Global scoping study on fruits and vegetables; results from literature and data analysis

Literature review and data analysis

Bart de Steenhuijsen Piters, Youri Dijkxhoorn, Huib Hengsdijk, Xuezhen Guo, Inge Brouwer, Likoko Eunice, Thomas Tichar, Caitlyn Carrico, Sjaak Conijn, Rene Oostewechel and Walter de Boef

WAGENINGEN
UNIVERSITY & RESEARCH

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Bart de Steenhuijsen Piters, Youri Dijkxhoorn, Huib Hengsdijk, Xuezhen Guo, Inge Brouwer, Likoko Eunice, Thomas Tichar, Caitlyn Carrico, Sjaak Conijn, Rene Oostewechel and Walter de Boef, 2021. *Global scoping study on fruits and vegetables; results from literature and data analysis; Literature review and data analysis.* Wageningen, Wageningen Economic Research, Report 2021-092. 160 pp.; 30 fig.; 13 tab.; 213 ref.

Wereldwijd lijdt een op de drie mensen aan een of meer vormen van ondervoeding. De teams van de Bill & Melinda Gates Foundation die zich bezighouden met landbouw en voeding, in samenwerking met het Britse Department for International Development (FCDO), willen het potentieel van groente- en fruitketens onderzoeken om het aanbod van voedzame voedingsmiddelen te vergroten en te versterken, en om de lokale marktkansen voor meer inkomsten te vergroten, speciaal voor vrouwen. Dit rapport belicht de conclusies van literatuuronderzoek en data-analyse en identificeert verschillende problemen en kennislacunes die tijdens de tweede fase van dit onderzoek diepgaand onderzoek nodig hebben.

Currently, one in three of the world's population suffer from one or more forms of malnutrition. The Agricultural Development and Nutrition teams at the Bill & Melinda Gates Foundation, in collaboration with the UK's Department for International Development (FCDO), seek to investigate the potential of vegetable and fruit supply chains to increase the supply of and strengthen demand for nutritious foods, as well as increase local market opportunities for increased income, especially for women. This report highlights the conclusions from literature review and data analysis, and identifies several issues and knowledge gaps that need further in-depth research during the second phase of this study.

Key words: fruit, vegetables, food system, nutrition, supply chains

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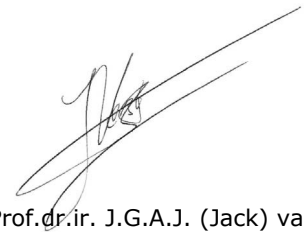
Preface

The world's population is expected to increase by 2 billion persons in the next 30 years, from 7.7 billion currently to 9.7 billion in 2050. In spite of progress made in the past decades, the number of people being undernourished is on the increase again. Globally, 462 million are underweight, while 1.9 billion adults are overweight or obese. This contrast highlights well one of the most prominent global challenges imposed on our food systems, which is: how to make available, accessible and affordable healthy food to all.

To meet the growing demand for food and improved nutrition, food production and its nutritional value need to be enhanced. Compounding this issue is the pressure that existing agricultural systems place on the environment. Although there is scope to bring new land under cultivation, for example in Africa and Latin America, this has the knock-on effect of damaging the climate, biodiversity, natural habitats and more generally the integrity of the Earth's environmental system. The challenge of achieving global food and nutrition security is underscored by Sustainable Development Goal (SDG) 2: "End hunger, achieve food security and improved nutrition, and promote sustainable agriculture."

Fruits and vegetables play a key role in achieving above mentioned goals. This was acknowledged by the Bill and Melinda Gates Foundation (BMGF) and the Foreign, Commonwealth & Development Office (FCDO) which realised that more knowledge on the current state of fruit and vegetable consumption, trade, processing and production worldwide, and notably in low- and middle-income countries, is needed. For that purpose, Wageningen University & Research was contracted to conduct a global scoping study including deep dives into selected countries. After more than a year and a half of research, we are happy to present a number of research outputs that address comprehensively the state of art and main challenges associated with fruits and vegetables. The reports take us through all aspects of food systems in which fruits and vegetables play a role, from consumption to production, but also around the world, from Nigeria to Nepal. The study provides BMGF and FCDO with a clear set of recommendations as to priorities for philanthropical investments that have the goal of enhancing consumption of and economic benefits from fruits and vegetables.

Fruits and vegetables play a key role in meeting current and future food system challenges. With this research we know better where we are and what is needed to address these challenges. I hope our work contributes to setting in motion food system changes urgently needed.



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Executive summary

Currently, one in three of the world's population suffer from one or more forms of malnutrition. The global population is projected to rise from 7.7 billion in 2019 to 9.7 billion by 2050 and to 10.9 billion by 2100 (United Nations, 2019). To meet the growing demand for food and improved nutrition, food production and its nutritional value need to be enhanced. Compounding this issue is the pressure that existing agricultural systems place on the environment.

The Agricultural Development and Nutrition teams at the Bill & Melinda Gates Foundation, in collaboration with the UK's Department for International Development (FCDO), seek to investigate the potential of vegetable and fruit supply chains to increase the supply of and strengthen demand for nutritious foods, as well as increase local and export market opportunities for increased income, especially for women. The aim is to gain a better understanding of current (a) global and (b) country-specific trends in this horticulture sector through a global level analysis and seven country case studies.

This report highlights the results from a literature review and data analyses. Seven themes were analyzed, which together explain trends in food systems globally and at the regional level for horticultural products (defined as fruits and vegetables). The report draws conclusions on each of these seven themes and identifies important issues for in-depth research, which was conducted during the second phase of this study.

Consumption of fruits and vegetables in the three regions of study remains too low to meet recommended targets for reducing risk of malnutrition. This under-consumption is observed in both West and East Africa as well as South Asia and irrespective of social strata. Consumer prices of fruits and vegetables are high and affect the affordability of these healthy foods, notably by less-endowed households. Women face specific barriers that prevent them from earning more from fruit and vegetable production, trade and processing. These inequalities are not idiosyncratic to fruit and vegetables but reflective of wider trends women face in the agricultural sector.

In all regions studied the dominant supply chain configuration involved the spot market as the leading marketplace. In South Asia the supermarket has a slightly higher market share compared to West and East Africa. Prices of fruits and vegetables are proportionally high across the three regions. Major food safety risks related to bacterial contamination are caused by supply chain operations, due to poor packaging and poor handling practices.

Technology and infrastructure influence production and supply and thus have a significant impact on consumer prices. Export supply chains can have a catalyzing effect on domestic fruit and vegetable production and supply chains. The question remains whether consumers are willing to pay more for higher quality fruits and vegetables, and whether lessons learned from export supply chains are translated into production and trade efficiencies that reduce the consumer price on the domestic market. Women do not have equal access to technology. However, where women can increase efficiency and overcome time constraints with access to technology, for example, using ICTs, it has been shown to have a real benefit as it overcomes issues, such as limited mobility and lack of market awareness. Access to capital is a constraining factor to expanding women's involvement in fruit and vegetable supply chains.

We observe that fruit and vegetable production remains too low to support healthy intake levels across the three regions. Based on the expected population growth till 2050 in the three regions and recent production growth rates, fruit and vegetable production in South Asia is best positioned to support healthy intake levels, production in East Africa will remain too low, and West Africa takes an intermediate position. Poor quality at harvest is a main source of low product quality and waste across the supply chains. Most of the fruits and vegetables are produced by small and medium-sized farming

households that lack scale advantages to reduce production costs. Improving the level of organization could be a solution, for example, through farmers' cooperatives, but external attempts to achieve this have often proven to be unsustainable and often unsuccessful.

Small and medium farmers lack access to capital for upfront production input costs, investments in technical innovation and maintaining a cash flow enabling the hiring of external labor. Producers must deal with a variety of risks, such as pests and diseases, variable precipitation, limited access to water for irrigation, uncertain labor markets, irregular markets and a poor bargaining position. The main coping mechanism is that farmers plant only small parts of their land with fruits and vegetables. Production specialization is rather the exception than the rule. Based on average yield levels across the regions, fruit and vegetable production is still mainly based on low external input levels. Where farmers have opportunities to intensify, often stimulated by the availability of irrigation water, input levels increase rapidly, resulting in over-supply of inputs and a variety of negative externalities.

Women are likely over-represented in higher risk/lower return portions of fruit and vegetable supply chains, for example, in informal production (reflective of 'feminization' of agriculture), while men control formal/higher income (with some specific exceptions in West Africa). While women's participation in fruit and vegetable production and supply chains varies, broadly speaking, women face a greater overall labor burden when combining agricultural and household work. This, together with other systemic constraints (low land and asset ownership, limited access to credit, lower mobility) limits their ability to generate more income. Despite these findings, evidence shows that, where women are given the opportunity to increase and control their income, it can translate into women's empowerment and improved nutrition.

Market transparency of fruit and vegetable supply chains is often low. This lack of consumer preference and market intelligence information is especially observed in the more traditional informal, product driven supply chains, where middlemen just buy what farmers produce. Farmers do not know consumer markets and middlemen may not disclose their insights to maintain their asymmetric information advantages. Only when larger players get involved, such as pack houses, is information on consumer markets disclosed to farmers, who then obtain incentives to adjust their production.

This report also identifies several issues and knowledge gaps that need further in-depth research during the second phase of this study. Examples of such research questions are: what is the effects of seasonality of fruits and vegetables on their availability and accessibility (prices) to consumers? Why are prices of fruits and vegetables higher than other foods? Why is there not higher production of (a diversity of) fruits and vegetables and not more fruits and vegetables on the market? These and other questions were investigated during the second phase of this study in the seven selected country, of which you find the results in the respective reports, as well as in the Synthesis Report of the Global Fruits and Vegetables Scoping Study: Assessing opportunities for philanthropic investment.

1 Introduction

Recent years have seen a shift in the discussion on food security from focusing on providing enough calories to the importance of the nutritional value of the diet. The nutritional dimension is now integral to the concept of food security, as reflected in the Food and Agriculture Organization (FAO) definition of food security as a situation "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (World Food Summit, 1996).

Currently, one in three of the world's population suffer from one or more forms of malnutrition. The global population is projected to rise from 7.7 billion in 2019 to 9.7 billion by 2050 and to 10.9 billion by 2100 (United Nations, 2019). To meet the growing demand for food and improved nutrition, food production and its nutritional value need to be enhanced. Compounding this issue is the pressure that existing agricultural systems place on the environment. Although there is scope to bring new land under cultivation, for example in Africa and Latin America, this has the knock-on effect of damaging the climate, biodiversity, natural habitats and more generally the integrity of the Earth's environmental systems (Lobell et al., 2008). The challenge of achieving global food security is underscored by Sustainable Development Goal (SDG) 2: "End hunger, achieve food security and improved nutrition, and promote sustainable agriculture."

Diets play a key role in the malnutrition pandemic, but the present dietary transformation observed LMICs is moving in the wrong direction, with increasing intakes of fat, sugar, salt, and animal sourced foods (HLPE, 2017). Specifically, low consumption of vegetables and fruits is a key dietary contributor to malnutrition, as fruits and vegetables are naturally rich sources of micronutrients such as carotenoids, vitamin C and minerals, including iron and zinc. The benefits of fruits and vegetables in preventing diet-related non-communicable diseases are well established (Afshin et al., 2019). Vegetables and fruits can therefore help to tackle the global malnutrition challenge, as stated in the EAT-Lancet report "a diet rich in plant-based foods and with fewer animal source foods confers both improved health and environmental benefits" (Afshin et al., 2019).

Gender inequality is an important aspect in malnutrition and hunger, both as a cause and consequence (FAO, 2019). Higher levels of gender inequality are associated with higher levels of undernutrition, interlinked with health and agriculture. Both men and women have important roles in achieving good health and nutrition, through working on family farms and in the labor market to earn income to buy food. Women are more likely to be caregivers and food providers within their families throughout much of the world, and thus are considered the guardians of household food security and nutrition. At the same time, economic and cultural factors, including gender norms — the socially-determined standards and expectations that define what is acceptable and appropriate behavior for women and men — limit women and girls from actively participating in economic activities that may improve their status and the household's wellbeing. Additionally, women and girls are often excluded from decision making related to food purchases and allocation that may improve their nutritional status. Biological factors increase women's and girls' risk of experiencing micronutrient malnutrition and poor health, especially during their reproductive years. Adolescent girls may be particularly vulnerable, owing to their higher nutrient requirements for physiological maturation but also owing to their low social status denying them from resources needed for maturation. Men face their own unique set of social and biological risks to attaining good health and nutrition. Addressing gender issues is essential in addressing health and nutrition and, in doing so, it is not enough to focus on women alone; they must also be viewed in the context of their relationships with men — how they are influenced by, and also how they influence, men.

The Agricultural Development and Nutrition teams at the Bill & Melinda Gates Foundation, in collaboration with the UK's Department for International Development (DFID), seek to investigate the potential of vegetable and fruit supply chains to increase the supply of and strengthen demand for nutritious foods, as well as increase local and export market opportunities for increased income, especially for women. The aim is to gain a better understanding of current (a) global and (b) country-specific trends in this horticulture sector through a global level analysis and seven country case studies.

This global scoping study on fruits and vegetables is conducted by an interdisciplinary team from Wageningen University and Research (WUR). The study started in May 2020 and is divided into three phases. In the first phase, we analyze seven themes, which together explain trends in food systems globally and at the regional level for horticultural products (defined as fruits and vegetables). For the regions that house the key geographies that will be the focus of phase II, we analyze and describe how current levels of production are tracking towards meeting dietary requirements, and how various food system drivers impact on production, supply and consumption of fruits and vegetables.

In this document we will first explain the general approach to phase I, and then present our view on food systems, food environments and fruits and vegetables supply chains, as a framework of analysis for the seven subsequent themes. We will then present our findings by theme and provide an integrated analysis of the food systems in which fruits and vegetables play an important role. We conclude this document with an overview of our main findings and areas for further investigation, which we propose to be addressed in the second phase of this study.

During the second phase, we will dive into seven country-specific food systems and focus on both private and public sector pathways to increase both supply and demand for vegetables and fruits. The second phase will aim to identify innovative business models, incentives, food and nutrient flows and critical investments needed to bring horticultural development to scale to support healthy and sustainable diets, while ensuring women's equitable inclusion through increased access to market opportunities and empowerment. We recognize women's empowerment as reflected both in economic terms (e.g., ability to contribute to improved household income and control over how it is spent), and in nutritional terms (e.g., recognizing that, especially in rural areas, women often retain the traditional roles of preparing food for the family, and so are important in deciding the nutritional value of household diets). This is reflective of the Gates Foundation's definition of Women's Market Inclusion in Agriculture, which focuses on women's equitable participation in markets (in both level and nature of participation), as well as women's empowerment to exercise their ability to capture value from agricultural market systems by earning income to strengthen their economic position through agricultural productivity.

2 General approach to phase I

The first phase started with an analysis of production, supply, demand and consumption trends for fruits and vegetables, excluding starchy vegetables and fruits like potatoes, cassava and bananas. The focus is on three regions, West Africa, East Africa and South Asia, as these regions house the key geographies that are the focus of phase II.

The regional analysis has been complemented by a comprehensive overview of global supply, demand — global, regional and domestic — and consumption trends for vegetables and fruits. The period for analysis is 2000-2018, data allowing, plus a trend-analysis for the period 2018-2030, based on existing studies.

The themes included in this phase are:
1. Gender trends in production and supply chains
2. Consumption
3. Production of vegetables and fruits
4. Supply chains and markets
5. Infrastructure and technology
6. Production
7. Fruits and vegetables in food systems
8. Towards desired system transitions.

Findings of the first phase are based on desk research and an analysis of quantitative data/statistics. The literature review includes:
- An analysis of existing studies on the vegetable and fruit sector in the selected countries of the three regions.
- A focus on identifying and elaborating the different drivers in the vegetable and fruit sector and any differential trends for women.
- Peer-reviewed articles but also grey literature (e.g., other professional output from research and other organizations).
- A comparison between fruits and vegetables in the different food systems in Asia, West Africa and East Africa.

The data analysis includes:
- Compilation of relevant FAO statistics. We calibrated data points with other observations and data sources where and when possible.
- Compilation of relevant statistics from the Global Burden of Disease database (Afshin et al., 2019), from the Food System Dashboard[1] complemented with Household Consumption and Expenditure Surveys.

[1] www.foodsystemdashboard.com

3 Food systems

Food systems comprise all the processes associated with food production and food utilization: growing, harvesting, packing, processing, transporting, marketing, consuming and disposing of food remains. All these activities require inputs and result in products and/or services, income, and access to food, as well as environmental impacts. In most rural areas, food systems are mainly "traditional", meaning foods are procured through home production and short supply chains. Fruits and vegetables are either self-produced, mainly in home-gardens, or collected from the wild. However, the role of capital in the procurement of food items in rural areas is increasing, as households increasingly depend on off-farm economic activities. In the studied regions, several export markets can be identified. These supply chains hardly contribute to urban and rural consumption diets, except for high-end consumers.

We distinguish between two overarching types of food environments (Downs et al., 2020): natural and built environments (Table 3.1). Food environments are where supply chains and consumers meet and take any form of markets. Natural food environments, also known as subsistence food environments, include two sub-systems: wild and cultivated food environments. Wild food environments include forests and jungles, disturbed habitat, open pastures, and aquatic areas. Cultivated food environments include fields, orchards, closed pastures, gardens, and aquaculture. Built environments include both informal and formal markets, where consumers procure their food. Food from large commercial farms makes its way through supply chains before being sold to consumers in the built food environment. Given that natural food environments are where people access food for their own consumption, the cultivated food environment refers to food production for own-household consumption; it does not refer to food cultivation for sale.

The three food environments are provisioned by specific fruit and vegetable supply systems, integrating both production systems and supply chains. They are also served with typical seed systems that vary from farm saved seed, to informal seed networks and markets, and certified seed of hybrid and, in cases, transgenic varieties from national and global commercial seed companies. Built food environments and formal markets are provisioned by formal supply systems with standards, registered businesses and often contracted arrangements (e.g., supplying supermarkets). Built food environments and informal markets are provisioned by dual supply systems, including a great variety of formal and informal businesses, mainly non-regulated standards, and a mix of formal and highly informal agreements, often based on networks and kinship relations.

Consumers in both 'traditional' and 'mixed' food systems are supplied with fruits and vegetables through multiple food environments. In the three regions, we distinguish between four fruit and vegetable consumer categories and three food environments:

Table 3.1 *Fruit and vegetable consumers and food environments*

	Rural consumers	Low-income urban consumers	Middle-income urban consumers	Far away export/foreign consumers and high-end urban consumers
Built food environments and formal markets			Decent quality fruits and vegetables from certified seed including hybrids. Low quality ("rejects") from the far away export market.	High quality vegetables and fruits meeting foreign quality for the export market, also phytosanitary standards.
Built food environments and informal markets		Low quality and/or low cost modern and local fruits and vegetables. Informal seeds.		High quality vegetables and fruits meeting foreign quality for the export market, also phytosanitary standards.
Wild and cultivated food environments: home garden grown fruits and vegetables	Home consumption of indigenous fruits and vegetables. Farmer saved seed.	Lower cost/quality indigenous fruits and vegetables. Farmer saved seed.	Indigenous fruits and vegetables. Farmer saved seed.	

Source: authors' own.

In West and East Africa, and South Asia, the three food environments, their fruit and vegetable supply chains and their related consumer categories, can be briefly characterized as follows:

A: Built food environments with formal markets and supply systems
These are highly specialized production systems and channels supplying fruits and vegetables for urban high-end and far away export markets. Fruit and vegetable production takes place in closed (greenhouse) or open-field systems with a great dependency on capital for external inputs including mechanization, irrigation, improved varieties, fertilizers, pesticides and hired labor. Hired female workers often fulfill well-defined activities, for example, in planting, harvesting and post-harvest operations. Supply is delivered through formal markets; it may be that vegetables and fruits of lower quality that do not reach the international standards, will appear at informal markets.

B: Built food environments with informal markets and dual supply systems
These are partially or non-specialized marketing channels that procure fruits and vegetables from mixed crop and livestock production systems. In peri-urban situations, fruit and vegetable production in such systems is only one of the livelihood strategies. Production is mainly marketed at local and national fresh markets, but linkages with more remunerative markets exist. The hiring of labor during peak periods, or the use of shared cropping arrangements, is common. Women carry out specific activities like planting and harvesting. The fruits and vegetables are mainly sold at informal markets but produce that meets quality standards can be sold at formal markets. There is also regional trade of fresh fruits and vegetables, which is much more significant compared to the export to far away markets.

C: Wild and cultivated food environments based on home garden grown fruits and vegetables with informal supply systems
Fruits and vegetables collected from the wild or produced in home gardens serve household consumption or are marketed through very short supply channels to other local consumers. Home- gardens are also known as homestead gardens, household gardens, backyard gardens, agro-forestry or kitchen gardens, but the meaning is often the same: small-scale production, often near the home, of various annual and perennial crops including vegetables and fruits, primarily intended for family (home) consumption. Though home gardens can differ in size, the area under vegetables and fruits is often much less than 0.1 ha and may include indigenous vegetables and fruits. Input use is often low, nutrients are often supplied through household composted waste and watering happens with cans. Local markets are outlets for surplus production not consumed by the extended household, or for satisfying cash needs. Generally, women are responsible for garden management and marketing activities. The home gardening systems can be part of commercial or semi-commercial vegetable production systems with clearly defined gender tasks. Fruits and vegetables may also be collected in the wild (e.g., mangos, indigenous fruits and vegetables) or appear in the informal market.

4 Gender trends in production and supply chains

4.1 Gender and fruit and vegetables

There is little research that indicates a causative link between either empowering or disempowering women that is specific to fruit and vegetable food systems. Some case studies illustrate fruit and vegetable products and supply chains wherein women have managed to (partially) empower themselves, though these examples can equally be found in other food and non-food types. Women's roles tend to be greater or lesser depending on the degree to which their activity in the supply chain contributes to overall household income; the greater the income there, the more men take ownership. Hence, kitchen-gardens and the like (predominantly for subsistence and sales in informal, local markets) are left for women to take care of (Coles and Mitchell, 2011; Pionetti, 2011). This same trend is true outside of agriculture, for instance, women are disproportionately over-represented in unstable, precarious, labor-intensive roles with lesser income and increasingly under-represented in positions of seniority (UNDP, 2020). So, while there is a link between choice of crop types grown and improvement in household nutritional intake, this does not necessarily automatically correspond to women's overall empowerment, for example, through a change in decision making in the household, including around spending on household income.

Food systems have an endemic gender problem characterized by significant barriers to participation in food supply chains, due to the cultural norms, identities, roles, rights and obligations of women and men, which come shrouded in structural and systemic inequalities. Applying a gender lens to food systems acknowledges that there is no one universal food experience. In strengthening the food system, there is a need to examine inherent inequalities due to gender (Halliday et al., 2020).

At household level, fruit and vegetable production is both a source of diverse foods and a source of income for food and non-food expenditure in households. Women's roles in agriculture, decision making and resource allocation in the household, therefore, is only understood alongside their male counterparts. The global maternal employment in agriculture, combined with childcare and feeding the family is often examined in parts and therefore fails to fully capture the cumulative effect of these roles on women's time and workload (KIT et al., 2017). In the household, the level to which women engage with a supply chain is not only affected by men but also affects men. Similarly, the extent of men's engagement in supply chains affects women in certain ways. Thus, gender relations at the household level play a key role in determining the extent to which men and women interact within a supply chain. Degrees of participation and gains are shaped at the household level by gendered divisions of labor and the corresponding time budgets.

In Africa, at production level, salient trends show that female resource control and labor autonomy continues to be impinged by pro-male socio-cultural attitudes. With urbanization, increasingly "older women are left behind" in the countryside, which has an overall effect on productivity and innovation levels (Bryceson, 2019; FAO, 2015). Women's agripreneurship represents an immense untapped source of innovation, job creation and economic growth for Africa. However, women agripreneurs face gender-based constraints in realizing their full potential. Being a woman entrepreneur in Africa brings additional challenges that male counterparts do not have to contend with. The five most widespread gender-based constraints to entrepreneurship that account for the majority of gender differences in entrepreneurial activities in Africa include a high share of domestic household work and care duties, as well as other socio-cultural constraints; poor access to finance and limited land rights; lack of appropriate business skills and education; lack of role models, mentors and networks; and lack of gender-sensitive policies (FAO, 2019). In Africa, a majority of women-owned businesses are informal and home-based, to allow women to combine household duties and entrepreneurship. This household tethered set-up can limit the growth of their agripreneurship ventures. These woman entrepreneurs can be profiled as a consumer-facing, one-woman business with no employees, and low potential for growth. Similarly in South Asia, women are responsible for all household work, in addition to paid production agricultural work and this has a bearing on their overall wellbeing.

4.2 Definitions and data around gender

For a scoping study such as this, it can help to understand whether gender inequalities have seen a noticeable change over the previous two decades. However, while there are rich sources of in-country qualitative reports of various countries, there is a paucity of consistent data trends addressing gender inequality, either across countries or over time. Various datasets have been set up, evolved and expanded to establish a more detailed picture of gender issues based on key proxies, though these have been developed over the last 15 years and the data available from many countries is still patchy.[2] The Organisation for Economic Co-operation and Development (OECD) has been publishing gender-related data for OECD and non-OECD countries since 2009 under its Social Institutions and Gender Index (SIGI), which itself has evolved over time. Just over a decade ago, almost all SIGI indicators were oriented around social norms (dress code, freedom of movement, female genital mutilation) and some economic aspects (access to loans and land). A number of these indicators have since been expanded (such as distinguishing between widows and daughters under inheritance law) and more indicators have been added that relate to women's ability to access productive and financial resources, access justice, exercise their political voice and workplace rights. This illustrates a trend from capturing data on women's personal rights, within their household and community, to also addressing women's rights as political actors and economic contributors (both self- and wage-employed). This evolution of data type and capture is similar across multiple datasets, reflecting the shifting debate of norms and elements around gender equality (at least in some circles), as opposed to various key macro-economic indicators — such as gross domestic product (GDP), gross national product (GNP), purchasing power parity (PPP), etc., — which have long been widely standardized and critically analyzed as proxies for economic health. The Women's Empowerment in Agriculture Index (WEAI) is another evolving methodology of capturing data. While the standardized methodology enables cross-country comparison, it has not yet widely been applied across, for example, an entire region or continent, to draw more general conclusions (Alkire et al., 2013).

Despite these variations, changes in gender inequality over time have been evaluated and, according to the latest Human Development Report, have shown to be progressing since the mid-90s. However, the pace of decline in inequality has slowed down in the last decade. These patterns can, in part, be explained by the greater granularity of data captured in more recent years as described above, such that "[w]omen make greater and faster progress where their individual empowerment or social power is lower (basic capabilities). But they face a glass ceiling where they have greater responsibility, political leadership and social payoffs in markets, social life and politics (enhanced capabilities)" (UNDP, 2020).

Definitions and measurement indicators for gender inequality vary considerably across geographies and organizational methodologies. Drawing direct comparisons across countries, or even different reports about interventions in the same country, is therefore challenging as the same umbrella terms are used for what, under further inspection of their indicators, mean different things in practice. Further to this, two commonly used terms, "women's empowerment" and "women's economic empowerment" are often used somewhat interchangeably. In this report, secondary and primary resources have been referenced which use both economic and non-economic indicators as proxies for women's empowerment. Although it is generally recognized that earning an income alone is a necessary but insufficient indicator for a change of women's status, beyond this there are no universally agreed non-economic indicators that should be measured to reflect a change in women's status. This is further elaborated in the pathways to empowerment of women in agriculture, in Box 1.

[2] A comprehensive overview of the progress made, as well as limitations of, data on gender equality in rural contexts can be found in Buvinic and Carey (2019).

Box 1: Pathways to empowerment of women in agriculture

Women's empowerment is conceptualized, analyzed and assessed differently in the various contexts of these regions. In some regions, empowerment may be used merely to communicate good intentions, to achieve some unspecified changes in the distribution of power, which makes it very difficult to define and assess it universally. By definition, gender empowerment implies a transfer or acquisition of power. The concept of power is closely linked with the concept of agency. An increase in the amount of a person's "power" means that a person's ability to make choices and the number of choices available to them expands. Women's choices contribute to practical or strategic gender needs that emerge from their subordinate position in society. Women's triple burdens within society as reproducers, producers and community managers mean that earning money may extend women's options, but may also intensify their workload and responsibilities without necessarily increasing their autonomy.

A key aspect of decent work opportunities is women's market inclusion in agriculture (WMIA), which includes women's equitable participation and ability to capture value from agricultural market systems. WMIA has a direct impact on women's economic empowerment (WEE). Exclusion from agricultural markets restricts women to low-skilled, low-paying work. Furthermore, as the agricultural sector evolves, women who lack access to agricultural markets often find themselves falling further behind men. In addition to earning less than men, these women are often unable to control or make decisions about their earned income, which further constrains their economic empowerment. WMIA potentially can increase poor women's incomes at scale, which in turn contributes to gender equality and poverty reduction. Women's overall agency in spending decisions increases as their earned income rises. Such gains benefit women and their families and can contribute to country-level economic growth.

The Kenyan horticulture firms are an example of significant employers of women in the food supply chain, hence they have great potential to bring about the empowerment of women, both individually and collectively, which makes them instructive case studies. However, for employment and agribusiness to facilitate empowerment for women in the food supply chain, it must contribute to an increase in women's positive forms of power while strengthening their ability to overcome other people's exercise of power over them (Said-Allsopp and Tallontire, 2015).

In this study, we define gender as the socially constructed roles and status of women and men, girls and boys. This includes people's normative perceptions of what roles or behaviors are suitable for men and women, and culturally specific characteristics defining the social behavior, roles, privileges and responsibilities of women and men, and the relationship between them. Throughout this study, we recognize that gender roles, status and relations vary according to place (countries, regions, and villages), groups (class, ethnicity, religion, caste), generations and stages of the lifecycle of individuals. Gender is not about women, but about the variations in relationship and interplay between women and men, and their role in reinforcing gender norms and perceptions (Mutua et al., 2014). The gender analysis in this study examines existing gender relations in the fruit and vegetable supply chains, ranging from within households to a larger scale of the community, nation, and region. By organizing and systematically interpreting information about gender relations, it seeks to clarify the importance of gender differences for achieving development objectives as described in Box 2. Of particular importance to this study is the gender blind discourse, which highlights the lack of awareness and consideration of gender dynamics by key stakeholders, policies, or institutions and the implications of this for fruit and vegetable supply chains (Rubin and Manfre, 2015). Finally, this study pays attention to the gender indicators used as a measure of the specific conditions of men and women, or the level of disparity between them (Rubin and Manfre, 2015).

Box 2: Mainstreaming gender in agriculture

The gender mainstreaming discourse in food supply chains is used as a key strategy to promote gender equality. Adopting a gender perspective means assessing the implications for women and men of any planned action, including legislation, policies or programs, in all areas and at all levels. Assessing the implication of women and men includes evaluation to ensure that there is equity in benefits. A key element of gender mainstreaming is making women's, as well as men's, concerns and experiences integral dimensions in the design, implementation, monitoring and evaluation of policies and programs in all political, economic and social spheres so that women and men benefit equally and inequality is not perpetuated. The ultimate goal is to facilitate processes that challenge existing gender power relations and achieve gender equality and equity. Success in gender mainstreaming is determined by commitment, at all levels, to change policies and procedures so that gender concerns, particularly those of rural women, are incorporated into programming and policymaking, and to mobilize resources that support the realization of this goal. Gender-aware supply chains are important to not only study women's experiences in the supply chain, but also to look at how their employment interacts with women's understanding of their roles in the home and community (Shirke et al., 2016).

4.3 Where in fresh fruit and vegetable supply chains are women more active?

For effective optimization of supply chains, there is a need to understand the different roles, opportunities and constraints faced by men and women to design, implement and monitor relevant supply chain interventions (Mutua et al., 2014). Gender is "often a strong determinant of whether a person working in the food system is engaged in farming or in other activities, such as food processing, marketing, retail or food service" (Glover and Sumberg, 2020). Distribution of the outcomes of the different supply chain components is gendered and varies from place to place. A key to understanding distributional outcomes is to focus on the profits in the different parts of the chain. Men tend to dominate functions with relatively high barriers to entry and correspondingly greater returns, and to control chain management functions (Coles and Mitchell, 2011). On the opposite end of the spectrum, there is a disproportionate representation of women in low-value supply chains and the lower nodes, particularly when they are more labor intensive (ADB, 2016). Globalized export chains, which are usually more lucrative and less labor intensive are male dominated, while the traditionally feminized domestic markets, such as selling farm produce at the farmgate and hawking it largely remain the domain of women. Exceptions to this are informal cross-border trade links, where in the Southern African Development Community region 70% of the traders are women (Quisumbing et al., 2014).

There is some evidence that there has been a "feminization of agriculture" over the past two decades (Slavchevska, 2016). Other studies give caution in how accurate these numbers are, given how data is collected (see definitions around data in Section 4.2), as often in practice much of the work is shared (Woodhill et al., 2019). However, what is clear is that women's combined household and agricultural responsibilities are much higher than those of men. This higher amount of daily work means women tend to execute their productive and reproductive roles simultaneously, causing them to engage mainly in supply chain activities/nodes that allow them to be closer to the homestead, whereas men may freely engage in activities that require them to be away from home at points of the supply chain which are often more profitable (HLPE, 2017; Mutua et al., 2014). This also lowers women's productivity and contribution to household income (Woodhill et al., 2019). Similarly, "women in Sub-Saharan Africa own about 15% of all land, with fewer than 5% in Mali, to over 30% in countries such as Botswana, Cape Verde and Malawi" (Mutua et al., 2014), so while women's contribution is generally equal or greater than men's, their control over its use is more often determined by the male owners.

Women tend to have lower access to capital and technologies than men (FAO, 2011a), which decreases their participation in levels of the supply chains with the highest economic returns and confines them to lower profit nodes. Analysis of some of the barriers to entry and opportunities presented by different supply chains for women can lead to an understanding of the possible supply chain interventions. Understanding women's position in a supply chain, how changes in a supply chain might affect gender inequality, and the main constraints for women in terms of gaining from supply chain participation, requires one to place gender in the context of intra-household bargaining and broader socio-economic processes. This context decreases women's participation in levels of the supply chains with the highest economic returns and confines them to lower profit nodes. Analysis of some of the barriers to entry and opportunities presented by different supply chains for women can lead to an understanding of possible supply chain interventions. Understanding women's position in a supply chain, how changes in a supply chain might affect gender inequality, and the main constraints for women in terms of gaining from supply chain participation, requires one to place gender in the context of intra-household bargaining and of broader socio-economic processes (Mutua et al., 2014).

4.4 Global and continental gender narrative

Continental African trends illustrate that, while women are equally or more engaged in agricultural production compared to men, they produce a third less per unit of land. Broadly speaking this is due to two reasons. First, the double burden of household and agricultural work does not allow women to fully focus on the production of produce. Second, despite women being just as much involved in agricultural production, the barriers in access to credit, land, information and services are disproportionately higher for women than men (Woldu et al., 2018).

As evidenced in the regional trend sections later in the report, women are over-represented in the higher risk (poor work conditions), lower-income part of the supply chain, and in control of fewer commercial-scale, high-income earning goods (Glemarec, 2017). This includes short supply chains with minimal processing, such as traditional vegetables, and local food varieties (Hoffmann et al., 2019). Evidence shows that women become more empowered when they do off-farm labor and can earn an income independently of their husband and his assets (land, machinery), including in sales of agricultural produce. This, however, tends to be the exception to the norm. For women involved in production, the cooperative sector shows evidence of helping; unlike the private sector, cooperatives can lower risks of women producers by providing them access to credit, training and other resources (see also Box 3). A multi-country Africa study illustrated that cooperatives focusing on social service provision "enable them to shift, in what is largely a female-dominated sector, from carrying out vulnerable work to decent jobs, and freeing them of care burdens" (ILO, 2012). There are an enormous variety of cooperative types and structures, some focused on a specific product or service, while others provide multiple service types (e.g., focusing on produce like mango, and improving access to finance for those working in this sector). While the success of cooperatives overall has a mixed track record, those that have good governance structures and are proactive in including women show evidence of benefiting all the members (ILO, 2012).

Box 3: Gender disparity

As seen in this study, there is a continued gender disparity in access to resources, information and agricultural inputs. This is despite policies and interventions supporting gender equality and women's empowerment and inclusion in governance. Women who engage at various levels of the food chain rely on social capital created through group-based approaches. This can improve their positions to obtain better access to resources, raises their bargaining power, improves their household nutrition by buying food in bulk as groups, and overall wellbeing. Social capital promotes livelihoods and access services (financial, policy support and training) and overall household resilience, including recovery from other adverse events (through easy access to low-risk loans), such as a calamity that affects agribusiness ventures. In strengthening women's fruit and vegetable agribusiness practices, there is a need for further research to understand the limitations within this social support system, and what kinds of groups are most effective. Understanding the potential for institutional support for gender-differentiated group-based approaches is relevant for policy formulation and program design (Bryceson, 2019; Ngigi et al., 2017).

Based on the above analysis and early findings, we identify the following emerging research questions for phase II:

- Are there "positive deviation" examples? Are there examples of outliers that can be taken as reference for the Gates Foundation investment options?
- There are some country examples wherein women play a more dominant role in processing/vending. Why is this and can it be replicated in other sectors?
- Is there further evidence of off-farm work, cooperatives or other group-based approaches specifically benefiting women in the countries we're looking at?
- What are the elements used to evaluate gender empowerment in the different regions?
- Examples of transition from sub-optimal fruit and vegetable supply chain incorporation to gender aware supply chains.

5 Consumption

5.1 Approach

Malnutrition in all its forms persists at unacceptably high levels on a global scale. It is estimated that in 2019, 144 million children under 5 years of age were stunted, 47 million were wasted, 38.3 million were overweight (UNICEF et al., 2020). Additionally, over 650 million adults are obese (WHO, 2020) and 613.2 million adolescent girls and women aged 15 to 49 years have anemia (Development Initiatives, 2020). Countries are often burdened by multiple forms of malnutrition, especially in low- and middle-income countries (LMICs) (Popkin et al., 2020). Although the most vulnerable groups are women and children, inequalities in nutrition are, besides age and sex, mostly driven by socio-economic disparities determined by location (urban/rural or geographical), wealth and education, and further compounded by conflict and other forms of fragility (Development Initiatives, 2020). Stunting and wasting are more prevalent in rural areas, in boys, in the poorest households and with less educated mothers. Being overweight is more prevalent among children — mainly boys — in urban areas, in the richest households and with higher educated mothers (Development Initiatives, 2020).

Progress towards the 2025 nutrition targets varies by country and by form of malnutrition, but no country is on course to meet these targets (Development Initiatives, 2020). Stunting rates have been slowly but steadily declining, with the largest decrease in the poorest low- and lower-middle-income countries. The number of underweight male and female individuals has reduced, but in contrast, the number of individuals classed as overweight or obese has increased sharply in men, women, children and adolescents, especially in Asian and sub-Saharan countries (Popkin et al., 2020). The incidence of chronic, diet-related noncommunicable diseases (mainly cardiovascular diseases (CVDs), cancer and type II diabetes) is increasing rapidly and is having a significant impact on society, the economy and health.

Dietary choices are a major determinant of malnutrition, mortality and morbidity worldwide, exceeding the burdens attributable to many other global health challenges (GBD 2017 Diet Collaborators, 2019). The shifts in diets towards intake of less healthy and low-nutrient-density foods and sugary beverages, and changes in away from home eating and snacking, have occurred worldwide but especially in LMICs (Imamura et al., 2015). These shifts have led to the increasing levels of people who are overweight or obese, along with slow declines in stunting (Popkin and Reardon, 2018). Targeting poor diets is one of the major strategies to reverse malnutrition in all its forms and related non-communicable diseases. Besides sufficient amounts of whole grains, nuts and seeds, and animal sourced foods, healthy diets comprise of adequate consumption of fruits and vegetables. In this section, the health and nutrition aspects of fruit and vegetable consumption are described and the global and regional trends in fruit and vegetable consumption are reviewed. The section also highlights the major constraints faced by consumers related to fruit and vegetable consumption as being affordability of fruits and vegetables in a healthy diet, safety of fruits and vegetables, and gendered barriers in fruit and vegetable consumption.

5.2 Health and nutrition aspects of fruits and vegetables

A wide variety of fruits and vegetables provide a range of essential nutrients and bioactive compounds, including vitamins (vitamin C, folate, and pro-vitamin A), minerals (potassium, calcium, and magnesium), phytochemicals (phenolics, flavonoids, and carotenoids) and dietary fiber (Liu, 2013). The nutrients and bioactive compounds differ widely in content and ratio between and within fruits and vegetables (Appleton et al., 2016; Slavin and Lloyd Beate, 2012); see also Appendix 1) depending on a multitude of factors related to, amongst others, variety, soil conditions, ways of production and which parts of fruits and vegetables are consumed. Green leafy vegetables are rich in

a variety of nutrients (iron, vitamin C, vitamin A and folate). Citrus fruits are an important source of vitamin C and folate and dried fruits are a good source of iron. Also, red/orange and yellow fruits and vegetables are key sources of vitamin C, provitamin A and folate. Moreover, fruits usually have a higher concentration in sugars than vegetables, while vegetables are more likely to have a higher concentration of fibers and proteins (Appleton et al., 2016). Although fruits and vegetables are generally low in energy density, fruits juices are known to increase energy intake due to a high (natural but sometimes also added) sugar content (comparable to sugar sweetened beverages) and are associated with a higher risk of non-communicable disease (Flood-Abbagy and Rolls, 2009).

The essential nutrients and bioactive components present in fruit and vegetables have been shown to be beneficial for overall health. Consumption of fruits and vegetables contributes to the intake of essential micronutrients, although the bioavailability of some micronutrients like iron, zinc and calcium may be low due to the presence of anti-nutrients like phytates and oxalates in some fruits and vegetables (Teucher et al., 2004; Zhou and Erdman, 1995).[3] Dietary fiber present in fruit and vegetables was found to reduce cholesterol levels and blood pressure and to improve overall vascular health and the immune function (Lampe, 1999; Anderson et al., 2009; Macready et al., 2014). Antioxidants in fruit and vegetables may prevent or reduce the damage of DNA, glucosinolates (found in cruciferous vegetables) stimulate detoxifying enzymes, and fruit and vegetable consumption may improve overall gut health (Steinmetz and Potter, 1991; Lampe, 1999; Anderson et al., 2009).

Inadequate fruit and vegetable consumption has a large impact on health outcomes (Afshin et al., 2019). In 2017, over 2 million deaths and 65 million disability-adjusted life years (DALYs) globally were attributable to low intake of fruits, while almost 1.5 million deaths and 34 million DALYs were attributable to low intake of vegetables (Afshin et al., 2019), see Appendix 2. In southern sub-Saharan Africa and Bangladesh, Ethiopia and the Democratic Republic of Congo low fruit intake was even identified as the main dietary factor responsible for deaths. Low fruit and vegetable intakes were among the leading dietary risks in low SDI (socio-demographic index, based on income per capita, educational attainment and fertility rate) countries (Afshin et al., 2019). The protective effects of combined fruits and vegetable intake were found to increase within the first 300-500g of intake daily, with very little additional benefit with higher intakes (Miller et al., 2017; Aune et al., 2017; Zhou and Erdman, 1995), see also Appendix 3. The consumption of tinned fruits increased all-cause mortality and CVD mortality (Aune et al., 2017; Yip et al., 2019). Aune et al., (2017), although based on a limited number of studies, showed that associations with different health outcomes might vary by types of fruits and vegetables (see Appendix 4), but further studies to confirm this are needed (Aune et al., 2017). Promoting intake of components of diets for which current intake is less than optimal, such as fruits and vegetables, might have a greater effect than targeting sugar and fat (Afshin et al., 2019).

Based on the associations with health and nutrition outcomes summarized, fruits and vegetables can be categorized in eight different groups (see Table 5.1). Some limitations of this review should be acknowledged. The foods categorized as fruits or vegetables vary and studies differ in whether legumes and starchy vegetables like sweet potatoes are included in the vegetable group or whether banana is included in the fruit group. In addition, many of the studies and meta-analysis on associations between fruit and vegetable consumption and health outcomes did include only very few studies in LMICs. Lastly, only the direct associations were reviewed, although it is recognized that fruit and vegetable consumption might also improve health and reduce risk of chronic disease indirectly, through substitution of unhealthy foods in the diets (high in saturated or trans-fat, sodium and with a high glycemic load).

[3] The bioavailability of a nutrient generally describes the proportion of the nutrient which is absorbed and utilized for healthy body functions. It is influenced by many factors including the food matrix, chemical form, age and health status of the individual, preparation method (Rock et al., 1998) and presence of other (micro)nutrients in the food. Phytic acid, present in plant-based foods including fruits and vegetables, forms complexes with minerals such as iron, zinc and calcium and inhibits absorption (Teucher et al., 2004; Zhou and Erdman, 1995), while vitamin C is known to increase iron absorption (Teucher et al., 2004).

Table 5.1 *Fruits and vegetables categorized according to associations with nutrition and health outcomes*

	Sub-group	Health association
1	(Dark) green leafy vegetables	Contributes to iron, vitamin C, vitamin A and folate intake. Reduces dietary risk for coronary heart disease (CHD), stroke, all-cause mortality, but negative with cardiovascular disease (CVD).
2	Red, orange and yellow vegetables	Contribute to vitamin A and folate intake. Reduces dietary risk for CHD, and total cancer[1].
3	Cruciferous vegetables	Reduces dietary risk for total cancer and all-cause mortality but increases dietary risk for CVD.
4	Other vegetables	No specific richness in relevant nutrients; no or unknown dietary risk for non-communicable diseases.
5	Red, orange or dark yellow fruits	Contribute to vitamin C, vitamin A and folate intake. Reduces dietary risk for CHD.
6	Citrus fruits	Contribute to vitamin C (and help to improve iron/zinc bioavailability) and folate intake. Reduces dietary risk for CHD, stroke, CVD, and all-cause mortality.
7	Apples, pears	Reduces dietary risk for CHD, stroke, CVD and all-cause mortality.
8	Other fruits	No specific richness in relevant nutrients; no or unknown dietary risk for non-communicable diseases.

[1] Total cancer refers to cancer not specified by type of cancer.

Summarized based on studies from e.g. Afshin et al. (2019); Alemu et al. (2019), Yip et al. (2019); Aune et al. (2017).

5.3 Recommendations for fruit and vegetable consumption

Based on scientific evidence of the association between food and food components with a wide range of health outcomes, the World Health Organization (WHO, 2018) recommends 400 g or more fruits and vegetables per day, generally translated to five servings per day (see Table 5.2). The Global Burden of Disease Group (GBD 2017 Diet Collaborators, 2019) provides separate recommendations for fruits (250 g) and vegetables (360 g). The EAT-Lancet diet to optimize health and minimize environmental footprint, recommends 200 g of fruit and 300 g of vegetables per day. Some other well-known general health-promoting diets include the Mediterranean diet, the Nordic diet, or the DASH (Dietary Approaches to Stop Hypertension) diet, tailored to a region or to specific health outcomes (Trijsburg et al., 2019). All of these diets include recommendations on fruits and vegetables, but recommended amounts differ based on the composition of the vegetable groups (including or excluding starchy vegetables, and legumes), health risk considered (blood pressure, cancer, CVD) and food preferences of the population targeted, see Appendix 5.

Table 5.2 *Optimal levels of fruit and vegetable intake according to global dietary recommendations*

Dietary Risk	UN recommendation (WCRF and IARC, 2018; WHO, 2018; and WHO, 2003)	Optimal level of intake (optimal range) (GBD 2017 Diet Collaborators, 2019)	EAT-Lancet reference diet (Willett et al., 2019)[1]
Low in fruits	≥400 g per day (excluding starchy roots)	250 g (200-300) per day	200 g (100-300) per day
Low in vegetables		360 g (290-430) per day	300 g (200-600) per day

[1] Based on an isocaloric diet of 2,503 kcal per day; GBD does not specify an optimal energy intake, and WHO (2018) states "Energy intake (calories) should be in balance with energy expenditure."

National food-based dietary guidelines (FBDG) are official definitions of a healthy diet published by governments to serve their citizens. Over 90 countries have a national FBDG, most published in the last 20 years (Herforth et al., 2019). However, these guidelines are often absent in LMICs: only seven out of 54 African countries have FBDGs. All FBDGs include a recommendation to consume abundant fruits and vegetables, but not all are quantitative or include grams or serving sizes (including a definition of serving sizes). An overview of FBDG key messages on consumption of fruits and vegetables conveyed by more than 5 countries, is given in Table 5.3.

Table 5.3 *FBDG key messages about fruits and vegetables conveyed by more than 5 countries*

Key massage	Number[1]	% (of 90)
Any key message about fruits and vegetables	84	93.3
Eat daily (or with every meal)	62	68.9
Five (or more) servings a day, or 400 g (or more)	30	33.3
Variety within	38	42.2
Eat plenty or 'a lot'	19	21.1
Eat more	16	17.8
Eat different colors or particular colors	17	18.9
Special mention/emphasis on whole, raw, or unprocessed	10	11.1
Eat fresh fruits/vegetables	9	10.0
Eat seasonal fruits/vegetables	6	6.7
Eat local fruits or vegetables	7	7.8
Not mentioned but implied in different message (by reference to food guide)[2]	3	3.3
No key message conveyed but fruits and vegetables are shown in food guide	6	6.7

[1] Sums to more than 90 because some countries have multiple messages about fruits and vegetables. Also many key messages contain more than one idea and are counted for several.

[2] Considered to be implied when a key message directs the reader to eat all food groups, and fruits and vegetables are separated food group(s) in the food guide (this is so in nearly all food guides).

Source: Herforth et al. (2019).

Most current FBDGs do not indicate whether the recommended amounts represent the raw or prepared (cooked, simmered, etc.) form. Although most fruits are consumed raw, preparation of vegetables may change their weight, as during preparation water may evaporate or be absorbed. In addition, the overcooking of vegetables is common in many parts of the world and causes vitamin and mineral degradation. The preparation of certain vegetables may also change the risk of diet related non-communicable diseases. Most guidelines use fruits and vegetables as one food group assuming that fruits and vegetables are interchangeable. Lastly, as mentioned before, the composition of the vegetable group, in particular, varies per country.

5.4 Global and regional trends in consumption of fruits and vegetables

There is a lack of globally and regionally representative data on what people actually consume. The Global Burden of Disease Study (GBD) is a dataset that provides worldwide consumption data modelled on the best available evidence of global dietary intake (Afshin et al., 2019). Information in this section is drawn from the Food System Dashboard indicators on adult fruit and vegetable intake[4], which is based on the GBD study (Beal et al., 2021).[5] Results are complimented with information from other studies that use a variety of other sources, including national and subnational nutrition,

[4] Vegetables include fresh, frozen, cooked, canned, or dried vegetables, excluding legumes and salted or pickled vegetables, juices, nuts, seeds, and starchy vegetables such as potatoes or corn. Fruits include fruits (fresh, frozen, cooked, canned, or dried fruits, excluding fruit juices and salted or pickled fruits).

