHO, 2015a; ICF International, 2015, The DHS Program STATcompiler). BMI is calculated by dividing body weight in kg by squared height in m.

Adult obesity/obesity among women of reproductive age: Percentage of adults aged 18 years or older/percentage of women aged 15-49 years whose body mass index (BMI) is equal to or greater than 30 kg/m^2 (WHO, 2015a; ICF International, 2015, The DHS Program STATcompiler).

Adult underweight/underweight among women of reproductive age: Percentage of adults aged 18 years or older/percentage of women aged 15-49 years whose body mass index (BMI) is below 18.5 kg/m^2 (ICF International, 2015, The DHS Program STATcompiler).

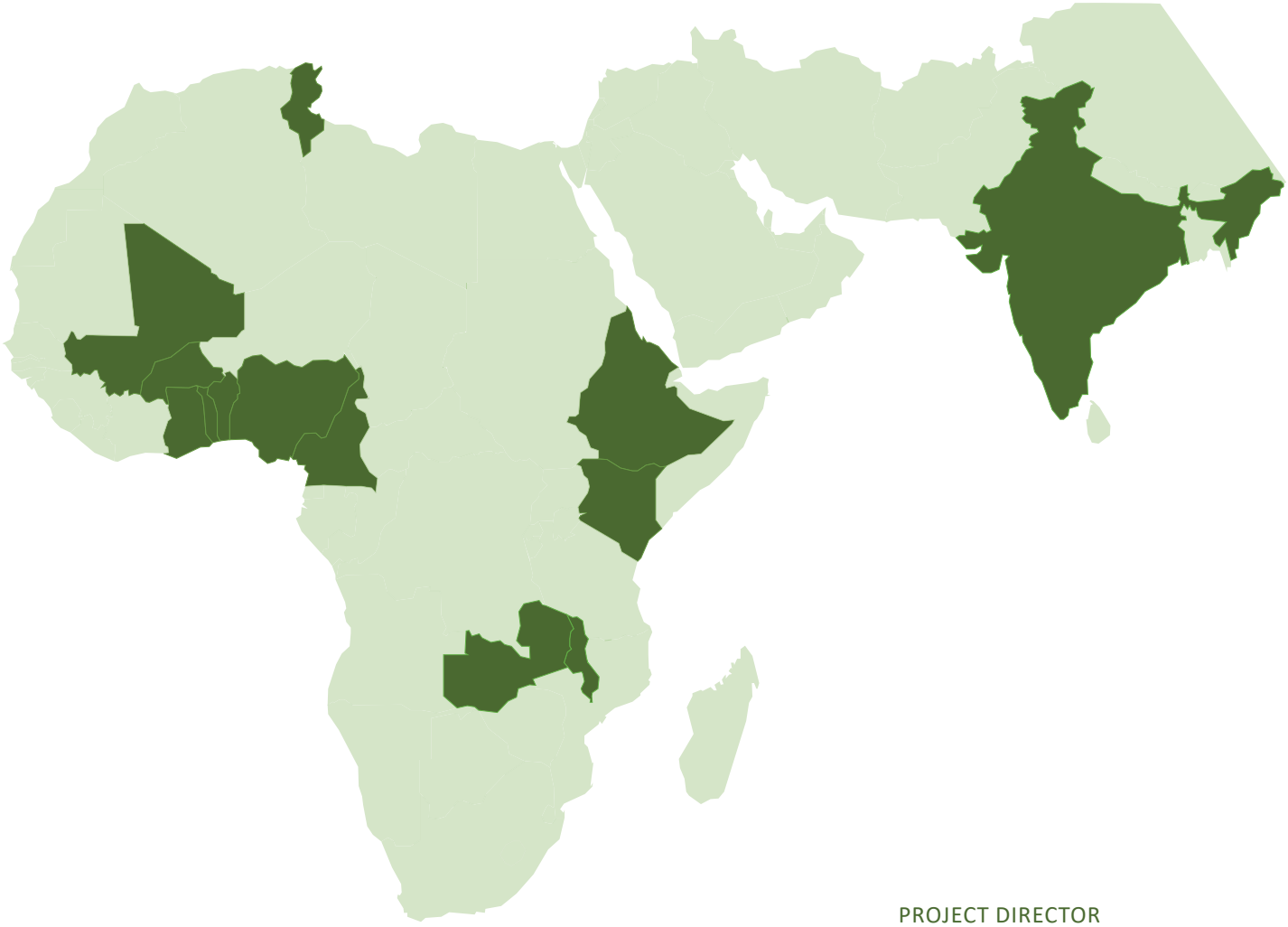
Vitamin A deficiency: Percentage of children aged 6-59 months with a serum retinol concentration below 0.7 µmol/l.

Anemia in children: Percentage of children aged 6-59 months with anemia, namely, a blood hemoglobin concentration below 11.0 g/dl.

Anemia in women: Percentage of women aged 15-49 years with anemia, namely, a blood hemoglobin concentration below 12.0 g/dl for non-pregnant women and below 11.0 g/dl for pregnant women.

ABOUT PARI

The Program of Accompanying Research for Agricultural 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 as part of the “One World, No Hunger” Initiative supported by the German government.



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