[5] The dietary data presented here is from GBD (ref: http://www.healthdata.org/gbd). It is important to note that the data is not actual dietary intake data, but instead modelled estimates based on data from multiple sources including national and subnational nutrition and household budget surveys, and food availability from FAO food balance sheets. The amount of data that these estimates are based on varies greatly nationally and sub-nationally and thus these estimates may under or overestimate dietary intake. Comparison of GBD and the Global Dietary Data estimates for fruits, nuts and seeds, unprocessed red meat and sugar-sweetened beverages showed considerable differences for many countries (Beal et al., 2021).

household budget surveys and food availability from FAO food balance sheets. Limitations in interpretation and use for cross-country or cross-region comparison are well acknowledged (FAO et al., 2020), see also Appendix 6 for a summary of differences in datasets used.

Global consumption of fruits and vegetables increased slightly from 1990-2017 but stayed well below the WHO recommended daily intake of 400 g (or 5 servings) or more (see Figure 5.1). The Food System Dashboard shows a slight increase in the global average fruit and vegetable intake from 1990-2017 of 62-90 g per day and of 121-179 g per day, respectively (Afshin et al., 2019). Other studies, although difficult to compare due to large differences in methodology (see Appendix 7), confirm that most adults worldwide are not likely to consume adequate amounts of fruits and vegetables (Frank et al., 2019; Hall et al., 2009; Kalmpourtzidou et al., 2020; Micha et al., 2012; Miller et al., 2017; Murphy et al., 2014). Using Food Balance Sheets, which indicate food availability rather than intake, Mason D'Croz et al. (2019) also found that in 1965 sufficient fruits and vegetables (≥400 g per day) were available for 17% of the global population, increasing to just 55% in 2015.

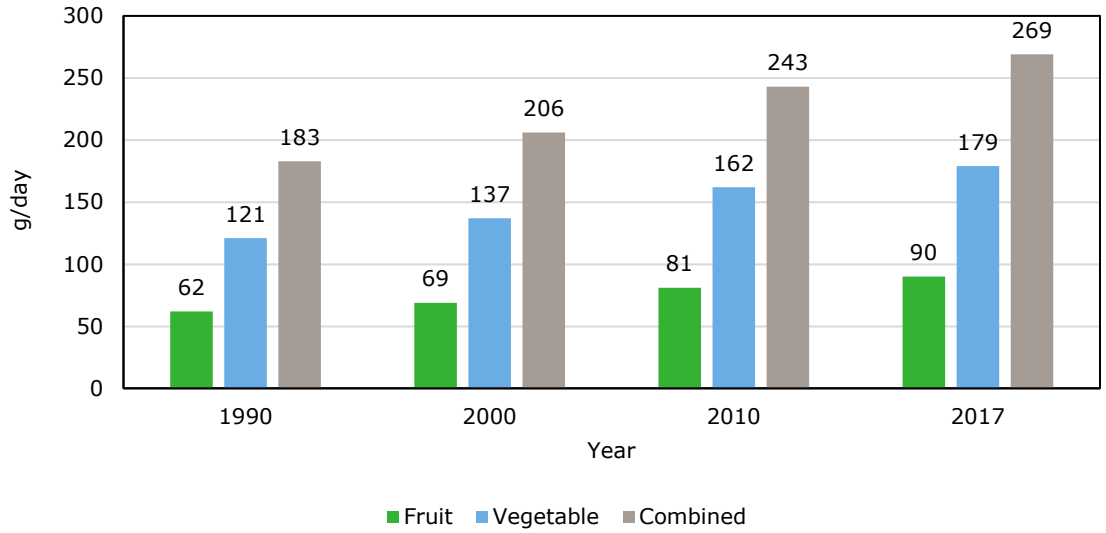


Figure 5.1 *Global estimates for fruit and/or vegetable intake (g/capita/day)*
Source: Afshin et al. (2019).

There are large differences between regions in fruit and vegetable intake, see Figures 5.2 and 5.3. Only Northern Africa, and Eastern and Central Asia meet the WHO recommendation of ≥400 g fruits and vegetables. Using disaggregated recommendations for vegetables (at least three servings or ≥240 g) and for fruits (at least two servings or ≥160 g), only a few regions (Central Asia, Northern Africa, Western Asia and Eastern Asia) show an adequate average intake of vegetables, but none of the regions show an adequate intake of fruits. In Africa (Western, Eastern and Southern regions), South America, and Polynesia and Melanesia, in particular, intake of fruits and vegetables is very low. Regional disparities were also confirmed by Frank et al. (2019), showing that less than 35% of households in the Middle East and Central Asia, less than 20% in South and East Asia, and less than 10% in sub-Saharan Africa, Latin America and the Caribbean consumed ≥400 g fruits and vegetables. Also, Kalmpourtzidou, Eilander and Talsma (2020) reported that vegetable intake was relatively high in East Asia, where 67% of countries met the recommendation for vegetable intake (≥240 g per day). Vegetable intake appeared low in North and West Europe, Central and North America, the Caribbean, Australasia, Micronesia and North and South Africa, where none of the countries met the recommendation (Kalmpourtzidou et al., 2020). Figure 5.4. shows the fruit and vegetable intake gap in the targeted countries, varying from very high (<250 g per day) to high (between 100-250 g per day) with only Iran showing no gap.

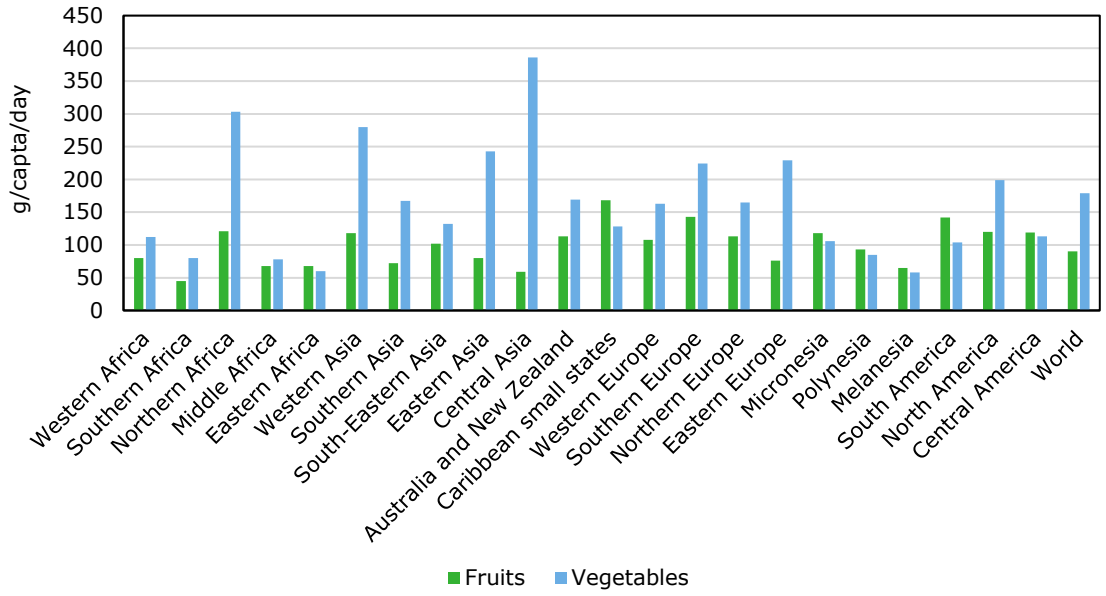


Figure 5.2 *Fruit and vegetable intake (g/capita/day)*
Source: Food Systems Dashboard, available at: https://foodsystemsdashboard.org/ [Accessed: 7 September 2020].

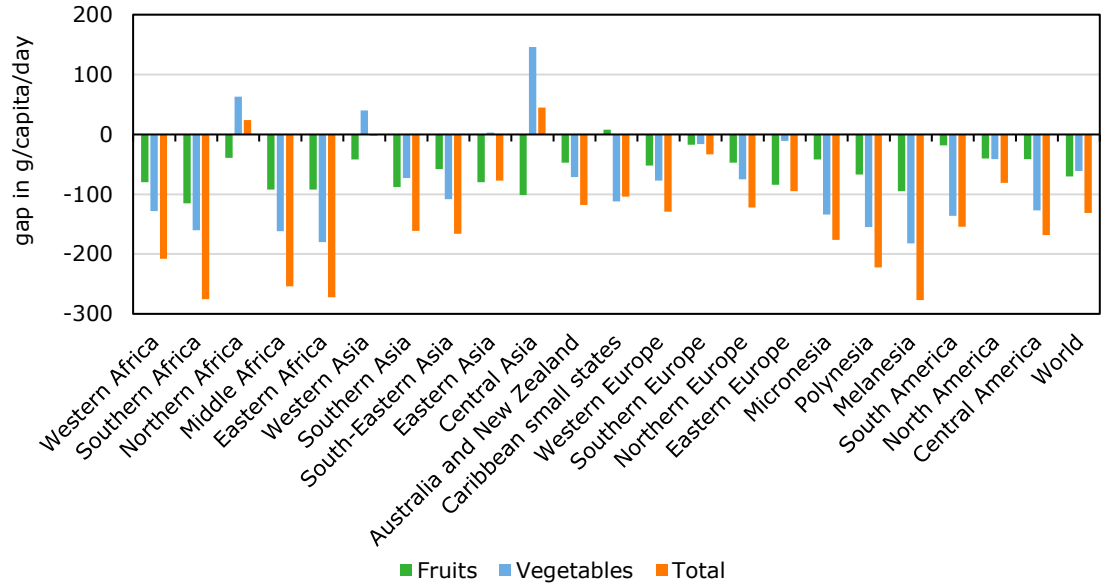


Figure 5.3 *Gap in fruit and vegetable intake (g/capita/day)*
Source: Food Systems Dashboard, available at: https://foodsystemsdashboard.org/ [Accessed: 7 September 2020].

Regional differences in fruit and vegetable consumption are often driven by large increases in fruit and vegetable intake in a few countries within the region. Mason D'Croz et al. (2019) show that the mean availability of fruits and vegetables in certain regions, for instance, East Asia and the Pacific, is highly affected by progress made in China and South Korea, while most other countries in this region do not manage to meet the level of WHO recommendations in 2015 (Mason-D'Croz et al., 2019).

Generally, it is suggested that the diets of urban residents are more diverse when compared to rural residents in the same country or region (Ruel et al., 2005), but studies show inconsistent results. Several explanatory factors are suggested for the urban/rural differences, like the wider availability of different foods in urban markets, the availability and use of storage space, transitions in lifestyle and cultural norms and the demand for processed foods. Unfortunately, the Food System Dashboard does not disaggregate intake data for urban and rural areas. Hall et al. (2009) observed significant differences in fruit and vegetable consumption between urban and rural/peri-urban residents using the results of individual countries, and found that the risk of low fruit and vegetable consumption was higher for urban residents in the 10 out of 11 analyzed countries (Hall et al., 2009).

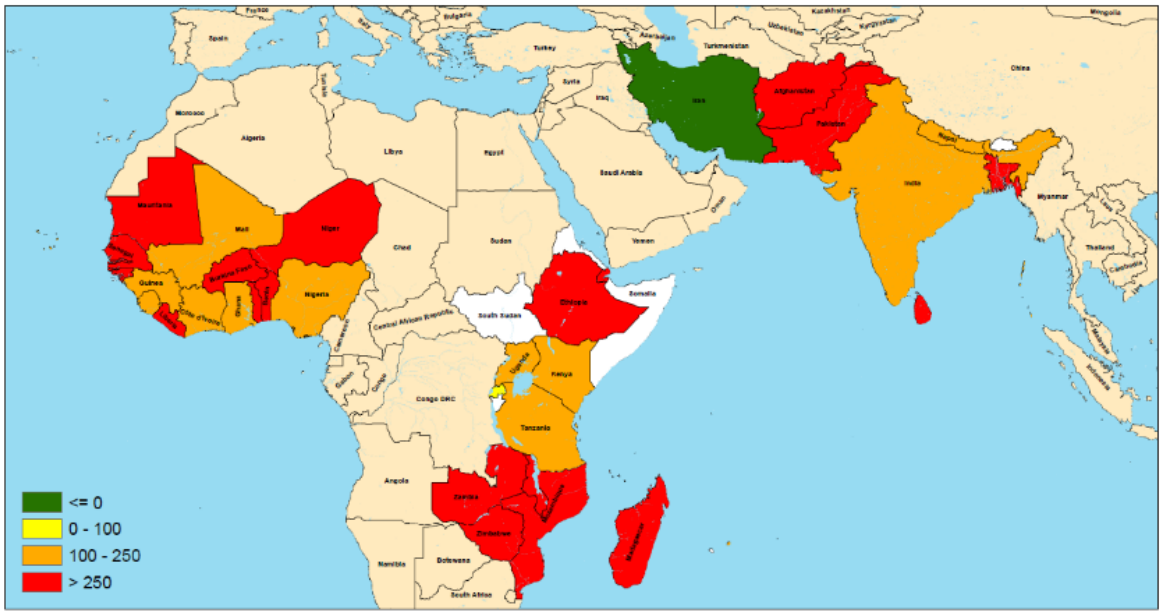


Figure 5.4 *Fruit and vegetable intake gap (g/capita/day) in the targeted countries*
Source: Food Systems Dashboard, available at: https://foodsystemsdashboard.org/ [Accessed: 7 September 2020].

However, Ruel, Minot and Smith (2005) showed a higher fruit and vegetable intake among urban consumers when compared to rural consumers, based on studies in sub-Saharan African countries (Ruel et al., 2005). Similar results were identified in a systematic review by Mayén et al. (2014), which showed a higher fruit and vegetable intake in urban compared to rural locations, although in two LMICs it showed a lower fruit and vegetable consumption in urban compared to rural locations (Mayén et al., 2014).

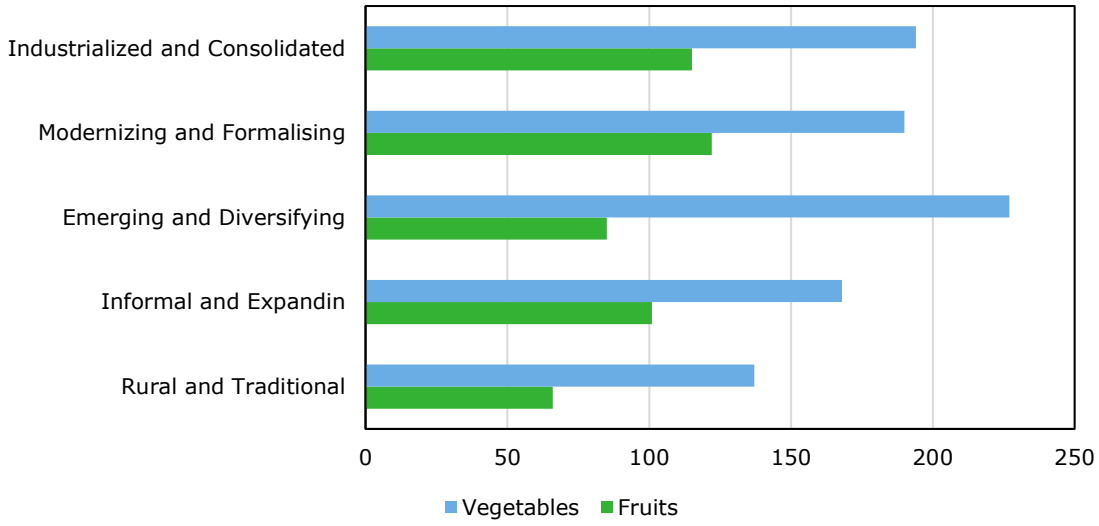


Figure 5.5 *Mean (weighted average) fruit and vegetable intake across different food system types in 2017*
Source: Food Systems Dashboard, available at: https://foodsystemsdashboard.org/ [Accessed: 7 September 2020].

Data presented in the Food Systems Dashboard[6] indicate that both fruit and vegetable intake increases when food systems become more complex, but suggest that intake does not further increase when food systems become more formalized and consolidated, see Figure 5.5. Using disaggregated recommendations for vegetables (at least three servings or ≥ 240 g) and for fruits (at least two servings or ≥ 160g), only the emerging and diversifying food system approaches the vegetable intake recommendation, while none of the identified food systems reach the fruit intake recommendation. For further information on the food system typologies, see Appendix 8. The food system typologies demonstrate heterogeneity across regions with the region of Africa having four of the five types, Asia representing all five types, three types throughout Europe, and North and South America with three and four types, respectively. Disaggregation by food system type might be more informative than disaggregation by region when aiming for food system transformations for healthy and sustainable diets, including through recommended intake of fruits and vegetables.

The Food System Dashboard shows that consumption of fruits and vegetables increases when income increases, but data also suggest that vegetable intake, in particular, does not further increase when countries move from upper-middle to high-income, see Figure 5.6. The increase of fruit and vegetable consumption as income increases exists across geographical regions and is confirmed in many studies, indicating that a low-income is a barrier to fruit and vegetable consumption and to achieving the intake recommendations (Frank et al., 2019; Hall et al., 2009; Miller et al., 2016). In the context of higher-income countries, studies in the United States, Australia and the Netherlands show that adults with higher incomes are more likely to meet the WHO recommendations for fruit and vegetable consumption (CDC, 2017; Dijkstra et al., 2018; Giskes et al., 2002). The analysis of fruit and vegetable consumption in 28 LMIC countries by Frank et al. (2019) also shows a higher percentage of individuals in the upper-middle-income class meeting the WHO recommendations when compared to the low-income class.

[6] The five food system typologies defined in the Dashboard (rural and traditional; informal and expanding; emerging and diversifying; modernizing and formalizing; and industrialized and consolidated) are based on a composite of four indicators: agriculture value added per worker; share of dietary energy from cereals, roots, and tubers; number of supermarkets per 100,000 population; and percentage of total population that live in urban areas.

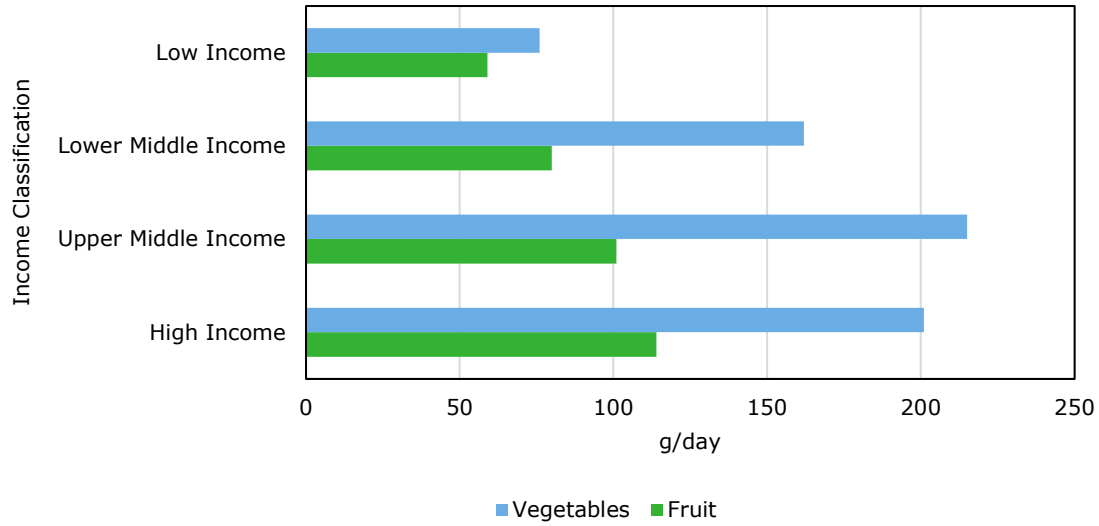


Figure 5.6 *Mean (weighted average) fruit and vegetable intake across income classifications in 2017*
Source: Mason-D'Croz et al. (2019).

For a better insight into the increase in intake when countries move to higher GDPs, we plotted countries' GDP against the intake of fruits and vegetables (Figure 5.7a and b). Results indicate that fruit and vegetable intake shows high variability at low GDP levels, varying from as low as 50 g/capita/day to above 600 g/capita/day. The intakes in Eastern and Western Africa and Southern Asia, however, are below the target of 400 g/capita/day with the exception of Iran, which shows an intake above the recommendation. Results also show that with increasing GDP, variation in intake reduces, with a minimum intake of around 300 g/capita/day and a maximum of 400 g/capita/day. Qatar is an anomaly with an exceptional fruit and vegetable intake of close to 800 g/capita/day.

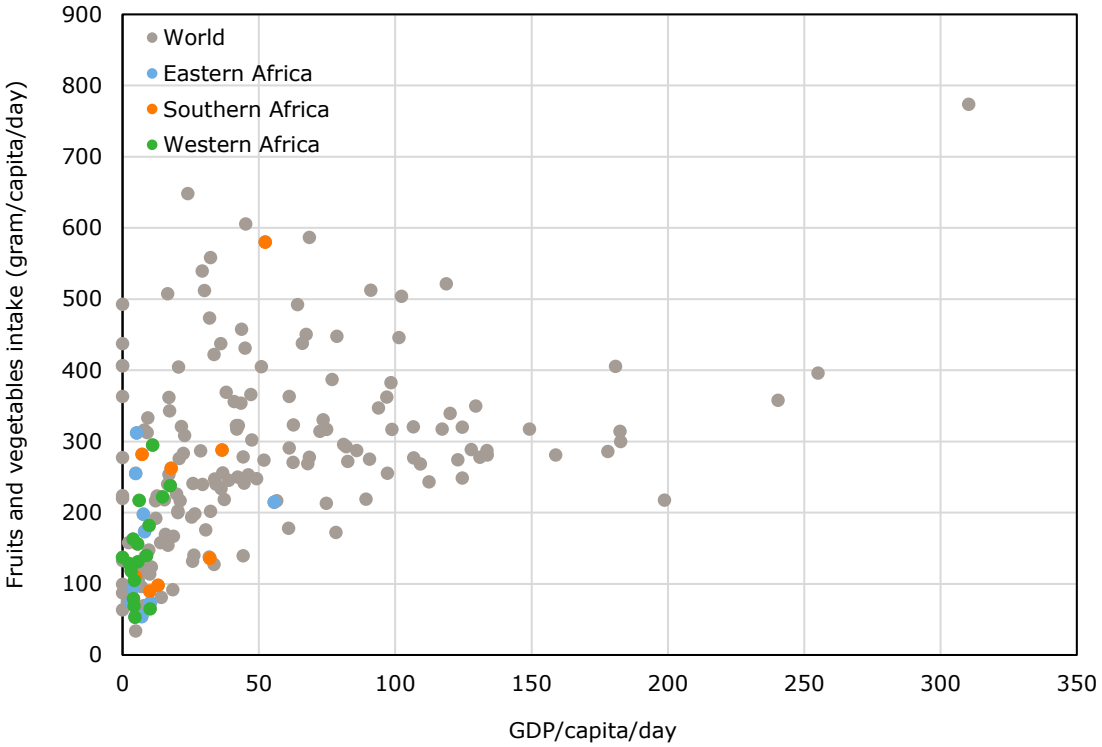


Figure 5.7a *National data on 2017 fruit and vegetable intake against 2017 GDP in constant 2011 international USD for the world (outlier: Qatar)*
Source: Food Systems Dashboard, available at: http://www.foodsystemdashboard.org/ [Accessed: 7 September2020] and FAOSTAT [Accessed: 7 September2020].

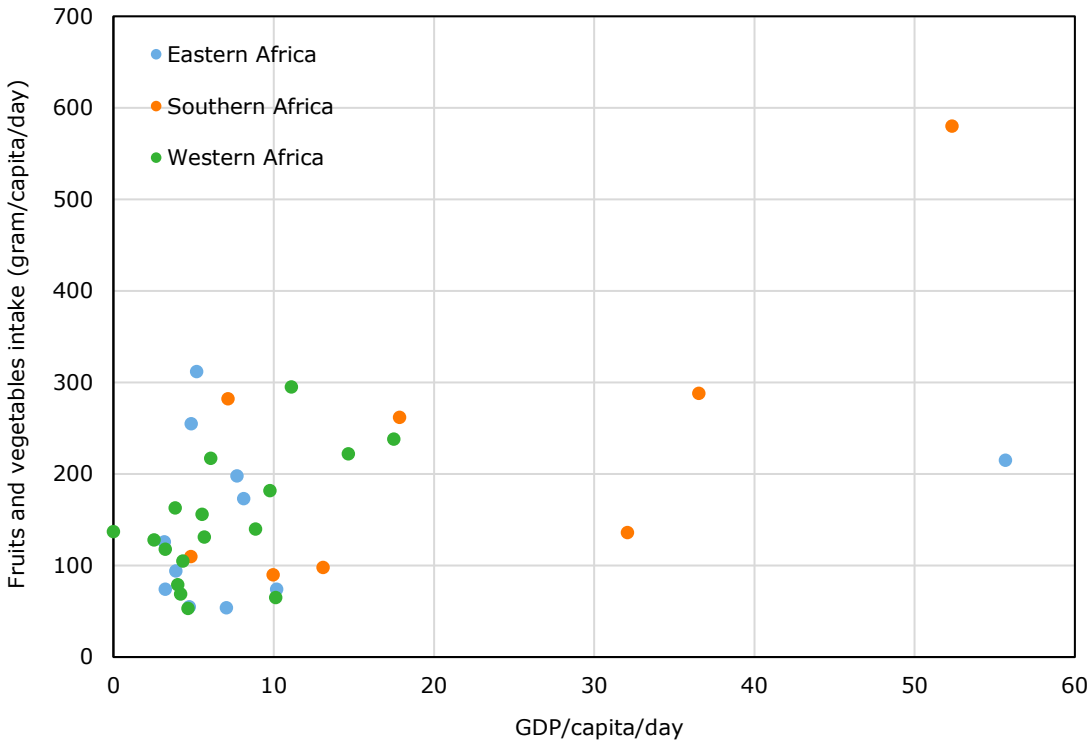


Figure 5.7b *National data on 2017 fruit and vegetable intake against 2017 GDP in constant 2011 international USD for the specific regions of Eastern Africa, Western Africa and Southern Asia Source: Food Systems Dashboard, available at: http://www.foodsystemdashboard.org/ [Accessed: 7 September2020] and FAOSTAT [Accessed: 7 September2020].*

Available literature does not suggest substantial differences in fruit and vegetable consumption between men and women, although there are regional differences. On a global level, Micha et al. (2015) found no substantial difference in fruit and vegetable intake between men and women within their sample (Micha et al., 2012). However, they observed that women nearly always consumed a diet with slightly higher intakes of healthy foods (including fruit, vegetables) and lower amounts of less healthy foods (including processed meats). Also, Frank et al. (2019) found no significant difference between men and women with regards to meeting the WHO recommendation for fruit and vegetable consumption at the global level, although in Latin America and the Caribbean women were more likely to meet the WHO recommendations when compared to men.

Results on associations between fruit and vegetable consumption and age in the adult population remain inconclusive, although adolescents seem to have lower intakes compared to adults. The Food System Dashboard does not report intake per age group. Whereas Frank et al. (2019) found no significant difference in the prevalence of adults meeting the WHO recommendations across different age groups, Micha et al. (2015) did find generally higher intakes of fruits and vegetables among older adults. The authors of both studies recognize that the relationship between age and fruit and vegetable consumption is affected by regional or country-specific differences. More information is available for adolescents, whose daily fruit and vegetable intake appears to be well below the WHO recommended amounts (Beal et al., 2019). This is confirmed by the 2018 Global Nutrition Report, stating that approximately a third (30.3%) of school-aged children do not consume fruits on a daily basis (UNICEF, 2018). Also, data from 2014, presented in the Food Systems Dashboard, indicates a large consumption gap among adolescents; however, only data on the European region is presented (see Appendix 9). Although Vereecken et al. (2015) observed an overall positive trend in fruit and vegetable consumption for adolescents living in European and North American countries/regions from 2002 to 2010, they also observed that a substantial proportion of adolescents do not consume fruits and vegetables on a daily basis. data for consumption of fruits and vegetables in children aged two to 13 years is, to our knowledge, not available. For children below the age of two, dietary intake is monitored through Infant and Young Child Feeding (IYCF) indicators. Global estimates from 2016 show that only 41.1%of the included children below the age of two consumed foods from the food group 'vitamin A-rich vegetables or fruits' in the

previous day and foods from the group 'other fruits/vegetables' were consumed by only 20.8% (White et al., 2017).

Future projections of expected intake of fruits and vegetables show that the intakes of fruits and vegetables may increase further, but it is likely that availability will remain below the WHO recommendations for many countries. To our knowledge, Mason-D'Croz et al. (2019) is the only study estimating global and regional future intake of fruits and vegetables. Based on Food Balance Sheet data and using three development pathway scenarios (anticipated optimistic, middle-of-the-road, and pessimistic), the global average availability of fruits and vegetables is projected to vary between 608 g and 862 g per person per day in 2050, see Figure 5.8. The study shows a large variability between and within regions. All countries in sub-Saharan Africa and numerous countries in Asia and the Pacific will not be able to supply the minimum of 400 g per person per day in 2050. In East Asia and the Pacific, and in South Asia, the regional increase in fruit and vegetable intake is mainly driven by improvements in availability in China and South Korea, and India, respectively. It should be noted that these availability estimates do not consider food waste at the household level. When including a food waste percentage of 33% (high countries estimate) in the projections for 2050, Mason-D'Croz et al. (2019) found that worldwide only 19 would have an adequate fruit and vegetable availability to meet the WHO recommendation of ≥400 g/ per person per day. The well-known limitations of using Food Balance Sheet data should be acknowledged, including the absence of data on food waste (from cooking, spoilage or plate waste), on meals consumed outside of the home, on home farming and/or production, and on food obtained from non-retail/informal markets. These factors can be common in many LMIC contexts. Del Gobbo et al. (2015) found an overestimation of vegetable intake by nearly 75% when based on the Food Balance sheets compared with data from the Global Dietary Database (GDD) while bean and legume intake was underestimated by 50%. The availability gap presented by Mason-D'Croz, even in the optimistic scenario, might therefore be larger than expected (Del Gobbo et al., 2015).

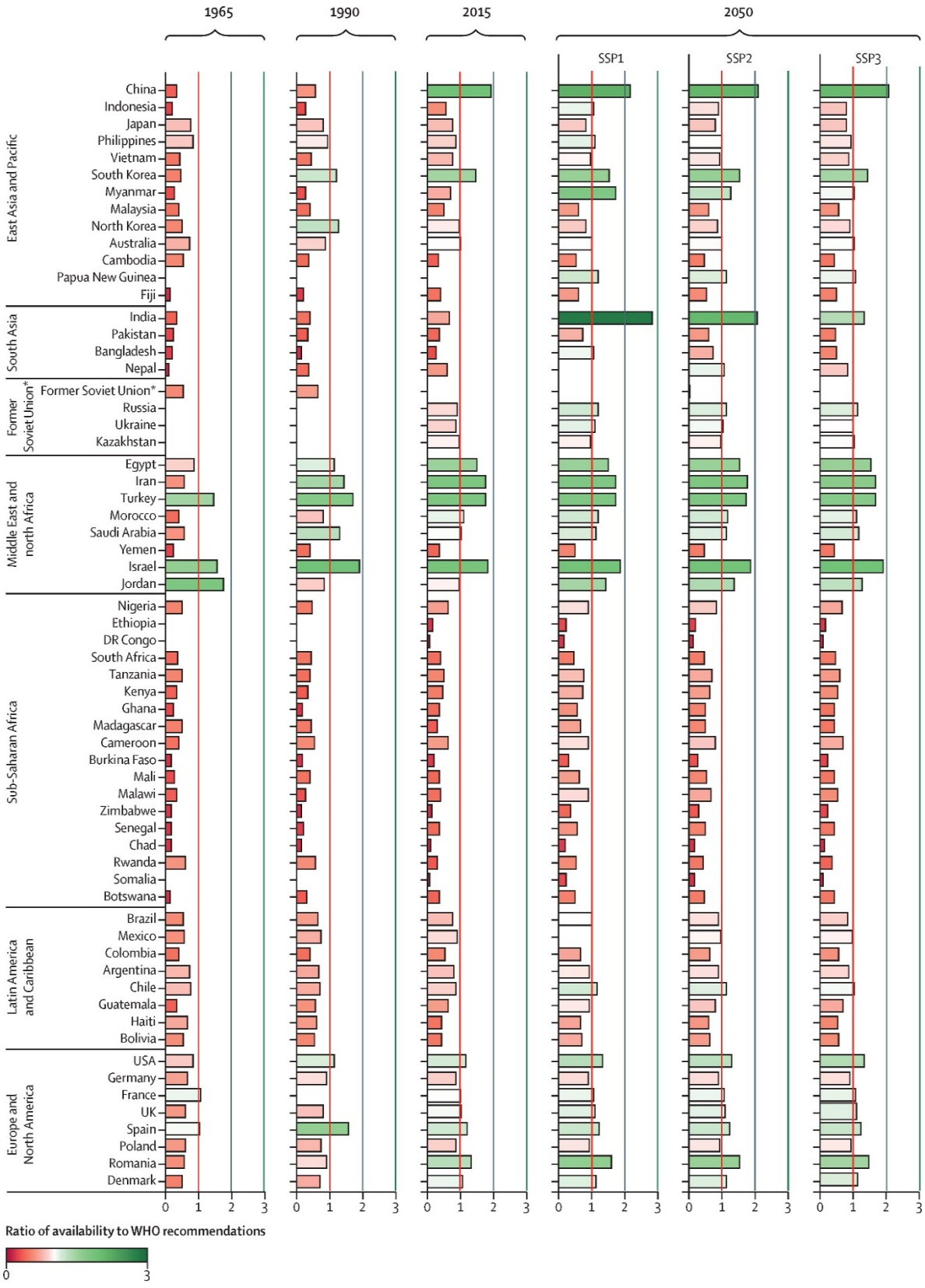


Figure 5.8 *Selected country ratios of fruit and vegetable availability to WHO age-specific recommendations*
Source: Mason-D'Croz et al. (2019).

5.5 Affordability of fruits and vegetables

To understand food purchases and consumption, it is important to explore the costs of food and its relationship with consumption and food security.

The recently launched FAO SOFI (State of Food Security and Nutrition in the World) report 2020 provides valuable insights for the costs of food groups by region, including fruits and vegetables (Figure 5.9). This figure was constructed based on the results from the World Bank's International Comparison Program (ICP) 2017. The regions shown do not include East Africa and West Africa separately, but aggregate these regions under sub-Saharan Africa. Figure 5.9 shows that the costs of fruits and vegetables in Southern Asia and sub-Saharan Africa are high (above global average).

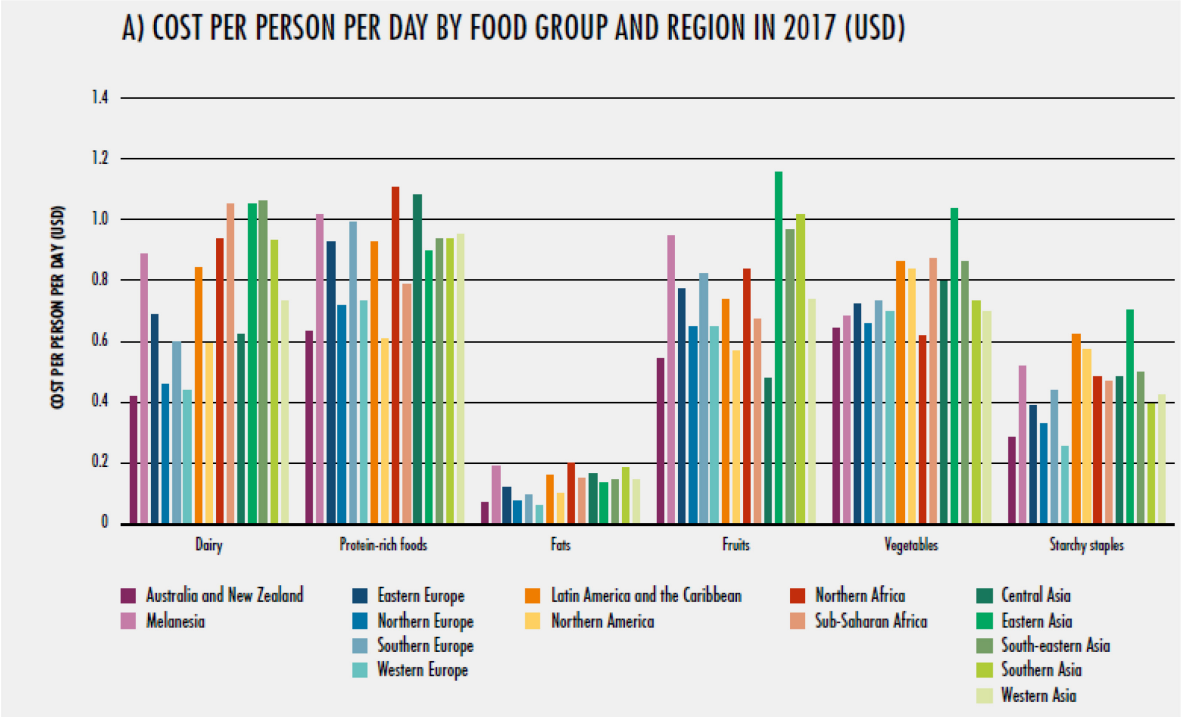


Figure 5.9 *Costs of food in USD per person per day by food group and region in 2017*
Source: FAO.

The money a person spends on fruits and vegetables per day is the highest in East Asia because people form that region have the tradition of eating more fruits and vegetables. North Africans spend the least money per person per day in purchasing vegetables, while Central Asians spend the least on fruits.

To gain insights into the costs of fruits and vegetables in the target countries, the indicator "Expenditure shares (GDP = 100)" from the ICP 2017 was used to show the percentages of the total GDP that is accounted for by fruits and vegetables (Figure 5.10). The costs registered in ICP 2017 are the retail costs, which can reflect the actual payments that consumers made to buy the food. In general, the expenditure on fruits and vegetables accounts for a significant proportion of the GDP in the target countries (see Figure 5.10). In addition, the target countries spent more on buying vegetables than fruits, except in Tanzania and India. All countries spent between 2.5% and 12% of GDP on purchasing fruits and vegetables, with Nigeria as an extraordinary exception with a GDP expenditure on fruits and vegetables of over 29%, although this high percentage is suspicious. This suggests that the prices for fruits and vegetables in the three targeted regions are high.

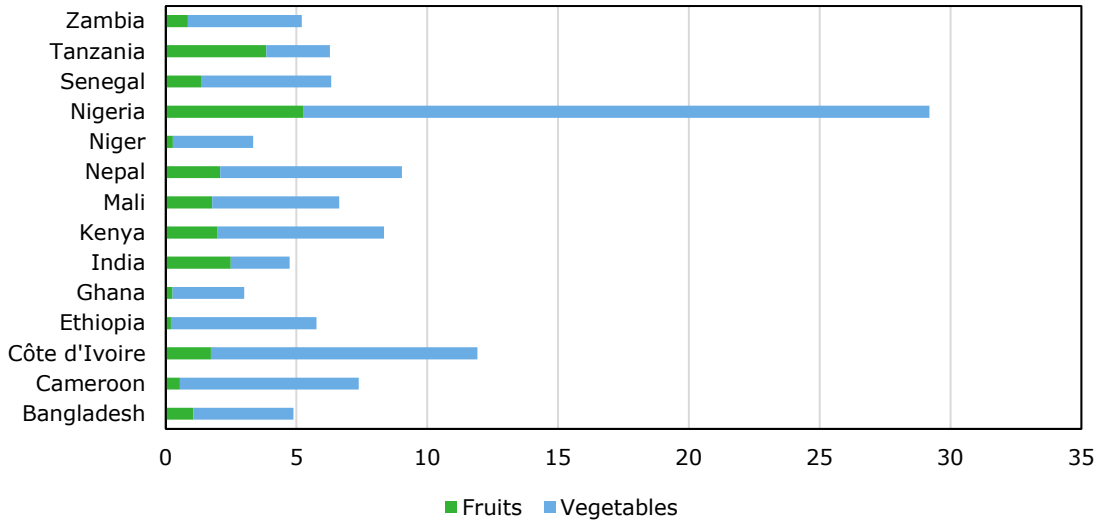


Figure 5.10 *Expenditure shares (GDP = 100) for fruits and vegetables*
Source: ICP (2017).

Prices of fruit and vegetables are usually very volatile. This is due to their seasonality and perishable nature. This differs per region and crop, but most fruits have a season of limited availability and within such a season, moments of peak production. With limited cold storage facilities in place, this often leads to bottom prices, whereas the prices increase rapidly when supply falls below demand. Figure 5.11 shows that the price volatility is high with a short supply window compared to when distributing the supply quantity throughout a longer period. When the price volatility is high, it means that the large numbers of people belonging to the low- and lowest income groups may only be able to purchase low-quality fruits and vegetables or only at moments of oversupply when prices are low (even though the diverse harvesting time for fruits and vegetables can mitigate this problem to some extent). This is in line with the finding from (Muhammad et al., 2017) that the purchase of fruits is sensitive to changes in income and prices. It also complies with the insights from the SOFI report 2020 that demand for fruits and vegetables has been traditionally more sensitive to price change than that of staple foods. This is because fruit and vegetable production is likely more labor-intensive and their storability is relatively low.

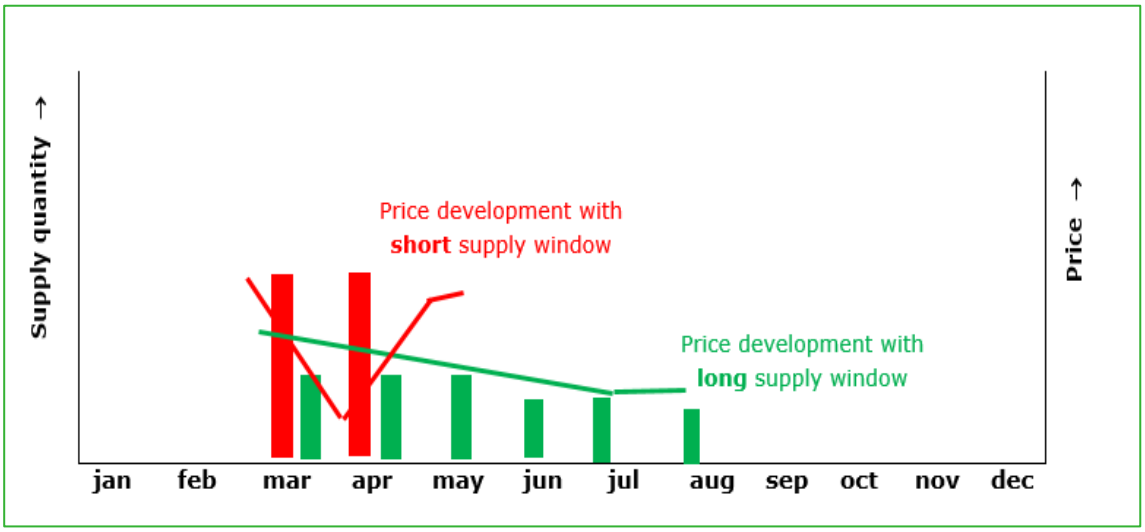


Figure 5.11 *Illustrative effect of supply quantity and window on prices for fresh produce*
Source: WFBR.

As fruit and vegetable prices show large fluctuation and the percentage of income spent on food is high for most population groups, it is important to understand the percentages of household income spent on food, particularly on fruits and vegetables. Prices appear to be the most decisive factor influencing food choice, as study results from South Africa indicate (Kroll, 2016). Food prices and energy density seem to be important drivers and constraints of food choices in South Africa to the extent that many people simply cannot afford a "healthy" diet (Temple and Steyn, 2011). There is reason to believe that this works the same way for people in the same circumstances (the poorest and the poor) in other regions. The availability window and corresponding price levels are the main influence on fruit and vegetable consumption for large groups of consumers.

The percentage of household expenditure on food is an indicator of food security as rising food prices significantly affect the household's expenditure. In general, the poorer the country, the higher the percentage of household income is spent on food. Rising food prices may drive the poorer households to reduce the quality and quantity of food they consume. FAOSTAT provides limited data on this as not all countries are covered and most of the data stems from 2000 to 2006. Households spending 50%-65% of their income on food are considered medium food insecure, while a 65-75% expenditure on food is considered high food insecurity. If a country on average spends less than 50% from income on food, however, a large part of its population may still spend a higher percentage of household income on food and have a lower food security rate. The populations of the targeted countries in the three regions, in general, spend more than 50% of their household income on food, which indicates concern about food security in these countries.

Access to a diverse diet is key in the prevention on chronic undernutrition (Arimond and Ruel, 2004). However, in many LMICs food consumption patterns are dominated by staple food crops, while little amounts of fruit and vegetables (especially vitamin A rich vegetables) and animal-sourced foods are consumed (Hirvonen et al., 2016; Ruel et al., 2005). This is even more apparent in rural areas. It was found that poor dietary diversity can be partly explained by a lack of knowledge on the beneficial health effects of a diverse diet and by limited access to markets. Yet, even when fulfilling these two conditions, the affordability of nutritionally rich foods was found to be the main constraint in the consumption of a diverse diet (Warren and Frongillo, 2017). In general, research into prices of nutritious food and its affordability, to better understand the determinants of poor dietary diversity, has received relatively little attention.

The consumer price patterns of different food groups were analyzed in Ethiopia during the period 2007–2016 (Bachewe et al., 2017). While prices of grains, roots and tubers, oils and fat, and sugar and honey decreased, an 80% increase in the vitamin A rich vegetable group was found, as seen in Figure 5.12. Also, the other fruit and vegetable food groups showed an increase by about 40%. A worrisome finding, as described by the authors, since these food groups contain essential micronutrients that are not abundant in staple crops and current price trends limit their accessibility for poor households. The higher cost of nutrient-dense foods when compared to energy-dense foods (grains, added sugar, added fats) is known and confirmed by several other studies (Drewnowski and Specter 2004; Maillot et al., 2010; Global Panel on Agriculture and Food Systems for Nutrition. 2016; Dizon and Herforth 2018). A global shift towards healthier diets requires the accessibility and affordability of nutritious food for all populations. The EAT-Lancet report aimed to describe a universal reference diet, healthy for both humans and planet (Willett et al., 2019). Although the importance of cost and affordability of the reference diet was recognized by the Commission, it was not considered in the report. Hirvonen et al. (2019) analyzed the proposed diet in the EAT lancet report and calculated its cost, as well as the costs of different components of the diet (i.e. food groups). On a global level, the costs of an EAT-Lancet reference diet exceed total income for at least 1.58 billion people, out of which 80% are in middle-income countries. The prevalence of individuals with total household income per person below the estimated least-cost Eat-Lancet reference diet is highest in sub-Saharan Africa (57.2%) followed by South Asia (38.4%). Globally, the price of fruit and vegetables were found to account for the largest share (31.2%) of the total costs of the EAT-Lancet reference diet (based on a daily fruit and vegetable serving of 423 g, excluding legumes). This share of the total diet cost equaled 26.7% and 29.7% in lower-middle and low-income countries, respectively. Comparing the costs of diets to 63% of the international poverty line of US$1.90 a day, Herforth et al. (2020) arrive at much larger figures: worldwide 3 billion people lack sufficient income to purchase the least-cost

form of healthy diets, the majority residing in South Asia (1.3 billion) and sub-Saharan Africa (829 million), with large numbers also in South- East Asia (326 million) and East Asia (230 million). Fruits and vegetables make up about 40% of the cost of healthy diets (Herforth et al., 2020).

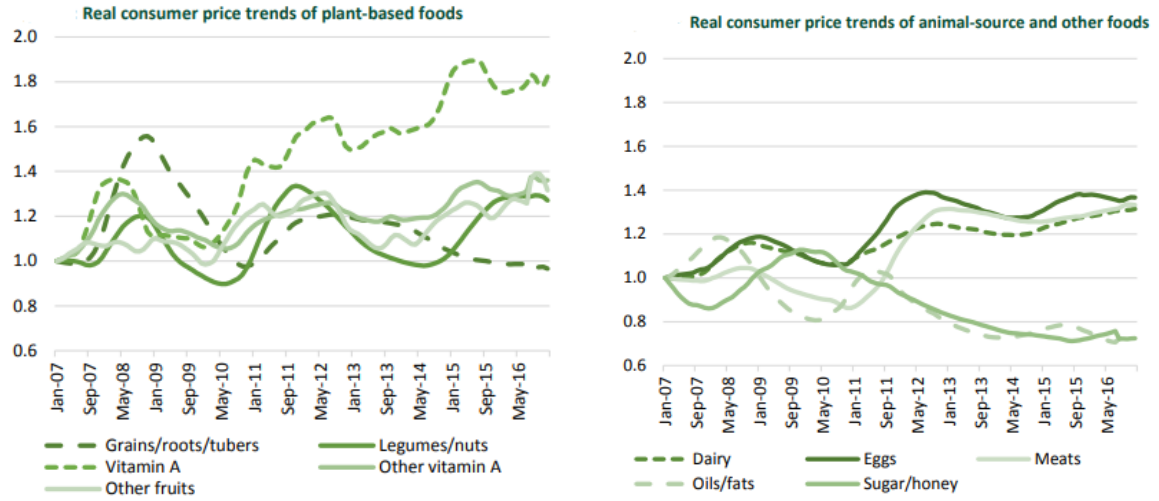


Figure 5.12 *Real consumer price trends of plant-based foods and other foods in Ethiopia, 2007-2016*
Source: Bachewe et al. (2017).
Vitamin A = Vitamin A rich dark green leafy vegetables; Other Vitamin A rich fruit and vegetable

5.6 Safety concerns of fruits and vegetables

In general, consumer perceptions of food safety affect their food choices and may reduce consumption of fruits and vegetables. A study in Vietnam reported that urban consumers' concerns about food safety in vegetables reduced their consumption by 14% (Ngo et al., 2020). Concerns about foods in LMICs are mainly related to the consumption of fresh, perishable foods, such as fresh fruits and vegetables and animal sourced foods (i.e. meat, milk, eggs and aquatic animals) from informal and domestic markets. These markets include wet markets for fresh produce, informal and formal micro and small enterprises engaged in the processing of foods and street foods. Food safety practices in these markets tend to be weak, compounded by risks in food preparation and consumption practices, for example the use of contaminated water to wash fresh produce or the absence of refrigeration in storage of fresh produce (Jaffee et al., 2019).

Foodborne diseases caused by biological contamination of food are an important threat to public health (Havelaar et al., 2015) in LMICs. Foodborne contaminants are numerous and comprise viruses, bacteria, parasites, chemicals, toxins and allergens. According to the WHO, 31 major food safety hazards were responsible for 600 million illnesses (95% uncertainty interval [UI] 420-960) and 420,000 deaths (95% UI 310,000-600,000) worldwide in 2010, and led to the loss of 33 million (95% UI 25-46) DALYs (Havelaar et al., 2015). The vast majority of the food-borne deaths and DALYs were found to be caused by diarrheal disease agents (54%), especially bacteria (44%). The health burden is disproportionally higher among children under five years of age and LMICs. Repeated episodes of enteric disease during early childhood interferes with nutrient absorption and is an important contributor to both stunted physical growth and impaired cognitive development, leading to negative impacts on long-term economic outcomes (Hoffmann et al., 2019). There are considerable regional differences in the burden of foodborne diseases (see Figure 5.13). The highest burden was observed in Africa and South-East Asia, especially due to diarrheal disease agents and, to a lower extent, to invasive infectious disease agents (South-East Asia) and helminths (Africa) (Havelaar et al., 2015).

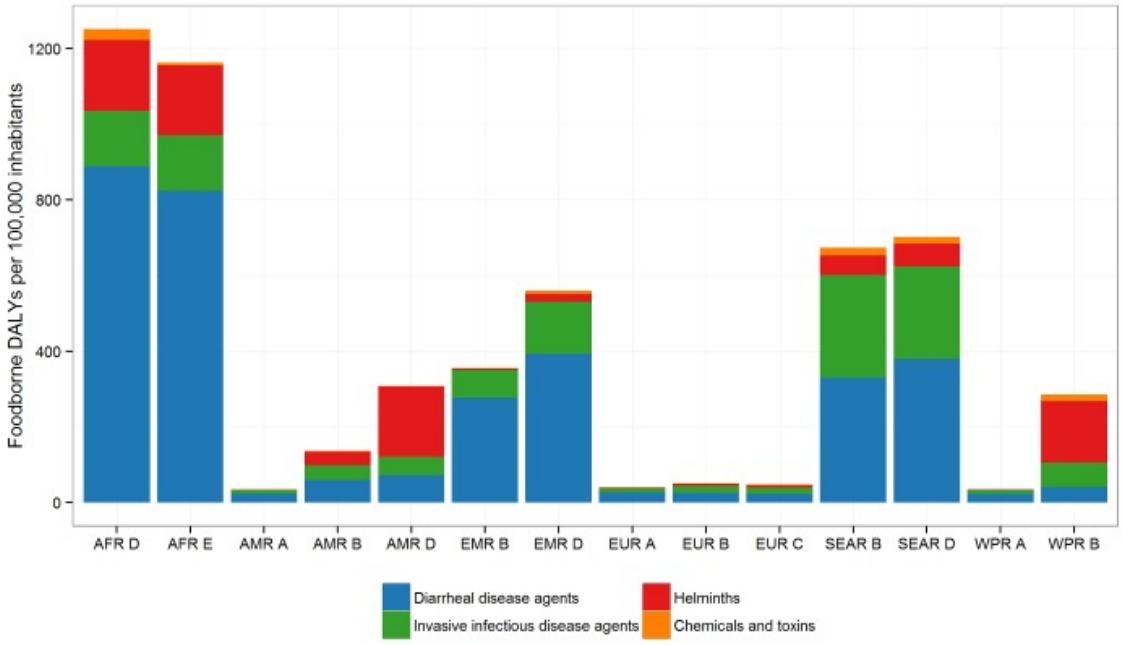


Figure 5.13 *The global burden of foodborne diseases: DALYs per 100,000 population by hazard groups and by sub-regions for 2010 (see Appendix 10 for the definitions of the sub-regions) Source: Havelaar et al. (2015).*

Based on structured expert elicitation, Hoffmann et al. (2017) developed estimates of the role of specific foods in 11 of the 31 foodborne diseases to the point of exposure. For the parasites, *Ascaris* spp., *Echinococcus granulosus*, *Echinococcus multilocularis*, *Entamoeba histolytica*, *Giardia* spp., and *Cryptosporidium* spp. (responsible for 13% of the 600 million diseases and 4% of deaths due to food-borne diseases), vegetables are estimated to be the largest source of foodborne illness, accounting for 60% to 80% of illness in most subregions. The role of vegetables is estimated to be particularly important for *Ascaris* (over 90% for several subregions). Fruits and nuts are the second-largest sources of parasite contamination, with limited variation between sub-regions. Although animal sourced foods are the major source of bacterial exposure, vegetables do play a (limited) role in toxoplasmosis (responsible for 2% of food-borne diseases), especially in the South-East Asia Region (causing about 20% of food-borne toxoplasmosis), while fruits and vegetables account for less than 15% of campylobacteriosis (in total responsible for 16% of total food-borne diseases) and for less than 10% of non-typhoidal Salmonellosis (in total responsible for 13% of total food-borne diseases) (Havelaar et al., 2015; Hoffmann et al., 2017).

The current state of knowledge is not sufficient to estimate the overall health burden associated with chemicals in foods in general, let alone for fruits and vegetables specifically, in LMICs. There is a high level of concern among the general public about the presence of chemicals in foods, including metals, pesticides, growth promotors, chemicals added to food during processing, chemicals added to adulterate food, dioxins and toxins produced by cooking (polycyclic aromatic hydrocarbons and acrylamides) (see also section 8 on production). Various studies show widespread misuse of chemicals (e.g., Schreinemachers et al., 2020); use of obsolete, unduly hazardous and banned chemicals; the presence of chemicals in food above permitted levels; and foods imported from LMICs having higher levels of chemicals than those imported from developed countries. As a result, the suspicion is that the impacts of such chemicals in food could be substantial (Grace, 2015). Use of pesticides is greater on high-value vegetables to protect investments (Schreinemachers et al., 2018). Farm workers are especially at risk through high exposure, leading to short-and long-term health effects like vomiting and different types of cancer (Bonner and Alavanja, 2017).

If strategies to increase fruit and vegetable consumption by improving knowledge, accessibility and affordability are to be successful and consumption indeed increases to meet the global recommendations, it is expected that the risk of food-borne diseases in LMICs will also increase accordingly. When food chains become longer and more complex, the spread of hazards and risks may

increase, especially when the chain expansion happens in advance of effective governance (Grace, 2015) and sacrifices on food safety may happen due to increased pressure on supply chain actors to reduce prices and meet ends (Tschirley et al., 2015). Although in LMICs, fresh fruits and vegetables are and will remain mainly sourced from informal or domestic markets (Jaffee et al., 2019), the role of supermarkets in providing these foods may increase. It is commonly believed that supermarket food is safer than informal market food, but for animal sourced foods, it is reported that food sold in the formal sector was no better (and sometimes worse) at meeting standards than food sold in the informal sector (Grace, 2015).

5.7 Gendered constraints and barriers to consumption of vegetables and fruit

Globally, women face structural and socio-cultural challenges that affect all areas of their lives (Halliday et al., 2020). Understanding the unique barriers women face in accessing fruits and vegetables in their diet can help strengthen approaches to increase their access to this important source of household nutritional security. Households are argued to be the primary sites of food consumption. The common assumption that women "steer" household-based consumption choices oversimplifies gender dynamics within households. Femininity and masculinity dynamically shape consumption decisions (UNEP, 2016). They introduce and re-produce gender related dynamics to all areas including household consumption trends. To achieve optimal food and nutrition outcomes through food production or nutrition practices, it is important to examine the synergies across agriculture, nutrition and gender, to identify the socio-cultural factors and institutions that gender dynamics introduce to consumption patterns of different populations (Fischer et al., 2017). This section examines the gendered constraints to the consumption of vegetables and fruits by looking at the socio-economic factors in different global regions.

Socio-cultural norms, beliefs and practices are a major consumption barrier in LMICs. This is orchestrated through household roles, cultural institutions and resource dynamics, which includes access to and allocation of time and money (Alkire et al., 2013; Kamga, 2013; Raj, 2017). Despite this, gender inequality remains a neglected aspect of the sustainable nutrition discourse, yet it can be explored to support nutrition security and more holistic consumption patterns. The food and nutrition security of women can be disproportionately compromised because they shoulder the responsibility for feeding their families and communities; while they often eat last and eat least, both in terms of quality and quantity. In global policy, providing food and nutrition security for women and girls is of foremost importance (UNEP, 2016). In practice, women's dominant role in family food preparation and care has seen that their nutritional needs are often highlighted in relation to their maternity roles (KIT et al., 2017). Gender narratives around food consumption emerge from the inequalities seen in food taboos that influence food allocation by sanctioning against and promoting certain foods for different groups (Kamga, 2013). Gender inequalities affect women's nutrition through unfavorable intra-household food distribution patterns and poor access to crucial resources. The dynamic socio-cultural institutions around these inequalities means there are no easy solutions (Niehof, 2019). Gender inequalities are embedded in cultural practices which propel an intergenerational cycle of female undernutrition. In developing countries, there is a visible differential food treatment of sons and daughters that starts at infancy leading to a vicious cycle of female undernutrition. In response to the consumption gender gaps, nutrition programs are primarily designed to target women, further reinforcing the absence of men from the food consumption dialogue. Adopting male-inclusive food and nutrition intervention as a strategy, is important for effective household nutritional wellbeing (van den Bold et al., 2013). Climate change amplifies existing gender inequalities in consumption patterns. Its related uncertainty puts pressure on the already fragile, under-valued and precarious gendered roles and responsibilities at the community level, and their impacts.

These gendered household roles, cultural institutions and resource dynamics translate to suboptimal nutritional outcomes. In South Asia, despite gender inequality intervention efforts, in different regions, the overall picture remains problematic (ADB, 2016). Patriarchal ideology and traditions, inequality legitimated by caste and notions of impurity contributes to son preference in large parts of South Asia.

The low social status of women and girls, means worse female nutrition outcomes. In India, lack of diversity in diets, especially with regard to fruits, vegetables and pulses, has contributed to deficient intake of essential micro-nutrients, especially among women (Narayanan, 2018). It also highlights the variations in nutrient intake across the life cycle, determined by gender and other socio-economic factors and lifestyles. Nutrition strategies need to consider the unique needs of both men and women with specific suggestions for increasing access to fruits and vegetables by way of better distribution and support for farming households for the production of food crops, including direct feeding programs (Niehof, 2019). Micronutrient deficiencies are a serious public health problem among women of reproductive age in LMICs, including India, affecting maternal and child health and human capital outcomes. Despite having a large vegetarian population, rural Indian women consume fruit and vegetables infrequently. Women's awareness that they should eat green leafy vegetables frequently does not translate into increased consumption due to challenges such as lack of availability of vegetables (Kehoe et al., 2019a). India's cereal dominated diet is woefully inadequate for meeting vegetable and fruit requirements. Under three-year-old children, adolescent boys and adult women are the most vulnerable. Child feeding is primarily considered a woman's activity, with women carrying the triple burden of home maintenance, participation in economic activity and childcare. Household food consumption choices are often influenced by these time constraints, with women settling for affordable, less time-consuming options; nutritional value in this case often becomes a secondary selection criterion. Adolescent boys face energy intake and micronutrient deficits. Vegetable consumption is lower among adult women as compared with men, hence increased anemia due to iron deficiency. Women are likely to be more disadvantaged than men due to social and cultural practices that deny appropriate food at critical developmental moments (Narayanan, 2018). In East Africa, food trees provide fruits, leaves and seeds that contribute substantially to the food and nutrition security of African rural households. A study done in Kenya and Uganda shows that there is a wealth of local knowledge on food tree species for cultivation and use for various household needs. For both old and young women, diverse food tree species help to fill food and nutrition gaps and provide nutritional diversity (Mutisya et al., 2015).

At the regional level, there is limited data that highlights gender related consumption patterns around fruits and vegetables (Miller et al., 2017). In addition, there is also the perception that vegetables are a "food for the poor". Eating meat is often interpreted as a sign of prosperity, therefore, when people become richer they do not want to be seen eating vegetables, especially among men. This influences consumption patterns amongst different household members and community groups (Kamga, 2013). Data is silent on the influence of gender-related household roles, cultural institutions and resource dynamics (time and money) on household consumption patterns. Despite the empirical data gap on urban and rural differences in fruit and vegetable consumption in LMICs, gender-related reflection can be harnessed to improve household nutrition (Afshin et al., 2019; Lentz, 2020). Although nutrition literacy programs consist of technical nutrition messages largely targeted at women, who are custodians of household nutrition, there is a need for community programs which target both men and women (van den Bold et al., 2013).

6 Fruit and vegetable supply chains

6.1 Approach

The previous chapter identified several factors constraining fruit and vegetable consumption. This includes high prices, low year-round availability, and limited consumer awareness about the importance of sufficient fruit and vegetable consumption. In this chapter, we study the fruit and vegetable supply chains and the market to understand how they relate to the uptake of fruits and vegetables. The sections within this chapter contain the following elements:

- *Value chain mapping*: Value chain maps provide a visual depiction of all the different flows and actors (e.g., input suppliers, service providers, producers, traders, retailers etc.). We drafted comparable value chain maps within the food system (including classifications such as informal, formal, rural, urban, export and regional). These fruit and vegetable supply systems function largely independently, although one system may use input from another system to balance demand and supply (including spillover effects from export markets to domestic markets).
- *Value chain analysis (VCA)*: We identify and assess the presence of all key value chain actors, including enabling and supporting actors. We describe the common network structure and the role of each actor involved in the fruit and vegetable supply chain and the chain network. A network has two dimensions: vertical and horizontal. The vertical dimension reflects the flow of products and services from primary producer up to end-consumer (i.e., the supply chain). The horizontal dimension reflects relationships between actors in the same chain link (e.g., between farmers in cooperatives, etc.).
- *Value added and the margin between actors*: Value addition is created at different stages and by different actors throughout the fruit and vegetable food supply system. The value added is quantified based on existing literature. The margin refers to the difference between the selling and buying price. The margin and producer share can indicate the performance of the supply chain.
- *Governance*: Elements of supply chain governance are studied as embedded in the value chain's business environment, where we focus on markets, resources and infrastructures and institutions. Most relationships in the supply chain are long term, with family members or intermediaries who are members of the same community, based on trust and commitment (Trienekens, 2011). We describe the relevant organizational arrangements in the fruit and vegetable supply chain. We describe relevant developments regarding certification of horticultural produce for the export market and emerging certification initiatives for local markets. We highlight the differences in the institutional environment and the (macro-economic) policies pursued in the three regions and how these have shaped the fruit and vegetable sector, as well as the types of institutional arrangements that have emerged.

6.2 Mapping

The configurations of fruit and vegetable supply chains in the studied regions can vary significantly by product and country. Nonetheless, it is possible to distinguish three broad common types (A, B, and C) as described in various studies (Ruben et al., 2007; Trienekens, 2011), see Figure 6.1. Type A serves the local low-income market, Type B serves the local middle- and upper-income markets, and Type C is export-oriented (exclusive of regional markets). By far most of the fruits and vegetables produced in South Asia, East Africa and West Africa are consumed locally and are produced by smallholder farmers. In Kenya, for example, 90% of all fruits and vegetables are consumed domestically (Gema et al., 2018).

Rural farmers are mostly trading on the informal market where prices are set on a spot market. A spot market is a cash market with an immediate exchange of goods. In the end, the produce is sold via many different steps in the chain to various types of informal traders who supply the local low-income retail markets.

In urban areas, fruits and vegetables produced for local markets are often grown inside or near the city limits (Levasseur et al. 2007). Shorter shelf life (highly perishable) products are generally grown in a first ring around the city and longer shelf life products are grown in a second ring. Less perishable crops are traded regionally, such as onions, which are transported via trucks across West Africa (Nugteren, 2018). However, Nigeria is one of many exceptions where the distance to market between farmers of perishable products (e.g., tomatoes) in the northern regions and consumers in the urban south is roughly 1,000 km and it can take several days before produce arrives at the urban markets (Plaisier et al., 2019).

Type B fruit and vegetable supply chains are where, recently, most growth and development has taken place in many emerging economies (Reardon et al., 2012, 2007). The rise of supermarkets in LMIC economies is made possible by the increasing urbanization and rise of the middle class. In Asia, the supermarket revolution has different drivers (Reardon et al., 2012, 2007). A key driver is that many international retailers started to become active, including through foreign direct investments. Asia's supermarket revolution exhibited pathways of procurement system change (i.e., the way the procurement took place) and there has been penetration of rural towns by rural supermarkets and rural business hubs. Several approaches were introduced to link small farmers to supermarkets. Some are unique to Asia, for example, assembling into a "rural business hub" or "platform" with various companies and services that link farmers to the supermarket market.

In sub-Saharan Africa, the developments in the value supply Type B, are mainly influenced by the rise of South African supermarket chains. However, supermarkets remain only a small share of the market. In urban areas, where incomes are higher and populations denser, supermarkets are more present. In East African cities, there are various large multinational supermarkets, several locally-owned small to medium-sized supermarkets spread out in all the suburbs, as well as different petrol stations that have small supermarkets. In urban areas, middle and upper class consumers in West Africa increasingly shop in supermarkets and retail shops, over marketplaces.

It is a challenge for smallholder farmers to supply supermarkets, since the scale of procurement is typically much larger and requires both volume and coordination among suppliers and between suppliers and retailers and their intermediaries. Aggregation seems to be a requirement to reduce transaction costs to sell to modern channels (Reardon et al., 2012). Growing domestic demand for quality fresh produce from supermarket chains in Africa and South Asia could be a key driver to support farming as a commercial business.

The third supply chain arrangement (Type C) is focused on the high-value export market and is found in all regions. Table 6.1 shows the export volumes of each region, by commodity and destination. South Asia exports relatively high volumes of fruit and vegetables to Europe, the Middle East and South-East Asia. East Africa exports vegetables to Europe, but also high volumes of fruit to the Middle East. West Africa mainly exports fruits to Europe. The third supply chain arrangement (Type C) is found, for example, in Kenya, Ethiopia, Burkina Faso, Côte d'Ivoire, Senegal and India. There are also significant import flows because mainly African countries are also importing fruits and vegetables from outside Africa (e.g., onions, tomato paste, carrots, potatoes).

Table 6.1 *Export volumes of fruit and vegetables (2018)*

	Destination:	**Europe**		**Middle East and North Africa**		**SE Asia**	
Exporter:	***Commodity:***	**Veg (t)**	**Fruit (t)**	**Veg (t)**	**Fruit (t)**	**Veg (t)**	**Fruit (t)**
East African Community		76,300	3,500	65,700	40,100	0.7	1,100
West Africa		78,100	724,000	191	16,700	237	18
South Asia		168,000	208,000	840,000	566,000	624,000	122,000

Source: UN Comtrade.

For the export markets, innovations in products and presentation (branding, package innovation, variety innovation, etc.) are a constant factor, which implies that farmers and exporters need to continuously

invest. In terms of the level of supply chain integration and transparency, this supply chain is most developed. Type C chains are also faced with a high level of international competition. Fruits and vegetables rejected by exporters are sold on the domestic market (van den Broek et al., 2016).

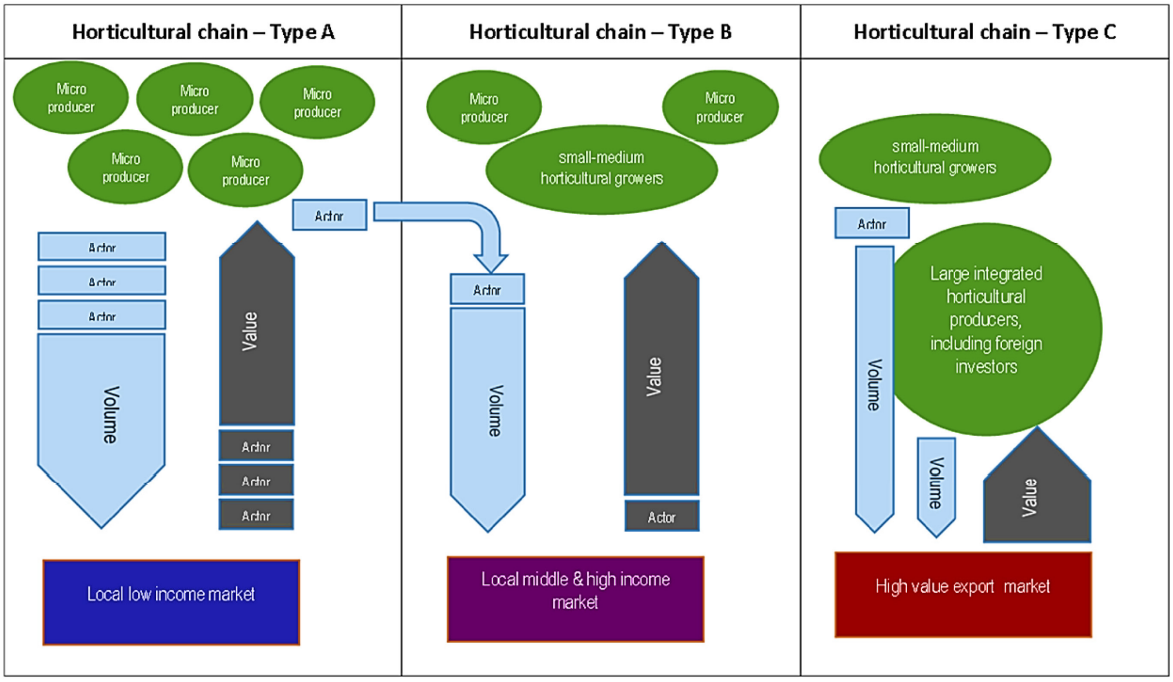


Figure 6.1 *Different fruit and vegetable supply chain configurations*
Source: Ruben et al. (2007); Trienekens (2011).

6.3 Value chain analysis

Each value chain configuration has a different market orientation and differs in terms of organization, number and type of actors, and governance. This will be discussed in the following sections.

6.3.1 Direct actors

Farmers
Most fruit and vegetable farmers in emerging countries face uncertainty due to the risk of crop failure, and unstable markets. Farmers reduce this risk by avoiding relying on one (high-income) cash crop and hence diversify their range of crops, including subsistence crops. As they do not specialize, they often will only be able to offer small amounts on the market. Smallholders most often grow for the domestic market and usually for urban consumers. Urban and peri-urban farming is increasing, although sometimes considered to be illegal. Urban and peri-urban farming is estimated to account for 60% of vegetables in Dakar. Peri-urban farmers also export some of their produce (Levasseur et al., 2007).

Mainly in Type B chains, there are specialized commercial farmers, that consolidate supplies, organize packaging and supply directly to supermarket chains. These entrepreneurial farmers have often invested in cultivation improvements (e.g., protected cultivation, irrigation, improved varieties) to increase production and to improve quality. Although requirements are not as stringent as EU standards, pesticide residue levels, packaging and product quality are checked. In Type B chains, there is also more attention for harvest practices and post-harvest handling, including cleaning, storage and cooling.

In export-oriented fruit supply chains (Type C), smallholder farmers grow for the overseas markets by supplying the large integrated producers. Because this necessitates a higher level quality of products, the smallholder farmers must comply with more stringent standards (e.g., European standards and

possible additional certification). Export-oriented farming requires a certain level of investment in inputs and know-how, which often comes directly from the export firm via contract farming (FAO and IFAD, 2013). Next to supplying the export market farmers also supply the domestic market.

Large producers
Increasingly, export firms show a preference for higher levels of vertical coordination. By maintaining greater control over farming practices, firms can increase production efficiency and obtain the necessary level of quality for meeting international standards, as well as certifications. The highest level of coordination culminates in estate production, with large-scale plantations employing wage laborers (FAO and IFAD, 2013).

Large producers have been more pro-poor than other sectors in rural areas, increasing income for the lowest earning rural households and decreasing inequality, as in the case of Senegal (Van den Broeck et al., 2017). While there are concerns that large-scale farming (or estate farming) may crowd out smallholders, the plantations provide important employment opportunities. Moreover, estate farming provides rural employment for female workers, who comprise the majority of the workers.

Pisteurs (trader-harvesters)
Pisteurs play a critical role as intermediaries between small-scale farmers and clients (exporters) in the fruit sector of West Africa and, in particular, the pineapple and mango industries. For the exporting client, *pisteurs* sort, grade, and select fruit to provide an export-ready product, and, for the smallholder, they may offer labor and harvesting. The *pisteurs* usually have their own truck, so they often also offer transportation of product from farm to exporting clients. The precise type of agreement and role of the *pisteur* can vary by region, by product, and by *pisteur*. The majority of *pisteurs* buy fruit themselves directly from farmers (acquiring ownership of the product) and, in turn, sell it to their client. The pisteur may select only export-grade product or they may take all product harvested for a fixed price, selling export rejects on the local market. Other *pisteurs* work as harvesters and transporters, paid by the client per kg (van den Broek et al., 2016).

There is controversy over the role of *pisteurs* in the supply chain, with concern that *pisteurs* reduce farmer incentive for investment. However, without training on farm maintenance and grading, smallholders are not well equipped to supply export-grade products and attempts to remove *pisteurs* from the supply chain have only seen quality declines. Exporters have the choice of working with larger scale professional farms which do not need the services of *pisteurs* or working with *pisteurs*. While increasingly export firms prefer to work with large-scale farms, the role of *pisteurs* remains vital in connecting the smallholders with the exporters (van den Broek et al., 2016).

Wholesale traders
Wholesale traders have a key position in linking rural producers to urban consumers. The traders in the national markets are often informal small and medium enterprises (SMEs). Wholesale markets are often degraded and congested (ADB, 2018a, 2018b; AGRA, 2019). There is a high level of specialization among wholesalers, which is expected as wholesale trade is often segmented per commodity. They can be vertically integrated by supplying logistics (instead of buying logistics), they sometimes process products, they provide finance to suppliers or buyers, and they can provide some sort of retailing. For example, in Kenya, there are about 10,000 fruit and vegetable traders (Gema et al., 2018) which are divided into collecting wholesalers and distributing wholesalers:

- *Collecting wholesalers:* Collecting wholesalers specialize in collecting produce from farmers in the region. They travel long distances to purchase commodities in spot markets from the producing areas and towns in Kenya. To facilitate operation, collecting wholesalers frequently employ purchasing commissioners who work in the production areas on their behalf.
- *Distributing wholesalers*: Collecting wholesalers operate in such a way as to allow distributing wholesalers to focus entirely on their urban clientele. This is important in large regional urban centers where wholesale and retail markets are operational six days a week.

Employment in the midstream (processing, wholesale, and logistics) and downstream generates another 25% of rural employment (e.g., in Africa according to AGRA, 2019), since the traders are either individuals or small informal firms that employ several people. Despite fulfilling a key function in

the supply chain, exploitative behavior and high levels of informality by traders to farmers is common. Also, the presence of trading cartels at urban markets is often mentioned as a barrier for farmers to enter markets (Dijkxhoorn et al., 2019).

Unfortunately, there is a serious problem of a dearth of statistics, either official data or data from studies. This lack of statistics extends to both large public assets like domestic wholesale markets, and the numbers, investments and behavior of traders and logistics actors (AGRA, 2019).

Commission-agents
Many commission-agents or agents buy on behalf of wholesalers while visiting the production areas. Commission-agents often have well-established personal contacts with actors as they have dealt with them for several years (Pokhrel and Thapa, 2007). They do not buy the produce, but they rather sell it on a commission basis, which is determined through mutual negotiation. On average, they get a commission at the rate of 7% of the selling price. Farmers, who are the legal owners of the produce, do not have any say in pricing. It is a matter of mutual trust built upon a gradually established business relationship over several years, and farmers accept whatever price the commission agent states. Because of such firmly established social business relationship, in most instances, farmers are not cheated by the commission agents (Pokhrel and Thapa, 2007).

Commission agents visit rural markets to aggregate truck loads. They identify produce for sale and carry out negotiations with farmers. Then, they accumulate, assemble and carry the produce to a nearby road for collection. In essence, they streamline the entire procurement process. Once enough produce is obtained, collecting wholesalers then transport the commodities to the main cities/towns, generally using large lorries.

Transporters
While transporters fulfil an important service, transportation remains one of the largest costs of horticulture production. For example, in West Africa there is a lack of conducive infrastructure, lack of competition in the trucking industry, and high levels of corruption (bribery) (van den Broek et al., 2016). FAO and IFAC (2013) give the example of a container moving from Tema, Ghana to Ouagadougou, Burkina Faso in 13-22 days for US$4,800, whereas a container in the US could cover the same distance in 5 days for US$650. Nearly all the vehicles that are used for the transport of fruit and vegetables are overloaded. Transporters often face costs of compulsory weigh stations, as well as illegitimate controls by police for bribes. The delays originating from these "hold-ups" can cause the product quality to deteriorate.

For local, short-distance transportation, informal arrangements are made and are very diverse. For example, a taxi driver may also take the product in his car or public transportation buses may be used. Drivers may get paid per basket or crate and therefore are incentivized to squeeze as much product in as possible, even if at risk of damage to the product (Kok et al., 2019).

Informal long-distance transportation also exists. Plaisier et al. (2019) found that, in Nigeria, oil tanker trucks informally transport tomatoes for 1,000+ km trips, storing the product in baskets on top of the tanker. Van den Broek et al. (2016) report that certain commodities (coconuts) may travel primarily as secondary load due to the high duties and bribes that come with dedicated transportation.

For fresh produce for export, refrigerated containers are highly desirable. However, these are often a scarcity. Mangos, for example, have a short season of 1.5 to 3 months, and during this time there is often a shortage of refrigerated containers for the mangos. This may lead to losses as some mangos may lose their quality and must be sold as second grade. In addition, during the peak season, other products (e.g., pineapples which grow year-round) lose priority, and there is difficulty finding transportation. For the regional markets, non-refrigerated trucks are used to transport export rejects and local varieties (van den Broek et al., 2016).

Informal retailers
The retailers sell to consumers at their retail shops and street food vendors (SFVs) and are mostly informal. Retailers are numerous in urban and peri-urban centers in the studied regions. Some

retailers are located at dedicated retailer markets, fresh-produce kiosks or have a roadside shop at a strategic location. Many of these kiosks operate informally without a license. They generally buy small volumes, and they source from the main urban wholesale markets.

Supermarkets
As stated before, a "supermarket revolution" has occurred in some LMICs in the past decades (Reardon et al., 2012, 2007). Especially in Asia, the supermarkets have become an important outlet for consumers to buy fresh fruit and vegetables.

In East Africa supermarkets only form a small share of the market. However, in urban areas, where incomes are higher, they are more present. In East African cities, there are various large multinational supermarkets, several locally owned small to medium-sized supermarkets spread out in all the suburbs, as well as different petrol stations that have small supermarkets. FAO and IFAD (2013) estimate that only 1-2% of fruit and vegetable farmers in Senegal are commercial farmers, who can meet sourcing conditions from supermarkets. A more recent study by AGCRA (2019) provides estimates of 10% market share of the supermarkets in Africa. In urban areas this share is likely to be higher.

In urban areas, middle and upper class consumers in West Africa increasingly shop in supermarkets and retail shops, over marketplaces. In addition to higher quality products, shoppers prefer supermarkets which can offer a more time-efficient shopping experience. This is particularly the case for middle class women shoppers who split their time between work and housework and have developed a preference for the same products year-round, as opposed to the traditional seasonal diets (Nugteren, 2018).

As supermarkets increasingly dominate supply chain conditions, this greatly impacts on the potential for small farms and intermediate firms to sell their fruits and vegetables to the rapidly expanding urban markets. In many economies, the rise of an emerging local horticultural sector that can consistently supply the supermarkets with the required volumes and correct quality can have an important development effect. However, for smallholders, it remains a big challenge to supply supermarkets since the scale of procurement is typically much larger and requires both volume and coordination among suppliers, and between suppliers and retailers and their intermediaries.

Exporters and contract farming
Exporters of horticultural produce play an important role in all regions studied. For example, in Kenya, they provide employment and generate substantial amounts of foreign exchange earnings for the country. In Kenya, there are over 200 fruit and vegetable exporters of whom 137 are active members of Fresh Producer and Exporters Association of Kenya (FPEAK) (Match Maker Associates, 2017). The majority are small and medium-sized and about 20% are large companies. Due to their links with the importers of vegetables and other products in the export market, they have a governance function in the supply chain (Kleih et al., 2018), and they introduce new knowledge and technology. They receive orders for produce and will then source the products from smallholder farmers or their large-scale farms. Among other things, orders will also include the implementation of food safety or pesticide application regulations. Therefore, in Kenya, export firms are important drivers for change in the national fruit and vegetable market (Kleih et al., 2018).

However, in other East African countries, the number of professional exporters is small. In Uganda, it was estimated that about 7-10 serious exporters supply the international market, supplemented with opportunistic so-called "briefcase" exporters (Dijkxhoorn et al., 2019). The more serious exporters often have their own production fields, work with additional out-growers, supply these out-growers with technical support, and have their own packing facilities. The "briefcase" exporters often buy produce at the open market or make informal agreements with farmers without providing any support or market security.

Horticulture exporters in West Africa are highly consolidated, often with one or just a few exporters dominating the sector. Further, there is one major multinational tomato exporter in Senegal, which likewise exports a high share of fruits and vegetables from Côte d'Ivoire and Ghana (FAO and IFAD, 2013).

Contract farming is often seen as a solution to rural development challenges and many exporters have been involved in contract farming. This holds for South Asia, East Africa and West Africa. Contracts are important for smallholder farmers who cultivate for the export market, as smallholders often face credit constraints and lack access to resources. Direct contracts from export firms help fill this gap by providing credit and resources to farms in exchange for retaining a higher degree of control of product quality as prerequisite for the export market. The contracts vary from firm to firm. While most contracts provide inputs on credit (seeds, fertilizer, pesticide), some additionally provide management and technical services (FAO and IFAD, 2013). For smallholders, contract farming is expected to reduce market uncertainty, to improve better access to inputs, knowledge and services, and, subsequently, to provide higher income (Holtland, 2017).

Setting up a contract farming scheme is an often-used approach by exporters and donors to achieve smallholder inclusion in export supply chains. However, reality shows that a positive impact for farmers and businesses is not guaranteed. Several schemes did not live up to expectations: sometimes because firms did not follow up on their promises, sometimes because farmers failed to deliver. One of the underlying problems proved to be the lack of investment by farmers and firms in a sustainable interface between them. In some cases, the firm or the interface effectively organized input supply, rural finance or marketing for farmers, where these services are poor. However, there is a risk that these schemes contribute to a further weakening of the service provision to other farmers (Holtland, 2017). In the past years, there has been a gradual reduction of smallholder contract farming arrangements due to increasing risks and transaction costs for the exporters.

Processing

Figure 6.2 gives an overview of the volumes of processed fruits and vegetables being exported and imported in the different regions. Processed fruits and vegetables are mainly exported by countries in South Asia. It appears that West and East Africa are net importers of processed fruits and vegetable and hardly export.

Only a few companies are active in the fruit processing sector in West and East Africa. Processed products include preserved (canned) fruits, dried fruit, frozen fruits, juices, pulp, and purées. Processors often work across fruit products and therefore can be integrated into multiple supply chains, such as drying mango in the peak season and pineapple and coconut in the offseason. While some of the fruit processing is geared for the international export market, most often being Europe, certain processed fruit products cannot compete on the international market and remain in the regional markets or the domestic market (Agri Logic, 2019). Quality requirements for processing fruits targeting the domestic market are much lower than that of the international export market, and often rejected fruits are used for processing. Local varieties, which are not exported, are also used for processing (van den Broek et al., 2016). Despite having backward linkages pursuing production agreements with fruit farmers or aggregators, supply of raw material remains a challenge. As a result, a large share of the processed juice consumed in East and West Africa is still imported to meet the local demand.

In contrast to fruit processing, little vegetable processing is performed domestically. Processing of vegetables is very limited, since it remains a challenge for local processors to compete with imported processed foodstuff like tomato ketchup, which is produced by a dedicated industry at a much larger scale and a lower cost of production. Besides, this is also in part due to an obvious preference of farmers and middlemen to sell fresh tomatoes to urban markets over processors. Processors tend to offer low prices to farmers to remain competitive with imports. During the times of peak supply at the markets, selling to processes might be an option for farmers. However, when there is low supply and prices are steep, this is no longer an incentivizing option for farmers, resulting in an absence of supply for processors.

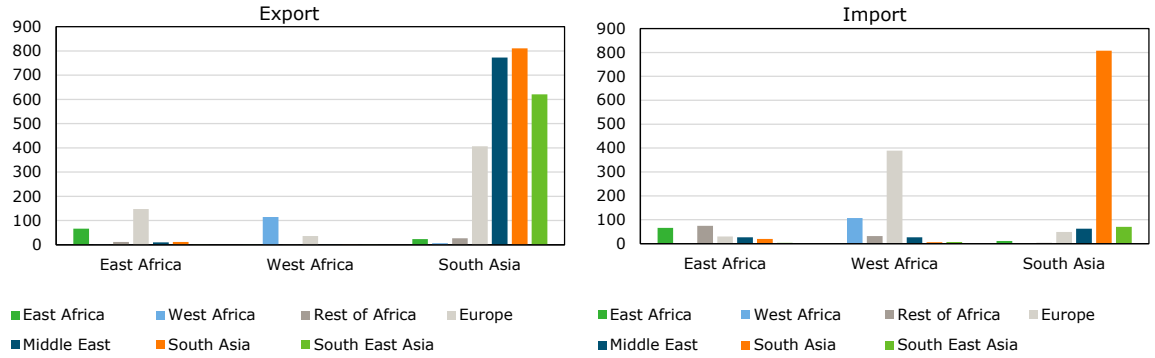


Figure 6.2 *Import and export of processed fruit and vegetables to and from East Africa, West Africa and South Asia, by trading partner, in 1,000 t, 2018*
Source: UN Comtrade [Accessed: 14 September 2020].

6.3.2 Enabling and supporting actors

Associations
In South Asia, markets are often governed by a market association. This is an association that operates the market. In many countries, they are characterized as weak from a managerial, operational and infrastructural perspective (ADB, 2018b).

Many informal wholesale markets in East Africa are dominated by associations of traders that manipulate supply to keep prices high. For example, the main fresh produce markets in Kenya have informal associations that are in constant contact with intermediaries to control the supply of produce, requesting more if demand is high or avoiding large surpluses (ADB, 2018c). Also, various formal private sector organizations exist (see Appendix 11).

In most studied regions, cold storage is absent. However, in the case of Bangladesh there is a cold storage association that represents the interests 428 cold storages, with an estimated capacity of 5.5 million t in 2019. Out of the total cold storages, only 30 were public and operated by the Bangladesh Agricultural Development Corporation with an estimated capacity of about 50,000 t, while the rest were privately owned. Although the number of private cold storages is increasing (ADB, 2018b),) poor post-harvest handling and storage technology remains a constraint hampering the Bangladesh sector.

Government
Government agencies for investment promotion exist in all regions studied. They all include the agricultural sector and often specifically address the horticultural sector, as a focus area. Many East African governments promote agricultural development and support supply chains that generate foreign exchange earnings by attracting foreign investors (e.g., through zero-rated value-added tax). Appendix 12 gives an overview of the various investment promotion agencies identified. For example in Kenya horticultural exports such as green beans are recognized to be a major export sector and, as such, supported by the national government and its institutes (Kleih et al., 2018). In Rwanda, there is also a strong focus on promoting exports through bodies like the National Agricultural Export Board (NAEB) and Rwanda's National Export Strategy (Dijkxhoorn et al., 2016). Box 4 gives an example of how Rwanda attracted foreign investments. However, the domestic sector is often lagging behind in terms of governmental support (Gema et al., 2018).

In general, transparent market information for fruit and vegetables is absent in all countries studied. No system provides up to date market prices from different wholesale markets. This is an important market shortcoming that is contributing to high transaction costs (Eaton et al., 2008).

Box 4: Attracting foreign investment

Rwanda welcomes foreign investment in policy and in practice for developing the domestic market. The NAEB, also an import governmental body, aims at developing agricultural export. In its Vision 2020 plan, Rwanda set ambitious goals for its development and the reduction of food imports. Rwanda aimed to achieve this vision by fostering investments in horticulture (Dijkxhoorn et al., 2016). Investment projects for the domestic market are also being supported by the government of Rwanda, and loans are made accessible for people willing to invest in agriculture. The Development Bank of Rwanda, a government implementing agency, has facilities to support investors in getting access to finance and was co-financing projects by provided up to 50% of investment in close cooperation with Rwandan banks.

The seasonality of production affects prices and investments aimed at making fresh produce available throughout the year are being promoted. As the production window of some products like onion or mango, are seasonal due to climatic conditions, expansion of availability could be reached through investments in storage or processing (drying).

Most countries seek (foreign) investments in irrigation, primary production, cold storage and handling of fruits and vegetables and input supplies. Investments in (rail) roads and airports are often addressed via special governmental programs. See box 5 for an example from Senegal.

Box 5: Exports from Senegal

In Senegal, several companies have made investments in horticulture, including companies from India, the UK, France and the Netherlands, specifically in the north near St. Louis and Lake Guiers on the border with Mauretania. According to van den Broeck et al. (2016) fresh fruits and vegetables are important agricultural export commodities. This concerns off-season products for the EU market like sweet potato, okra, sweet corn, French beans and cherry tomatoes. Further, the local production of potatoes and onions as replacement for imports contribute to the development of the local horticultural sector. During the last 15 years, the government has imposed temporary bans on imports of specific commodities, including onions and potatoes, to stimulate the production and marketing of local products.

In Nigeria, the agriculture sector is largely dominated by subsistence farming. However, according to the Nigerian Investment Promotion Commission, Nigeria's investment promotion agency, the government has set some objectives to modernize agriculture and increase self-sufficiency in food production. In the early 2000s, Nigeria introduced an import ban on fruit juices in an attempt to stimulate the domestic processing industry, and, in 2019 Nigeria placed an import ban on tomato paste and concentrate. These products are listed on the Nigerian Customs Service Import Prohibition List.[7] In addition to outright import bans, other fruit and vegetable products face prohibitively high tariffs, such that the outcome is the same in preventing (legal) imports. These bans are intended to spur the domestic processing industries. However, as Hollinger and Staatz (2015) note, the import ban on fruit juices has led to imports of fruit juice concentrates, which are reconstituted and sold on the Nigerian market (doubtlessly competing with domestic fruit juice). Various West African countries have implemented trade policies intended to encourage domestic processing for the local market, as is the case of the import bans in Nigeria (Hollinger and Staatz, 2015).

In addition to national governments, the East African Community (EAC) is gaining regional importance. The EAC is a regional inter-governmental organization of six Partner States, comprising Burundi, Kenya, Rwanda, South Sudan, Tanzania and Uganda, with its headquarters in Arusha, Tanzania. It compromises the second-largest market in Africa, with a growing middle class whose demand for products and services has driven growth on the demand side. The EAC seeks to transform into a single market that allows for free movement of goods, persons, services, labor and capital, while guaranteeing rights to residence and establishment. Likewise, there is the Economic Community of West African States (ECOWAS). Asia also has various regional economic partnerships (e.g., the Association of Southeast Asian Nations Economic Community).

[7] https://customs.gov.ng/?page_id=3075

Non-governmental organizations (NGOs) (to be complemented with an overview from the phase II study)

Many NGOs are active in the fruit and vegetable sector, they provide inputs, training and various other services, like access to finance, but they are also involved in connecting farmers to markets by providing essential infrastructure such as pack houses. We highlight the following:

- TradeMark East Africa (TMEA) tackles the existing barriers to trade in East Africa, aiming to achieve positive and sustainable change in the region through a combination of regional and national initiatives and an investment of over US$500 million. TMEA has national and regional dimensions with many projects implemented across some East African countries. TMEA was launched in 2011 as a not-for-profit company limited by guarantee and funded by the UK's Foreign, Commonwealth and Development Office.
- The International Fertilizer Development Center (IFDC) strives to develop better fertilizer and production technologies, transfer these improved technologies to smallholder farmers, and connect these farmers to efficient and profitable markets. By working with strategic partners, they build local capacity and ensure sustainable impact.
- SNV focuses on increasing people's incomes and access to basic services in agriculture, energy, water, sanitation, and hygiene. Their projects drive systems change by strengthening institutions and kickstarting markets. By connecting global expertise with a longstanding in-country presence, they help to realize locally-owned solutions. They work in more than 25 countries worldwide.

6.3.3 Seed systems are diverse

Seeds are a key input for smallholder farmers. Farmers in least and low-income countries cultivate their vegetables and fruits in a diversity of production systems, which have implications on the types of varieties, seed and planting materials they use. The varieties vary from local varieties, old varieties being released decades ago, to more recently released varieties developed by the public and primarily private sectors. Seed varieties may differ in being open-pollinated (OPV) or hybrid, and in a few isolated cases being transgenic. The reproduction system of the crop (open or cross pollinated, or vegetatively propagated) and the opportunities to develop, particularly hybrid, varieties defines the degree in which formal and commercial seed systems are viable. This in turn defines whether it is profitable for commercial seed companies to invest in varietal development, or whether seed companies decide instead to source varieties from public programs or other commercial companies. Seed systems for fruit vegetables such as tomato, peppers, eggplant or okra vary from saved farm seed, to informal seed networks and markets, to certified hybrid and in some cases transgenic (e.g., eggplant) seed varieties from national and global commercial seed companies. For commercial vegetables such as onion, carrots, cabbage and lettuce, farmers source seed from national and global seed companies. National seed companies usually source their seed from global or regionally operating companies, which license seed of particular varieties to them or sell them seed of varieties that are no longer protected. Varieties for traditional leafy vegetables, fruit crops and trees are a different game — to a large degree varietal development and seed business is not viable for such produce, and thus only common varieties and types are available for purchase.

A diversity of seed systems exist in the production of vegetables and fruits, and it is well possible that one finds different seed systems represented in one home garden or with a commercial vegetable or fruit farmer in varying contexts of Type A, B and C supply chains. The figure below provides a generic overview and description of seed systems relevant for vegetables and fruits. It should be realized that between geographies, major differences are possible, but the overview provides ample insights in the diversity of situations that exist. With this diversity, it is important to take an integrated seed system perspective on the structure of the seed sector for vegetables and fruits (Louwaars et al., 2013), which recognizes and accepts this diversity of seed systems. The approach takes into consideration that seed value chains differ by crops and proposes different options instead of one-size-fits-all solutions for variety release, seed quality assurance, plant variety protection and promotion of seed entrepreneurship. It looks at how stakeholders in a sector interact in formal, intermediary and informal seed systems through their operations, or in provision of services, is subject to the enabling environment, including the legislative and business environment. It does not make sense to take a linear and oftentimes commercial approach to the development of the vegetable and fruit seed sector; instead, in promoting vegetables and fruits one should identify and select the relevant seed systems

and ensure to have the proper resources to develop them (Louwaars and De Boef, 2012). With an integrated perspective, one explores ways to strengthen the functioning of the seed system relevant to fruit, leafy or other type of vegetable, fruit, tuber and root crops, as well as ways to increase farmers' access to quality seed or planting materials of superior quality and farmer preferred varieties.

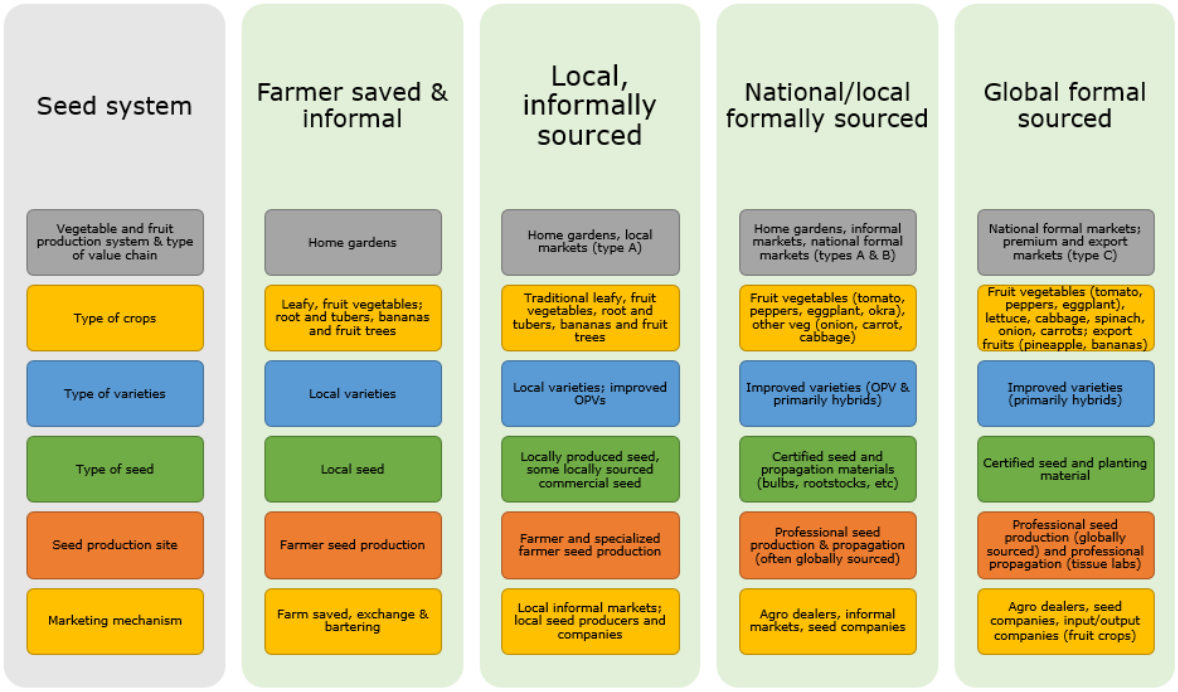


Figure 6.3 *Generic overview and description of seed systems relevant for vegetables and fruits Source: Louwaars et al. (2013).*

Promoting vegetable and fruit consumption has implications on the types of production systems that need to be promoted. Promoting home gardening in rural and semi-urban areas has implications on the resources available for farmers to invest, and thus the type of seed systems relevant to that production system. However, if the aim is to promote commercial local and informal markets or more distant urban markets, the production systems allow for more investments and thus also investing in quality seed and planting materials. When promoting more commercial production systems, the use of quality or certified seed of preferably hybrid varieties, if accompanied by advanced cultivation practices, will result in major yield jumps. A jump in productivity requires investment in seed and inputs, soil management and advanced cultivation practices — investment across this combination elements is required. The introduction of certified seed of hybrid varieties is critical in such a package; it is a crucial component in the professionalization and transformation of the horticulture sector to a sector with increased volumes of regularly available, affordable and quality products, allowing consumers in both rural and urban areas to purchase vegetables and fruits (Schreinemachers et al., 2018). Within such a development, the professionalization of local seed companies in selling seed and planting materials and promoting superior and, if possible, hybrid varieties is required. The seed industry in many countries catering for such a demand is still in a nascent stage. It should be realized that in many countries, locally operating seed companies source their vegetable seed from globally or regionally operating seed companies, or they act as representatives of globally or regionally operating seed companies. Vegetable is one additional product in the crop portfolio. Local seed companies, thus, act as seed traders rather than as seed companies. A division of responsibilities exists, the global or regional companies cover variety development, seed production and processing; while the local companies do the repackaging, promotion and marketing. Once vegetable markets further develop, some globally operating companies may explore entering seed markets, and start to sell seed with their own brand and reputation.

For many locally important vegetables and for most fruits, this situation is not applicable. Crop improvement is not profitable and, if done at all, it is done by a few public research institutes. These

public research institutes may be linked to seed producers, but the limited profitability may hamper the way that quality seed reaches farmers. For such vegetables and fruits, farmers continue to rely on local varieties or landraces, and the seed systems are and continue to be predominantly informal.

6.3.4 Cooperatives are not common in the fruit and vegetable sector

There is very little information regarding cooperatives for fruit and vegetable producers in the studied regions. However, in general, it appears that cooperatives are not common in the fruit and vegetable sector. They appear to be more common in typical cash crop sectors such as cacao and coffee, though they do have a place with relatively more individualist fruit and vegetable farmers. In West Africa, mismanaged funds and political use of agricultural cooperatives have weakened their appeal to farmers, however many development organizations continue to work with cooperatives for ease of business (Nugteren, 2018).

Cooperatives come in many forms and structures. For example, cooperatives in countries like Rwanda and Ethiopia are mainly governmental vehicles to distribute inputs and to control rural areas. According to the Rwanda Cooperative Agency, as mentioned in Dijkxhoorn et al. (2016), there are about 7,100 cooperatives focused on primary producers. It is not clear how many of these cooperatives are active in horticulture. Most of these cooperatives distribute subsidized fertilizes on behalf of the national government, but do not provide support in activities such as marketing, sorting, storing and grading.

Cooperative participation can vary by country, crop, and supply chain. In the mango sector in Mali and Burkina Faso, for example, producers often participate in cooperatives, and some cooperatives operate pack houses. However, in Côte d'Ivoire, many pineapple cooperatives dissipated in the 2000s, as farmers moved away from growing pineapple during the pineapple crisis (due to political instability, as well as competition from Latin American countries growing a new crop variety) and exporters began working with individual farmers via *pisteurs* (van den Broek et al., 2016). Existing pineapple cooperatives in Côte d'Ivoire are oriented towards the domestic market, where they hold a 95% of the market share (Agri Logic, 2019).

Cooperatives may operate independently or through a cooperative union or association. For example, in Côte d'Ivoire, three principal cooperative associations are OCAB (*L'Organisation Centrale des producteurs-exportateurs d'Ananas, de Bananes et de Mangues*), OBAM-CL (*L'Organisation de producteurs-exportateurs de Bananes, d'Ananas, de Mangues et d'autres fruits de Côte d'Ivoire*), and FENA-COFRUITEL (*La Fédération Nationale des Coopératives Fruitières et Légumes de Côte d'Ivoire*). These associations are comprised of several cooperatives as well as some farmers (Agri Logic, 2019).

In addition to export and domestic markets, cooperatives may serve the regional market. One example is the Burkina Faso cooperative SOCAMAD (*Société Coopérative Agricole et Maraîchère de Débé*), which made a deal with GAPTO (Ghana Agricultural Producers and Traders Organization) to sell onions after being cut off from their typical market in Côte d'Ivoire due to political instability. This deal provided SOCAMAD farmers with certainty of payment for their crop and GAPTO traders with certainty of supply, all at a set rate for a set period of time. Further, this deal provided both parties with formal access to credit to both grow and sell before exchanging of payment (Peppelenbos, 2008).

If farmers have alternative outlets for their produce, or if there is a mistrust of cooperatives, there is little incentive for farmers to participate in cooperatives focusing on the marketing of produce. Unfortunately, this lack of incentive is not strengthening the bargaining power of farmers towards traders. Further, individual farmers may not be able to access the same level of credit or micro-finance as under affiliation with a cooperative.

6.3.5 Poor packing, storage and transportation practices

Poor product quality and a lack of post-harvest technologies for locally traded fruits and vegetables remain an important cost and an impediment to supply chain development. FAO and IFAD (2013) reported that transportation costs account for 40% of food costs in West Africa, much in part due to

the lack of paved roads, as well as inefficiencies in trucking regulation. In addition to inadequate physical infrastructure, lacking storage, transportation, and processing contribute to significant losses in the fruit and vegetable sector in West Africa. Various studies have indicated that the share of post-harvest losses in fruit and vegetable supply chains ranges from 10-50% (Kok et al., 2019; Lans et al., 2012). In the next chapter we will discuss this topic on post-harvest losses in more detail. As a result of cash constraints and the lack of storage space, especially cold storage, wholesalers try to sell all vegetable stocks by the end of each day, causing volatility of market prices even throughout the day.

In most African countries, vegetables are traded in large traditional local braided baskets that contain large volumes of produce. After collecting the goods from the farmer or the urban market, the baskets are often squeezed in the back of a small pickup truck. The transport by (pickup) trucks often causes serious damage to the produce. Produce is also often transported uncovered, and this poses a serious threat to food safety. Some fruits are traded on the branch (e.g., bananas) and are sold as such. Other fruits like avocado or passion fruit are sold in crates. In addition, market infrastructure and handling practices of traders are not conducive for safe handling of food products.

In South Asia, it appears that plastic crates are more common. A study in Nepal shows that producers still use traditional packaging such as traditional bamboo baskets, though most traders have adopted plastic crates (Chaudhary, 2010). Vegetables are transported from production areas and collection centers to markets mainly on trucks and buses. No specialized vehicles are used for transportation of perishable vegetables. In Nepal, the mode of transportation is diverse. Farmers sell tomatoes at the farm gate. Wholesalers are found to go to the farmer's field to buy tomato with their own vehicles. Tomatoes are transported from farmers' fields to the market centers with buses and pick-up vans. Retailers are found to transport tomatoes from wholesale market centers to the retail markets by pickup vans and rickshaws. Retailers also use bicycles, motorbikes, and mobile trading carts or push cars for transporting the fresh produce (Chaudhary, 2010; Gautam et al., 2020).

For the export market, the more dominant exporting countries like Kenya have a dedicated packing industry (Kleih et al., 2018). Fruits like pineapples and avocados exported to Europe are graded and packaged according to export standards. However, other countries, that only have an emerging export sector, lack facilities and access to affordable packing material. For example, the facilities in Uganda are not up to date with export market requirements and many pack houses are in residential houses that were turned into pack houses. Cold chain facilities during transportation from the farmers' fields to the packhouses and from the packhouses to the airport are also reported to be lacking (Dijkxhoorn et al., 2019). This is comparable for export chains in West Africa.

Innovations in products and presentation (branding, package innovation, variety innovation, etc.) are a constant factor, which implies that farmers and exporters need to continuously invest in cultivation and packing innovations. In terms of the level of supply chain integration and transparency this supply chain is most developed and is faced with a high level of international competition. In Kenya, only 2% of the farmers engage in the export segment (Gema et al., 2018). Often fruits and vegetables rejected by exporters go to local markets. While horticulture produce is often rejected from the export market for quality reasons, rejection can also occur if the fruit is not the desired size, for instance, if it is too large or too small (van den Broek et al., 2016).

6.3.6 Sorting and grading is often absent

In the domestic market, quality is often assessed by visual appearance, there is hardly any agreed and standardized quality grades, leaving much room for negotiation for traders, and between traders (e.g., collectors and wholesalers). A recent study mentions that tomatoes traded on the domestic market in Uganda are not sorted and graded (Type A). Instead, consumers can select for themselves when buying. Not even the damaged or old tomatoes are sorted out, which results in an overall unappealing appearance and quality in the market display (Dijkxhoorn et al., 2019). However, sorting and grading take place at different points along the supply chain which differ by commodity. Often, horticulture produce for domestic markets is sorted at the end of the supply chain by the retailer. For example, in the Nigerian domestic-oriented tomato sector, retailers do the sorting and grading of tomatoes (Kok et al., 2019).

In a study in India (Kehoe et al., 2019a), farmers indicated said they would receive a higher price for their produce if the quality was maintained. Furthermore, vendors had to consider the quantities that they dealt with to ensure that they did not suffer losses due to spoilage or wastage. If vendors sold poor quality produce, this was likely to affect their business and customers might purchase fruit and vegetables elsewhere.

In the export-oriented fruit sectors, *pisteurs* or exporters sort and grade products from smallholders before taking the export-grade products to the exporter. This, however, also varies by commodity and region. Mango *pisteurs* in Mali, for example, buy all products from the farmers to sort and grade for their clients (export-oriented vs local); whereas *pisteurs* in Côte d'Ivoire sort and grade on the farm, only taking export quality fruits. Larger, more professional farms sort and grade their product by themselves (van den Broek et al., 2016).

6.3.7 Value added

High margins for actors in the fruit and vegetable chains
There are only a limited number of studies that provide insights into the net profit margin between the different direct actors in the vegetable supply chain. Often the margin is expressed per kg or per sales unit. For example, in the study on the tomato sector in Nepal (Chaudhary, 2010), it was estimated that the margin was NPR20 per kg (approximately US$0.27 per kg) for the producer. This represents a 67% profit margin (Chaudhary, 2010). They found that the producers' share was highest among all actors involved (wholesalers have a margin of 8% and retailers of 25%). Another study in India indicated a 54% profit margin for tomato producers and 82% for traders (Singh, 2005). Some statistics are available on wholesale market prices in other countries (such as Ethiopia), but little is available of a systematic and geographically broad nature regarding trader and logistics agents' numbers, sizes, behavior, margins, and so on. The wholesale market policies and regulations are often made at the municipal level and information about them is difficult to access. Studies of public investments and policies regarding domestic traders and logistics are largely unavailable. Data on the profit margin for retailers has hardly been studied.

Pineapple *pisteurs* in the pineapple sector of Côte d'Ivoire have a profit margin of around 20% (van den Broek et al., 2016). Farmers in Uganda also have relatively high profit margins ranging between 45% and 65% (Dijkxhoorn et al., 2019). It appears that these margins are much higher for fruits compared to vegetables produced in LMICs, where typical profit margins are less than 30% per unit sold. We expect that this is related to some sort of compensation for the risk that actors in the fruit and vegetable sector take, mainly due to the perishability of the product and sometimes a lack of market demand.[8]

There is no comparative information on the different profit margins that farmers have for supplying to supply chain Types B (formalized domestic markets) or C (the export market). However, the principal driver for farmers to engage in a contract farming system, such as in supply chain Type C, is to ensure a secure market for their product and to benefit from better prices (higher or more stable) and secure payments (Holtland, 2017).

It should be noted that actors in vegetable supply chains often have a wide variety of different income sources. In particular, farmers and retailers have a mixed income consisting of various sources. For example, rural farmers also have non-farm income that together compromises the household income. Also, most studies that look at the profitability of vegetable or fruit production and trade look at historic prices or average prices. However, the market of fresh produce is very dynamic, and prices fluctuate heavily based on supply and demand, hampering reliable forecasts based on such studies.

There is little information on the contribution to the national economy
Overall, LMIC economies rely heavily on the agricultural sector as a contributor to the national economy. In West and East Africa, this agriculture's share of the national economy is almost

[8] This is in contrast to farmers in developed countries, who often produce for agreed contracts with retailers or wholesalers, reducing the risks.

25 percent. In South Asia, this share is 16.4% (see also Appendix 13). The literature on the contribution of the fruit and/or vegetable sector to GDP is very limited. A study by Kleih et al. (2018) estimates that the green bean supply chain contribution to the agriculture sector of Kenya is 0.3%. In addition, the green beans supply chain is a major foreign exchange earner for the country and a contributor to poverty reduction in that it provides income for about 52,000 producers (i.e., mainly smallholder farmers) and many hired workers (about 40,000 to 70,000).

6.4 Enabling environment

6.4.1 Chain organization

Trust between actors is important on spot markets
Contracts are hardly used in informal economies, so trust is considered to be essential and is often considered an effective substitute for contracts (Fafchamps, 2004). In informal markets, relationship-based networks are therefore important, and repeated exchanges and aspects such as the reputation of a business partner are considered to be important in a business transaction. Therefore, in the informal market situation, buyer-to-seller trust is critical, because it concerns direct trading partners, not only now but also for future exchanges. However, only very limited studies examined trust between actors in the fruit and vegetable sectors.

For example, improving the quality of agricultural inputs used by farmers is a potentially important instrument to improve productivity and food security. A recent study by the De Brauw and Kramer (2018) found that sellers in Bangladesh provide mostly low quality input products and buyers reveal low demand for more expensive, high quality inputs. The scheme improved average earnings for sellers but not for buyers because the performance of quality signals remains weak. Thus, although small incentives may be particularly effective at improving market outcomes, they do not necessarily enhance quality signals and farmer welfare (De Brauw and Kramer, 2018).

Contracts are only used for the formal markets
Contracts are an important element for enforcing arrangements between buyers and sellers. In the studied regions, contracts are absent in the informal trade of fruits and vegetables. This is especially the case for the local and regional supply chains (Type A) where spot market transactions in which producers and buyers agree on a price at the time of selling are predominant. It is estimated that not more than 5% of smallholder farmers in Africa are in contract farming schemes (Minot and Sawyer, 2014).

Among the more formal export-oriented supply chains (Type C), contracts are prevalent. As exporters have increased vertical coordination between farmers and buyers, contract farming has become more important. Moving away from spot market transactions, contract farming is a buyer driven market mechanism that relies on strictly binding contracts between actors, which are agreed before starting production. Contracts between farmers and exporters can include the following elements (Eaton and Shepherd, 2001):

1. A provision by the contractor of inputs and/or technical assistance to farmers;
2. A guarantee by the contractor to buy the product from the farmer, as long as the product matches the agreed standards in terms of quantity, quality, and time of delivery;
3. An agreement to ensure a basic price at the time of purchase.

Enforcement of contracts with small-scale producers is a challenge, especially when market prices exceed the contracted price and side selling occurs.

Certification is a requirement to supply far away markets only
There have been serious efforts to introduce GLOBALG.A.P. certification among fruit and vegetable producers in the export sector. GLOBALG.A.P is a minimum requirement set by (European) buyers to supply the market and to ensure a level of social and environmental sustainability, but also to safeguard a good level of tracking and tracing. Only exports aimed at the ethnic market, supplying

typical products like hot peppers, for the African or Asian diaspora are excused from this type of certification and only need to comply with minimum phytosanitary and maximum residue level (MRL) requirements, as set by the European Commission.

Certification can be at exporter level, but also at farm level. In general, it requires serious investments by the company to implement related measurements for improving the company process, as well as high costs for (frequent) audits. Often, the certification schemes that are needed in the international market can cause exclusion of small farmers given that the costs of such systems are a function of production volume. For example, high volume makes standards feasible because the cost per unit of product is low. For many smallholders, however, volumes are low and the unit cost for standards high. Despite a need for fruits and vegetables that meet minimum food safety requirements, there is hardly any relevant certification scheme for fruits and vegetables in West Africa, East Africa or Asia aimed at the domestic market.

Pricing
In the informal market prices are set through a spot market system (Type A). A spot market is a cash market with immediate exchange of goods. A trader or his agents contacts a farmer (or vice versa) and inspects the products, negotiates a price, sets the deal, pays and collects the products all within a few hours or less. In the end the produce is sold via many different steps in the chain to various types of informal traders, who supply the local low-income retail markets. Public price information is hardly available for fresh fruit and vegetables. Traders operating at urban wholesale markets often use their collective power (e.g., an informal traders' association of a certain product) to monitor and forecast expected inflow of produce to make price offers. For supply chain Type B and C, prices are often set in advance.

6.4.2 Institutional environment

The institutional environment is weak
Institutional arrangements refer to a set of rules or agreements governing the activities of a specific group of people pursuing a certain objective (Eaton et al., 2008). The institutional environment consists of the broader socio-economic framework within which different institutional arrangements take place, such as market transactions (agreements to exchange goods). In considering the institutional environment, a distinction can be made between *formal* and *informal* institutions. Formal institutions are "embodied in constitutions, laws, the structure of state decision (the number of veto players and their mode of selection) and regulations enforced by judges, courts, police, bureaucracy, and the like"; whereas informal institutions are "norms of conduct, perhaps historical traditions or religious precepts" enforced by custom or habit (Keefer and Shirley, 2000).

Within the various components making up the formal institutional environment, differences in terms of applicable scope and specificity are apparent. For example, legal frameworks, especially property and contract laws and their supporting institutions, have a fundamental and broad significance for the cost and uncertainty associated with exchanging goods and services in general. On the other hand, government macroeconomic policy, which may involve regulations concerning taxation, government spending, monetary policy and exchange policy, is also part of the institutional environment (Eaton et al., 2008).

Institutional arrangements are mostly informal
A weak institutional environment, particularly in terms of legal frameworks, leads to difficulties in enforcing contracts and fosters rent-seeking behavior by politicians, bureaucrats, criminals and the private sector. All these factors consume resources and inhibit economic and technological development, which inhibits access to markets and market development. A well-functioning institutional environment is important for economic development. Numerous indicators give an impression of how conducive national policies are for business. For example, the World Bank ranking on the ease of doing business provides an annual performance measurement for 190 countries (World Bank, 2020). This ranking also has various relevant subcategories related to accessing credit, enforcing contracts, and time and cost to resolve commercial disputes.

Informal marketplaces are the "default" marketing options for rural farmers. Literature indicates that "markets play an important role in Africa, arguably more so than in developed countries". As observed in the supply chain analysis, there are many intermediaries and most transactions are small leading to high transaction costs (Fafchamps, 2004). In addition, the transaction costs, particularly for traders, include the time required to obtain information from the location of the likely supply in terms of quantity and quality of produce (e.g., has it been a good season or not), which may involve travelling to the production area several times. However, securing supply may be difficult when there are many buyers but few sellers, and traders may prefer to secure an agreement in advance to assure supply.

Accountability of the legal institutional environment

Legal institutions are an important component of the institutional environment, underpinning economic growth and specialization, though this does not imply that there is a blueprint or single approach. The presence of legal rules can foster efficient coordination. The studied countries are in general characterized by weak institutional capacity and a relatively high degree of corruption in the public sector. In general, corruption imposes high costs on society (Eaton et al., 2008). The average Corruption Perception Index score for East Africa averages 26.5 (TI, 2018). This is low with Rwanda being a positive exception, see the Figure 6.4.

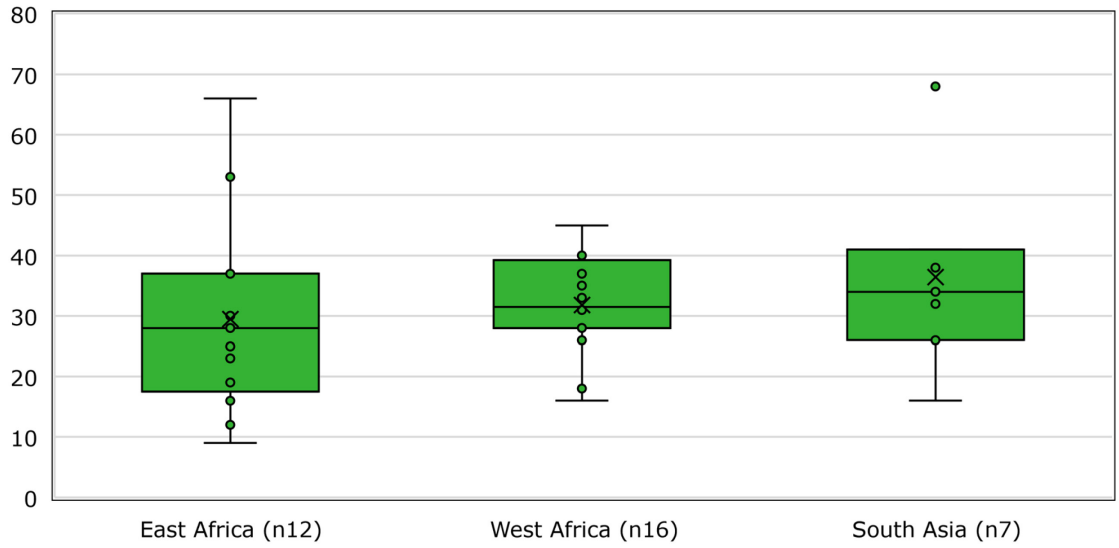


Figure 6.4 *Corruption Perception Index score*
Source: TI (2018).

Doing business

The formal institutional environment in the studied regions is generally weak. However, informal institutions based on ethnicity and family-based linkages are very important and are key for doing business successfully. Sub-Saharan Africa remains one of the weak-performing regions on the ease of doing business with an average score of 51.8, well below the OECD high-income economy average of 78.4 and the global average of 63.0, see Figure 6.5 (World Bank, 2020). Among the countries in East Africa, Rwanda is one of the top performers. South Asia is, on average, performing better in terms of doing business. A recent study (AGRA, 2019) mentions the difficult importation processes of vehicles, equipment and machineries as a big constraint for doing business. Nearly all the trucks and cooling equipment in Africa are imported at high costs. It is important to develop policies and procedures that are simple and efficient to facilitate business. Kenya has been successful in the export of horticulture and is the largest supplier of vegetables to the EU, exporting green beans, peas and avocados. This success has always been considered largely a private sector effort, however, the Kenyan state has played a much stronger facilitative role then has previously been considered due to informal support to entrepreneurs in the private sector by government (Tyce, 2020).

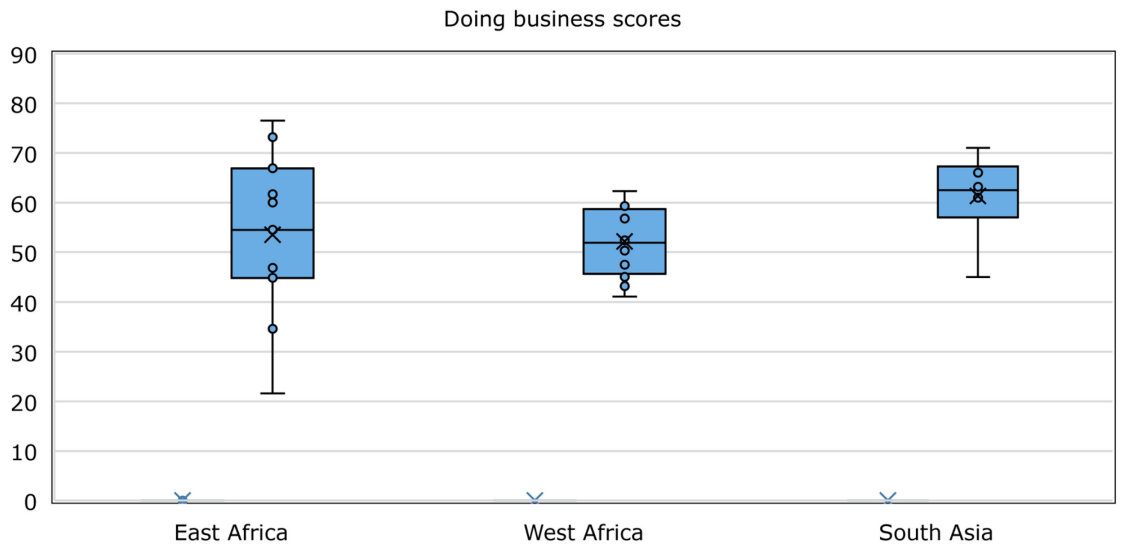


Figure 6.5 *Ease of doing business scores*
Source: World Bank (2020).

6.4.3 Transaction costs in the fruit and vegetable sector are high in informal markets

The studied markets are characterized by high transaction costs (Fafchamps, 2004). Transaction costs consist of the efforts dedicated to finding a market, negotiating, controlling compliance, and any lost opportunities. In general, three types of transaction costs are distinguished (Williamson, 1979):

- *Search and information costs:* Someone considering a certain transaction must search for a suitable party with whom to trade, and this search process involves costs. These costs may consist of visits to possible traders (e.g., in markets), communication (e.g., telephone calls). Acquiring information on where what is grown plays an important role.
- *Bargaining and decision costs:* These costs relate to time that is put into bargaining and negotiating the agreement between parties. This agreement can be put into an informal (verbal) deal. Again, information plays an important role as some parties may have information that they do not disclose (called asymmetric information).
- *Supervision and enforcement costs:* These costs are related to time and costs to monitor whether the agreement is implemented, to avoid opportunistic behavior by parties, and to enforce (informal) agreements. Information also plays an important role here, as monitoring consists basically of gathering information, which may be costly.

Two assumptions on which transaction cost economics relies are (1) bounded rationality and (2) opportunism. Bounded rationality implies that agents experience limits in formulating and solving complex problems and in processing (receiving, storing, retrieving, transmitting) information. The main consequences of these behavioral assumptions for economic organization are that all contracts are unavoidably incomplete and thus many complex incentive alignment processes cannot be implemented. Therefore, relying on "contract-as-promised" is fraught with transaction risks (because of opportunism). Opportunism extends the assumption of self-interest. Opportunistic behavior includes disguising attributes or preferences, distorting data, concealing issues and otherwise confusing or deceiving partners in exchange. Combined with asymmetric information it becomes very costly to distinguish opportunistic from non-opportunistic behavior ex-ante.

Bounded rationality and opportunism provide the behavioral basis for factors influencing transaction costs. Transaction costs are affected by four kinds of attributes of the transaction in question (Eaton et al., 2008):

- Asset specificity (the specificity of investments required);
- Uncertainty;
- The difficulty of measuring performance in fulfilling the terms of an agreed transaction;

- The need for coordination between other transactions with other actors. Coordination is defined as the extent to which transactions are dependent on other transactions in the supply chain or the sector.

Asset specificity is important since produce is highly perishable
Perishability is an important factor in spot markets for fruits and vegetables. Most products are highly perishable; once picked, they need to be traded and transported within a certain period. It was found in Tanzania that farmers avoid hold-up problems with tomatoes by picking tomatoes only after they have secured an agreement with collectors who have arrived in the village (Eaton et al., 2008). Another way farmers avoid potential hold-up problems is that they will sell it to the first collector who offers a reasonable price. There is a trade-off between the risk of not selling produce in time and obtaining a good price. Because farmers do not know what price the next collector will offer, they take a risk when they decide not to sell and wait for another collector to pay a better price.

Farmers and collectors do not establish an agreement about repeated contracting. Reasons for not doing this are the combination of risk aversion by the farmer, the availability of many collectors, high price fluctuations and a perishable product. The advantages of being able to sell to more collectors (at different prices and at different times) outweigh the advantages of relying on one collector. Establishing a relationship with one collector through repeated transactions may also involve high costs of coordinating the timing of transactions, failure to do so will involve high costs of unsold and spoilt produce or unfulfilled orders (Eaton et al., 2008).

Uncertainty is high
Farmers deal with production uncertainty and the risk of crop failure. Production variation, in turn, causes price fluctuation. In the spot markets, production risks are borne mostly by the farmer. Therefore, farmers reduce this risk by avoiding relying on one cash crop and diversify the range of crops, including subsistence crops such as maize or sorghum. This means that they will only be able to offer small amounts on the market and are not able to specialize. This increases their transaction costs where different traders buy different crops.

Spot market trading leads to high levels of information asymmetry
Spot markets leave much room for opportunistic behavior of market participants, especially in the form of incomplete or distorted disclosure of information (Eaton et al., 2008):
- In transactions involving fruits and vegetables in spot markets, there does not seem to be a problem of compliance concerning production. Collectors and traders have no interest in the way the fruits and vegetables are produced and are merely interested in the product. When performance measurement does become an issue, for instance in supply chains Type B or C, a spot market arrangement would no longer suffice, and a different institutional arrangement is needed.
- In the commonly used pack materials (e.g., baskets, buckets or raffia baskets), produce of inferior quality is often hidden. In Tanzania, buyers complain that the bottom of the buckets is filled with paper, instead of fruit or vegetables. It is known that in the market, unripe tomatoes are packed at the bottom of crates, while the best quality tomatoes are packed at the top (Eaton et al., 2008).
- Quality is assessed by appearance, and there are often no agreed and standardized quality grades (as discussed in section 6.3.6), leaving much room for negotiation between farmers and traders, and between traders (e.g., collectors and wholesalers).
- Another source of information asymmetry stems from market prices. Many farmers fail to have up to date information about prices, which puts them in a disadvantaged bargaining position. Often mobile phones are used to collect price information. Collecting wholesalers may not have an incentive to decrease information asymmetry because they are the ones who profit most from it. It was found that collectors have established a close-knit network by forming associations (which are divided according to market segment). Many farmers complained that collectors conspire on price agreements. Collecting wholesalers in the main Dar es Salaam Kariakoo market indicated that they coordinate amongst themselves where and from whom to source from, thus decreasing competition (Eaton et al., 2008). Collecting wholesalers do compete with other traders from other markets, although even amongst traders from different locations and associations price agreements seem to be in place.

Coordination
A lack of standard weights and measures effectively reduce the costs of coordinating otherwise unrelated transactions by a range of actors. It is common practice that fruits and vegetables traded in spot markets are not weighed and paid by the kilogram, but by the crate or bag (of standard size, but they are usually topped up to 150% and can vary in weight). Eaton, Bijman and Meijerink (2008) explain that collectors favor larger bags because a tax is paid per bag to local governments by the collectors. If more produce can be transported in fewer bags, then less tax is paid. Further, bargaining over issues like weight and measures increases transaction costs. Because the coordination task is complex (sourcing different types and quantities of fruits and vegetables from different, remote locations to different markets), traders operating in the main markets usually employ or contract other actors such as brokers to contact farmers, gather information on supply, quality and prices, purchase, inspect, pack and transport goods. This can result in a long supply chain involving many actors and increasing prices for consumers.

6.5 Gendered roles and opportunities in the fruit and vegetable supply chains

This section gives an overview of the role and experience of women in fruit and vegetable supply chains in three regions. In addition, this section also highlights some emerging opportunities for women to engage in and benefit from economic activities in the supply chain. This includes the variations in how men engage in production, access to trade capital and production related services. Section 6.5.4 provides a synthesis of the gender realities that are present in these supply chains.

6.5.1 Women's contributions to agricultural production remains limited

In South Asia, Bangladesh's economic growth is in part thanks to the garment and textile industry, established since the 1980s, which depends on a labor force that is 80%. While this has benefited the country, as well as many women working in this sector by improving their decision making power over household income and increasing self-esteem (World Bank, 2017); it has not translated into wider public debate around women's roles as economic actors. In agriculture, as in many other countries, the proportion of women amongst rural households that have sole or joint ownership of land is just 13 percent, whereas for men it is 70% (World Bank, 2019a). Evaluations of women's contributions to agricultural production can be a challenge as the degree to which what they do is considered actual work, rather than "just" part of their overall domestic responsibilities is very much down to individual (and often gendered) perceptions (Rubin et al., 2018). Even more so, according to one study "employment on their husbands' farms gave Bangladeshi women no more autonomy than doing housework, despite the fact that it generates income," which concludes that "[i]t is when the income is possessed by women that it contributes to their autonomy" (Anderson and Eswaran, 2009). This ownership is typically found more when women work off-farm, selling products such as agricultural produce, input supplies or dried goods (Rubin et al., 2018). On the consumption side, Bangladeshi women bear the responsibility of collection and preparation of food, but impacts on the time burden of this or childcare were not clear (van den Bold et al., 2013). Among household members, men continue to get the main share of food from meals at household level (KIT et al., 2017).

Nepal provides an illustrative example of the feminization of agriculture, albeit one that has been taking place for longer than in other countries. Nepal has a long history of laborers going abroad to work for shorter or longer periods (anywhere between a year to over a decade) in Malaysia or the Middle East, as well as for short stints in India with which they share a long and very porous border. While the trend is changing as female laborers have become more sought after abroad for household work and childcare, traditionally this labor migration has been heavily male-dominated, leaving women in rural areas to look after farmland (if they have it), as well as the family (Sunam, 2017). For those women seeking work as farm laborers, one study indicated that men would earn NPR300 (US$2.53), while women only earnt NPR200 (US$1.69) on a daily basis (Rahut et al., 2014). Overall, this can mean an increasing amount of work on a daily basis, covering both household and income-generating responsibilities. Whether this translates into a greater degree of autonomy for women,

however, is another question. In some cases, this has shown to be true, while in other cases men still make many major decisions over the phone from a distance, and any relative degree of autonomy lasts only as long as the men are abroad (Sunam, 2017). A factor of control is shown to be whether women manage the processes of both production and sales (in this case of organic fresh vegetables), which translated into full control of income (ILO, 2018). If this is divided up between women and men, the latter are more inclined to determine the use of the money. A more positive policy change is that Nepal provides a 25% tax concession if the land is purchased by women (Adhikari and Hobley, 2015).

In India, rural women are overrepresented in agriculture with 73.2% of women involved in the sector (Bartlett and Bush, 2013) which, like in other countries, has increased in the last two decades as (young) men seek off-farm employment more than women. Women's contribution to fruit and vegetable production and post-harvest handling is no exception to this, wherein they play a major role in both production and post-harvest handling (Tripathi, 2016). Both rural and urban-based women have relatively lower levels of education at all levels (basic, intermediate and advanced) versus men. Correlations between income and education mapped to urban versus rural contexts illustrate that lower educated women in rural areas are the hardest hit in terms of their ability to generate an income (Bartlett and Bush, 2013). Besides education, this also comes from an imbalance in "formal" work and household responsibilities, whereby "women tend to spend a disproportionately greater amount of time, often twice as much, than men on household work and almost five times more than men on childcare" (Duflo, 2012). However, when women can access training that is tailored to their specific needs, this can help tremendously in contributions to household income. In one case study focused on the preservation of fruits and vegetables, the training helped women to be able to sell these goods outside of the peak harvest periods, wherein prices decrease due to a temporary glut in the market; selling them out of the harvest season enabled them to make a greater profit than if they had sold them fresh. To complement this technical training, self-help groups (SHGs) were also set up, which helped build the confidence of the women members. The combination of training and SHGs helped increase income and build the entrepreneurialism of the participating women (Sharma, 2017).

Box 6: South Asia regional gender summary

- Working in family farms generates income for the family but does not give women autonomy and economic empowerment; women's ownership of income is typically greater when women work off-farm, selling products such as agricultural produce, input supplies or dried goods.
- When women manage the processes of both production and product sales, they have an overall increase in the control of income; in households where income from the food supply chain is divided up between women and men, the latter are more inclined to determine the use of the money.
- Women spend a disproportionately greater amount of time, often twice as much, than men on household work and almost five times more than men on childcare.
- Training and SHGs have helped build the confidence of women to promote increased income and entrepreneurialism of the participating women.

6.5.2 Women experience a significant increase in their overall workload

Land is an important form of collateral for formal credit. With less land ownership than men, few women can use it to gain access to financial services — though it is especially critical for women in terms of enhancing their ability to participate in supply chains beyond current producer roles to grow their agribusiness (Mutua et al., 2014). In East Africa, evidence of the impact of agricultural projects on women's time and workload is mixed and largely showed that while women experienced an increase in income from agricultural production, they also saw a significant increase in their overall workload. In Ethiopia, areas where non-labor-intensive production techniques have been used, have seen a significant reduction in women's workload. In Tanzania, improved production technology contributed to a reduction in women's and children's time allocation (van den Bold et al., 2013). Despite the benefits of women's participation in onion supply chain activities, leadership and decision making over the income accrued from vegetable production and women's participation in marketing is constrained by socio-cultural factors, such as limitations on women's movement placed by their

husbands or male partners. The study recommends supply chain interventions to address gender roles and relations in supply chain development activities to facilitate gender sensitive intervention strategies and to increase long term benefits from onion production for both genders (Jeckoniah et al., 2013). Another study found that husbands in Tanzania often hinder their wives' entrepreneurial development by undervaluing their capabilities and frustrating their attempts to grow their enterprises. Male clients often demand to deal with men in business transactions, hence the woman entrepreneur's husband, brother or son may have to lead the deal, despite the woman's business competence (FAO, 2019).

6.5.3 Cooperative membership of women remains limited

There have been various initiatives in Ethiopia to encourage greater membership in cooperatives by women across different sectors, including changing cooperative bylaws to allow two household members to gain membership. Despite these types of local-level efforts, female membership remains low, at around 2%, while the proportion of women in leadership positions is at 18% (Woldu et al., 2018). Cooperatives play both important economic as well as social functions, more so than purely business-oriented initiatives, and can be established to support both women and men to join, or specifically focus on women only membership (Woldu et al., 2018). Unlike entrepreneurship, wherein individual women set up a small-scale enterprise, cooperatives, especially women-only cooperatives, have the added value of promoting collective action, going beyond just generating an income, to also (attempt to) address time constraints and access to credit issues that women are more challenged by than men (Pionetti, 2011). When women do become genuine members of cooperatives (e.g., not just in name only) and can reap the benefits of increased production, this translates not just into increased household income, but also changes in community attitudes of women's roles (Citypress, 2018).

6.5.4 Men control household income

Studies in Tanzania show evidence of unequal distribution of income control by greater vs. lesser commercial value. Women and men are overall equal contributors to production of various vegetables and staple crops, while men have much greater control over income generated from staple crops, and women have higher control over income generated from fresh vegetable sales — but which provide smaller amounts of income in absolute terms. Furthermore, women tend to sell greater amounts at wet markets (e.g., end consumers), while men sell their produce to retailers grocery stores or local restaurants (Fischer et al., 2017). A gender study of leafy vegetables in Kenya shows similar dynamics, but indicates that improved access to technical support or extension can help improve women's gross margins (Mwaura et al., 2014).

Box 7: East Africa regional gender summary

- Increase in income from agricultural production-comes with a significant increase in women's overall workload; the introduction of technology into production reduces labor time allocation.
- Cooperatives play both important economic as well as social functions: with evidence of increased production capacity and household support for care responsibilities.
- Men have much greater control over income from staple crops, whereas women have higher control over income generated from fresh vegetable sales, which provide smaller amounts of income. Therefore, vegetable production presents an opportunity for income and consumption gains for women and households.

6.5.5 Women are more active at the level of production

While overall women are proportionally more active at the level of production, and less so higher up the supply chain, there are exceptions to this trend. In Nigeria's capital city of Lagos, over 90% of resellers in informal markets are women (79% of whom completed primary education). Similarly, in Ghana's capital Accra, the city's informal markets are controlled by "market queens," women who "rule a market and represent its traders to the outside world, even though they do not occupy a

formally recognized administrative position," and who — when appointed — hold this position for life. However, "market queens rule only over market traders, who are mostly women. Their following is thus highly gendered" (Hendriks, 2017), such that, though they have higher status, confidence and control over their income, it is not necessarily an example of a fundamental shift in gender relations. Both examples moreover reflect an urban context, which remains representative of only a minority of women in these countries.

In the absence of literature that elaborates on women's role in fruit and vegetable production, we highlight the example of cassava in Côte d'Ivoire, where the sector is heavily dominated by women, from production to sales. As cassava can be stored for longer periods, it provides a useful "food bank" to be sold when money is required, giving flexibility for women to access funds independently when they need it. However, it often runs into conflict with their household work, such that household labor is much higher for women than men. This double burden reduces their ability to maximize economic gains despite controlling an important staple, as "they are often unable to harvest the cassava at times when market prices are more favorable, and harvest instead when school starts and household expenses are higher, thus receiving less money for their product" (FAO, 2018).

6.5.6 In Burkina Faso women do not have property rights on land

In Burkina Faso, the mango sector plays an important role nationally and for women; it makes up 50% of the country's national fruit production and up to 18% of West African production. It also plays an important role in employing women in processing and packaging. While in Burkina Faso's production dynamic women do not have property rights on land, they can have user rights — this is most often on less fertile land. Even though the national land policy in Burkina Faso theoretically allows women to obtain land rights, the actual implementation of the policy is bureaucratically unenforceable (Parrot et al., 2017). Land access and tenure is organized through customary law, which does not allow women to plant trees. This not only bars them from engaging in fruit tree production, but also in essence does not allow them to traditionally claim land ownership, which was done by planting trees to mark your land. This difficulty in access to land also translates into inaccessibility of training and other production resources, such as equipment, inputs and products, agricultural services (agricultural, entrepreneurial, legal advice) and credit. Hence, socio-cultural factors hinder the growth of female entrepreneurship by curtailing their engagement in production. In addition, women are not involved in orchard work — pruning, weeding and the application of manure are male dominated activities. However, women can play a modest role in harvesting activities by providing unpaid family labor (Parrot et al., 2017). On the nutrition front, household decision making practices allow women responsibility over household fruits and vegetables subsistence production and purchase, as the men focuses on the production of the staple foods as indicated by Parrot et al. (2017).

Box 8: West Africa regional gender summary

- Ninety percent of resellers in informal markets are women. Formal supply chains have more men. Women managers only manage female dominated market spaces.
- Women do not have property rights to land, they can have user rights — this is most often on less fertile land, during short rain seasons and staple produce off-season. Inaccessibility of training and other production resources is tied to land ownership.
- Customary law does not allow women to plant trees. This curtails fruit tree production among women.

6.5.7 Gender synthesis

Time allocated to daily farm labor is equally distributed or more for women, but additionally 1) women's overall working hours are more than men's when including household responsibilities; 2) while kitchen garden work contributes to overall nutrition, it is predominantly for subsistence use and is often not recognized as actual agricultural work; 3) women do not technically own the assets they manage; 4) women are over-represented in the low-income/higher risk/high manual labor areas

of agricultural supply chains. Even though there are some exceptions where women are involved in high-income agricultural production, such as the mango supply chain in Burkina Faso, the processing work is still labor intensive. Hence, women are less productive. At the regional level, existing data does not examine the arrangements that dominate fruit and vegetable supply chains. Specifically, the gender differentiation among actors in producer farming and markets are invisible at the regional analysis level. The fruit and vegetable supply chain discourse (Kehoe et al., 2019b) shows that the women who are commercially incorporated in the supply chain are predominantly engaged in informal markets and sell directly to consumers, while men have more options, as they sell at the farmgate to other traders such as restaurants, and market based traders, and to consumers. Similarly, women tend to manage smaller parcels of land that are closer to home, so as to be able to juggle between household and farm work (agribusiness). Therefore, land intensification strategies and technological solutions could potentially have a benefit for women who have to practice agribusiness in close proximity to the home and have limited time. This should be considered in addition to improving women's access to training, agricultural labor and entrepreneurship options. Unlike staple food supply chains, which are predominantly male dominated, fruit and vegetable supply chains can provide a culturally accessible agribusiness venture for women. Even though fruit tree farming may present tree ownership challenges, vegetable and fruit varieties are fast maturing and can be practiced on smaller parcels of land. In addition, their supply chains can be short and still generate income — hence, women can better benefit from fruit and vegetable farming. In addition, identifying where women are predominantly involved in the various fruit and vegetable supply chains can expose existing gaps, and promote support for optimal income generation.

There is potential to increase income through improving market access for higher value fruit and vegetables and focusing on women leading in this. Some markets in West Africa already show evidence that women can hold leading roles in high value sectors — though they are exceptions to the norm. However, good practice case studies need to be found wherein a product becomes more "commercial" while women remain in control, and optimal agribusiness practices are followed. If women can do off-farm economic activities that do not involve their husbands, it raises the chances that the income women earn can also be spent or saved in the way that they prefer. Agribusiness solutions along the supply chain that increase women's involvement in agricultural production and value addition needs to be balanced with household responsibilities, e.g., increasing labor time through intensification can likely mean adding working time to women's already long days. Approaches that balance household care responsibilities with agribusiness solutions increase the chances of strengthening the outcomes for the women agripreneurs. Complementary to this, getting women involved in cooperatives or other organizational structures provides a social capital advantage, as well as access to financial and technical training. Cooperatives provide women with platforms to share their personal challenges and experiences, which helps to build their collective confidence.

6.6 Conclusions: Possibilities for upgrading supply chains

In this chapter, we analyzed supply chains and markets for fruits and vegetables in South Asia, East Africa and West Africa. While most of the supply chains in studied regions are comparable at a broad level, we identified three different generalized types of supply chains: Type A, Type B, and Type C (Table 6.2). Each type has different actors and governance structures, and each targets a different market segment. Type A serves local and domestic low-end markets, Type B serves local and domestic mid- to high-end markets, and Type C serves the export market (e.g., predominantly Europe and the Middle East). While Type C is the most formalized with foreign resources driving supply chain development, Type A is by far the most prominent and the most important for sustaining the food system of the local and regional populations. Type B remains a small share in the overall market, serving only a certain segment of the population.

Table 6.2 *Overview of the different supply chain types*

Type A	Type B	Type C
Many steps in the chain, mostly based on informal linkages. High costs for sourcing products.	Improved cultivation practices (e.g., protected cultivation, irrigation, certified varieties).	Full assurance of quality and safety (MRL, GLOBALGAP, BRC, QS, IFS, HACCP, etc.) is a prerequisite for market access
Spot market trading. Lack of market transparency, high seasonal price fluctuations, and uncertainty on demand and prices.	Specialized commercial farmers or local traders consolidate supplies, organize packaging, and direct supplies to supermarket chains.	Gradual reduction of smallholder contract farming arrangements due to increasing risks and transaction costs.
Little or no value addition through grading, packing, quality, and food safety improvements.	Quality and food safety standards are introduced. While normally not as stringent as export standards, packaging and product quality are checked. Sometimes pesticide residue levels are also checked.	Worldwide sourcing by declining number of fresh produce buyers.
Low quality demands. Post-harvest losses due to lack of storage, no proper packaging, excessive handling, etc. Food safety risks.	More attention for harvest practices and post-harvest handling, including cleaning, storage and cooling.	Direct relationships between EU importers and partner farmers in sourcing countries.

Source: Adapted from Joosten (2016).

In all regions, the dominant Type A supply chain is characterized by spot markets. In this supply chain, post-harvest losses are high due to a lack of (conditioned) storage, no proper packaging, and excessive handling. On the demand side, these challenges, among other factors such as misused pesticide application and irrigation from an unsanitary source, lead to a serious food safety risk for consumers. On the supply side, most actors are exposed to a high risk of perishability amidst inadequate logistics, and this risk factor also contributes to high prices. Other risk factors include climatic variability, which forces farmers to deal with production uncertainty and the risk of crop failure. Resultant production variation, in turn, causes price fluctuation.

Another challenge for Type A supply chains is efficiently sourcing fruits and vegetables from many different remote, rural locations to various urban markets. Therefore, traders operating in this supply chain usually work with other actors such as brokers to contact farmers and to gather supply information. As a result, Type A is a long supply chain involving many actors, and each actor requires a margin, which in many cases can be relatively sizeable, increasing the price for consumers.

Therefore, in Type A supply chains, consumers face high prices for often unsafe produce due to the combination of risk from inadequate logistical capabilities to handle product perishability, production uncertainty and variation, and the many margins accumulated in long supply chains. Adding to these factors are transportation costs and transaction costs (search and information costs; bargaining and decision costs; supervision and enforcement costs). Transaction costs are relatively higher in informal markets, which are characterized by asymmetric information and informal institutional arrangements. These factors can explain the relatively high prices of fruit and vegetables in Type A, despite the relatively low cost of inputs and, in particular, agricultural labor.

Type B supply chains serve the middle and upper class consumers in urban markets. Supermarkets have been able to expand their market share in South Asia; as the study by Reardon, Timmer and Minten (2012) shows, the supermarket is estimated to have a market share of 15-2%. In Africa, the Type B supply chain is upcoming and still only serves a small portion of the market. Different studies estimate that this segment has a share ranging between 2% and 10% of the market.

The export orientated configuration (Type C) is strong in East Africa and South Asia with many firms active in the export of fruits and vegetables to markets such as the EU, the UK and the Middle East. Export firms have been working closely with smallholder farmers through contract farming, but this has been a risky business, so a gradual reduction of smallholder involvement has been observed. Preferences have shifted towards increasing vertical coordination and estate production.

Overall, the fruit and vegetable market is characterized by a weak institutional environment and lack of enforcement mechanisms. Examples include:

- There is a lack of capacity of governmental bodies to coordinate their actions and implement policies (e.g., effective seed regulations).
- Taxes are levied by district government on bags or crates instead of according to kilogram of produce, and, as such, traders have an incentive to increase the quantity of produce per bag. As farmers are paid per bag, they receive a lower price when traders increase the amount of produce per bag. Negotiations about the volumes of bags increase transaction costs.
- A lack of a well-functioning legal system also affects the agreements between buyers and sellers. Informal enforcement mechanisms or mechanisms that avoid disputes (such as bargaining, exchange, inspection and payment on the spot) are used to fill this void in the institutional environment. Informal governance systems are available and are considered to be efficient.

Supply chain actors are often interested in improving their position in the chain by adding value. This can be done by rearranging relationships (governance) with other actors in the supply chain and by choosing different market channels for their products. We address several possible upgrading strategies for each chain type:

Type A:

- Increase market transparency to address seasonal price fluctuations and uncertainty on demand and prices. This can be done by providing market information on price development across different markets.
- Increase the value added of the product through grading, packing, quality and food safety improvements along the entire supply chain.
- Introduce proper storage, proper packaging, good handling practice to reduce losses along the chain and further to increase food safety for consumers.
- Support other actors in the supply chains such as traders that have a key role in connecting farmers to markets. Stimulate private sector investments in the middle of fruit and vegetable supply chains to encourage agribusiness owners to invest in their business. For example, enable SMEs to invest in trucks, cooling, warehouses at affordable interest rates or facilitate a smooth importation process.
- Support public investment in infrastructure (e.g., wholesale markets), as well as policies and regulations aimed at reducing transaction costs and at increasing capacity to reduce supply chain risks for all actors.
- Organize farmers in cooperatives to enable them to achieve economies of scale to increase market power.

Type B:

- With expanding prevalence, supermarkets will increasingly influence the structure and conditions of the horticultural supply arrangements, in terms of standards, pricing, payment, and logistical arrangements. For entrepreneurial farmers and the more serious traders, this could be an opportunity to increase product quality and to start supplying a more formal market and to reduce market uncertainties and to move up towards Type B.
- Enable agri-food SMEs to connect smallholder farmers to the middle-upper consumer markets. And gradually, they may also be encouraged to link farmers to modern retailers that have emerged. For example, support specialized commercial farmers or local traders to consolidate supplies and organize packaging and direct supplies to a supermarket (chain).
- Further investment in advanced cultivation improvements (e.g., protected cultivation, irrigation, uptake of certified varieties) so that farmers can supply retailers year-round.
- Support the development of local quality and food safety standards. Although not as stringent as EU standards, pesticide residue levels should be checked to secure public health.
- Support further development of correct storage, proper packaging, good handling practice to reduce losses along the chain.

Type C:

- Develop opportunities to implement quality and safety standards.
- Increase competitiveness through more efficient logistics. The public sector has a key role to play by fostering proper market infrastructure (formal institutional arrangements and the efficacy of such

arrangements). The availability and quality of good roads, airports, and ports with proper handling facilities and other infrastructure is critical to the competitiveness of the fruit and vegetable sector.

Enabling these upgrading strategies may rely on public, public-private, or private initiatives. Overarching public sector actions have the power to influence all supply chain types. The fruit and vegetable sector as a whole requires efficient and effective public policies in the field of food safety, phytosanitary inspections, pesticide regulations, and breeders' rights. Further, these policies depend upon having the required legal frameworks in place, which will have to be aligned with international regulatory systems governed by institutions such as the International Plant Protection Convention, the International Union for the Protection of New Varieties of Plants and FAO/WHO Codex Alimentarius. Further, policies which ensure market efficiencies and facilitate cross-border transactions will also serve the fruit and vegetables sector and the farmers at its backbone.

Public-private initiatives, such as government supported farmer cooperatives, can help build capacity, such as training in proper handling techniques and food safety practices. They can work to connect producers to markets. Further, they can help direct investments towards improved cultivation and open opportunities for accessible credit.

Private initiatives, likewise, can introduce targeted interventions to support supply chain upgrading. For example, private investments in certifications, logistics, and infrastructure (physical, internet, etc.) would benefit all supply chain types. Investment in retail and supermarket expansion could likewise be far-reaching, especially if linking smallholders to a new clientele. It is likely that the most important impacts on opportunities for supply chain upgrading will come from the cross-initiative cooperation of public and private actors.

7 Infrastructure and technology

7.1 Approach

To explore the role of infrastructure and technology in enabling a vigorous fruit and vegetable sector, we conducted a literature review on the infrastructure and technology use, investment possibilities and conditions in the fruit and vegetable sector. It is important to have a broad view of the sectors' infrastructure and technology, including its status, shortcomings and barriers, developments, and possibilities. This gives insight into how different parts of food systems are connected. Any improvement should be addressed as an improvement of a food system and fit its infrastructure and technology level. Where available, studies on investment opportunities are highlighted and give insights on the appropriate level of infrastructure and technology, as well as other relevant aspects of the enabling environment.

Infrastructure includes the availability of and access to land and irrigation water, as well as road, rail and ports infrastructure. The relevant technologies include cultivation, post-harvest (storage and handling) and processing technologies. The status of national research and development in supporting the development of the fruit and vegetable sector is also discussed.

The basic rationale behind the necessity for investing in infrastructure and technology is that it will not only benefit the formal retail or export-driven supply chains, but also the informal supply chains, which are more important for ensuring the intake of fruits and vegetables by low-income consumers and maintaining the livelihood for smallholder farmers. People may argue that the food price in the formal channel could be much higher than that in the informal channel; moreover, the formal channel tends to exclude the small-size farms from the supply chains. These factors make investments in infrastructure and technology, which are considered as primarily beneficial to formal supply chains, less justifiable from the perspective of inclusive food chains to benefit low-income and vulnerable groups. In response to this point, our argument is that this view may be valid for staple foods, which have relatively low perishability and long shelf-lives, but it may not be applicable to the highly perishable fruit and vegetable products. For fruits and vegetables, without decent infrastructure and post-harvest technologies, they will decay much faster than grains. In this case, even though during the harvesting period, consumers may take advantage of the low prices due to the flooding of fruit and vegetable products into the market, the price will go up very quickly because the availability of the products rapidly becomes a bottleneck. The high price due to product shortages outside the harvesting period leads to big issues for low-income households to consume stable intakes of fruits and vegetables throughout the entire year. In many cases, poor people try to consume fruits and vegetables when their prices are low. This has also been observed during the COVID-19 pandemic in South Africa, where poor people's intakes of fruits and vegetables has declined significantly due to the rise in the price or decrease in their income. Furthermore, the high price volatility for fruits and vegetables caused by low product storability will harm the businesses of smallholder farmers and seriously threaten their livelihoods. Finally, poor infrastructure, like bumpy roads, can cause physical damage to fruits and vegetables, which can severely accelerate the decay process during product transportation and affect the smallholder farmers' incomes as well. Therefore, investing in the infrastructure and technology to improve the storability of products and the stability of prices is very relevant to ensure the stable consumption of fruits and vegetables for low-income groups and to keep smallholder farmers in business.

7.2 Infrastructure

7.2.1 Availability and access to land and irrigation water

Land and irrigation water are crucial inputs for fruit and vegetable production. The availability and accessibility of those two inputs are, in general, quite limited but differ in degree by country.

The arid zone of India covers around 12% of the country's geographical area occupying 31.8 million ha of land. The main area is to be found in Rajasthan, although it also covers parts of Andhra Pradesh, Gujarat, Haryana, Karnataka, Maharashtra and Punjab. These areas experience an annual rainfall of between 100 and 500 mm and extreme temperatures (1–48°C). Greenhouse agriculture is most suitable for this type of climate and, as a result, irrigation is a basic requirement for sustainable fruit and vegetable production systems based on drip irrigation and fertigation. Bangladesh, being a delta country, does have easier access to surface water for irrigation. However, lack of irrigation facilities is one of the major challenges in Nepal that prevent farmers from achieving the expected returns. The most common irrigation source is pumped groundwater, followed by streams. A small number of farmers use local reservoirs for irrigation purposes. In most fruit and vegetable crops, irrigation is a pre-requisite to achieve high yields. In Nepal, most of the cultivated orchards are rainfed, while some commercial farmers have started using various types of irrigation methods such as plastic ponds, drip, sprinklers.

East Africa holds vast areas of arable land, much of which is suitable for irrigation. According to the Ethiopian Investment Promotion Commission, for example, Ethiopia has 74.3 million ha suitable for agriculture within eighteen major agro-ecological zones. Tanzania has 44 million ha of arable land with an estimated 29.4 million ha suitable for irrigation. Zambia also holds vast areas of land.

Smallholder production constitutes the main part of production in East Africa. Eighty percent of all farmers in Kenya are smallholders, and 70% in Tanzania. Some producers have formed groups to produce as contract farmers or out-growers to large-scale export firms. This occurs in all East African countries.

Land ownership remains restrictive in Ethiopia and Tanzania. Under the Land Act of 1999, all land in Tanzania belongs to the state. Procedures for obtaining a lease or certificate of occupancy can be complex and lengthy, both for citizens and foreign investors. Less than 10% of the land has been surveyed.

In West Africa, there are millions of hectares of arable land available that could potentially be used for agriculture, including fruits and vegetables. Much of the horticultural land under cultivation is located near the main cities and thus has rather good access to infrastructure and the market. In countries like Ghana, Nigeria, and Côte d'Ivoire, due to the climate, the vegetable cultivation is more concentrated in the north, hundreds of kilometers from the main consumer areas.

In Senegal, competition for land between the export sector and domestic food production is low. In 2016, horticultural export companies cultivated approximately 2,700 ha in total in the departments of Dagana and Saint-Louis. They do not own this land but lease it from the rural communities. Before the land lease deals, most of this land was common pasture land and extensively used by (semi-)nomadic pastoralists (van den Broek et al., 2018). An issue related to land is its ownership registration.

Specifically, in Côte d'Ivoire, only 0.09% of the total agriculture land is registered and the lack of land certificates is worse for women farmers, who face additional gender-related constraints, including legal or social norms that prevent them from inheriting or simply owning land.

There is a serious lack of irrigation infrastructure in West Africa. Most crops are produced under rainfed conditions with low yields. Agricultural productivity remains low, and productivity growth has been low, largely because of the low input/low output agriculture practiced by the clear majority of farmers, an underdeveloped inputs market, and very little investment in productivity-enhancing agricultural practices and technology. Only a small part of cropped land under is irrigation (less than

1% in Nigeria). But in general, vegetable production makes more use of irrigation than other crops. Irrigation by small- and medium-scale farmers, who farm the low-lying valleys relies on rivers, streams, and small dams to do simple irrigation by hand. Mostly, these farmers use the inundation of small plots with water through the use of gravity furrow irrigation.

For a small percentage of the arable land, surface water management infrastructure was built in the 1960s (Niger) and 1970s to irrigate rice and cotton; however, those installations are old and dilapidated, suffering from poor maintenance and management that prevent proper system use.

The dryer regions like Mali and Niger do have access to aquifers next to the Niger and other rivers. Access to aquifer water is costly though, as it requires permits, deep wells and high-capacity pumps. Mostly, it is used by larger companies that can afford the investment and operational costs. Irrigation water taken from streams and rivers may be polluted with heavy metals and organic pollution (from industry or tanneries), causing food safety issues and MRL issues in export.

7.2.2 Road, rail and port infrastructure

Road, rail and ports are important infrastructures that determine the efficiency of the fruit and vegetable post-harvest supply chains. Underdeveloped rural roads and other key physical infrastructure have led to high costs of transporting horticultural products to the markets and farm inputs to the famers. This will influence the competitiveness of the horticultural sector. Although some progress has been made in certain cases, the general infrastructure of road, rail and ports is still lacking in the studied countries.

Distances are large in the countries on the Gulf of Guinee: between the northern production areas and the urban centers in the south can cover 900-1,200 km and road transport takes up to 5 days. Though recently some investments have been made in road, rail, and port infrastructure, the clear majority is old, unreliable, slow, and unable to cope with the transport volumes. For example, in Côte d'Ivoire, as described by van den Broek et al. (2016), inland transport is expensive: transport of a 40 feet container from Ferkessedougou to Abidjan costs around US$2,000. In addition to the long distances between production and consumer and the poor quality of the road infrastructure, tax and bribe flashpoints also often negatively influence road transport. In Côte d'Ivoire, the train from the north takes two days to cover 900 km, while trucks take up to five days to reach the docks from the start of the port.

Cameroon seems to have the least developed fruit and vegetable sector in West Africa. The country has poor roads, a limited capacity of aging rails, and an unreliable national airline. The government has engaged in an ambitious program to upgrade and build new transport infrastructure and incentives to invest exist, though administrative procedures cause long delays.

The logistics system of Ghana can be taken as an example as it is seen as one of the strongest points of the horticultural sector with good quality facilities and infrastructure. At the same time, the availability of vessels is limited and dominated by one company (Compagnie Fruitière). Besides, the companies complain about constant changes in the port's regulations concerning security and handling arrangements. A new terminal will be built at the Port of Tema by Maersk/APM Terminals in the coming years, creating sufficient capacity for imports and exports that might be the largest and most modern terminal in sub-Saharan Africa.

Investments also take place in the railway connections between Port Cotonou-Niamey-Ouagadougou-Abidjan, which connects Niger by rail to the Atlantic ports in Benin and Côte d'Ivoire, as well as to neighboring Burkina Faso. Van Der Waal (2015) noted that a container terminal operating with a reach stacker that was able to take containers on and off railway carriages was built on the railway line in Abidjan. The operation of the railway line was entrusted to a French private company that assured two daily trains in every direction between Abidjan and the Burkina Faso capital of Ouagadougou. For the mango season, they provided a dedicated train capable of carrying 11 refrigerated containers. The advantage of the railway line was not its speed, but the steady operation of the system. It is very stable with no vibrations or shocks. Once it was rolling, it ran uninterrupted from station to station,

not being held up by traffic congestion, administrative issues, police roadblocks and so on. Most importantly, it offered direct access onto the container quay. Also, the rehabilitation of the Nigerian railway system is now well underway. The Western railway line from Lagos to Kano is being reconstructed and new rolling stock has been acquired. The challenge will now be to keep the reconstructed lines well maintained and keep high levels of serviceability and reliability. When operated efficiently, the Western line will be an important backbone for horticulture development.

Export market infrastructure
According to the horticultural sector (NEA, 2015), the Julius Nyerere Airport (JNIA) in Dar es Salaam and Kilimanjaro International Airport (KIA) are important cargo terminals. Royal Dutch Airlines (KLM) is a major cargo handler at both JNIA and KIA. However, the capacity and provided services are limited in terms of handled volume and value-added activities. The cargo quantity is too small to allow for regular and cost-effective services. The Dutch government has made available funds to improve and upgrade the cargo handling facilities at KIA. Under-developed export infrastructure in Tanzania is due to the small size of the horticultural export-oriented sector (both at airports and the harbor of Dar es Salaam).

According to the World Bank, Ethiopia relies heavily on the port of Djibouti for the import and export of goods. Ethiopia has built seven inland ports in Modjo (70 km from Addis Ababa), Kallity, Semera, Mekelle, Dire Dawa, Gelan and Kombolcha, with an installed handling capacity of 22,000 containers. The dry ports, serve as intermediate logistics destinations for cargo. Most goods are transported by trucks from the ports to Addis Ababa and other parts of Ethiopia. The Addis Ababa Bole International Airport is the major gateway for air shipments and the airport has cold storage houses that facilitate shipments of perishable goods, such as cut flowers, fruits, and vegetables. Ethiopia's state-owned companies dominate the truck transportation market. The overall number of trucks is presently insufficient to meet demand. Moreover, a Chinese-led infrastructure project to revamp Ethiopia's rail system which connects Djibouti port to Addis Ababa began operations in 2018 (World Bank, 2019b).

In Côte d'Ivoire, ships cannot dock to load and unload containers due to port congestion. A lack of competition in the transport sector means that rates are high and service is often poor. A difficulty is that there is in effect only one ship per week, which goes to Antwerp and a second ship goes to France. Packhouses that are used by small producers and exporters do not have cold storage, the harvest needs to be scheduled around the arrival of the containers and the departure of the ship. There is limited flexibility in the system, and non-delivery of containers has a severe impact on exports. Road congestion makes it problematic to reach the seaports fast without delay.

7.3 Technology

7.3.1 Cultivation

Protected cultivation is increasing. For example, India shows an increase of around 75,000 ha in protected cultivation in the last two and half decades (Singh, 2019). That is roughly 1% of the fruit and vegetable area in India. The basic purpose of protected cultivation in arid and semi-arid regions like Rajasthan is to address high-temperature fluctuations, low soil fertility, low biomass, high wind velocity and high solar radiation, peculiar to these regions. Water, being the most limiting factor in these regions, increases the level of constraints for promoting protected cultivation. Protected cultivation includes different forms of adoption, like plastic mulching, temporary plastic walls, plastic low tunnels, plastic-covered walk-in tunnels, plastic-covered high tunnels, temporary and permanent insect-proof net houses, shade net houses and different kind of greenhouses, etc. Research and development work carried out by various public-sector institutions in collaboration with developed countries gradually modified the technical designs of different protected structures to determine the most suitable to the specific needs of prevailing climatic conditions in India. This led to the expansion in the area and production under protected cultivation.

Since arid and semi-arid areas are less prone to major fungal, bacterial, and viral diseases, this provides one advantage for developing protected cultivation of horticultural crops. Suitable technical solutions in protective horticultural production are presented in Table 7.1.

Table 7.1 *Suitable protected structures for different horticultural crops in arid and semi-arid regions*

	Protected structures	Suitable crop
1	Shade net house	All kinds of vegetables and fruit orchards
2	Modified insect-proof net houses	Tomato, cucumber, capsicum, okra, brinjal, other cucurbits, etc.
3	Naturally ventilated greenhouses	Tomato, cucumber, capsicum, etc.
4	Plastic low tunnels	Mainly cucurbits, strawberry, French bean, etc.
5	Temporary plastic walls	Vegetables, seed spices like cumin
6	Plastic mulches	All kinds of vegetables and fruit orchards

Source: Singh (2019).

Protected cultivation for arid regions needs to be expanded under the proper technical guidance and to be carried out in a phased manner. The success of the technology depends primarily upon the profit farmers can make, but also knowledge, skills, capital, markets, etc. There is room for increasing farmers' income in arid/semi-arid regions by innovatively promoting protected farming. Nepal and Bangladesh have entirely different climatic conditions compared to Rajasthan and although protective cultivation of vegetables is suitable for all climates, vegetable cultivation in the areas with more moderate weather conditions can also be practiced in an open field.

Because of the great demand for perishable commodities, such as vegetables, as well as the high land prices needing to be covered by high revenue, most farmers around urban and peri-urban areas are moving towards the commercial production of vegetables. In the urban fringes, vegetable farming has emerged as a productive enterprise for cash generation and self-employment.

With huge populations, increasing numbers in the middle class, and a history of fruit and vegetable consumption, South Asia has the potential to increase its horticultural production, whilst increasing its quality and reducing losses. The (semi-)arid zones of India are suitable for further increasing horticultural production, following the example of similar regions in other parts of the world like Spain, the US or Israel, for example. The infrastructure is largely already available in India to support further development.

For Nepal and Bangladesh, there is already a growing demand for fruits and vegetables of better quality. The producers are often located closer to the consumer areas but improvements in transport, packing, and the cold chain are required to improve the quality and extend the shelf life of fresh produce, and subsequently reduce waste. Investments in these areas are quite likely to pay off as prices increase through quality improvement and spreading supply.

High-yielding vegetable seed varieties are tested for admittance in Ethiopia, which is required to boost production and there have already been many improved vegetable varieties released in Ethiopia and other countries. Low productivity in horticulture in Kenya is caused by inadequate credit to finance the purchase of inputs and capital investment. High-interest rates make it difficult for horticultural farmers to access credit. This results in unaffordability, adulteration, and consequently low application of key inputs (Hunde, 2017).

As the greenhouse sector is relatively small, few if any technology suppliers are operating in Tanzania. This lack of technology suppliers with a local presence to provide after-sales and maintenance services is an issue, especially in Tanzania. Dutch farmers in Tanzania indicate that most of them rely on the import of inputs and services from Kenya. This relates to fertilizers, crop protection products, biological control, substrate, plant care products, trays, and packaging materials**.** According to a report on the horticultural sector by (Agriprofocus, 2015), the following issues are hampering the Zambian vegetable sector:

- *Lack of good seeds:* The farmers indicated that some seed vendors sell mixed material or material with poor germination and they travel to urban areas to buy seed. Seed suppliers revealed that the main varieties sold were the old varieties improved hybrids are available, but more expensive.
- *Lack of and cost of fertilizers*: Although the various types of fertilizers used for fruit and vegetable production are available in cities and towns, the farmer must incur the extra cost of transporting the fertilizer to the village, hence increasing production costs.
- *Inadequate production technologies*: The horticultural sector does not have a coordinated approach to adapting to foreign technology. The sector lacks an inventory of available foreign technology, including sources and costs. This high dependence on foreign technology has resulted in smallholder farmers being unable to access technologies appropriate to their specific needs.
- *Very few smallholder farmers have access to loans for horticultural production*: The major vehicle through which smallholder farmers are accessing inputs is contract farming.

In general, technology should be simple, smart and cost-effective to attract the interest of an increasing number of small but developing commercially oriented fruit and vegetable farmers. However, there is a technology gap in the agricultural sector. Specifically, in Côte d'Ivoire, but this is also the case for most West African countries. The combination of the low level of education and the other gaps highlighted above (such as access to finance) leads to low usage of technology and agriculture inputs, such as equipment and fertilizers. Several market failures characterize inputs markets, including inconsistent rules and standards requirements, unrealistic standards, and lack of equipment and capacity at the rural level to ensure compliance. Moreover, the cost of technology and agriculture inputs for smallholders tend to be too high due to several factors: (i) weak bargaining power of smallholders; (ii) poor transportation and energy infrastructure.

According to Nugteren (2018) the fruit and vegetable sector of Côte d'Ivoire for the local market is characterized by a multitude of small farmers growing vegetables and fruits on a low technological level. Old varieties and extensive techniques are used. The markets are shattered, no cool chain is employed, other than at the supermarkets. The quality of products is in general low. This forces high-end supermarkets in Côte d'Ivoire, for example, to import high quality fruits and vegetables from Morocco and France. This can be noted in the other capitals as well.

The larger exporters of mangos tend to own their own packhouses but the majority of exporters rent a packhouse including staff, from a cooperative or private service provider. Some non-refrigerated or refrigerated facilities are available but generally, they are lacking. Pack houses tend to have simple, automatic washing and sorting lines, where mangos are sorted according to size.

Current technology gaps include:
- The lack of adapted mechanization for vegetable farmers. In Asia, small farmers have access to buy small two-wheeled tractors with tools that enhance their productivity enormously. In Côte d'Ivoire, paid labor becomes too expensive to be used in low productivity activities. This calls for higher productivity of the farm and/or more mechanization and rationalization of the techniques used.
- Lack of access to soil laboratories.
- Yield per hectare has been low due to poor and limited farming inputs, such as seedlings, pesticides and fertilizers (even counterfeit inputs).
- Low knowledge of good agricultural practices and post-harvest management (farmers, extension staff, dealers).
- Limited access to good quality, improved varieties and disease-resistant seeds. Sector dominated by informal seed supply chains and relies on saved seeds.
- No seed quality control system and monitoring/tracing in place.

Under investment in the agricultural sector has limited the development of agribusinesses and agricultural supply chains in much of Nigeria. The low level of agricultural services (finance, extension, quality inputs) is an issue in most – if not all – supply chains. An issue related to the export of fruits and vegetables is MRLs. The EU could ban fruits and vegetables from Cameroon because of their questionable quality and, above all, because of the loopholes in the Cameroonian sanitary and phytosanitary control system. Also, for other West African countries, this is an issue that needs attention.

7.3.2 Post-harvest (storage and handling) technologies

Nepal's fruit and vegetable markets are not that well-developed, and markets are congested and unhygienic. All the markets lack both infrastructure and required investment in post-harvest technologies. Some of the other generic problems faced are the lack of modern transportation, lack of storage facilities including cold chain storage, and missing quality control measures. According to the Asian Development Bank (ADB, 2018b), apart from improvements at wholesale markets, collection centers with cold chain and other agri-logistics must be developed in the production area for farmers and small traders. These centers should also provide spaces for sorting, cleaning, grading, packaging, and storage.

There are over 200 fruit and vegetable exporters in Kenya and 40 large-scale farmers and exporters (off-takers). Most exporters in Kenya do not have cold chain facilities and technologies and therefore focus on less perishable products. The large exporters do have access to third-party logistics (3PL) cold chain facilities and technologies. At present, as 3PL is a new concept in the country, the bulk of 3PL services are offered by multinational firms (e.g., Kuehne + Nagel). Other large exporters manage their own cold chains.

Improved and affordable post-harvest handling and storage technologies to prolong shelf life and minimize post-harvest losses are needed in East African countries like Ethiopia (Hunde, 2017). Also, in Kenya, where access to post-harvest facilities is almost non-existent for most fruit and vegetable farmers. Lack of storage facilities and cooled trucks contribute to large post-harvest losses, often reported for the horticultural sector: in Kenya, post-harvest losses are indicated to range between 20-50% (Lans et al., 2012).

Also for Tanzania, post-harvest losses are indicated to range between 20-50% (Lans et al., 2012) and access to post-harvest management facilities is almost non-existent for most fruit and vegetable farmers. Through donor-funded projects, initiatives have been developed to organize collection points for fruits and vegetables with storage and handling facilities for groups of farmers in East Africa.

A closed cold chain is essential for most export products. It requires continuous cooling and is used to keep fresh produce in good condition. Cooling requires electricity and this is unreliable and expensive in most regions studied. Therefore, there are only limited facilities to keep cargo refrigerated until departure. There is a lack of affordable and effective post-harvest storage solutions. Low-cost evaporative cooling devices, such as clay pot coolers and emergency core cooling systems, have the potential to benefit both off-grid populations with limited access to electricity and on-grid populations with high electricity and/or equipment costs for refrigerators. Also, in West Africa, cold storage is lacking in most packing stations.

7.3.3 Processing technologies

Several technologies have been developed to satisfy the demands of the processing sector in Nepal (Bhattarai, 2018). These include dehydration technologies to produce apple rings and cubes; juicing technologies to produce concentrates from apples, sweet orange, mango, pineapple, lime, lemon, banana and other fruits; cider and brandy production technology for apples and apricot; and pickle, jam, jelly, nectar, candy, sauces production technologies for small and medium-scale fruit and vegetable processing enterprises (Bhattarai, 2018). These technologies are disseminated through training and are being widely used by small-scale enterprises, especially women's groups and cooperatives.

Mango, guava, tomato, banana, and litchi are the main processed fruits in Bangladesh. The fruit processing industry has been boosted over the last decade by increasing demand, but still lacks capacity. The biggest challenge faced by the fruit processing industry in India is limited and inconsistent availability of fruits as most fruits are supplied to the fresh market. Additionally, low farm productivity results in relatively high prices for the raw material. Presently, both fruit and fruit juice concentrate prices in India are way higher than the global prices. India is among the top 5 producers of all these commodities, but has a negligible presence in their processing. To develop the sector, significantly improving both overall fruit availability and farm productivity is a pre-condition.

The most important processed products in the domestic market for processed fruits and vegetables in Kenya include canned tomatoes and tomato products, canned French beans, fruit juices and juice concentrates, sauces and chutneys, and jams. A range of fruit and vegetable processing facilities exist in Kenya. These range from modern, fully integrated plantation processors like Del Monte, to micro-enterprises (very small home/street operations). The processing industry can be broken into four segments: integrated plantation processors, modern mechanized processors, cottage industry processors, and micro-enterprises (Lans et al., 2012).

Nigeria produces less than 25% of its fruit juice demand according to Yahaya (2018) and information from the Raw Material and Research Development Council (RMRDC). Ninety-five percent of this juice is made from imported concentrates. The market for fruit concentrate, pre-mix and syrup (concentrates) rose from 1.5 million kg in 2002 to about 40 million kg in 2017. Firms in the EU, South America, Asia and South Africa are among the major suppliers of fruit juice and concentrate to Nigeria. However, with the import ban on consumer-pack fruit juice/drinks, local processing activities have increased rapidly to meet domestic demand. Common packaging includes Tetra Pak, cans, bottles (plastic and glass) and pouches. At present, juice processing technology in Nigeria ranges from individuals preparing juice at home for family consumption to multinational conglomerates. However, many problems constrain fruit juice production in Nigeria. One of the most important is that most tropical fruits are seasonal and highly perishable, which is actually not a unique constraint to Nigeria. The fruit juice producers complain about the lack of good quality materials for fruit juice production. A closely related challenge is how to improve the flexibility of the product lines to optimize the utilization of processing capacity by processing different fruits in different periods of the year.

The production of tomato paste has been taken-up in 2016 by Dangote, Nigeria's billionaire. However, this is such a low margin commodity that the cost of the raw material is the main determining factor for feasibility and Nigeria's yields are 5.5 t/ha, too low. The factory was closed in 2017. Spanish food multinational GBfoods, which produces Gino Tomato Paste in tins and sachets, set up a tomato processing plant in Kaduna state in 2019 with a capacity of 30 t per day. Raw tomatoes are to be sourced from a 30 ha pilot farm that grows more than 15 different varieties, averaging a yield of 40-50 t/ha. Tomato Jos is another large tomato processing actor in Nigeria.

Most West African countries have local juice production, like SIAGRO-Kirène in Senegal, Ivorio in Côte d'Ivoire, Delicio in Burkina Faso, Bravo in Benin. However, the African fruit juices are still struggling to go beyond their local market because going to industrial production remains a challenge due to difficulties related to packaging, international standards for export, training etc. The brand Ivorio can be found all over West Africa, and since the factory was taken over by a Malian industrial family, packaging has been modernized. However, the shortage of pineapple makes it difficult to produce in volumes. Sometimes the factory is forced to buy the first-grade pineapple at export prices for juicing (van den Broek et al., 2016). Export opportunities for processed fruits are also limited due to the often high prices of West African fruits, transport difficulties and regulatory barriers.

At a lower technology scale, drying of fruits and vegetables takes place (Rwubatse et al., 2014). The traditional method of drying, known as sun drying or open-air drying, involves simply laying the product in the sun on mats, roofs or drying floors. Other methods include hanging the crop underneath a shelter, on trees and rocks in the field. Even though this type of drying is frequently the most commercially used and viable technique to dry agricultural products in Africa, its full utilization by farmers, sellers and processors of fruits and vegetables is still needed. Solar drying uses an enclosed unit, to keep the food safe from damage, birds, insects and unexpected rainfall. The food is dried using solar thermal energy in a cleaner and healthier way.

It appears that mango processing is most advanced in Burkina Faso, where a large mango drying sector developed in the late 1990s. Burkina Faso is also home to DAFANI, a modern plant producing mango pulp for the EU market and juice for the local and regional markets. Due to poor marketing, lack of market research, and poor financial, production and supply management, the factory has gone bankrupt more than once. At present, it is unclear whether they are exporting mango pulp to the EU, but the juice is still produced for the regional market and is well-appreciated by consumers. Mali also has a new mango juice/ pulp factory, but it is unclear whether they are producing or profitable.

In Burkina Faso and Mali, the size of the processing industry provides an attractive market for farmers and local sellers. The quality criteria for processing mangoes are much lower than for fresh export. Besides, local varieties not suitable for export can be used. In Burkina Faso and Mali processors are now worried about the availability of mango and have started to invest, together with the World Bank, in the development of modern commercial orchards with irrigation. Local demand for mango juice is high, and artisanal juice factories are common in Mali, but fail to reach the scale of required production because of a lack of modern packaging equipment. There are opportunities in the EU market for mango pulp, but only for high quality products. The lack of processing in Côte d'Ivoire means that the market for second-grade mango is limited. Prices in Côte d'Ivoire for non-export grade fruit are only one-third to half of those in Mali and Burkina Faso. For processors, Hazard Analysis and Critical Control Point (HACCP) certification is essential. There is generally a 2-year period in which it is sufficient to show you are applying most principles and that you are in the process of certification.

7.3.4 Research and Development

Research and development centers were established in colonial times in many African countries, as well as in South Asia. However, most research has been focused on staple crops. Although there are some national centers focused on fruits and/or vegetables (like the National Horticultural Research Institute in Ibadan[9] most research on fruits and vegetables is organized via overall agricultural research institutes. An exception is the World Vegetable Center (WorldVeg), which is the main international research and development organization active in Asia and Africa with a unique mandate for vegetables. It was founded as the Asian Vegetable Research and Development Center in 1971 with headquarters in Taiwan, but gradually expanded its activities into Africa after 1992. WorldVeg has four regional research centers in the study locations:

- A South Asia office (established in 2006) on the campus of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) near Hyderabad, India.
- An Eastern and Southern Africa office in Arusha, Tanzania (established in 1992).
- A West and Central Africa – Dry Regions office in Bamako, Mali (established in 2014) on the campus of ICRISAT.
- A West and Central Africa – Coastal and Humid Regions office in Cotonou, Benin (established in 2017) on the campus of the International Institute of Tropical Agriculture.

WorldVeg holds the largest publicly available collection of vegetable genetic resources in its gene banks in Taiwan and Tanzania, including the largest collection of African indigenous vegetables. It works closely with national agricultural research systems in Asia and Africa, but also with the private sector. Current crop breeding programs focus on tomato, sweet and hot pepper, tropical pumpkin, bitter gourd, loofah, mungbean, and African traditional vegetables. Breeding lines are shared with public and private sector partners and are widely used by farmers in Africa and Asia (Ochieng et al., 2019; Schreinemachers et al., 2019, 2017b, 2017a; Sequeros et al., 2020). WorldVeg operates with a current staff of 350 persons, of whom are 43 are internationally recruited scientists and professionals, and a US$21 million annual budget in 2019.

In Africa's diverse agroclimatic zones, there is enormous potential for smallholder farmers to produce numerous vegetable crops for domestic and international markets (OECD and FAO, 2016). Urbanization and urban lifestyles are also accompanied by shifts in dietary patterns. More fruits and vegetables and processed foods are being consumed, while the share of cereals and pulses is declining.

The emergence of local food industries and processing facilities creates increasing employment. The demand for convenience is an overarching trend across income groups. This is reflected in the strong demand for processed and prepared foods and the expansion of street food. In urban areas, processed foods represent 41% of food budgets. Rural households, although less than their urban counterparts, still spend 36% of their budget on processed foods. Opportunities in processing, packaging, distribution and retail in urban and rural areas also have an impact on research and development, which needs to investigate innovative approaches.

[9] https://nihort.gov.ng

The strategic development of the agricultural sector would benefit from an increased policy focus on infrastructure, research and extension. Consistency of policy applications will remain a key factor in shaping the success of the sector within the development agenda and promote the rapid rise of medium- and large-scale "emergent" commercial farms (Jayne et al., 2016). This changing production structure requires research and development.

Vegetables are often the most important source of cash income for smallholder farmers, and indigenous vegetables provide an important source of nutrition, particularly for poor people. New varieties and improved management methods have been developed and extended through training programs for research and extension workers and smallholder farmers.

Increasing population pressure, agricultural intensification, and inappropriate farming practices seriously threaten the rural environment, especially in South Asia. New technologies are becoming increasingly complex, knowledge-intensive, and location-specific compared with those developed during the Green Revolution. This shift necessitates more decentralized research and extension systems and increased and well-targeted investments in public and private agricultural research and development. Further, population growth and economic development are significantly increasing the demand for fruits and vegetables, amongst other products. This means that sustainable support for agricultural research and development, both financially and politically, is crucial if important challenges are to be addressed.

Several countries have sought to fund agricultural research and development by a tax on agricultural production or exports, while other countries have been successful in commercializing their research results. In South Asia, research and development is mostly funded by the government in India and Bangladesh (>80%), whereas Nepal depends on donor funding for almost 80% of its research and development. Own income generation for the national research institutes is either absent or marginal. India has realized much growth in its spending on research and development since the beginning of this century.

7.4 Women's access to technology, infrastructure and institutions

This section reflects on gender differences in access to technology and infrastructure, and the implications of these differences to women's income generating capability and household nutrition and wellbeing.

Studies on commonly used technologies such as improved seeds, fertilizers, farm mechanization, improved management practices, transporting technologies, and information and communication technologies show that women have much lower rates of technology adoption than men (Beuchelt and Badstue, 2013; Ragasa et al., 2014). Differentiated access to complementary inputs and services is a major reason for the disproportionate uptake of technology. Although various labor and energy saving technologies have a huge potential to reduce the considerable time burden of women and increase labor productivity in general, their use has remained low due to a mismatch with cultural-appropriateness, accessibility and affordability (Simiyu and Foeken, 2013). Beyond the time and labor challenges, the relative limitations that women face in accessing funds, credit, information, education, training, opportunities to participate in innovation and decision making processes (Ragasa et al., 2014) — and the accompanying agribusiness inputs and services — continues to limit equal access to and opportunities for women and men. Similarly, regarding agribusiness support services, there are limited gender responsive innovations that effectively respond to the needs of women and men farmers. Even though there are some efforts to have gender aware responses, there remains large underrepresentation of women and women's perspectives in the crucial contributions made by scientists, educators, managers and extension agents, hence the need for more to be done.

To enhance the adoption of technology, there is a need for innovation processes that address women's and men's needs by examining the contextual preferences and opportunities to ensure that both

women and men can access and benefit the technology. This involves looking at constraints to production and marketing and promoting equity in the playing field by strengthening women's land, property and water rights (use and access). Genuine technological empowerment among women goes beyond the actual technology to include confidence building, decreasing time burdens, training and capacity strengthening. Empirical gender-disaggregated data and gender analysis in technological needs research are needed to provide a nuanced gender analysis that addresses the inherent diversity in typologies of women and men agripreneurs.

7.5 Conclusions: Opportunities for investment

Adequate infrastructure and technologies (land access, irrigation, port handling, transport, cold chain) are pre-requisites for the development of a viable horticultural sector. The key to improving the availability of fruits and vegetables for consumers depends on the type of product and area, but is either found in irrigation, cold storage or a combination of these. It especially requires the investment in infrastructure and technologies that can improve the storability of fruits and vegetables. Many horticultural crops are seasonal, and the storability is very limited for most products, especially under warm tropical ambient conditions. Therefore, the supply and availability of fresh fruits and vegetables throughout the year is an issue that needs addressing to meet consumer demand and intake recommendations. The lack of short and medium-term cold storage capacity means that the availability of products comes in peaks, which brings down the price and increase losses and wastes. The peaks in availability do not necessarily mean that the same fruit or vegetable is available year-round because different fruits or vegetables are available in different periods of the year. Except for some temperate, seasonable products, cold storage facilities do not need the capacity to store for many months. In many cases, the capacity to preserve fresh produce for several weeks already contributes to increased availability and better quality of fruits and vegetables. It will ultimately lead to more stable prices of the products, which is a crucial factor to determine the viability of the fruit and vegetable sector (Gilbert et al., 2017). Investments should focus on infrastructure for on-farm or near-farm cooling and handling in reefers, rather than on huge storage facilities near the consumer areas. Shortening the time between the moment of harvest and cooling the fresh fruit or vegetable to its optimum temperature is the main influence on its shelf life and therefore has a key impact on food loss reduction and profitability. Apart from short and medium-term cold storage capacity, in many areas, irrigation infrastructure is the most likely contributor to enabling year-round, or at least extended, availability of fresh fruits and especially vegetables. Moreover, the export industry and the emergence of a more organized retail sector are the pulling factors that can accelerate the upgrading of informal supply chains. This can benefit smallholder farmers as well (van den Broek et al., 2018). Investment or subsidy schemes can be applied to promote the development of modern and export-oriented downstream supply chains (e.g., modern retailers, traders, pack houses, processors). Furthermore, some processing technologies, including dehydration, juicing, cider and brandy production technology and sauce production technologies, are being widely used by small-scale enterprises, especially women's groups and cooperatives. Investments can therefore be directed in this direction as well.

All in all, it is not possible to draw one conclusion that fits all regions fully. However, there are some general situations:

- Improving availability:
  - If irrigation is available, dependency on rainfed cultivation vanishes and vegetables can be cultivated a second or third time. Also, the harvest window can be evenly spread, leading to a more even supply throughout the year and avoiding extreme low or high prices, which occur when the harvest comes all at once with little offer the rest of the year.
  - Medium and long (or even short) period storage is a second means to improve fruit and vegetable availability over a longer period and avoid high price fluctuations.
  - An export industry and the emergence of a middle class/organized retail sector, lead to a necessity to invest in cold storage. Organized retail also demands long-term availability of products and pushes producers to arrange that.
- Both the export sector and the emergence of organized retail act as catalyzers for the development of the fruit and vegetable sector. Money is being made to enable investments (also by out-growers

in the contract farming context) and there is a demand for agricultural inputs, technical developments and infrastructure. Suppliers thus start to assure the required inputs become available and governments focus on developing the required infrastructure like (rail) roads, harbors etc., because the profitability of the sector leads to the creation of employment and the investments are likely to be paid back over time.

- Evaporative cooling is capable of preserving most of the quality of a product. Because it is cheap, it can also be realized in small units, close to the producer. This results in a time advantage, which is important when realizing that reducing the temperature immediately after harvest has a significant effect on shelf life. Next to the organized retail, there are huge market segments where consumers are not able or willing to pay high prices that could pay back investments in sophisticated cooling systems. Cheap, evaporative cooling can serve as an intermediate solution to improve quality, extend shelf life, and therefore also extend the travel distance in which the products can become available.
- Above 2,000 m altitude, there is a huge advantage in storability. Because night temperatures get below 11°C, relatively cheap cooling systems, based on natural ventilation without mechanical cooling support, can be applied to maintain quality and extend shelf life.

8 Production of fruits and vegetables

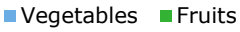
8.1 Approach

This chapter aims to describe production characteristics of current fruit and vegetable production in the three regions, West Africa, East Africa and South Asia.

First, we describe production trends in fruit and vegetable production in the three regions over the last two decades, and we map where this production within the three regions takes place. Based on the available production and population data, the production per capita per day is calculated at country level. Two sections focusing on sources of recent production growth and yield trends of major fruits and vegetables at regional level follow. Subsequently, farming systems that produce fruits and vegetables are characterized using production structure data from Nigeria, Ethiopia and India as an illustration. Based on general agronomic knowledge and case study data, insight in the production costs of vegetable production is provided. Finally, we summarize the major messages from a production perspective based on the presented analyses.

8.2 Production trends and places of production

Fruit and vegetable production trends in the targeted areas for the years 2000 to 2018 are based on the FAOSTAT "Crops" database[10], which contains national production data of agricultural crops. In total 64 different vegetables and fruits are distinguished in the FAOSTAT database. Because national reporting on vegetable and fruit production differs across countries, some vegetables and fruits are reported in groups "not else specified (nes)" and often include vegetables and fruits of minor local or international importance. However, Schreinemachers et al. (2018) showed that this group of vegetables and fruits is of major economic importance and represents the highest farmgate value of vegetables in low and lower-middle-income countries. We excluded starchy fruits and vegetables including potatoes, cassava, yams and banana/plantain in the following analyses. In general, FAOSTAT data refer to fruit and vegetable crops grown mainly for *sale*, thus excluding crops cultivated in home gardens that are mainly used for household consumption. Our own high estimates of the area with home garden grown fruits and vegetables varies between 3% in East Asia and 13% in East Africa of harvested fruit and vegetable area of FAOSTAT (Appendix 14).



[10] http://www.fao.org/faostat/en/#data/QC

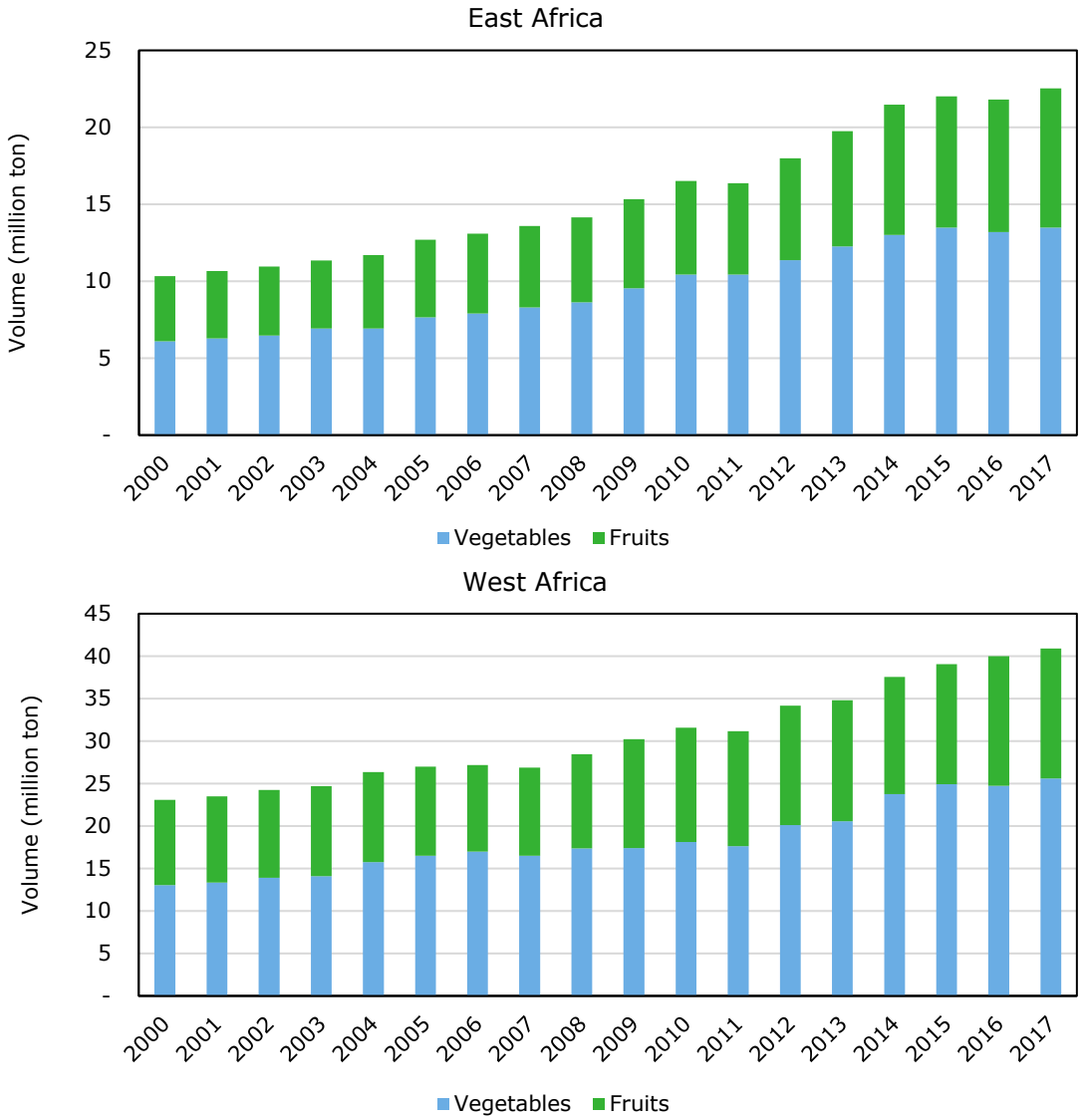


Figure 8.1 shows the trend of the total fruit and vegetable production in South Asia, East Africa and West Africa between 2000 to 2018. Appendix 15 shows the production figures for a selection of countries in these regions. In general, fruit and vegetable production increased steadily in this period in the three regions, but the growth rate appears to have slowed down in South Asia and East Africa after 2014. Note the different scale of fruit and vegetable production among the regions: current fruit and vegetable production in South Asia is about 12 times higher than in East Africa and about six times higher than in West Africa.

Figure 8.2 shows the place of fruit and vegetable production in the three regions based on MAPSPAM data from 2010 (www.mapspam.info). The greener parts show hot spot areas with a lot fruits and vegetables, such as large parts of India and Nigeria, while the white parts show areas without fruits and vegetables, such as the northern part of West Africa and large parts of East Africa. Using a different and older database (http://www.earthstat.org/), Appendix 16 shows the harvested areas of fruits and vegetables around the year 2000 sub-divided into five groups based on their nutritional value.

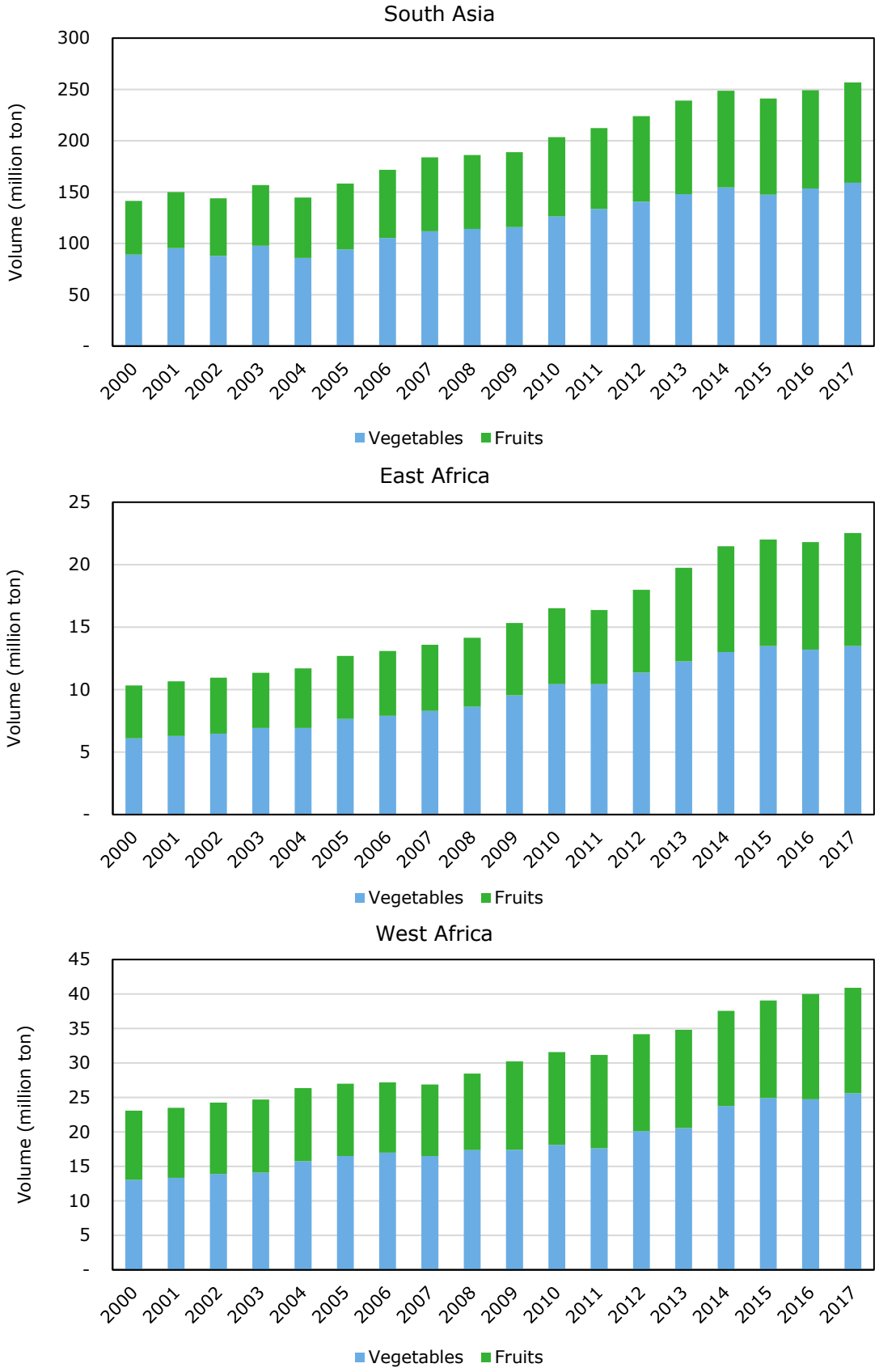


Figure 8.1 *Production of fruits and vegetables in South Asia (top), East Africa (center) and West Africa (bottom) during 2000-2018*
Source: FAOSTAT [Accessed: September 7, 2020].

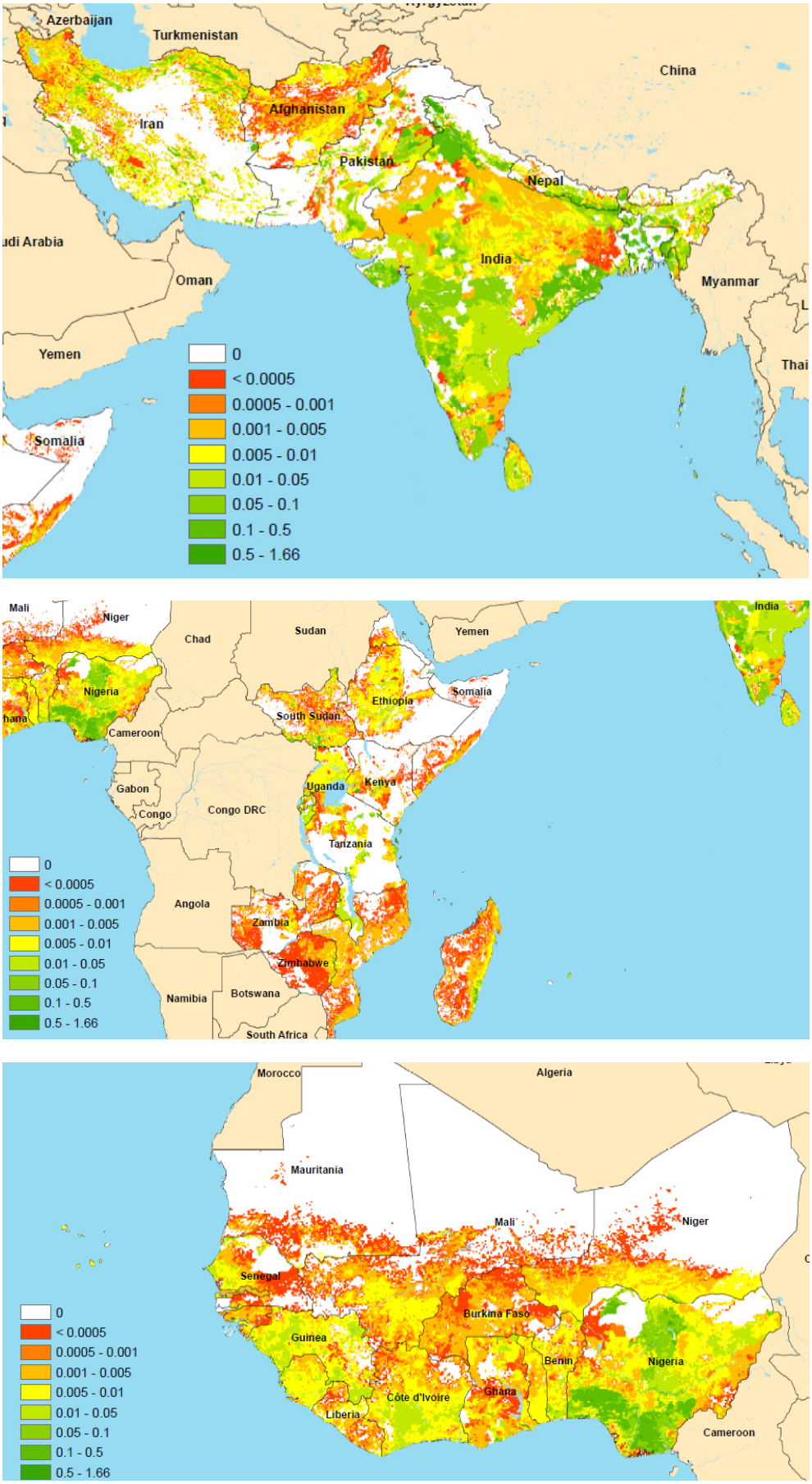


Figure 8.2 *Harvested area of fruits and vegetables in South Asia (top), East Africa (center) and West Africa (bottom) in 2010. Harvested area expressed as fraction of a pixel, which is the smallest unit of the used raster map. In these maps, pixels have an approximate size of 8,600 ha (5 arcmin resolution). Fractions can be >1 in situations where more than one vegetable crop per year is cultivated*
Source: MAPSPAM [Accessed: 9 September 2020].

8.3 Availability of fruit and vegetables

While Section 8.2 gives insight into the development of the total fruit and vegetable production over the last two decades in the three regions, it does not provide insight in the amount of fruits and vegetables produced and available for consumers because population sizes differ across the regions. Figure 8.3 shows the total production of fruits and vegetables expressed per capita per day at country level. In reality, the fruit and vegetable availability for consumers will be lower because of post-harvest losses. Therefore, the data shown represents the maximum availability of fruits and vegetables.

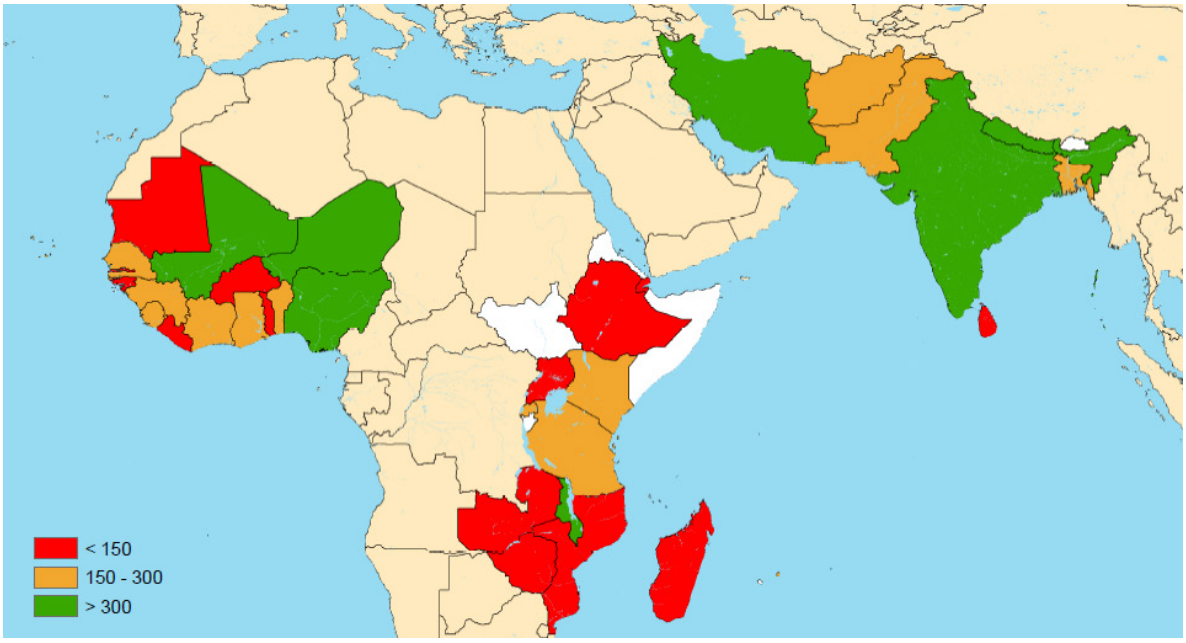


Figure 8.3 *Total fruit and vegetable production per capita per day in countries of West Africa, East Africa and South Asia, based on the average production and population in the years 2015-2017. White countries indicate missing data.*
Source: FAOSTAT [Accessed: 7 September 2020].

The WHO recommended daily per capita intake of 400 g or more of vegetables and fruits is only produced in Malawi, Nepal, and Iran. In general, production volumes per capita in South Asia are highest with the exception of Sri Lanka. In West Africa, production per capita is high in Nigeria, Mali, and Niger, but in the other countries per capita production levels are medium (150-300 g per day) to low (<150 g per day). In East Africa, overall production is low, except in Malawi, and to a lesser extent in Kenya and Tanzania.

Because losses within the chain up to the consumer will happen (FAO, 2011b), the main conclusion from Figure 8.3 is that current production of fruit and vegetables in most countries is far too low to support a healthy intake of fruit and vegetables.

8.4 Regional changes in fruit and vegetable production

Section 5 showed that current production of vegetables and fruits in many countries limits healthy intake levels of fruits and vegetables. This section further analyzes at regional level i) recent fruit and vegetable production changes in relation to population growth, and ii) the sources of production changes, i.e., through expansion of the area with fruits and vegetables or yield increase, the production per unit of land.

Based on FAOSTAT,

		Population growth (%)	Percentage change in production volume	Percentage change in production area
South Asia	Population growth	25		
	Vegetables		69	48
	Fruits		77	58
East Africa	Population growth	55		
	Vegetables		113	73
	Fruits		100	86
West Africa	Population growth	50		
	Vegetables		87	94
	Fruits		46	24

shows the relative change in population, production volume and harvested area of fruits and vegetables in South Asia, East Africa and West Africa in the period 2000-2017. To limit the effect of annual fluctuations in reported production data, the data for the year 2000 is the 3-year average data from 2000-2002, and 2017 is the 3-year average data from 2015-2017.

		Population growth (%)	Percentage change in production volume	Percentage change in production area
South Asia	Population growth	25		
	Vegetables		69	48
	Fruits		77	58
East Africa	Population growth	55		
	Vegetables		113	73
	Fruits		100	86
West Africa	Population growth	50		
	Vegetables		87	94
	Fruits		46	24

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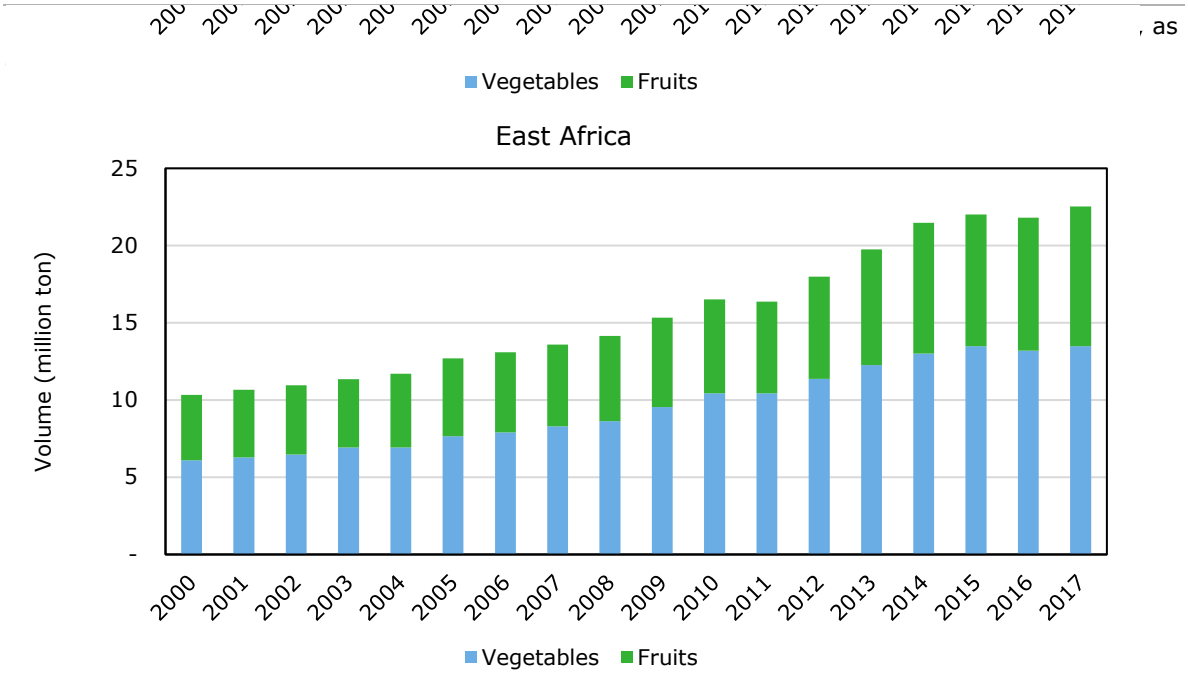

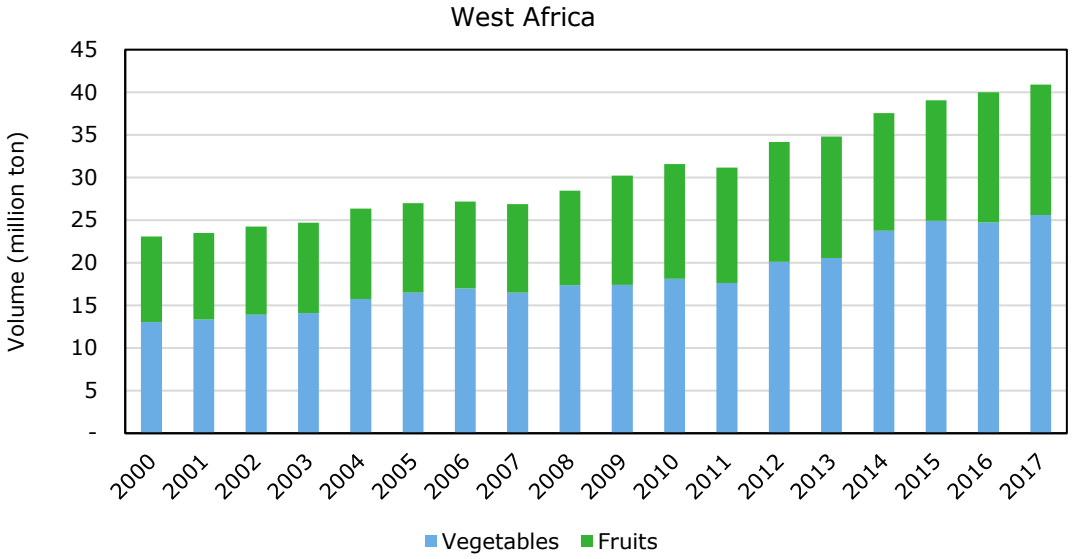

Figure 8.1. The lowest relative production growth was in the volumes of fruit (4%) in West Africa, and largest growth (113%) in the volumes of vegetables in East Africa. Furthermore,

		Population growth (%)	Percentage change in production volume	Percentage change in production area
South Asia	Population growth	25		
	Vegetables		69	48
	Fruits		77	58
East Africa	Population growth	55		
	Vegetables		113	73
	Fruits		100	86
West Africa	Population growth	50		
	Vegetables		87	94
	Fruits		46	24

shows that the growth in fruit and vegetable production has outpaced population growth in the last 20 years, except for the production of fruits in West Africa. The data in

		Population growth (%)	Percentage change in production volume	Percentage change in production area
South Asia	Population growth	25		
	Vegetables		69	48
	Fruits		77	58
East Africa	Population growth	55		
	Vegetables		113	73
	Fruits		100	86
West Africa	Population growth	50		
	Vegetables		87	94
	Fruits		46	24

also shows that the production growth is for a large part explained by area expansion, i.e., the increase in harvested areas of fruits and vegetables. On average over the regions, 75% of the growth in fruit and vegetable production volume was related to area expansion. The growth in vegetable production in West Africa was even lower than the increase in harvested vegetable area, suggesting decreasing vegetable yields. In contrast, fruit production in West Africa was for about 50% based on increased yields and for 50% based on an increase in area. Changes in the produced crop types, either a change in vegetable or fruit type, in the analysis period is a confounding factor impacting production growth. Section 8.5 therefore analyzes trends in the yields of selected vegetables and fruits in the three regions.

Table 8.1 *Change in population, production volume and harvested area of fruits and vegetables in South Asia, East Africa and West Africa between the 2000 and 2017*

		Population growth (%)	Percentage change in production volume	Percentage change in production area
South Asia	Population growth	25		
	Vegetables		69	48
	Fruits		77	58
East Africa	Population growth	55		
	Vegetables		113	73
	Fruits		100	86
West Africa	Population growth	50		
	Vegetables		87	94
	Fruits		46	24

Source: FAOSTAT [Accessed: 7 September 2020].

8.5 Yield trends of selected vegetables and fruits

Because aggregated fruit and vegetable production data hinder the assessment of yield trends, in this section we analyze the yield trends of the two most important fruits and vegetables in terms of production in each region. The selected fruits and vegetables in each region are based on Appendix 17, which shows that the selected four fruits and vegetables present approximately 50% of the total fruit and vegetable production in East Africa and West Africa, and roughly 40% of the more diverse fruit and vegetable production in South Asia.

Though some crop types differ across the regions because of their relative local importance Figure 8.4 gives several types of information. First, yield levels in West Africa are lower than in East Africa and especially, South Asia. Yields of tomatoes and onions in West Africa show large fluctuations in the analyzed period, but the essential point is that current yields of both crops are not much different from 20 years ago. Second, pineapple yields strongly declined in the last two decades in East Africa, but the other three crop types show a steady yield increase. However, the observed growth rates are lower than the population growth in the same period (

		Population growth (%)	Percentage change in production volume	Percentage change in production area
South Asia	Population growth	25		
	Vegetables		69	48
	Fruits		77	58
East Africa	Population growth	55		
	Vegetables		113	73
	Fruits		100	86
West Africa	Population growth	50		
	Vegetables		87	94
	Fruits		46	24

). In South Asia, yield levels of all four major fruits and vegetables showed a steady yield increase, and the growth in yield improvement of three crops (tomatoes, onions and mangos) outpaced the population growth, as shown in

		Population growth (%)	Percentage change in production volume	Percentage change in production area
South Asia	Population growth	25		
	Vegetables		69	48
	Fruits		77	58
East Africa	Population growth	55		
	Vegetables		113	73
	Fruits		100	86
West Africa	Population growth	50		
	Vegetables		87	94

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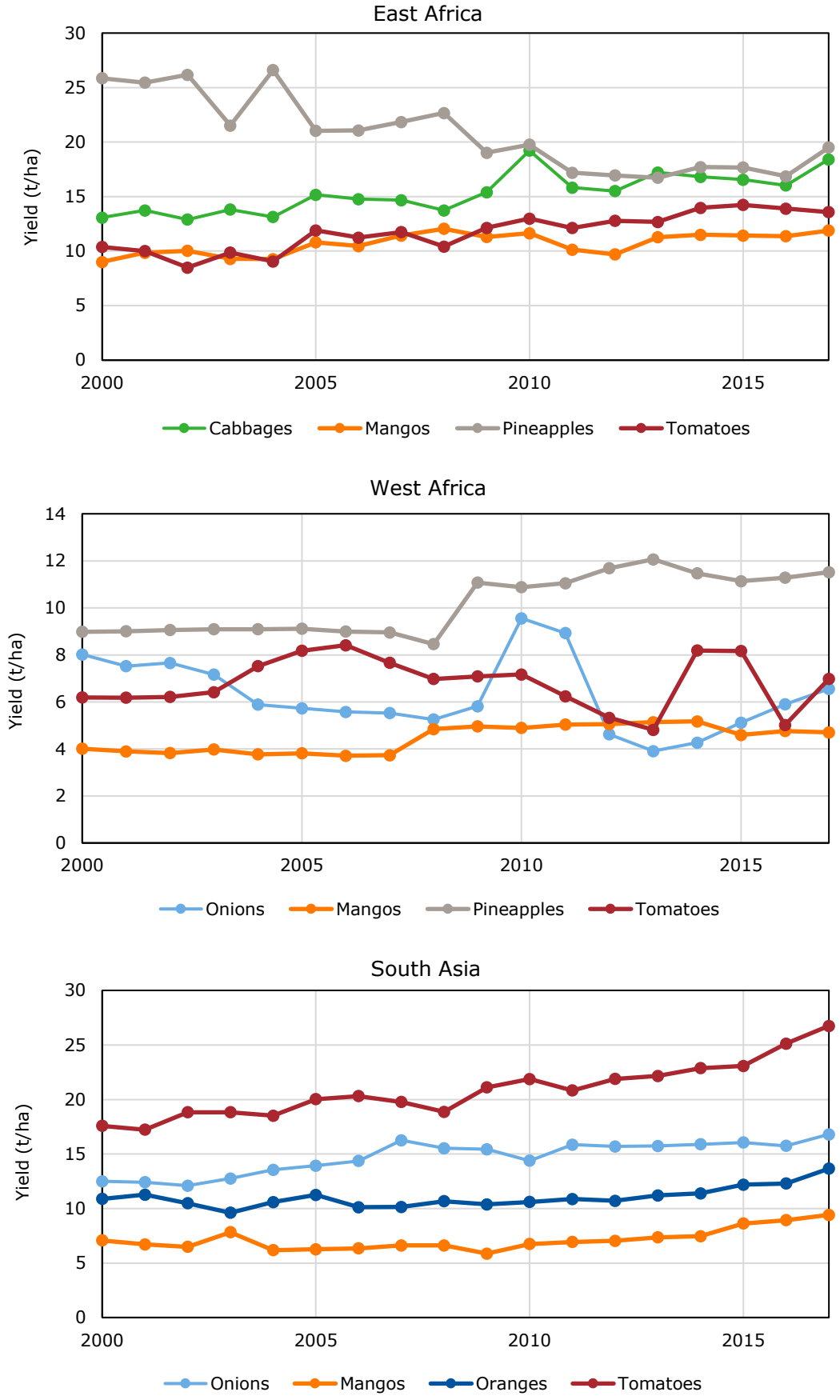

Figure 8.4 *Yield trends of the four most important fruits and vegetables in East Africa (upper left panel), West Africa (upper right panel) and South Asia (bottom panel) during the period 2000-2017. Source: FAOSTAT [Accessed: 7 September 2020].*

Results of the yield trends of major fruits and vegetables confirm the main findings of Section 8.4, i.e., improvements in crop yield has been low or even stagnant in the last two decades, especially in Africa, and that the growth in fruit and vegetable production was mainly associated with an expansion of the fruit and vegetable area. However, yields of mangos, tomatoes and onion in South Asia are an exception, as yield growth outpaced population growth.

8.6 Characterization of fruit and vegetable farming systems

Farming systems have diverging opportunities to increase the production of fruits and vegetables. In addition, the type of farming system determines how fruit and vegetable producers are linked to the food supply system and to what extent they contribute to improved food and nutrition. Integration of fruit and vegetable production systems in the food supply system is important given the perishable nature of vegetables and fruits, and consumer demand.

Here, we show the production structure of fruits and vegetables in Nigeria, Ethiopia and India, representing West Africa, East Africa and South Asia, respectively. The information provided illustrates the relative importance of fruit and vegetable production in farming systems compared to farming systems that do not produce fruits and vegetables, and it indicates the importance of large to small farming systems in the production of fruits and vegetables in the three regions.

The information for Nigeria and Ethiopia is based on data from the Living Standard Measurement Study (LSMS) of the World Bank, both from the years 2015/16, and the data from India is based on the national agricultural census data from 2011/12. The data shown for India is based on 138 million operational holdings, cultivating 159 million ha. The LSMS data for Ethiopia is based on approximately 2,945 households, and for Nigeria on 2,837 households.

Figure 8.5 shows the agricultural production structure in the three countries and the importance of large farming systems (>20 ha), medium farming systems (1-4 ha) and small farming systems (<1 ha) that produce fruits or vegetables. Figure 8.5 shows that more than 65% of all farms in the three countries are small farming systems (<1 ha). In both India and Nigeria, most of these small farms produce fruits or vegetables, but not in Ethiopia. The share of medium-sized farms (1-4 ha), about 25%, is also quite similar across the three countries. The importance of fruits and vegetables in medium-sized farming systems is lower in Ethiopia compared to India and Nigeria. The share of large farms (>20 ha) is small in all three countries, less than 5% of all farms.

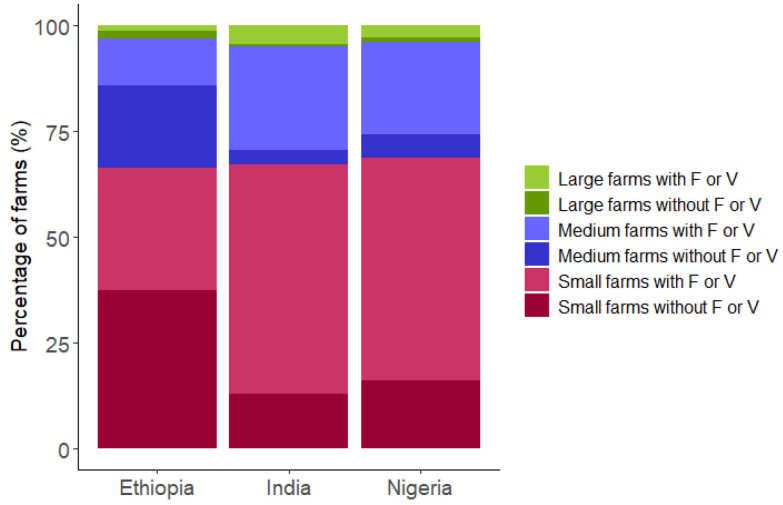

Figure 8.5 *Share of large (>20 ha), medium (1-4 ha) and small (<1 ha) farming systems with and without fruits (F) and vegetables (V) in Ethiopia, India and Nigeria. Source: LSMS for Ethiopia and Nigeria and the national agricultural census data for India.*

Figure 8.6 shows the share of the crop areas of the three farm size classes for Ethiopia, India and Nigeria with and without fruits and vegetables. Small farms cultivate approximately 25% of the total crop area in the three countries, medium-sized farms about 50% and the large farms the other 25% with generally small differences between the three countries. The area under fruits and vegetables is very small in all farm size classes, only a few percent of the cropped area is cultivated with fruits and vegetables.

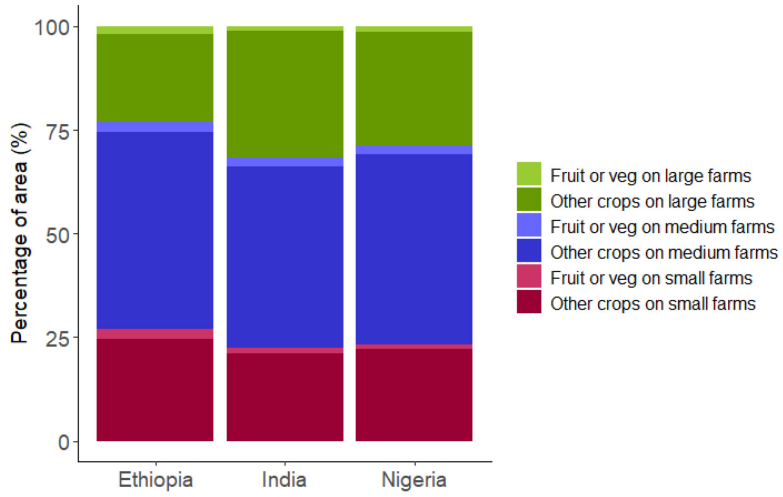

Figure 8.6 *Percentage of total crop areas of large (>20 ha), medium (1-4 ha) and small (<1 ha) farming systems with and without fruits and vegetables in Ethiopia, India and Nigeria*
Source: LSMS for Ethiopia and Nigeria and the national agricultural census data for India.

Figure 8.5 and Figure 8.6 indicate that many of the small, medium and large farms have fruits and vegetables, especially in India and Nigeria, but the cultivated land with fruits and vegetables is limited. The data suggest that many farms have small areas with some fruit or vegetable production. Consequently, the production of fruits and vegetables per farm is small. Such farms lack scale advantages to reduce production costs of fruits and vegetables and to provide retailers with fruits and vegetables over an extended period, as demanded.

Based on farm structure data, it is difficult to quantify the contribution of small, medium and large farms to national fruit and vegetable production in the three countries. Area-wise, small and medium farms provide the major share of fruit and vegetable production, though differences in yields among farm types is a confounding factor. An indication of the contribution of large farms is in Tanzania, where large fruit and vegetable farms (>20 ha, or >0.5 ha of intensive horticulture production) produced less than 2% of the national mango and orange production and less than 1% of national production of tomatoes, onions and green bean (GoT, 2016).

Box 9: Booming vegetable clusters in East Africa

In the slipstream of the large-scale export flower industry in Kenya and Ethiopia booming fruit and vegetable clusters have been developed around Lake Naivasha and Lake Ziway, respectively. The area around Lake Naivasha is the largest exporter of flowers and vegetables from East Africa, and one of the largest earners of foreign currency in Kenya Horticultural development around Lake Ziway started about 20 years later than in Kenya, but Ethiopia has now developed as a major competitor for the Kenyan flower industry. In addition, small and medium-sized farmers around Lake Ziway have become important vegetable suppliers for the national and regional markets.

Key factors to the development of both clusters are the favorable soil and climate conditions and the access to ample irrigation water, which were important investment conditions for the large-scale horticultural farms around Lake Naivasha and Lake Ziway. In Ethiopia, the political stability and a broad range of financial incentives for foreign investors were key drivers for the establishment of large-scale horticulture farms from the beginning of this century. Inspired by the success of these farms and the availability of small and affordable irrigation pumps imported from China, well-off locals started to invest in vegetable production. This development was further accelerated by the public investments in community-based irrigation schemes for small farmers.

However, the development in both clusters is largely uncontrolled and, for example, has resulted in tensions between pastoralists about the access to water resources (Macharia, 2015). In addition, the profitability of vegetable production stimulated the over-supply of inputs resulting in a variety of negative externalities related to occupational health, water pollution (Loha et al., 2020; Teklu et al., 2016), food safety (Asfaw 2010; Loha, Lamoree and de Boer, 2020) and unsustainable irrigation water extraction (Getnet et al., 2014).

8.7 Production costs

Global databases on the cost of fruit and vegetable production are lacking and hinder, for example, a comparison with the production cost of cereals. However, agronomic knowledge and case study information gives some insight on the general production structure of vegetables, the relative size of cost components, and differences in cost structure with cereals.

Most field operations in fruit and vegetable production still depend on manual labor, especially in the small- and medium-sized fruit and vegetable production systems of West Africa, East Africa and South Asia. This is not so much different from other crops, such as cereals, but total labor requirements in most fruits and vegetables are considerably higher than in cereals. Table 8.2 illustrates the differences in labor requirements for a selection of vegetables and staple crops as compiled in Sri Lanka (CIC, 2010). The higher labor requirements in vegetables, up to 10 times more depending on crop type, is related to the higher skills needs of vegetables for proper land preparation, seed beds, transplanting/sowing (often in beds), higher frequency of operations (fertilizer and pesticide applications, weeding, irrigation), and selective and multiple harvesting operations (e.g., in tomato and mango).

Table 8.2 *Labor requirements (in labor days) in selected vegetables, rainfed maize and irrigated rice production in Sri Lanka*

	Carrot	Tomato	Okra	Onion	Maize	Rice
Yield (kg/ha)	30,000	35,000	25,000	37,500	6,250	6,150
Nursery		15		75		
Land/bed preparation [1]	50	50	25	150		15
Planting/seeding/transplanting	75	25	30	100	15	1.25
Fertilization	35	28	25	25	15	3.75
Irrigation		45	30	100		17.5
Pest and disease control	20	45	5	25	5	
Tying up plants		45				
Weeding/ridging	60	48	40	75		10
Harvesting	70	95	35	100	20	20
Collection						12.5
Post-harvest handling				40	5	10
Transport					2.5	5
	310	396	190	690	62.5	95

[1] Excludes labor requirements for mechanized field preparation.

Source: CIC Institute of Agri Businesses (2010).

Although these indicative labor requirements are difficult to extrapolate to other countries because of differences in local conditions, they confirm other empirical studies that quantified labor requirements and associated costs in vegetables (De Putter et al., 2012; Everaarts, Putter and Maerere, 2017; Weinberger and Lumpkin, 2007). Based on the first two studies, Appendix 18 shows the production cost structure of 16 vegetable crops in Tanzania and Ethiopia. On average, more than 50% of the total input costs are related to labor, followed by fertilizers (17%), seed/planting material (13%), and crop protection (8%). Other costs like fuel for irrigation pumps, stakes and trellising make up on average 9% of the costs. With increasing input intensity, represented by the Ethiopia data in Appendix 18, the relative importance of labor costs diminishes to 30-40%, while costs for crop protection and other costs become more important.

8.8 Conclusions

1. Fruit and vegetable production have outpaced population growth in South Asia, East Africa and West Africa in the last two decades.
2. However, fruit and vegetable production remains too low to support recommended healthy intake levels across the three regions.
3. Growth of fruit and vegetable production in the past two decades is 75% based on land expansion and only 25% on increased crop yields.
4. In the past two decades, yield growth of major fruits and vegetables was stagnant in West Africa, sluggish in East Africa and steady in South Asia.
5. Based on the recent yield developments of major fruits and vegetables, low external input levels are the norm. Where farmers have opportunities to intensify, often stimulated by the availability of irrigation water, input levels increase rapidly resulting in over-supply of inputs and various negative externalities.
6. More than 65% of the farms in regional representative countries are <1 ha. These small farms lack scale advantages to reduce production costs.
7. The area with fruits and vegetables on small and medium-sized farms is very small across the three regions. This risk coping mechanism allows farmers to deal with a variety of uncertainties, such as variable weather conditions, uncertain product and labor markets, pests and diseases and a poor bargaining position. Consequently, specialization in fruit and vegetable production is rather the exception than the rule.
8. Total labor requirements in fruit and vegetable production are considerably higher (up to 10 times higher) than in cereal production. This is related to the need for more skilled and intensive field operations. Consequently, labor costs make up an important part of the production cost, i.e., up to 50%, depending on crop type and production intensity.

9 Fruits and vegetables in food systems; from feedback loops to options for system transformation

In this chapter we reflect on the roles, relations and perspectives of fruits and vegetables in the food systems of the three regions. The various components of a food system are interlinked, not only in terms of product and capital flows, but also through feedback loops and tradeoffs (Section 9.1). A defining feature of systems thinking is that it views the behavior of a system as an interplay of interacting subsystems, in which feedback plays a key role, rather than as a simple chain of cause-effect relationships (van Berkum et al., 2018). Feedback loops can be both positive and negative. Where negative feedback loops are often self-regulating and useful to bring a system back into its state of stability, positive feedback loops amplify a desired variable and naturally move the system away from its starting state to a desired state. Tradeoffs refer to a balancing of factors all of which are not attainable at the same time. In other words, tradeoffs are understood here as negative by-effects of greater gains.

In Section 9.2 we reflect on the different actors and agents that influence fruits and vegetables in food systems, and how they are related to each other. In Section 9.3 we take a closer look at the opportunities and barriers to enhancing the performance of the food system components that we have investigated. Based on the previous sections we present some future projections on production and consumption in Section 9.4. Finally, in Section 9.5 we discuss emerging options for enhancing food system performance that results in enhanced consumption of fruits and vegetables, as well as sustainable and inclusive economic development.

9.1 Feedback loops and tradeoffs

Based on our analyses of the three regions we identified the following feedback loops and tradeoffs in the food systems with prominent roles of fruits and vegetables:

- Food prices and energy density seem to be important drivers and constraints of food choices. With reference to fruits and vegetables, many people simply cannot afford these products, which are essential for a "healthy" diet.
- Fresh fruits and vegetables are income elastic products in emerging economies, so an increase in average income level has a direct effect on the volume and type of fresh produce consumption. Yet, all fruit and vegetable consumption reaches a certain ceiling, well below the recommended daily intake.
- Trends of urbanization and increased mobility are more often male-biased, meaning women are more regularly (seasonally) managing smallholder plots, though without the "recognition" — land rights, access to credit, training, etc., — or reduction in household responsibilities. This leads to women-owned income being more risk-exposed due to the double-burden (internal risk) and climate shocks (external risk).
- Export firms can be important drivers of change in the domestic fruit and vegetable production systems and supply chains oriented towards national food environments. These effects are mainly caused by the introduction and adoption of technology and the transfer of know-how. Yet, production and supply to national food systems operate under very different terms of trade and cost/benefit ratios, often constraining the application of export-oriented modes of production and marketing.
- Storage has a positive effect on seasonal price fluctuations of fruits and vegetables due to the capacity to distribute supply over longer periods. This can contribute to stabilizing prices across the year.
- Negative feedback loops are frequently observed in informal markets characterized by information asymmetry between food system actors. The domination of informal markets may also cause limited possibilities for farmers to engage directly in the supply chains (e.g., through direct sales to retail).

9.2 Actors and agents

Food systems are man-made configurations in which human interactions link components which are not interactive by nature. Actors and agents communicate with each other, trade produce, provide services, impose restrictions, exchange capital for goods etc. In this complexity of human activities, we can bring some order by categorizing the actors and agents. Based on our study we propose the following typologies by food system component.

9.2.1 Consumers

Although often referred to as a rather homogenous large group, we observe a great diversity in consumers, which calls for a more detailed consumer categorization and segmentation. Among the major distinctive features, which to a large extent determine consumer choices, are geographical location, income, purchasing power and gender. Geographical location is associated with availability and variety of, in our case, fruits and vegetables through production, markets and, to a lesser extent, the prevailing preferences for fruits and vegetables related to the culture of the groups living in the geographical locations. A second feature that differentiates consumers is income level and purchasing power, defined to a large extent by the affordability of healthy food for people. Gender of consumers is also a differentiating feature, as men and women have different food behaviors, which can be partly explained by their role in the household, but also by historically evolved gender-based differences. Age may also be a dominant characteristic of consumers — young people may have different knowledge about and preferences for food and so may adopt new consumer habits more easily as compared to adults.

Fruit and vegetable consumers															
Urban consumers								Rural consumers							
Well-endowed households				Poor households				Well-endowed households				Poor households			
Male consumers		Female consumers		Male consumers		Female consumers		Male consumers		Female consumers		Male consumers		Female consumers	
Young	Adult	Young	Adult	Young	Adult	Young	Adult	Young	Adult	Young	Adult	Young	Adult	Young	Adult

Figure 9.1 *Consumer diversity*
Source: Authors' own.

9.2.2 Intermediary actors

Traders come in many different forms, but they have a key role in the supply chain. They link consumers with producers and are sometimes referred to as the "missing middle" or "hidden middle" (AGRA, 2019). However, in reality they are all but missing or hidden in LMIC economies. It appears that policymakers have given little attention to SMEs over the past decades. The fact that a majority of SMEs in LMICs operate informally and are therefore not registered and "captured" by formal institutions, including the tax office, may explain this.

Processors in the studied regions face serious problems in competing with imported processed fruit and vegetable products. Often products are imported at lower costs than they are produced domestically. This makes it very difficult for processors to establish a successful business model. In addition, the continuous sourcing of sufficient raw materials is a challenge. Farmers are not eager to sell to processors most of the time since they get higher prices at the fresh market. Only when markets are saturated are farmers willing to sell to processors.

Supermarkets have been increasing their market share in LMIC economies in the last decades. Especially in South Asia, they have become dominant in urbanized areas and many smallholder farmers are supplying supermarkets. In East and West Africa, this share is still very limited. However, supermarket procurement drives systemic change due to their high requirements related to quality, hygiene and also supply consistency.

Various types of informal retailers sell fruits and vegetables to urban consumers. They often gather their produce at major urban wholesale markets and resell it in populated areas where the consumers live. In this way they provide important fruit and vegetable outlets for the urban poor and middle classes because travelling to wholesale markets can be time-consuming and expensive in many cases.

9.2.3 Producers

For smallholders, fruits and vegetables are often part of more comprehensive farming systems which include other crops and livestock. As such, the production of fruits and vegetables "compete" with these other crops and livestock for attribution of often scarce resources, including labor and capital. Smallholders, both men and women, make frequent decisions about where to allocate these resources depending on access and availability, and production goals. Considering the great variation in these production factors, smallholders cannot be considered as a homogenous group of producers. But often they can be categorized in their respective contexts using criteria of ownership and access to production assets and gender. As such, a simplified producer landscape could consist of smallholder households with ample access to and ownership over production factors, for whom agriculture is not only a source of food, but more importantly a source of income. In contrast, smallholder households with (very) limited access to and ownership over production factors are often engaged in agriculture for purposes of feeding the family, while being engaged in wage labor and off-farm activities for the generation of income. In these two basic categories, gender is a dominant factor as it limits female access to production factors.

There are numerous exceptions to the above categorization, which always has to be validated in its context. Examples of other categories of fruit and vegetable producers are (often young) people cultivating small areas of land in peri-urban settings, who are fully oriented towards producing for local markets to generate income. Another category can be identified by capital and technology intensive export producers, with often international ownership and management. In their vicinity may emerge a category of fruit and vegetable producing smallholders taking benefit from the infrastructure and access to technology associated with the export firms. These smallholders are often driven by commercial motifs and seek to supply domestic markets with their produce.

9.2.4 Input and service providers

A specific group of supply chain agents, also referred to as supply chain supporters or intermediate actors, are input suppliers and service providers. The inputs provided range from seed, chemical inputs, machineries etc., and services include, for example, finance, agricultural advice and information and communication technologies (ITC) support or market intelligence. These agents can be public or private. Civil society organizations, such as farmer cooperatives and NGOs, may also provide inputs and services. Private suppliers and providers can be differentiated between formal and informal enterprises, as well as by their size and scope, ranging from locally operating SMEs to international businesses.

Categorization of suppliers and providers matters as the quality and affordability of inputs and services are affected by the type of supplier or provider. Within the food system we observe causal relations between categories of suppliers and providers and categories of fruit and vegetable producers. Export oriented producers are very dependent on high quality inputs and often refer to internationally operating supplier firms. On the contrary, less-resourceful producers depend on local SMEs and public agricultural advisory services. Women producers frequently encounter obstacles to access inputs and are frequently excluded from public services. On the contrary, they may have organized themselves in self-help groups or informal associations with the objective of accessing inputs or obtaining services.

9.2.5 Public policy makers and research and development

Government policy makers can be important drivers of changes in food systems through legislation, market regulation and measures to stimulate desired behavior of various food system actors and agents. Policymakers can also be categorized in more or less homogenous clusters, for example, by their level of authority, ranging from local to national and even regional or international, as well as

their sphere of influence (e.g., food import policy, input subsidies, food safety regulation etc.). Different policy interventions should ideally come together in a coherent national or sub-national food policy that links them to specific actors and agents in the food system in order to achieve desirable transitions. However, to date, such food policies are not very common and the reality is that government policies are often conflicting, as they are conceived in an arena of political influence.

Research and development is an indispensable component of the capacity of a food system to bring about innovations that support transitions. This is particularly relevant in the context of fruits and vegetables, which are generally knowledge intensive crops to produce, while in the later stages of the chain, storage, logistics and marketing require well thought-out management and coordination. Research and development can be either public, serving the creation of public good, or private. In the latter case research and development supports the business development of intermediate actors in the food system. It must be acknowledged here that not all innovations in a food system emerge from public or private research and development, as other actors may have innovation capacities and supporting networks as well.

Inadequate access to technical knowledge for smallholder farmers is observed, especially for those who want to start growing fruits or vegetables. Agricultural extension in Africa is generally under resourced and often biased towards supporting staple crop production for food security purposes. Knowledge on how to grow and produce vegetables is hard to access for smallholder farmers in rural areas. Farmers need new skills and knowledge to produce marketable fruits and vegetables, but new production insights and knowledge do not reach them in remote, rural areas. Lack of knowledge and low technical skills result in low resource use efficiencies and increased occupational health problems, which increase the production cost of fruits and vegetables.

9.2.6 Actors' and agents' landscape

When analyzing a food system, we are struck by the multitude of actors and agents that interact in numerous ways with each other. A first glance may give a chaotic impression. But as we have seen in the previous sections, distinct categories can be identified with more or less homogenous features and between these categories, we can identify causal patterns of relations that evolve over time, but maintain their coherence. To understand these patterns, political economic analysis is needed to understand the motifs and interests that drive the behavior of the actors and agents.

These patterns or configurations are often based on constructive, positive feedback loops, which are reproduced in time as they reflect mutual interests and, hence, are "protected" against external influences. Yet, they may also have emerged due to systemic barriers, which impose themselves on specific actors and agencies and their ability to establish constructive links. Both vested interests as well as systemic barriers may impede change processes required to achieve enhanced levels of performance of a food system. Examples of systemic actor and agency configurations are:

1. Foreign-owned fruit and vegetable companies, including their contract farmers, often maintain strong links with foreign investors and other financiers, as well as foreign input suppliers. They often rely on their own, company based, research and development, which may entertain links to foreign knowledge centers, including public universities and privately owned laboratories for soil analysis, for example. This specific actor and agency configuration may restrict the uptake and scalability of technology and know-how to their contract farmers and exclude access to knowledge by domestic firms operating in local supply chains and supplying local consumers.
2. Smallholders producing vegetables and fruits for domestic consumer markets mainly operate through informal networks composed of a large number of SMEs. Access to finance is offered by traders, but is strongly related to obligations to provide produce at pre-harvest price settings. Smallholders have marginal to no access to public extension (Dijkxhoorn et al., 2019; Guijt and Reuver, 2019; Plaisier et al., 2019) and therefore rely on their own capacity to innovate. This may take the form of smallholder networks, which are capable of improving certain production practices, but often lack market intelligence to steer their innovation towards meeting consumer preferences. It is, as yet, unclear whether and how informal trader networks can be mobilized to strengthen the feedback loops between urban consumers and their preferences and smallholder

farmers. Moreover, more investigation is needed into the capacity of informal SME networks to innovate, for example, by developing novel consumer products.

3. Women producers may be engaged in strong producer networks, but they are most constrained in their access to financial services and public extension. They may also hold a difficult position in relation to (male) traders and be disadvantaged due to limited access to important market intelligence (information asymmetry). It merits further attention how gender barriers in informal SME networks can be overcome, and whether women's empowerment in such networks also improves the position of women producers, for example, through strengthened networks with female-owned SMEs.

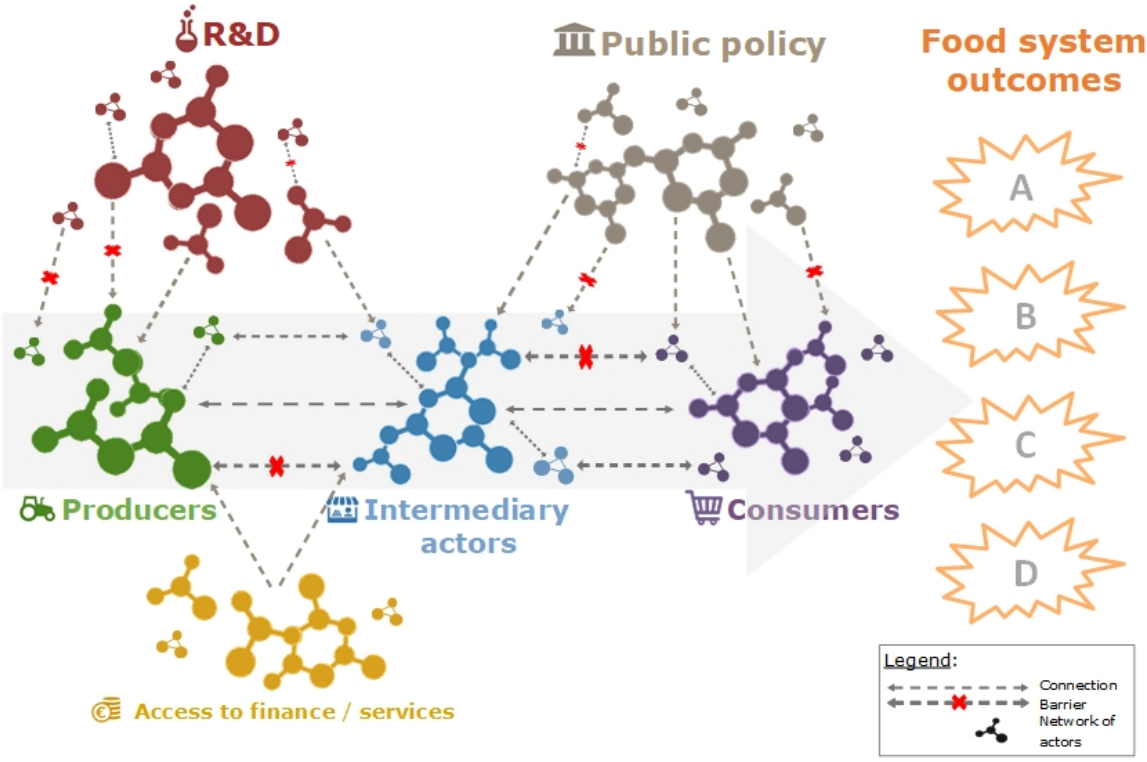

Figure 9.2 *Diversity of fruit and vegetable actors and agents in food systems*
Source: Author's own.

9.3 Opportunities and barriers to enhanced food system performance

9.3.1 Consumption

Irrespective of food system type, region, gender and social class, consumption of fruits and vegetables remains below recommended targets for healthy nutrition. Increases in intake are observed as a function of rising income levels and dependent on food system type. However, there seem to be net ceilings to the consumption of fruits and vegetables at around 300 g per day, although there are large variations. The main barriers to higher intake emerging from a consumer point of view are affordability (price), availability (across the year), acceptability (cultural habits, convenience), food safety, and fruit and vegetable diversity.

Understanding consumer food choices is, however, more complex than considering drivers related to the previously mentioned barriers. Research on drivers of food choice is abundant for consumers in high- and middle-income countries, but much less is known about consumer choice drivers in low-income countries. Systematic mapping reviews of determinants of dietary behavior in low- and middle-income urban African populations, however, suggests that in low-income countries, similar

determinants play a role in food choices as in high-income countries. These drivers can be categorized by the individual level (income, employment, education level, food knowledge, lifestyle, time), the social environment (family and peer influence, cultural factors), the physical environment (food expenditure, lifestyle), and the macro environment (Gissing et al., 2017).

Cognitive psychologists and behavioral economists have extensively described how psychological traits influence human behavior: people do not like change (status quo bias), do not like to lose anything (loss aversion), have a strong preference for "free" products, would rather not make a choice (default bias), prefer immediate over long-term benefits (discounting delayed events) and imitate others (social proof) (Ariely, 2010). Therefore, the short-term pleasure of consuming an unhealthy food or meal has sometimes more weight than the expected long-term benefit of a healthy diet. Though most people like to see themselves as rational human beings making conscious choices, behavior is 95% driven by subconscious determinants, which may favor impulsive alternatives that have an immediate benefit (Logue, 1998; Zaltman, 2003). Subconscious motives include status, comfort, fear, disgust, attraction, love, and play, amongst others (Aunger and Curtis, 2013). To achieve behavior change it is therefore insufficient to rely only on planned, conscious and rational decisions of consumers; emotional and subconscious motives that deliver more immediate, though not always rational, benefits should also be tapped into. A deep understanding of the multiple consumer motives and determinants of choice is crucial to influence choices towards more healthy foods and diets.

There is ample evidence of the effectiveness of nutrition-focused social and behavior change communication in LMICs to improve infant and young child feeding practices. Several reviews have identified the positive impact on breastfeeding practices and to a lesser extent also complementary feeding (Benedict et al., 2018; Webb Girard et al., 2020). However, much less is known about influencing healthy diet choices among other population groups (households, women, youth) in LMICs. The bulk of evidence on the impact of consumer motives, individual behavior and social norms on diet and nutrition comes from high-income countries. Most innovative approaches make use of nudges such as social norms, digital technology and social media, which complement more traditional inter-personal and mass-media behavior change approaches. There are examples of innovative approaches to increase fruit and/or vegetable intake in LMICs, but there is very little evidence of their impacts in the contexts where they have been implemented, and there is no evidence of whether or not they would work in different types of food systems and how they would need to be adapted to these different systems. There is also little evidence regarding the potential and challenges for scaling-up these innovations in different contexts. More investment is needed in testing these promising interventions in different contexts, and in compiling evidence on what works where and how.

9.3.2 Fruit and vegetable supply chains

In all studied regions, the informal market is the dominant configuration. Often quality requirements are absent and post-harvest losses are high due to a lack of (conditioned) storage, no proper packaging, and excessive handling. Besides high waste, this is leading to a serious food safety risk for consumers. Another challenge related to informal markets is the efficient sourcing of quantities of fruits and vegetables from many different remote locations and their supply to different urban markets. Therefore, wholesale traders operating in this supply chain configuration usually work with other actors, such as brokers, to contact farmers and gather supply information. As a result, wholesale traders and brokers have a key position in linking rural producers to urban consumers. The traders in the markets are often informal SMEs. This results in a long supply chain involving many actors, which increases the end price for consumers. Also, most actors in the chain are exposed to high financial risks since perishability is an important constraint, contributing to a high consumer price. On the other side, farmers have to deal with unpredictable ecological events and climatic variability, inducing high levels of production uncertainty and risks of crop failure. Variation in production volume and quality causes price fluctuations. Wholesale markets are often considered to be in a degraded condition and can be very congested at peak times (ADB, 2018a, 2018b; AGRA, 2019).

In South Asia, the Type B supply chain configuration is more present compared to Africa (Type B: slightly more formalized by supplying supermarkets). Here, supermarkets have been able to expand market share as the study by Reardon et al. (2012) shows. Supermarkets in Asia are estimated to

have a market share of 15-20%. However, in Africa, Type B supply chains are still supplying only a small share of the market — different studies estimate that this is only 10% of the market.

The export supply chain (Type C) is present in all regions studied, with exporters serving markets like the EU, the UK and the Middle East. Exporters have been working closely with smallholder farmers through contract farming. This makes this supply chain configuration the most formalized with a high level of coordination. For this supply chain type, efficient infrastructure and good logistics are required (Joosten, 2016).

Overall, the fruit and vegetable market is characterized by a weak institutional environment and lack of enforcement mechanisms:

- There is a lack of capacity of governmental bodies to coordinate their actions and implement policies (e.g., effective seed regulations).
- Taxes are levied by district government on bags or crates instead of the kilogram of produce and, as such, traders have an incentive to increase the quantity of produce per bag. As farmers are paid per bag, they receive a lower price when traders increase the amount of produce per bag. Negotiations about the volumes of bags increase transaction costs.
- The lack of a well-functioning legal system also affects the agreements between buyers and sellers. Informal enforcement mechanisms or mechanisms that avoid disputes (such as bargaining, exchange, inspection and payment on the spot) are used to fill this void in the institutional environment. On the other hand, informal governance systems are available and are considered to be efficient.

The table below gives an overview of the different upgrading strategies:

Table 9.1 *Supply chain upgrading strategies*

Type A: informal markets	Type B: supermarket	Type C: export market
Increase market transparency.	Invest in cultivation improvements (e.g. protected cultivation, irrigation, uptake of certified varieties).	Develop new opportunities to affordably access additional quality and safety standards.
Increase value addition through grading, packing, quality and food safety improvements.	Support specialized commercial farmers or local traders to consolidate supplies and organize packaging and direct supplies to supermarket chains.	Increase competitiveness through more efficient logistics.
Introduce storage, proper packaging and good handling practice to reduce losses along the supply chain.	Support the development of local quality and food safety standards, normally not as stringent as EU standards, but pesticide residue levels, packaging and product quality should be checked.	
Make the transition from Type A to Type B, through better access to retail and supermarkets.	Support further development of storage, proper packaging and good handling practice to reduce losses along the chain, etc.	
Empower traders to invest in the supply chain.		
Public investment in infrastructure.		

Source: Adapted from Joosten (2016).

9.3.3 Infrastructure and technology

The basic rationale behind investing in infrastructure and technology is that it will not only benefit the formal retail or export-driven supply chains, but also the informal supply chains which are more important for ensuring the intake of fruits and vegetables for low-income consumers and supporting the livelihoods of smallholder farmers. One may argue that consumer prices in the formal channel are higher compared to informal channels, which exclude the poorer segments from access to these

improved products. Moreover, formal market channels exclude, in many cases, smallholders from participation due to their higher requirements. These two arguments make investments in infrastructure and technology less justifiable from the perspective of optimizing public good in the form of reducing poverty or enhancing food and nutrition security. In response, we argue that this view may be valid for staple foods, which have relatively low perishability and a long shelf life. However, for the highly perishable fruit and vegetable products, investments in infrastructure and technology can also benefit smallholders and low-income consumers, as they will facilitate consumers' access to and the affordability of fruits and vegetables in the long term, as well as support smallholders to develop as more professional fruit and vegetable producers. Without decent infrastructure and post-harvest technologies, fruits and vegetables will decay much faster than grains. During the harvesting period, consumers may take advantage of low prices due to the flooding of fruit and vegetable products into the market. However soon after, prices will go up because the availability of the products quickly becomes a bottleneck. The high prices outside the harvesting period prevent low-income people from having a balanced intake of fruits and vegetables throughout the year. In many cases, poor people try to consume fruits and vegetables when their prices are low. This pattern was also observed during the COVID-19 pandemic in South Africa where poor people's intakes of fruits and vegetables have declined significantly due to a combination of increased product prices and decreased consumer incomes. Furthermore, the high price volatility of fruits and vegetables caused by low product storability will harm the businesses of smallholder farmers and seriously threaten their livelihoods. Therefore, investing in the infrastructure and technology to improve the storability of the products and the stability of prices has the potential to ensure the stable consumption of fruits and vegetables for low-income groups and keep smallholder farmers in business. Investing in irrigation infrastructure has a similar effect because it can increase the number of times fruits and vegetables are cultivated in a year and make the supply more evenly distributed throughout the year.

We also observe that research and development and extension services for fruit and vegetable production are virtually lacking in most sub-Saharan African countries. Only a few private sector companies are filling the void through seed improvement and extension as part of their business model. National research and development institutes by tradition focus more on staple crops and livestock, without having adequate capacity to contribute to innovations in fruit and vegetable production.

9.3.4 Production

Although fruit and vegetable production in the three regions has increased in the last two decades, production per capita is still too low in many countries to support the recommended levels of consumption for a healthy diet. Most fruits and vegetables are currently produced by small to medium-sized farmers, who must deal with different risks, such as pests and diseases, variable precipitation, limited access to water for irrigation, uncertain labor markets, irregular consumer markets, and a poor bargaining position. The main coping mechanism of these farmers is to plant only small parts of their land with fruits and vegetables. As a result, individual farmers lack the scale to supply markets with fruits and vegetables continuously (year-round supply) and they lack economic scale advantages to reduce production costs.

A majority of smallholders are not able to intensify production due to a variety of interrelated barriers linked to the availability of production factors:

- The unavailability of good quality planting material and seeds (Baruwa, 2014; Kayitesi, 2011). Until recently, most commercial seed companies were not much interested in producing vegetable seed suitable for the local conditions prevailing in Africa and South Asia. For a large part, farmers still rely on farmer-saved seeds, which have lower genetical purity, lower germination rates, lower physiological vigor and can be contaminated with viruses and diseases, all factors that reduce final crop yields.
- The unavailability of nutrient inputs. While the availability of nitrogen and phosphate fertilizers has improved in various parts of Africa in recent years; the availability of macronutrients, such as potassium, magnesium and calcium fertilizers, lags behind. The availability of fertilizers is still difficult for many farmers because of remoteness and the lack of a service infrastructure.

- Pest and disease control is a major bottleneck because of the limited availability of a broad variety of pesticides with different action modes and due to limited integrated pest management options. Farmers have little choice other than the repeated use of the same type of pesticides. The frequent use of the same type of pesticides increases pesticide resistance, further hampering the control of pests and diseases. In many countries, the availability of pesticides is limited to few and relatively old pesticide types because of lengthy admission and registration procedures for new products.
- The limited availability of irrigation water, especially in West and East Africa. Because of lower pest and disease pressure and higher radiation levels, farmers prefer to produce vegetables in the dry season if irrigation water is available (Everaarts et al., 2014). When irrigation water is available, vegetable production is potentially possible year-round and allows farmers to increase the number of crops grown per year. Though a fair share of the fruits and vegetables in India are already produced under irrigated conditions, in West and East Africa less than 10% of the vegetable and fruit production area is irrigated. In general, Africa lacks irrigation capacity. FAO's Aquastat database estimates the total irrigated crop area in 2015 at only 3% of the total cultivated area in East Africa. In South-Asia, about 56% of the cultivated crop area is irrigated[11].
- In addition to the availability of production factors, there are the general constraints associated with their accessibility due to insufficient access to capital for upfront input costs, investments in technical innovation, and supporting a cash flow. Costs of fruit and vegetable production are higher than for staple crops because of higher input requirements. For perennial fruit, considerable investments are needed for the planting material and to overcome the less productive establishment period. High labor inputs need permanent cash flow to enable the hiring of laborers.

9.4 Future fruit and vegetable production forecasts

As shown in Chapter 8 current production of fruits and vegetables is too low to support recommended healthy intake levels across South Asia, East Africa and West Africa. One of the future challenges relates to how agriculture can feed a rapidly increasing population, especially in Africa (Godfray et al., 2010; Van Ittersum et al., 2016). We first analyze how the production of fruits and vegetables is projected to increase in the future based on recent regional production growth (Section 9.4.1). Second, we analyze how much this projection of production will contribute to the required production for healthy intake levels by 2050, considering losses that happen in the food chain before produce reaches the consumer (Section 9.4.2). We also show possible consequences for harvested fruit and vegetable areas in the three regions. We do not account for possible imports and exports of fruits and vegetables.

9.4.1 Projections of fruit and vegetable production

We have analyzed the development of total fruit and vegetable production in each region (2000-2017) and extrapolated these past trends into the future until 2050 considering projected population growth. The extrapolation is based on a linear regression of production against the population (for which data was taken from 2000-2017; n=18) and projected population growth towards 2050[12]. The projections for the period 2018-2050 illustrate the possible challenges of producing sufficient fruits and vegetable for growing populations in a business as usual situation.

Figure 8.3 illustrates the development of fruit and vegetable production in each region during 2000-2017 and the extrapolation of this development towards 2050, considering regional population growth. Based on these trends the following production volumes are projected:
- East Africa: from 22,500 million kg in 2017 to 59,600 million kg in 2050 (+165%).
- West Africa: from 40,900 million kg in 2017 to 98,200 million kg in 2050 (+140%).
- South Asia: from 257,000 million kg in 2017 to 417,000 million kg in 2050 (+62%).

[11] http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en
[12] World Population Prospects: The 2019 Revision from the UN Population Division. https://www.un.org/development/desa/pd/

Figure 8.4 shows the change in per capita production per region between current and projected production. The per capita production increases in each region since during 2000-2017 the production increased at a higher rate compared to the growth in population (see also Section 8.4). Despite the projected large increase in fruit and vegetable production in East and West Africa (>100%), this does not result in major production improvements when expressed per capita because of a stronger population growth than in the past. In South Asia, production is projected to increase less rapidly, but also the population growth rate is lower than in Africa (Table 8.2). Therefore, improvements in per capita production in South Asia are higher than in East and West Africa.

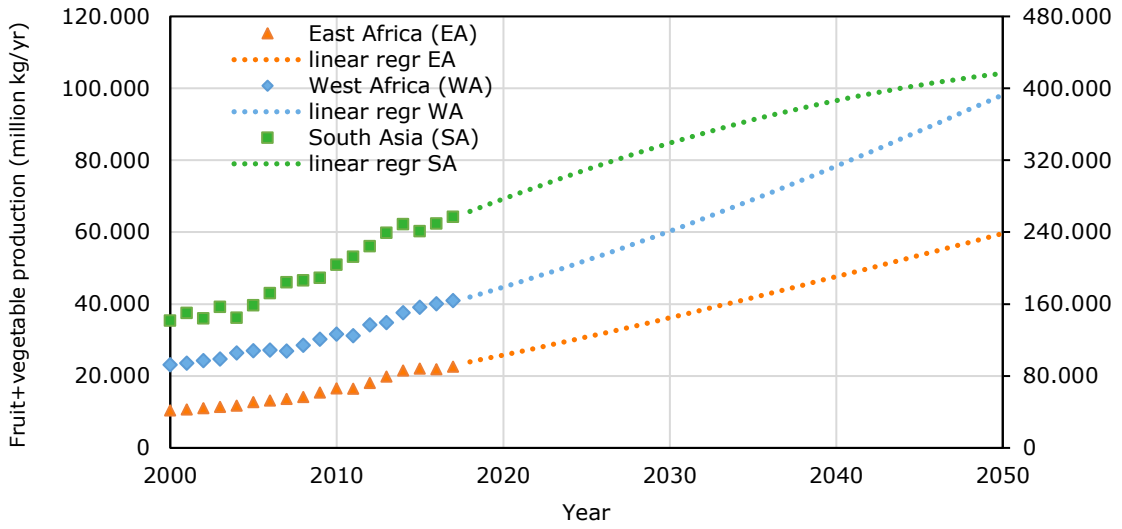

Figure 8.3 *Development of total production of fruits and vegetables in the three different regions (left panel). For data for West Africa and East Africa refer to the left axis, for data for South Asia refer to the right axis. Results are based directly on regional data from FAOSTAT (2000-2017; colored markers) and on an extrapolation of the production (period: 2018-2050; dashed line)*
Source: FAOSTAT [Accessed September 7, 2020 and own calculations].

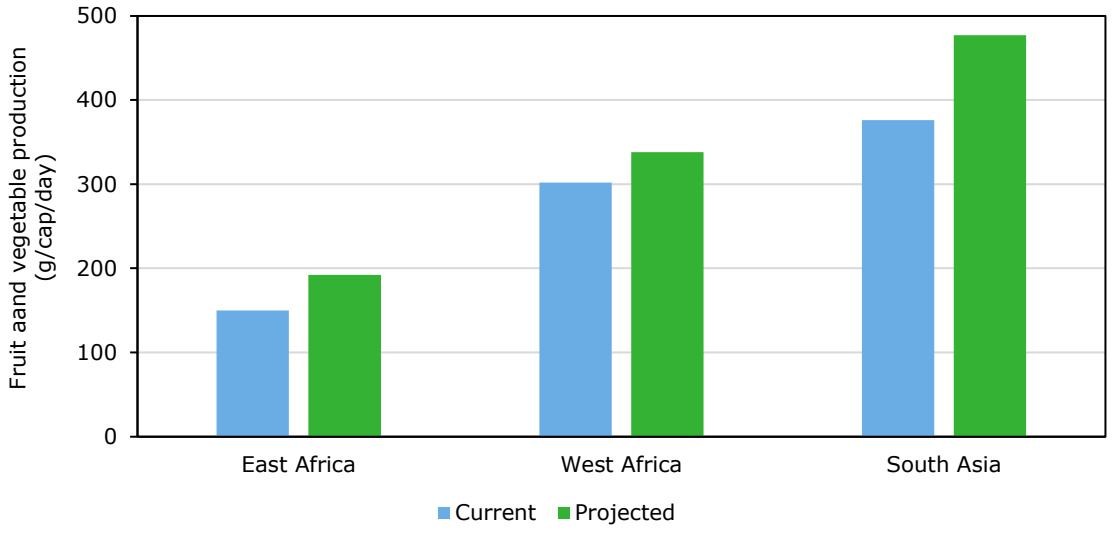

Figure 9.4 *A comparison between current and projected per capita production of fruits and vegetables in the three regions*
Source: FAOSTAT [Accessed September 7, 2020] and own calculations.

9.4.2 Required fruit and vegetable production by 2050

In this section, we estimate how much the production of vegetables and fruits needs to increase in the three regions to allow healthy intake levels (see Section 5.3, 400 g per capita per day) by 2050, taking into account expected population growth (based on FAOSTAT) and losses that happen in the food chain from the farm to the consumer (FAO, 2011b).

Current fruit and vegetable losses between production and consumption have been estimated at 43% in South Asia and 46% in sub-Saharan Africa (FAO, 2011b). Therefore, fruit and vegetable production needs to be considerably higher than the recommended intake of 400 g per capita per day (i.e., 700 and 743 g per capita per day in South Asia and sub-Saharan Africa, respectively). Using these minimum production requirements, Table 8.2 shows the current production per capita versus the required production per capita. It reveals that current production is only 20% in East Africa, 41% in West Africa and 54% inSouth Asia of the required production per capita. This situation is forecast to further deteriorate in the future because of the forecasted population growth, especially in sub-Saharan Africa (Table 8.2): in both West Africa and East Africa, the population is projected to double or more by 2050. If recent fruit and vegetable production growth is maintained, the per capita production by the year 2050 could increase by 101 g per day in South Asia, 36 g in West Africa and 42 g in East Africa (Section 9.4.1). The projected production gap, (i.e., the difference between the required production and projected production), varies between 551 g per capita per day in East Africa and 224 g per capita per day in South Asia, while West Africa takes a middle position. This shows that in South Asia the production gap slightly reduces, but the gap in East and West Africa remains comparable. However, in all regions, the 2050 estimated gaps are still unacceptably high if business continues as usual.

If losses throughout the chain, from production to consumption, can be reduced by 50% by 2050, the required production per capita would reduce to 550 g per capita per day in East Asia and 572 g per capita in sub-Saharan Africa. Even then, the autonomous production growth of fruit and vegetable is insufficient to support the recommended intake level. This further underlines the challenge to produce sufficient amounts of fruits and vegetables to enable recommended intake levels.

Table 8.2 *Current and required production per capita per day, forecasted population growth by 2050, production by 2050 (based on recent production growth, see Figure 8.4), and the production gap in 2050 (required production minus forecasted production) in East Asia, East Africa and West Africa*

Region	Current production (g/capita/day)	Required production (g/capita/day)	Forecasted population growth by 2050 (%)	Projected production in 2050 (g/capita/day)	Production gap in 2050 (g/capita/day)
South Asia	375	700	28	476	224
East Africa	150	743	107	192	551
West Africa	302	743	115	338	405

Source: FAOSTAT (Accessed September 7, 2020) and own calculations.

9.4.3 Consequences for harvested areas of fruits and vegetables

This section analyzes the consequences of autonomous production growth for the annually harvested area of fruits and vegetables. In addition, consequences are shown in the case that production is increased to levels sufficient to supply the recommended intake of fruits and vegetables. In our analysis we consider the very modest aggregate yield increase of fruits and vegetables in the last decades by extrapolating these to the future (Sections 8.4 and 8.5).

To support the forecasted production growth presented in Section 9.4.1 the current harvested fruit and vegetable areas in South Asia need to increase by about 50%, while they need to increase by about 210% in East Africa and 230% in West Africa by 2050 (Table 8.3). To support sufficient fruit

and vegetable production volumes to supply recommended intake levels the current harvested areas in South Asia need to double, quadruple in East Africa and quintuple in West Africa by 2050 (Table 8.3).

Table 8.3 *Current harvested fruit and vegetable area and yields, extrapolated yields in 2050, harvested area in 2050 (based on autonomous growth of production and yields), and the desired harvested area in 2050 (required to produce recommended fruit and vegetable intake levels) in South Asia, East Africa and West Africa*

Region	Current harvested area (million ha)	Current average yield (t/ha)	Extrapolated yield in 2050 (t/ha)	Forecasted harvested area in 2050 (million ha)	Required harvested area in 2050 (million ha)
South Asia	19.8	12.6	15.2	27.5	40.4
East Africa	2.7	8.2	10.4	5.7	10.7
West Africa	7.0	5.7	6.1	16.0	35.2

Source: FAOSTAT (Accessed September 7, 2020) and own calculations.

Table 9.3 shows a large increase in the harvested area associated with the autonomous production increase up to 2050, considering modest yield growth in the same period. Without faster yield growth, results also show that the harvested areas in the three regions need to increase enormously to enable the supply of recommended intake levels of fruits and vegetables in 2050.

9.5 Leverage points for food system transformation

Based on our analysis we identify various leverage points for interventions in the food system that promote the production, trade and consumption of fruits and vegetables. These leverage points impact on specific components of the food system, but have systemic effects through their feedback loops. Together, they represent an emerging theory of change that can be considered when designing an intervention strategy and related investment policies:

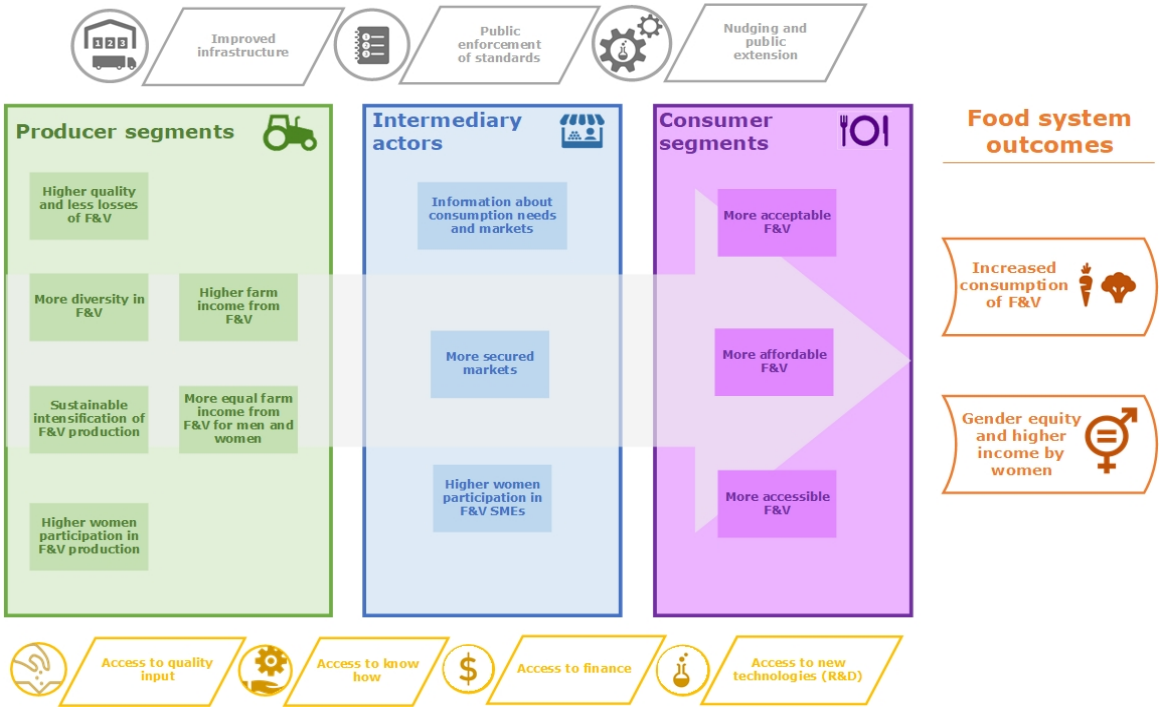

Figure 9.5 *Leverage points for fruits and vegetables in food systems*
Source: Authors' own.

Leverage points for food system change are based on assumptions regarding their causal pathways from the point of intervention to expected impact. Based on the findings of this phase of the study, we highlight the main assumptions as to the plausible effects of the leverage points identified, and whether we have identified adequate evidence to support their validity (see Table 9.4).

With reference to the last column in the table, we must conclude that many leverage points are based on assumptions for which we still have limited evidence available of their validity. Rigorous evaluations of impact are scarce and if they are conducted, do not follow the whole impact pathway, from intervention to changes in consumption and related health effects. The impacts of these interventions on women's empowerment are largely unknown. However, we do observe an increase in novel intervention practices, sometimes taking the form of new business concepts, which offer promising results. These need to develop from anecdotal evidence to proven concepts, which are to be rigorously evaluated as to their sustainability and impact at scale.

Table 9.4 *Leverage points, assumptions and their evidence for the food system transition*

Leverage point	Assumptions	Evidence and plausibility
Increase in production leads to lower fruit and vegetable consumer prices.	Seasonal variation is sufficiently taken into account.	Limited evidence and considered unlikely (see, for example, price differences in developed countries between fruit and vegetables and cereals).
	Losses and waste in fruits and vegetables are known and taken into account. Most losses and waste happen at farm level.	
	Farmers are willing to produce more fruits and vegetables.	
	Intensification is more profitable as compared to extension of land under production.	Evidence mainly found in South Asia. In sub-Saharan Africa we observe more extension than intensification. Yet, intensification is plausible as yields are very low and offer opportunities for improvement by optimizing production factors (e.g., quality seeds, fertilizers, water).
	Intensification of production may introduce additional, labor demanding, tasks for women that are difficult to balance with their household tasks.	Limited evidence.
Reduction in production costs will make production of fruit and vegetables more profitable for smallholders.	Lower costs of production translate into higher margins for producers. Lower farm gate prices will not affect the income of farmers if yields increase at the same time.	Considerable evidence, as the relatively higher fruit and vegetable prices, are determined by more factors than production, such as more materials and labor inputs, high losses, low storability etc.
More efficient supply chains can lead to lower fruit and vegetable consumer prices.	Lower farm gate prices lead to lower fruit and vegetable prices. Reduced risk, lower transaction costs and increased coordination will reduce costs for intermediary actors.	Considerable evidence that this is likely to occur.
More secure fruit and vegetable markets increase supply chain efficiency, farmer income and reduce wastage.	Secured markets (formal and non-formal agreements) reduce risks and transaction costs, reduce the time between harvest and retail, and result in better handling of fruits and vegetables. Farmers benefit from supply contracts.	There is evidence showing that a stable and secured market (export or formal supermarket chain or contract farming) can increase chain efficiency, farmer income, and reduce wastage.

Leverage point	Assumptions	Evidence and plausibility
Intermediary actors communicate consumer needs to producers and (jointly) develop innovative food products.	Traders and processors collect consumer information and translate these as product requirements to producers.	Limited evidence.
	Traders and processors are capable of responding to consumer needs by developing innovative food products.	Limited evidence.
	There is currently information asymmetry between intermediary actors. They do not share information between competitors, nor with producers. This increases their profit levels and negatively affects the affordability of fruit and vegetable consumer products.	Strong evidence.
Increased diversity in fruit and vegetable crops produced and traded leads to more and more diverse fruits and vegetables available in the food environment.	There is sufficient demand for diverse fruits and vegetables. Selling more and more diverse fruits and vegetables is a profitable business. There is sufficient knowledge among consumers on more diverse, including indigenous, vegetables.	There is some evidence that there is not sufficient demand among consumers, but this needs more research. There is limited evidence that public procurement and "nudging" stimulate consumer demands.
Prices of fruits and vegetables are always higher compared to other food categories.	There is understanding of why prices of fruits and vegetables are higher compared to other foods.	
Women's participation in fruit and vegetable production and supply chain operations leads to higher income and empowerment among women.	Fruit and vegetable production and supply chain operations can be profitable to women. Structural barriers to women's participation can be overcome.	There is mixed evidence of successful women's empowerment in production and supply chain operations. Novel business cases announce themselves, but face challenges as to their scaling up.
Higher income by women leads to higher consumption of fruits and vegetables.	More control of income from fruit and vegetable production for women will lead to more fruit and vegetable consumption.	Strong evidence that increases in women's income translate into better diets for household members. No evidence yet on increased expenditures on fruits and vegetables. Some evidence that children benefit in general, but not specifically in regards to fruit and vegetable intake.
Public enforcement of standards will enhance food safety for consumers of fruits and vegetables.	Sufficient capacity and institutions to control food safety standards are available and effective.	There is limited evidence as assumptions are not supported by reality. Therefore, strengthening institutions prevails the enforcement of standards.
Nudging and public extension will improve consumer awareness of recommended fruit and vegetable intake and influence consumption preferences.	Policies are formulated and implemented. Innovative ways to improve consumer awareness and preferences are available and well described for all contexts. These innovations are scalable. Incentives to make these innovations more powerful are known and implemented. Retailers are willing to implement the innovations and consumers sufficiently trust the innovations and the retailers. The information reaches all consumer groups, especially the most vulnerable consumers.	The evidence is still limited: there are innovative pilots, but these have not yet been rigorously evaluated (e.g., on their applicability in different contexts since most innovations have been developed for high-income countries). There is limited to no evidence of engagement by retailers. There is ample evidence that trust matters to consumers. There is no evidence that these innovations reach vulnerable

Leverage point	Assumptions	Evidence and plausibility
	The innovations are gender sensitive and improve women's status or at least do no harm it.	groups or improve women's status.
Increased food safety, consumer awareness and responses to consumer preferences lead to higher acceptability of fruits and vegetables.	Safety, knowledge and alignment with preferences are the major barriers for acceptability of fruits and vegetables to all groups of consumers. Cultural behavior and norms determine food consumption patterns for different household members.	There is limited evidence to support this and the validity of these assumptions is almost unknown in LMICs.
Improved availability, affordability and acceptability leads to sufficient intake of fruits and vegetables to meet the recommendations.	When fruits and vegetables are available at a low price and in an acceptable form to consumers, consumers will eat more fruits and vegetables.	There is limited evidence for this assumption, and we do not know whether consumers can absorb an almost doubling of fruits and vegetables to reach the recommended intake.

10 Conclusions: toward desired system transformation

10.1 General conclusions

1. Consumption of fruits and vegetables in the three regions of study remains too low to meet recommended targets for reducing risk of malnutrition. This under-consumption is observed across the three regions and irrespective of social strata.
2. Consumer prices of fruits and vegetables are high and affect the affordability of these healthy foods, notably by less-endowed households.
3. Women face specific barriers that prevent them from earning more from fruit and vegetable production, trade and processing. These inequalities are not idiosyncratic to fruit and vegetables but reflective of wider trends women face in the agricultural sector.

10.2 Consumption

1. Irrespective of food system type, region, gender and social class, consumption of fruits and vegetables remains below recommended targets for healthy nutrition. Increases in intake are observed as a function of raising income levels, and depending on food system type, but there seem to be net ceilings to consumption of fruits and vegetables at around 300 g per capita per day.
2. The main constraints to higher intake emerging from a consumer point of view are affordability (price), availability (across the year), acceptability (cultural habits, convenience), food safety and fruit and vegetable diversity.
3. Knowledge gaps to be explored during phase II include:
    a. The effects of seasonality of fruit and vegetable availability and accessibility (prices) on consumption.
    b. Sub-national differentials in fruit and vegetable production, availability, accessibility and consumption. Is consumption of fruits and vegetables higher in production hotspots?
    c. Diversity of fruits and vegetables: role of indigenous and underutilized fruits and vegetables, especially in shortage times (and how women can play a role specifically in this). What are policy investments to promote consumption, and what types of fruit and vegetables are a priority? Are these the nutritious ones or limited to tomatoes and onions, and if so, why?
    d. Why are prices of fruits and vegetables higher than other foods? Why is there not higher production of (a diversity of) fruits and vegetables and not more fruits and vegetables on the market?
    e. If the price of fruits and vegetables reduces, will consumers indeed purchase (and consume) more?
    f. Do the present dietary patterns and the dishes/meals allow for increased fruit and vegetable proportionality (in other words: if you double the amount of fruits and vegetables, will households be able to consume these in the existing dietary pattern or will it have an impact on the amount of accompanying foods)?
    g. Gendered urban/rural differences in fruit and vegetable consumption and drivers of these differences.

10.3 Supply chains and markets

1. We identified different types of supply chains in the fruit and vegetable sector. In all regions studied the dominant supply chain configuration involved the spot market as the leading marketplace. In South Asia the supermarket has a slightly higher market share compared to West and East Africa.

2. Prices of fruits and vegetables are proportionally high across the three regions. Key factors contributing to high fruit and vegetable prices are:
    a. High post-harvest losses due to low product quality and poor packing, handling and transportation. The relatively long supply chain, leading to high transaction costs (e.g., costs for finding produce in rural areas and connecting rural producers to urban markets).
    b. The high risk for all actors in the supply chain due to the limited shelf life of fruit and vegetables.
    c. A lack of market transparency due to a high level of information asymmetry between the actors.
3. Major food safety risks related to bacterial contamination are caused by supply chain operations, due to poor packaging and poor handling practices.
4. Potential incentives to upgrade the supply chain are:
    a. Increase market transparency by unlocking market information related to price development to reduce uncertainty. This can be done by providing day to day market information on price development in different markets.
    b. Upgrade the supply chain away from a spot market, towards a more formal market where farmers can rely on contracts with buyers to reduce market uncertainty and to reduce market prices. The increasing market share of the supermarkets is an important driver for this.
    c. Introduce storage and proper packaging and handling practices to reduce losses along the chain and enhance food safety.
    d. Develop conducive public policies in the field of food safety, phytosanitary inspections, crop protection agents and breeders' rights.
5. Emerging opportunities for investing in inclusive economic growth:
    a. Fruit and vegetable supply chains being perceived as an opportunity for culturally accessible agribusiness ventures (as opposed to the male managed income generating staple foods supply chain).
    b. Identifying where women are involved in the supply chain and focusing on existing gaps to promote support for optimal income generation.
6. Knowledge gaps to be explored during phase II include:
    a. Data on structural variables for the country studies (number of actors etc.).
    b. Data on the added value of the different (sub)sectors.

10.4 Technology and infrastructure

1. Technology and infrastructure influence production and supply and thus have a significant impact on consumer prices.
2. Export supply chains can have a catalyzing effect on domestic fruit and vegetable production and supply chains. The question remains whether consumers are willing to pay more for higher quality fruits and vegetables, and whether lessons learnt from export supply chains are translated into production and trade efficiencies that reduce the consumer price on the domestic market.
3. Women do not have equal access to technology. However, where women can increase efficiency and overcome time constraints with access to technology, for example, using ICTs, it has been shown to have a real benefit as it overcomes issues, such as limited mobility and lack of market awareness.
4. Access to capital is a constraining factor to expanding women's involvement in fruit and vegetable supply chains.
5. Knowledge gaps to be explored during phase II include:
    a. An assessment of the greatest barriers globally preventing increased production and consumption of vegetables and fruits (i.e. market failures, high transaction costs and risks, inadequate policy attention, lack of improved seed varieties, food environment constraints, consumer motives and drivers such as knowledge, etc.)
    b. An analysis of key global and regional actors working in the horticulture space.
    c. An assessment of key evidence gaps in the field (both with regards to implementation and research) that future work could help to fill.

10.5 Production

1. We observe that fruit and vegetable production remains too low to support healthy intake levels across the three regions.
2. Based on the expected population growth till 2050 in the three regions and recent production growth rates, fruit and vegetable production in South Asia is best positioned to support healthy intake levels, production in East Africa will remain too low, and West Africa takes an intermediate position.
3. Poor quality at harvest is a main source of low product quality and waste across the supply chains.
4. Most of the fruits and vegetables are produced by small and medium-sized farming households that lack scale advantages to reduce production costs. Improving the level of organization could be a solution, for example, through farmers' cooperatives, but external attempts to achieve this have often proven to be unsustainable and often unsuccessful.
5. Small and medium farmers lack access to capital for upfront production input costs, investments in technical innovation and maintaining a cash flow enabling to hire external labor.
6. Producers must deal with a variety of risks, such as pests and diseases, variable precipitation, limited access to water for irrigation, uncertain labor markets, irregular markets and a poor bargaining position. The main coping mechanism is that farmers plant only small parts of their land with fruits and vegetables. Production specialization is rather the exception than the rule.
7. Based on average yield levels across the regions, fruit and vegetable production is still mainly based on low external input levels. Where farmers have opportunities to intensify, often stimulated by the availability of irrigation water, input levels increase rapidly, resulting in over-supply of inputs and a variety of negative externalities.
8. Women are likely over-represented in higher risk/lower return portions of fruit and vegetable supply chains, for example, in informal production (reflective of "feminization" of agriculture), while men control formal/higher income (with some specific exceptions in West Africa).
9. While women's participation in fruit and vegetable production and supply chains varies, broadly speaking, women face a greater overall labor burden when combining agricultural and household work. This, together with other systemic constraints (low land and asset ownership, limited access to credit, lower mobility) limits their ability to generate more income.
10. Despite these findings, evidence shows that, where women are given the opportunity to increase and control their income, it can translate into women's empowerment and improved nutrition.
11. Market transparency is often low. This lack of consumer preference and market intelligence information is especially observed in the more traditional informal, product driven supply chains, where middlemen just buy what farmers produce. Farmers do not know consumer markets and middlemen may not disclose their insights to maintain their asymmetric information advantages. Only when larger players get involved, such as pack houses, is information on consumer markets disclosed to farmers, who then obtain incentives to adjust their production.
12. Emerging investment opportunities for inclusive economic growth should focus on identifying suitable locations for developing fruit and vegetable hubs to concentrate critical knowledge and services and to make use of scale advantages.
13. Knowledge gaps to be explored during phase II include:
    - Why fruit and vegetable crops seem more vulnerable to pests and diseases than cereals?
    - What are the options for sustainable intensification, including irrigation, and reducing the cost of vegetable production?
    - What organizational structures (cooperatives, community-based organizations, self-help groups) work better to support women socio-economically? What are the key features of successful fruit and vegetable cooperatives?
    - What are the effects of climate change on fruit and vegetable production?

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Appendix 1 Key nutrients food in fruit and vegetables

Key nutrients food in fruit and vegetables and their main sources (food groups and specific foods). GLV: green leafy vegetables

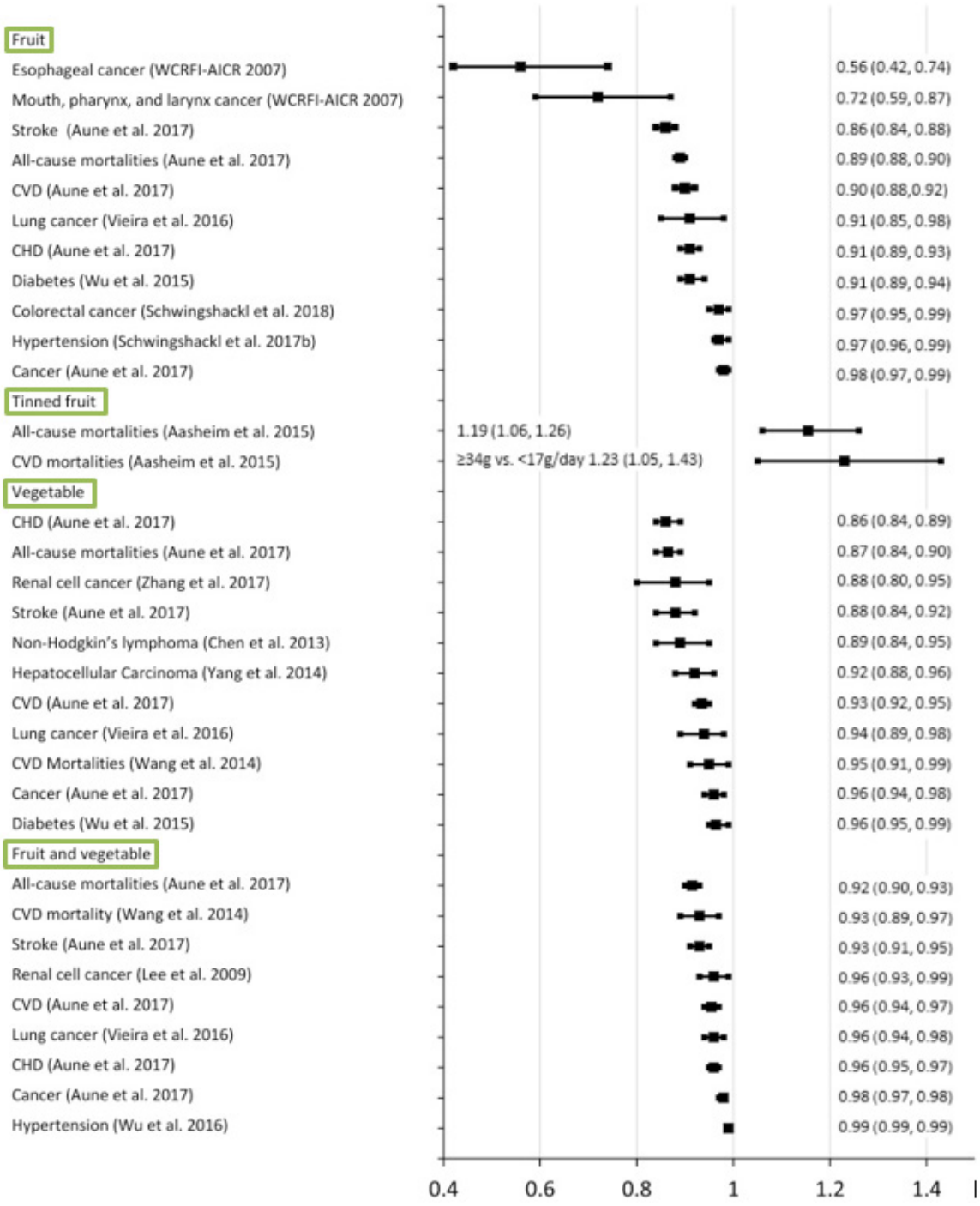
	Iron	Vitamin C	Vitamin A	Folate
Food group	GLV Dried fruit	Citrus fruits Red and yellow fruits GLV	GLV Orange and yellow FV	GLV Citrus fruits Red and yellow fruits
Examples	Spinach Kale Broccoli Brussel sprouts Dried apricots Dried dates	Orange Lemon Guave Pineapple Strawberry Spinach Kale Broccoli Brussel sprouts	Spinach Kale Broccoli Brussel sprouts Carrot Pumpkin Mango Papayas	Spinach Kale Broccoli Brussel sprouts Orange Guava Papaya Mango
Source	(Posen, 2013) (Alemu et al., 2019)	(Alemu et al., 2019) (Domínguez-Perles et al., 2014)	(Alemu et al., 2019) (Gilbert, 2013)	(Alemu et al., 2019) (Tucker et al., 1996)

Appendix 2 DALYs and deaths attributable to diets low in fruit and vegetables in 2017

Disability-adjusted life year (DALY) and deaths attributable to diets low in fruit and vegetables in 2017 (Afshin et al., 2019)

Diet	Measure of disease	DALYs (million)	Deaths (million)
Low in fruit	Cardiovascular Disease	52.1	2
Low in fruit	Diabetes Mellitus type 2	5.9	0.08
Low in fruit	Neoplasms	6.8	0.3
Low in vegetables	Cardiovascular Disease	34.2	1.5

Appendix 3 Dose-response associations between burden of disease and the first 100 g of fruit and vegetable intake



Thirty Dose-response associations between burden of disease and the first 100 g of fruit and vegetable intake. A full list of references is available through the article by Yip et al. (Yip et al., 2019)

Appendix 4 Fruit and vegetable sub-types found to have an inverse association with disease

Fruit and vegetable sub-types found to have an inverse association with disease in the high versus low intake analysis. With an exception for tinned fruits as a positive association with disease was found (Aune et al., 2017)

Coronary heart disease	Stroke	CVD	Total cancer	All-cause mortality
Apples, pears	Apples, pears	Apples, pears	Cruciferous vegetables	Apples, pears
Citrus fruits	Citrus fruits	Carrots	Green-yellow vegetables	Berries
Fruit juices	Fruit juice	Citrus fruits		Citrus fruits
GLV	Grapes*	Cruciferous vegetables*		Fruit juices
Tomatoes*	GLV	GLV*		Cruciferous vegetables
Beta-carotene rich FV	Pickled vegetables	Non-cruciferous vegetables		GLV/Salads
Vitamin C rich FV		Tomatoes*		Potatoes
		Tinned fruits		Cooked vegetables
				Tinned fruits

*: Inverse association found in dose-response analysis, CVD: Cardiovascular Disease, GLV: Green Leafy Vegetables, FV: fruit and vegetables

Appendix 5 Relative risk per 200 g/day for fruit, vegetables and combined for different burdens of disease

Relative risk (RR) and 95% confidence interval per 200 g/day for fruit, vegetables and combined for different burdens of disease (Aune et al., 2017).

	Coronary heart disease	Stroke	CVD	Total cancer	All-cause mortality
Fruit and vegetable combined	0.92 (0.90-0.94)	0.84 (0.76-0.92)	0.92 (0.9–0.95)	0.97 (0.95–0.99)	0.90 (0.87 – 0.93)
Fruit	0.90 (0.86-0.94)	0.82 (0.74-0.90)	0.87 (0.82-0.92)	0.96 (0.94–0.99)	0.85 (0.80-0.91)
Vegetable	0.84 (0.79-0.90)	0.87 (0.79-0.96)	0.90 (0.87-0.93)	0.96 (0.93-0.99)	0.87 (0.82 – 0.92)

Appendix 6 Summary of datasets and differences in these used by food intake studies referred to in the current review

Use of different datasets

Whereas Hall et al. (2009) and Murphy et al. (2014) use fruit and vegetable intake data from the World Health Survey (2002-2004), Miller et al. (2016) uses data from the PURE study (2003- 2013), Frank et al. (2019) and Kalmpourtzidou et al. (2020) make use of the STEPS database combined with a variety of other national representative surveys. Lastly, Micha (2015) used the GDD which comprises of many dietary surveys originating from large local cohorts, the STEPS database and household level surveys. A short description of the different datasets can be found in Table 4.4.2. The use of data obtained through different methodologies and dietary assessments limits the comparability of results of the different studies.

Age of the respondents

The use of different datasets results in differences in the age of the respondents included in the different studies. Whereas Hall et al., Murphy et al., Micha et al. and Kalmpourtzidou et al. include adults aged ≥ 18, Frank et al. included adults aged ≥ 15, Afshin et al. included adults ≥ 25 and the target group of Micha et al. was specified to adults aged 35-70. These differences in target group might complicate the comparison of results. Furthermore, little to no information is included on the fruit and vegetable consumption of children and adolescents.

Geographical focus

When describing a global estimate for fruit and vegetable intake the different authors and the different datasets unsurprisingly include a different set of analyzed countries. It was seen that both Hall et al. (2009) and Murphy et al. (2015), who used the data from the World Health Survey, based their estimations on the same 52 countries. These countries represent mostly LMIC. Also Frank et al. (2019) based the estimations on the data of 28 LMIC. Miller et al. (2016), made use of data from 18 different countries distributed along the four income strata of the World Bank. Finally, Kalmpourtzidou et al. (2020), Micha et al. (2015) and Afshin et al. (2019) based their estimations on the data of 162, 113 and 195 countries respectively and thereby aimed to create a more global perspective on fruit and/or vegetable intake.

Definition of low fruit and vegetable consumption

All authors depicted in table 1 recognize the WHO/FAO recommendation to consume a minimum of 400g of fruit and vegetables daily and most used this recommendation to define low fruit and vegetable consumption. This recommendation is often translated to the consumption of 5 servings of fruit and vegetables a day, assuming portion sizes of 80g. Except for the study by Micha et al. (2015) and Kalmpourtzidou et al. (2020), as they chose to formulate their estimations based on the number daily servings as opposed to quantifying the mean intakes of fruit and vegetables. Kalmpourtzidou et al. (2020) quantified the global vegetable consumption but did not look at fruit consumption and Micha et al. (2015), while recognizing the WHO/FAO recommendations, developed their own optimal consumption levels on which they based their estimations. Their cut-off point for low fruit and vegetable consumption was consequently set at <300g/d and <400g/d respectively, explaining the relatively high percentage of respondents not meeting the recommendations.

Definition of fruit and vegetables

The exact definition of fruit and vegetables differ among countries and regions worldwide and impacts the intake recommendations. The definition of fruit and vegetables as agreed upon by the 2003 Joint WHO/FAO Expert Consultation on Diet, Nutrition, and the Prevention of Chronic Diseases states the inclusion of berries, green leafy vegetables, cruciferous vegetables, and legumes in the recommended

400g/d (FAO/WHO, 2002). However, most surveys (including the WHO STEPS survey) do not include legumes in their definition of vegetables. This might partly explain the seemingly low adherence to the WHO/FAO recommendations on vegetable intake as found by the studies listed in Table 1. Frank et al. (2019), Murphy et al. (2014), Kalmpourtzidou et al. (2020) and Afshin et al. (2019) based their estimates of fruit and/or vegetable consumption exclusive of legumes, while the results of Micha et al. (2015) are inclusive of legumes. The definition of fruit and the possible inclusion of fruit juices is not clear. However, Hall et al. (2009) and Murphy et al. (2014) based their estimates on data of the World Health Survey which included fruit juice.

Overview of different datasets

Food balance sheet
The objective of food balance sheets is to present a comprehensive overview of the food supply of a country during a specific reference period. For each primary commodity (and some processed commodities) the sources of supply and utilizations are shown. From this data, the availability of the included food items for human consumption can be obtained and thereby estimating dietary consumption (FAO, 2001). In short, Food Balance Sheets can be used to measure consumption from a food supply perspective.

Although food balance sheets cover nearly all countries globally, use a methodology that is reasonably comparable across countries and are an open source data, we can also identify several limitations to its use (Del Gobbo et al., 2015). Firstly, information of each food item is linked to a variety of different input variables (total import, total export, total national production etc.) which are all subject to considerable error (Jacobs and Sumner, 2002). Second, there is a variety of factors that are not considered but are relevant when estimating dietary intake. These include, food waste (from cooking, spoilage or plate waste), meals consumed outside of the home, home farming and/or production and food obtained from nonretail/informal markets. These factors however can be common in many LMIC contexts. Furthermore, as the estimates are presented at a national per capita level, intake differences per age group or sex cannot be assessed.

Global Dietary Database
To address the described limitations of the Food Balance Sheet and to better assess global dietary intakes the Global Dietary Database was created (Khatibzadeh et al., 2016). The GDD systematically measures global dietary intake levels based on nationally representative nutritional survey data on the individual level (Micha et al., 2012). It contains measures of the intake of major foods and nutrients by country during the period of 1980 – 2010. Included are age and sex specific sub-groups.

The dietary data included in the Global Dietary Database was mostly obtained via single short-term diet recalls or records (30.5% of the total surveys), followed by FFQ (27.4% of total surveys), simple food survey or household expenditure survey (24% of total surveys) and multiple (2+) diet recalls or records (19.4% of total surveys).

A study by del Gobbo et al. compared the FAO Food Balance Sheets dataset with the nationally representative, individual-based dietary surveys from the Global Dietary Database (GDD) and found that FAO data on food supply has the tendency to substantially over- or underestimate the intake levels from individual-based national surveys worldwide (Del Gobbo et al., 2015).

It should however be noted that the GGD dataset also has limitations. For example, global data coverage is not as complete for certain regions of the world, the data covers only broad food categories (as opposed to single commodities) and, as described above, methods for dietary assessment vary. Besides, the data presented in the GDD cover a period from 1980 – 2010 and could already be seen as outdated. The more recent 2015 data is expected to be published by August 2020.

World Health Survey
In 2002 – 2004 the World Health Survey (WHS) was implemented by the WHO to obtain information on the health of adults and health systems in 70 countries worldwide (WHO | World Health Survey, n.d.). These countries represent the six WHO regions and include high-, middle-, and low-income

countries. Besides the standard questions asked to each participant, 52 countries (mainly LMIC) chose to additionally include questions on diet and nutrition. The target group of the WHS included male and female adults.

The questions in the WHS related to fruit and vegetable intake were as follows:
- How many servings of fruits do you eat on a typical day?
- How many servings of vegetables do you eat on a typical day?

In this survey one cup of green leafy vegetables, one-half cup of other vegetables (cooked or raw) or one-half cup of vegetable juice was considered to be equal to one serving. Similarly, a medium-sized piece of fruit, a half cup of fruit (cooked, canned, or chopped) or a half cup of *fruit juice* was considered to be equal to one serving. To standardize serving size and the number of servings reported nutrition cards containing information on categories and amounts of fruits and vegetables were showed to respondents (Hall et al., 2009). Information on specific types of fruits and vegetables consumed was not included in the WHS (WHO, 2002). It should also be noted that in these questions a 'typical day' was considered a day when the respondent ate fruit or vegetables.

Hall et al. and Miller et al. both used the WHS data to estimate the fruit and vegetable intake and assumed a default serving size of 80g (based on the WHO recommendation of 400g or 5 portions of FV). In reality, serving sizes may be different depending of the specific type of fruit or vegetable or local consumption patterns (Hall et al., 2009; Miller et al., 2016).

WHO Stepwise Approach to Surveillance (STEPS)
In response to the global need for data on key risk factors for NCD (such as tobacco use, alcohol consumption, unhealthy diet and physical inactivity) the WHO initiated the STEPwise approach to surveillance (STEPS) in 2002 (Riley et al., 2016). STEPS is an approach used to collect, analyze and disseminate data regarding these key NCD risk factors in the WHO member countries. The use of standardized questions and protocols allows countries to monitor within-country trends as well as to make comparisons across countries, according to the WHO.

The survey is organized according to three different steps whereas step 1 includes questions on tobacco use, alcohol consumption and fruit and vegetable consumption, physical activity and cervical cancer screening. Step 2 includes questions on the physical measurements and step 3 on biochemical measurements. Ministry of Health officials in collaboration with local technical partners are usually initiating and conducting the STEPS surveys (Riley et al., 2016).
The questions in the STEPS survey related to fruit and vegetable intake were as follows:
- In a typical week, on how many days do you eat fruit?
- How many servings of fruit do you eat on one of those days?
- In a typical week, on how many days do you eat vegetables?
- How many servings of vegetables do you eat on one of those days?

The results of the 2002 – 2004 STEPS survey were published by 114 countries across the different WHO regions in the form of a STEPS report, a factsheet, journal article or poster.

The Prospective Urban Rural Epidemiology study (PURE)
The PURE study was designed to investigate the effects of lifestyle on the health of over 100,000 people aged 35-70 in 18 countries across the world for a period of up to 10 years (2003 – 2013).

The selected countries corresponded to four income strata from the World Bank and included four LICs, four LMICs, seven UMICs and three HICs. To assess fruit and vegetable intake across these countries Miller (2016) made use of the data collected through validated semi-quantitative FFQs (Miller et al., 2016).

Appendix 7 Characteristics of the main studies describing global fruit and/or vegetable intake

Characteristics of the main studies describing global fruit and/or vegetable intake

Author (year)	Dataset used	Target group	% low FV consumption	Defined as:	Mean intake as reported	Mean intake (g/d)
(Kalmpourtzidou et al., 2020)	A variety of databases (including STEPS and local studies) (2000 – 2019)	≥ 18	88% (vegetables only)	< 240 g/d	Vegetable: 186 g/day (56 – 349)	Vegetable: 186 (56 – 349)
(Afshin et al., 2019)	(sub)nationally representative nutrition surveys, Global Heath Data Exchange Website (1980 – 2016)	≥ 25	N/A	N/A	Vegetable: 179 g/day Fruit: 90 g/day	Vegetable: 179 Fruit: 90
(Frank et al., 2019)	Mostly STEPS surveys (2005 – 2016)	≥ 15	81.8%	< 5 servings of FV daily	Vegetable: 2.46 (2.40–2.51) servings/day Fruit: 1.15 (1.10–1.20) servings/day	Vegetable: 196.8 (192 – 200.8) Fruit: 92 (88 – 96)
(Miller et al., 2016)	PURE study (2003 – 2013)	35 – 70	N/A	< 5 servings of FV daily	Vegetable: 2.19 (2.13 – 2.55) servings/day Fruit: 1.62 (1.53 – 1.72) servings/day	Vegetable: 175 (170.4 – 204) Fruit: 129.6 (122.4 – 137.6)
(Micha et al., 2015)[1]	GDD (1980 – 2010)	≥ 20	99.6% (fruit) 99.6% (veg)	< 300 g/d (fruit) < 400 g/d (veg)	Vegetable: 208.8 g/day (203.4–214.3) Fruit: 81.3 g/day (78.9–83.7)	Vegetable: 208.8 (203.4–214.3) Fruit: 81.3 (78.9–83.7)
(Murphy et al., 2014)	World Health Survey (2002 – 2003), Food Balance Sheets (…)	≥ 18	58 – 88%	< 5 servings of FV daily	Respondents with low FV intake (<5 servings): 1.6-2.8 servings/d Respondents with high FV intake (≥ 5 servings) 6.0-7.6 servings/d	Low FV intake (<5 servings): 128 – 224 High FV intake (≥ 5 servings): 480 - 608
(Hall et al., 2009)	World Health Survey (2002 – 2003)	≥ 18	78%	< 5 servings of FV daily	N/A	N/A

[1] Estimates for vegetable intake includes legumes.

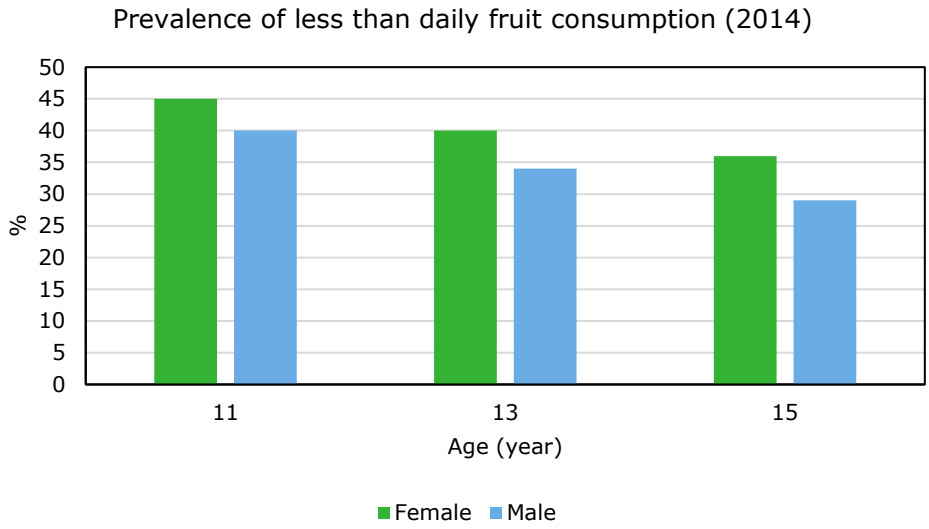
PURE: Prospective Urban Rural Epidemiology, STEPS: Stepwise approach to Surveillance, GDD: Global Dietary Database, FV: Fruit and Vegetable, g/d: gram per day, LIC: Low-income country, HIC: High-income country, LMIC: Low- and middle-income country, s/d: servings per day.

Appendix 8 Description of the five food system typologies as defined in the Food System Dashboard

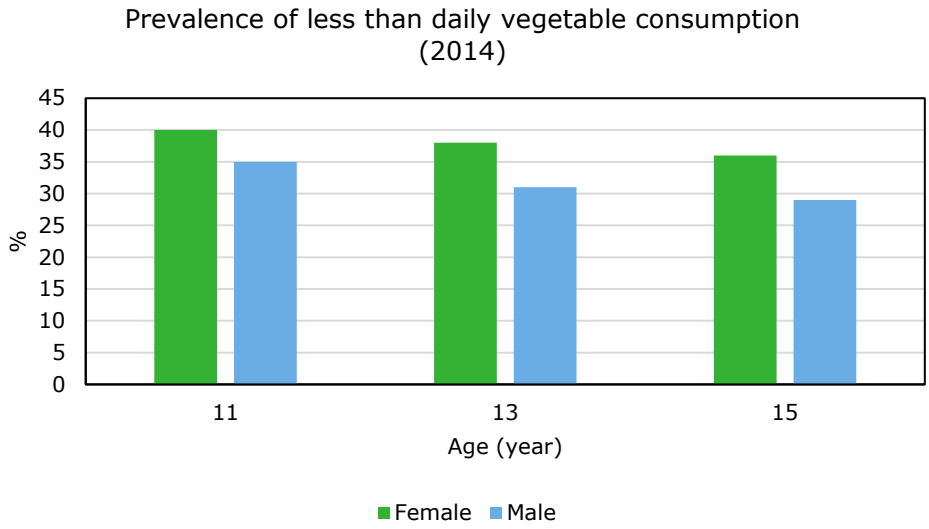
Rural and Traditional	In rural and traditional food systems, farming is mainly done by smallholders, and agricultural yields are typically low. Limited infrastructure for refrigeration and storage can results in large food losses for some crops and limit diversification into perishable foods. The quantity and diversity of foods available varies seasonally. Food is mainly sold in informal market outlets, including independently-owned small shops, street vendors, and central/district markets. Supermarkets are rare outside of capital cities, though they are beginning to grow in number along with fast food chains.
Informal and expanding	Processed and packaged foods are available in both urban and rural areas. Food processing may include a combination of locally-sourced and imported ingredients. Demand for convenience foods increases as the formal labor force grows and includes more women. Urbanization and income growth also play a role in dietary shifts. Supermarkets and fast food are rapidly expanding and, compared to rural and traditional food systems, are more accessible to middle-class consumers. However, most consumers continue to obtain most of their food from informal market outlets, especially for animal source foods, fruits and vegetables. Few food quality standards are in place and advertising is not regulated.
Emerging and diversifying	In emerging and diversifying food systems, an increased number of medium- and large-scale commercial farms co-exist alongside large numbers of small-scale farms. These small-scale farms are more linked to markets than in more traditional food system types. Modern supply chains for fresh foods, including fruits, vegetables, and animal source foods, are developing more rapidly. Supermarkets are common even in smaller cities and towns, and their market share is growing rapidly. Processed foods, including ultra-processed foods, are common in urban areas and also found in many rural areas. Most fresh food continues to be acquired through informal markets, but the share of supermarkets is rising and significant. A greater proportion of countries in this food system type have adopted food-based dietary guidelines.
Modernizing and formalizing	In modernizing and formalizing food systems, agricultural productivity is generally higher than in emerging, informal, and traditional systems. Larger farms rely more on mechanization and input-intensive practices. Food supply chain infrastructure is more developed, which results in fewer food losses on the farm and beyond the farm gate. Better national distribution chains enhance the role of food imports in enabling more year-round availability of diverse foods. Multiple supermarket chains exist within cities and larger-sized towns. These supermarkets and other modern retail outlets hold a large share of processed and dry goods sales, have captured a larger market share of fresh foods, and low-income consumers are much more likely to shop in them. Government regulation and monitoring of food safety and quality standards are more common. Most recently, aggressive food labelling is emerging for ultra-processed foods.
Industrialized and consolidated	In industrialized and consolidated food systems, farming is a small proportion of the economy. There are a small number of large-scale, input-intensive farms that serve specialized domestic and international markets (e.g., horticulture, animal feed, processed food ingredients, biofuels). Supermarket density is high in cities and most towns have multiple outlets. The formal food sector has captured nearly all of the food eaten domestically, including fresh foods. There is growth in luxury food retail, as well as "fast-casual" restaurants, which market higher-quality fast food. Pockets of food insecurity persist, along with economic disparities. A greater proportion of countries in this type of food system have adopted policies that ban the use of industrial trans fats and encourage the reformulation of processed foods to reduce salt intake.

Source: Adapted from Food System Dashboard, available at https://foodsystemsdashboard.org/ [Accessed 15 July, 2020]. Typologies are based on a composite of four indicators; agriculture value added per worker, share of dietary energy from cereals, roots, and tubers, number of supermarkets per 100,000 population and percent urban population of total population.

Appendix 9 Prevalence of less than daily fruit and vegetable consumption (2014)



Prevalence of less than daily fruit consumption in 2014 for male and female adolescents aged 11, 13 and 15 from the WHO European region. Data obtained from Food Systems Dashboard (Inchley et al., 2017)



Prevalence of less than daily vegetable consumption in 2014 for male and female adolescents aged 11, 13 and 15 from the WHO European region. Data obtained from Food Systems Dashboard (Inchley et al., 2017)

Appendix 10 WHO sub regions

World Health Organization Member States by Subregion	
Subregions	WHO member states
AFR D	Algeria; Angola; Benin; Burkina Faso; Cameroon; Cape Verde; Chad; Comoros; Equatorial Guinea; Gabon; Gambia; Ghana; Guinea; Guinea-Bissau; Liberia; Madagascar; Mali; Mauritania; Mauritius; Niger; Nigeria; Sao Tome and Principe; Senegal; Seychelles; Sierra Leone; Togo
AFR E	Botswana; Burundi; Central African Republic; Congo; Côte d'Ivoire; Democratic Republic of the Congo; Eritrea; Ethiopia; Kenya; Lesotho; Malawi; Mozambique; Namibia; Rwanda; South Africa; Swaziland; Uganda; United Republic of Tanzania; Zambia; Zimbabwe
AMR A	Canada; Cuba; United States of America
AMR B	Antigua and Barbuda; Argentina; Bahamas; Barbados; Belize; Brazil; Chile; Colombia; Costa Rica; Dominica; Dominican Republic; El Salvador; Grenada; Guyana; Honduras; Jamaica; Mexico; Panama; Paraguay; Saint Kitts and Nevis; Saint Lucia; Saint Vincent and the Grenadines; Suriname; Trinidad and Tobago; Uruguay; Venezuela (Bolivarian Republic of)
AMR D	Bolivia (Plurinational State of); Ecuador; Guatemala; Haiti; Nicaragua; Peru
EMR B	Bahrain; Iran (Islamic Republic of); Jordan; Kuwait; Lebanon; Libyan Arab Jamahiriya; Oman; Qatar; Saudi Arabia; Syrian Arab Republic; Tunisia; United Arab Emirates
EMR D	Afghanistan; Djibouti; Egypt; Iraq; Morocco; Pakistan; Somalia; South Sudan2; Sudan; Yemen
EUR A	Andorra; Austria; Belgium; Croatia; Cyprus; Czech Republic; Denmark; Finland; France; Germany; Greece; Iceland; Ireland; Israel; Italy; Luxembourg; Malta; Monaco; Netherlands; Norway; Portugal; San Marino; Slovenia; Spain; Sweden; Switzerland; United Kingdom
EUR B	Albania; Armenia; Azerbaijan; Bosnia and Herzegovina; Bulgaria; Georgia; Kyrgyzstan; Montenegro; Poland; Romania; Serbia; Slovakia; Tajikistan; The Former Yugoslav Republic of Macedonia; Turkey; Turkmenistan; Uzbekistan
EUR C	Belarus; Estonia; Hungary; Kazakhstan; Latvia; Lithuania; Republic of Moldova; Russian Federation; Ukraine
SEAR B	Indonesia; Sri Lanka; Thailand
SEAR B	Bangladesh; Bhutan; Democratic People's Republic of Korea; India; Maldives; Myanmar; Nepal; Timor-Leste
WPR A	Australia; Brunei Darussalam; Japan; New Zealand; Singapore
WPR B	Cambodia; China; Cook Islands; Fiji; Kiribati; Lao People's Democratic Republic; Malaysia; Marshall Islands; Micronesia (Federated States of); Mongolia; Nauru; Niue; Palau; Papua New Guinea; Philippines; Republic of Korea; Samoa; Solomon Islands; Tonga; Tuvalu; Vanuatu; Viet Nam

AFR = Africa Region; AMR = Region of the Americas; EMR = Eastern Mediterranean Region; EUR = European Region; SEAR = South-East Asia Region; WPR = Western Pacific Region.

Appendix 11 Examples of sector organizations

Country	Association	Name	Sector	Description	Members	Source
Kenya	FPEAK	Fresh Producer and Exporters Association Kenya	Flowers, fruits and vegetables	Representing growers, exporters and service providers.	137	(Match Maker Associates, 2017)
	FPC	Fresh Produce Consortium of Kenya	Fruits and vegetables	Producers, traders and service providers for Kenya's fresh produce. Focus on domestic, regional and global trade	x	www.fpckenya.co.ke
Uganda	UHEPA	Uganda Horticulture Export Promotion Board	Fruits and vegetables	Export	12	(Dijkxhoorn et al., 2019)
	UFVEPA	Uganda Fruit and Vegetable Export Promotion Board	Fruits and vegetables		X	(Dijkxhoorn et al., 2019)
	Hortexa	Horticulture Exporters Association of Uganda	Fruits and vegetables		x	(Dijkxhoorn et al., 2019)
Ethiopia	EHPEA	Ethiopian Horticulture Producer and Exporters Association	Flowers, fruits and vegetables	Support the production and export of flowers, vegetables, fruits, herbs, and cutting	119	www.ehpea.org

Appendix 12 Examples of investment promotion agencies

Region	Country	Investment Promotion Agency	Website
South Asia	India	BIP	https://industries.rajasthan.gov.in/
	Nepal	Investnepal	http://www.investnepal.gov.np/
	Bangladesh	BIDA	http://bida.gov.bd/
West Africa	Senegal	APIX	http://www.investissements.gouv.sn/apix
	Mali	API-Mali	https://apimali.gov.ml/
	Niger	CPI	http://www.investir-au-niger.org
	Ivory Coast	CEPICI	https://www.cepici.gouv.ci/
	Cameroon	CIPA	https://www.prc.cm/en/invest-in-cameroon/api
	Nigeria	NIPC	https://nipc.gov.ng/
	Ghana	GIPC	https://www.gipcghana.com/
East Africa	Ethiopia	EIC	http://www.investethiopia.gov.et/
	Kenya	Keninvest	http://www.invest.go.ke/
	Tanzania	TIC	http://www.tic.go.tz/
	Zambia	ZDA	https://www.zda.org.zm/

Appendix 13 Contribution to the GDP

South Asia

	GDP (current USD) 2019	Agriculture, forestry, and fishing, value added (% of GDP)	Contribution of fruit and vegetable to the agricultural GDP
Bangladesh	302,571,254,131	12.7	Not available
Bhutan*	2,446,674,102	15.9	Not available
India	2,875,142,314,812	16.0	Not available
Sri Lanka	84,008,783,756	7.4	Not available
Pakistan	278,221,906,023	22.0	Not available
Nepal	30,641,380,604	24.3	Not available

Source: World Bank. *Bhutan 2018 data.

East Africa

	GDP (current US$) 2019	Agriculture, forestry, and fishing, value added	Agriculture, forestry, and fishing, value added (% of GDP)	Contribution of various fruit and vegetable sub sectors to the agricultural GDP
Burundi	3,012,334,882	870,491,231	28.9	
Ethiopia	96,107,662,398	32,565,885,477	33.9	
Kenya	95,503,088,538	32,613,973,919	34.1	Green beans for export (2016) 0.33% studied by Kleih et al. 2081
Rwanda	10,122,472,590	2,436,183,819	24.1	
Tanzania*	63,177,068,175	18,158407,314	28.7	
Uganda	34,387,229,486	7,537,083,027	21.9	
Zambia	23,064,722,446	632,784,521	2.7	

Source: World Bank. *Tanzania 2017 data.

West Africa

	GDP (current USD) 2019	Agriculture, forestry, and fishing, value added	Agriculture, forestry, and fishing, value added (% of GDP)	Contribution of fruit and vegetable to the agricultural GDP
Burkina Faso	15,745,810,235	3,196,110,461	20.3	Mango: export value chain contributed in 2015 2.9% to the value added of agriculture or 0.5% of the national economy (Parrot et al., 2017)
Ivory Coast	58,792,205,642	9,227,330,349	15.7	
Cameroon	38,760,467,033	5,959,495,554	15.4	
Ghana	66,983,634,224	11,592,419,078	17.3	
Mali	17,510,141,171	6,534,245,014	37.3	
Niger	12,928,145,120	4,936,353,188	38.2	
Nigeria	448,120,428,859	98,166,587,269	21.9	
Senegal	23,578,084,052	3,487,568,295	14.8	

Source: World Bank.

Appendix 14 Estimation of home garden production in three regions

The coverage of the reported vegetable and fruit production data in FAOSTAT differs among countries. In general, the data refers to crops grown in field and market gardens mainly for sale, thus excluding crops cultivated in kitchen gardens or small family gardens mainly for household consumption. The question is how the production of such home gardens for household consumption relates to the fruit and vegetable production data reported in FAOSTAT. Here, we estimate the total area of home gardens and relate it to the total harvested area with fruits and vegetables as reported at regional level in FAOSTAT.

Our estimation method is based on the rural population in East Africa, West Africa and East Asia (FAOSTAT), average household size (UN, 2019), and an assumed home garden area of 50 m^2 with fruits and vegetable per rural household. In much home garden literature, entire mixed farming systems are considered home gardens (e.g. Abebe and Bongers 2012; Mellisse et al. 2018; (Castro Gbedomon et al., 2017). Some of these systems measure up to 1 hectare, which is 200 times larger than we assume in our calculations. Such complex mixed but relatively large farming systems produce beyond household needs, and the marketable products are reported in FAOSTAT. In our calculation, we only focus on the area of real home gardens that produce mainly for household consumption.

The share of the rural population in the total population in 2017 ranged from 74% in East Africa, 65% in West Africa to 54% in East Asia. We assume that only the rural population has home gardens.

The average household size, i.e. members per household, is based on country data in the Database on Household Size and Composition 2019 of the UN (2019). Data is not available from all countries and does not distinguishes between rural and urban households. We used the average of the national data from the countries available in the database for estimating regional average household sizes:
4.4 persons in East Africa, 5.8 in West Africa and 5.4 in East Asia.

The estimation method is now as follows: Dividing the rural population with the average household size gives the number of rural households with home gardens in a region. Multiplication with an average home garden of 50 m^2 gives the total fruit and vegetable area in home gardens for home consumption. Expressed as percentage of the total reported harvested fruit and vegetable area in FAOSTAT, the area with home gardens varies from 13% in East Africa, 6% in West Africa and 3% in East Asia. The higher share in East Africa is associated with the larger rural population share and smaller household sizes (see before).

Three important underlying assumptions of this estimation method are:

1. The average home garden area of 50 m^2 with fruits and vegetables: Because of the seasonality of production, much larger home gardens will produce fruits and vegetables in amounts beyond the immediate intake capacity of household members. For example, based on average regional fruit and vegetable yields, home gardens of 50 m^2 produce approximately 250 kg in East Asia and 115 kg in West Africa. In addition, it should be realized that not all rural households have (access to) home gardens. Because it is not easy to divide the inhabited territory into urban and rural areas (United Nations, 2018), part of rural population lives in rural villages and settlements with little possibilities for home gardens. In addition, home gardens are often also used for legumes, cereals and other non-fruit and vegetable crops such as spices and medicinal plants (Abebe and Bongers, 2012; Mellisse et al., 2018; Thamilini et al., 2019). Therefore, the assumed average home garden size with 50 m^2 fruits and vegetables is considered an upper limit.
2. The average size of households in rural areas may be larger than the average household sizes at country level used in the calculations. This means that the number of rural households maybe overestimated in our calculations and thus also the area with home gardens.
3. Only rural households have home gardens: With decreasing rural populations in favour of a growing urban populations, the area with, and thus the importance of home gardens will decrease

in the future. Part of the decrease may be compensated by smaller rural households in the future, i.e. less members per household, and by an increasing number of urban households with home gardens. However, it is difficult to assess how these processes will develop and affect total home garden production in this estimation procedure, apart from technology-driven changes in crop yields.

Sources:

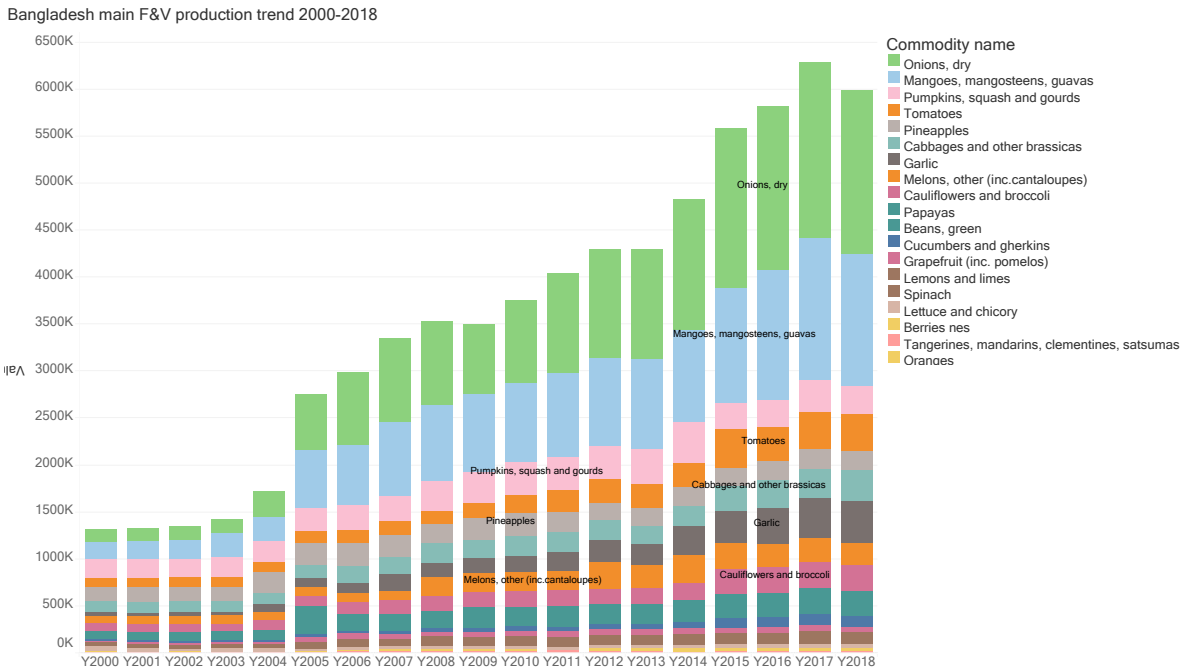
United Nations, Department of Economic and Social Affairs, Population Division (2019). Database on Household Size and Composition 2019.
https://population.un.org/Household/index.html#/countries/840 [accessed September 15, 2020]

Appendix 15 Production volumes of fruits and vegetables for selected countries

South Asia

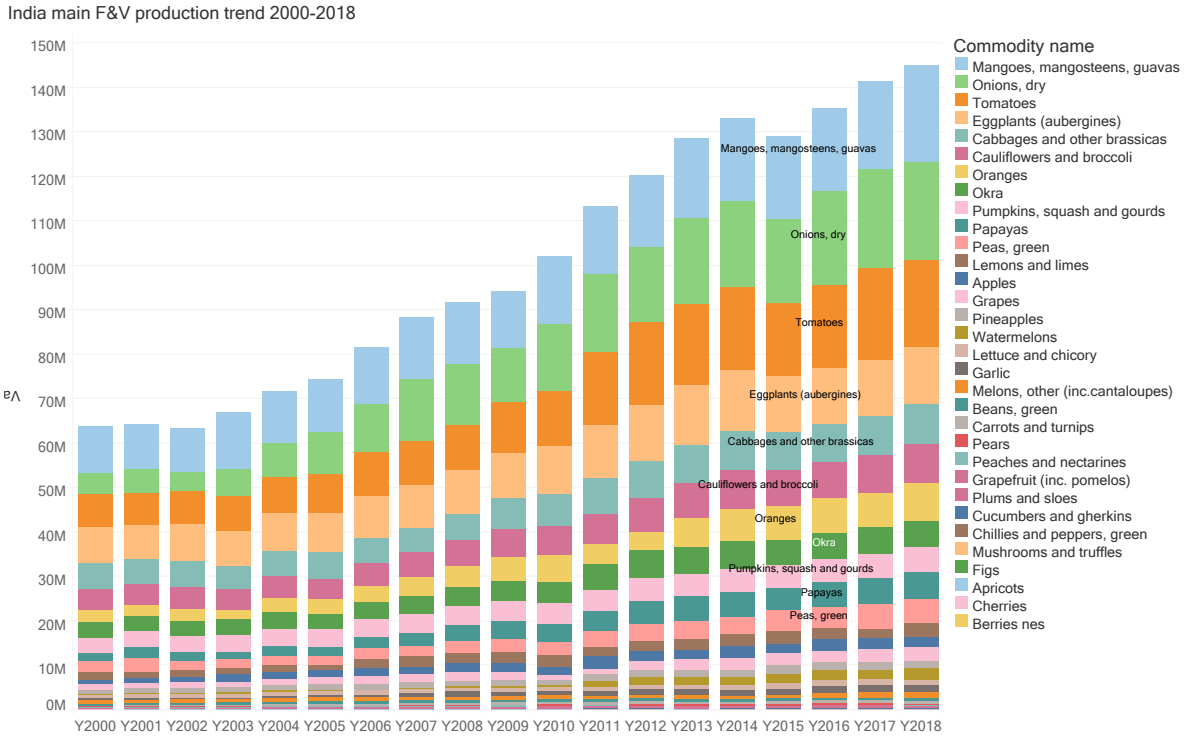
The following figures**Fout! Verwijzingsbron niet gevonden.** present the different fruits and vegetables being produced for a number of selected countries in South Asia.

Dry onions and mangoes (including mangosteens and guavas) are two prominent items that account for a large proportion of the fruits and vegetables production in Bangladesh.



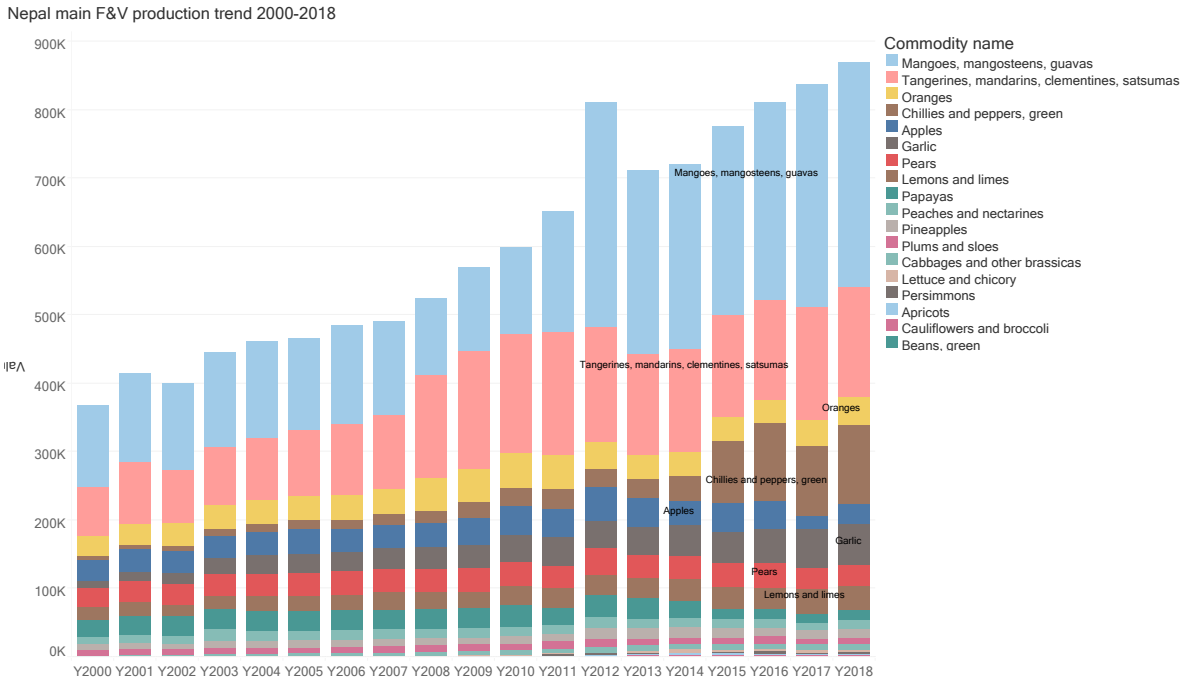
Bangladesh main fruits and vegetables produced 2000-2018 in tonnes (FAOSTAT)

For India, mangoes (including mangosteens and guavas) and dry onions are still the top 2 products but with switched rankings. Moreover, the top 2 items account for a smaller part of the fruits and vegetables share compared to that for Bangladesh.



India main fruits and vegetables produced 2000-2018 in tonnes (FAOSTAT)

Mangoes, mangosteens and guavas ranks the first in Nepal followed by tangerines, mandarins, clementine's and satsumas. Those two contribute a significant part to the Nepal's fruits and vegetables production.

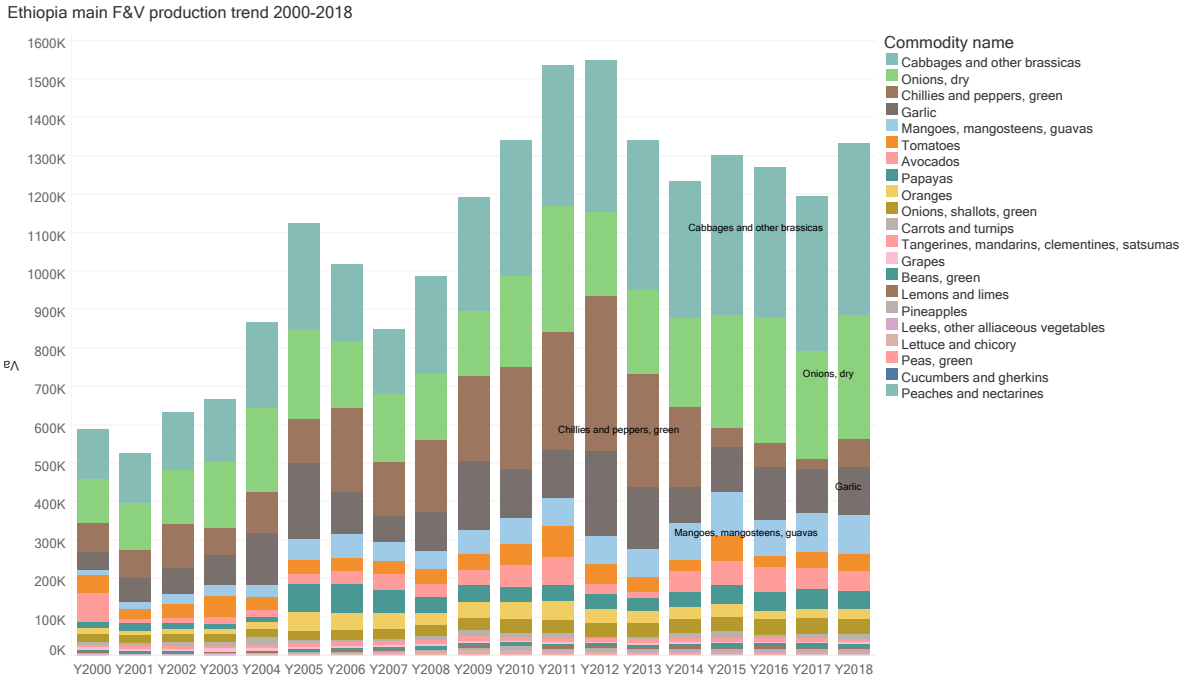


Nepal main fruits and vegetables produced 2000-2018 in tonnes (FAOSTAT)

East Africa

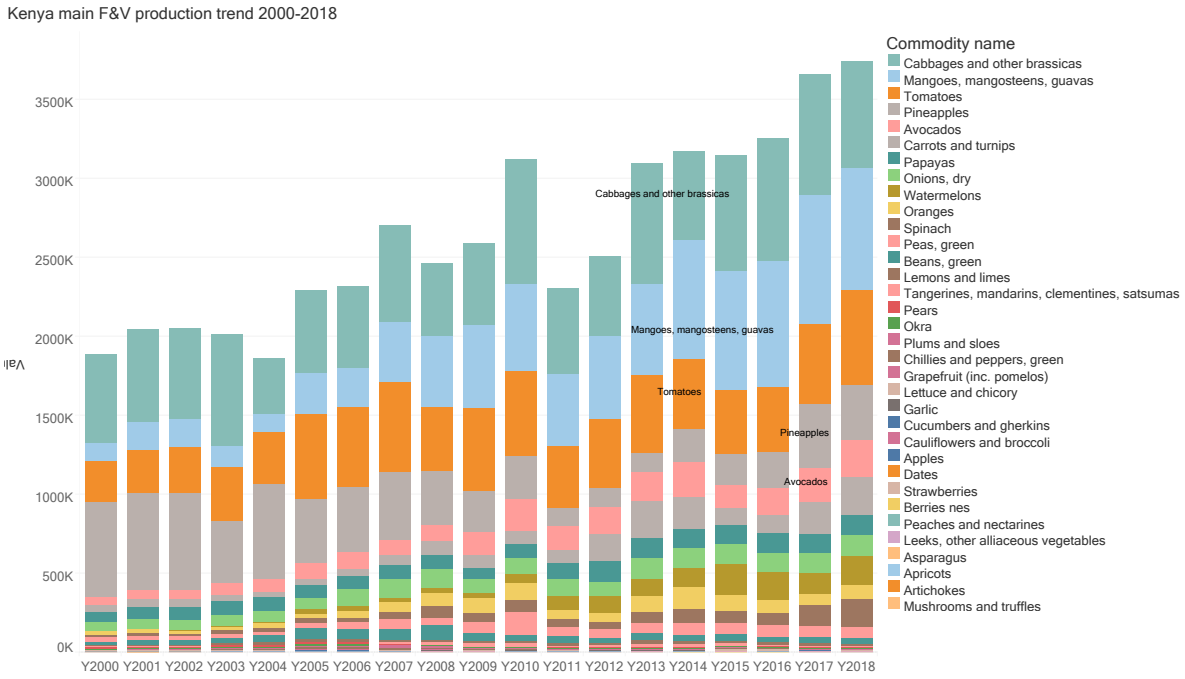
The following figures demonstrate the fruit and vegetable production for selected countries in East Africa.

For Ethiopia, cabbages and other brassicas and dry onions are the major contributors. Chilies and peppers (including green peppers) used to be a big item produced but became smaller from 2014 to 2015.



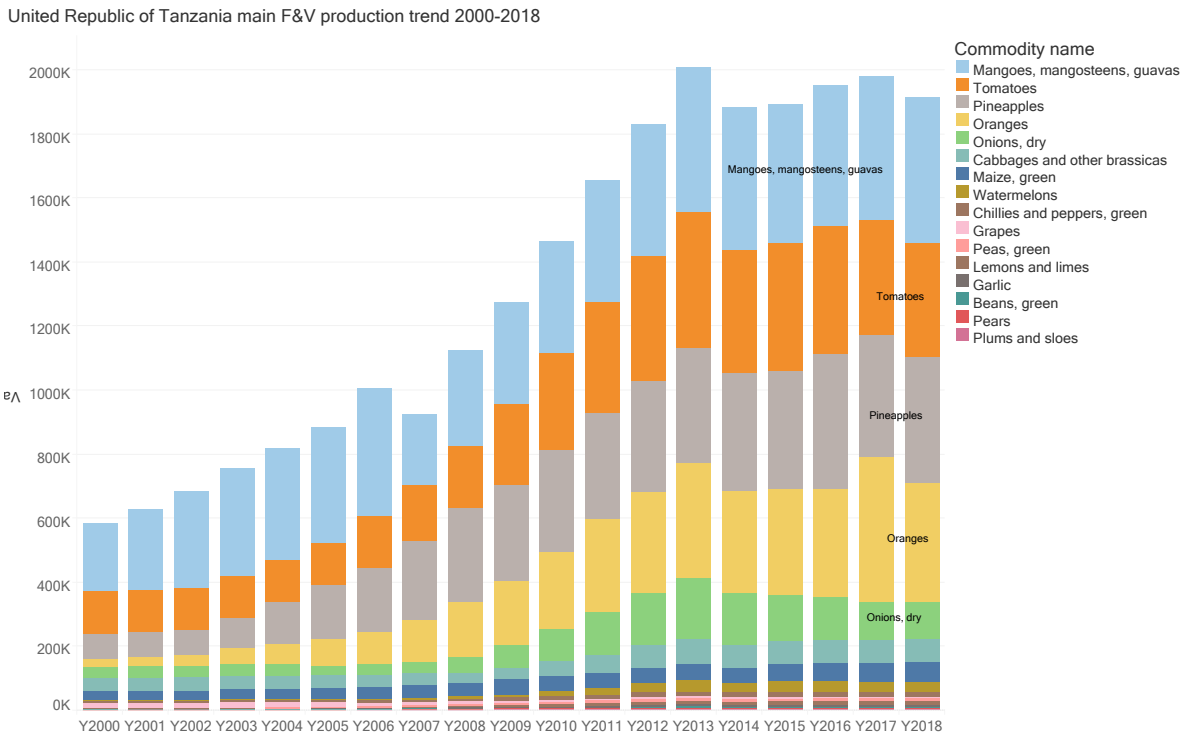
Ethiopia main fruits and vegetables produced 2000-2018 in tonnes (FASTAT)

For Kenya, cabbages (and other brassicas), mangoes (including mangosteens and guavas) and tomatoes are the three major products.



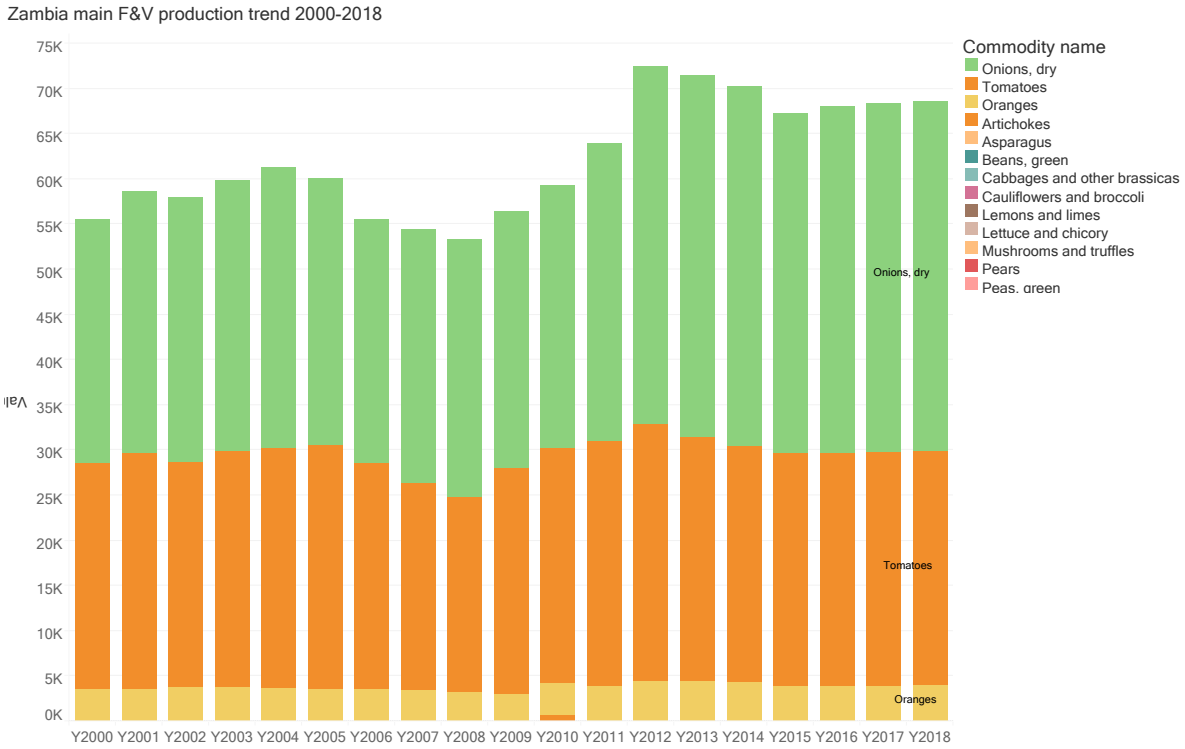
Kenya main fruits and vegetables produced 2000-2018 in tonnes (FAOSTAT)

For Tanzania tomatoes and pineapples are the top 3 fruits and vegetables.



Tanzania main fruits and vegetables produced 2000-2018 in tonnes (FAOSTAT)

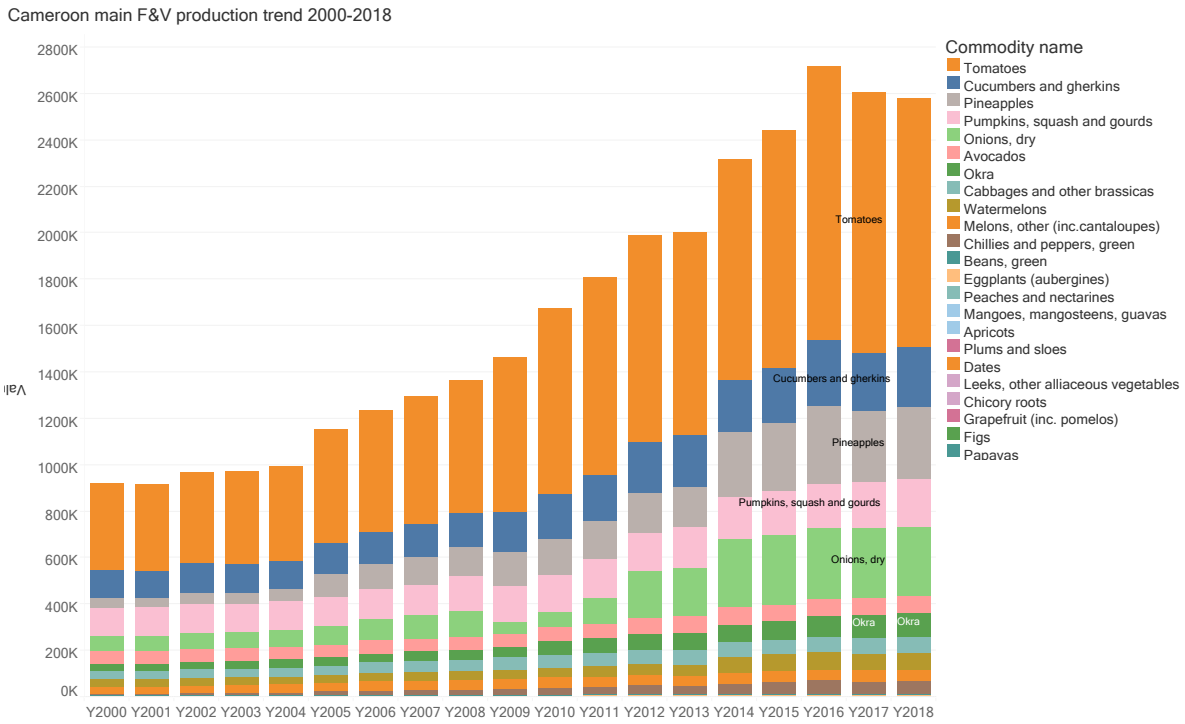
Dry onions and tomatoes are two dominating crops in Zambia.



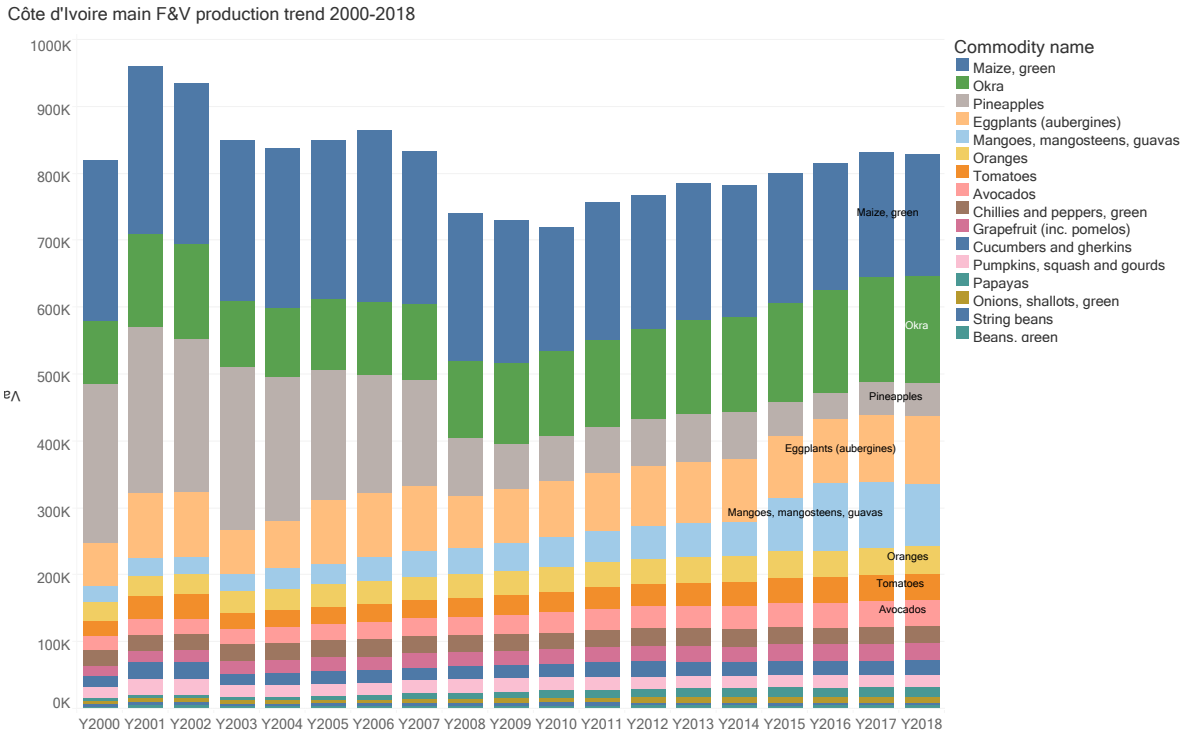
Zambia main fruits and vegetables produced 2000-2018 in tonnes (FAOSTAT)

West Africa

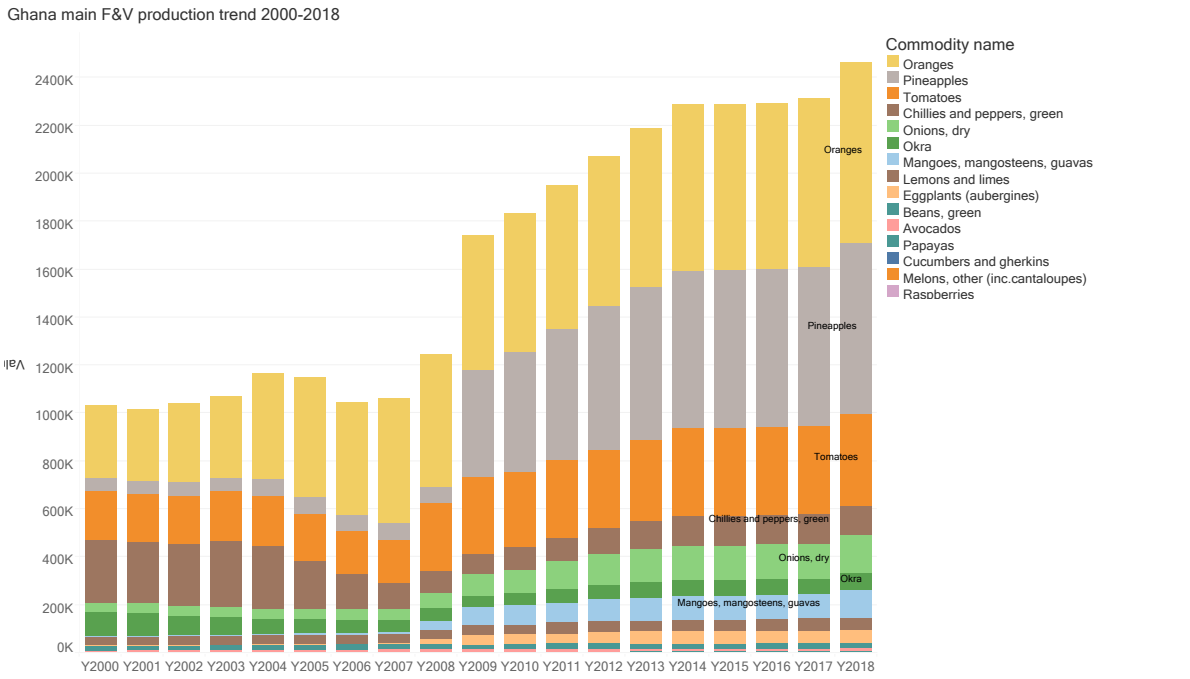
The following figures present the fruit and vegetable production for selected countries in West Africa.



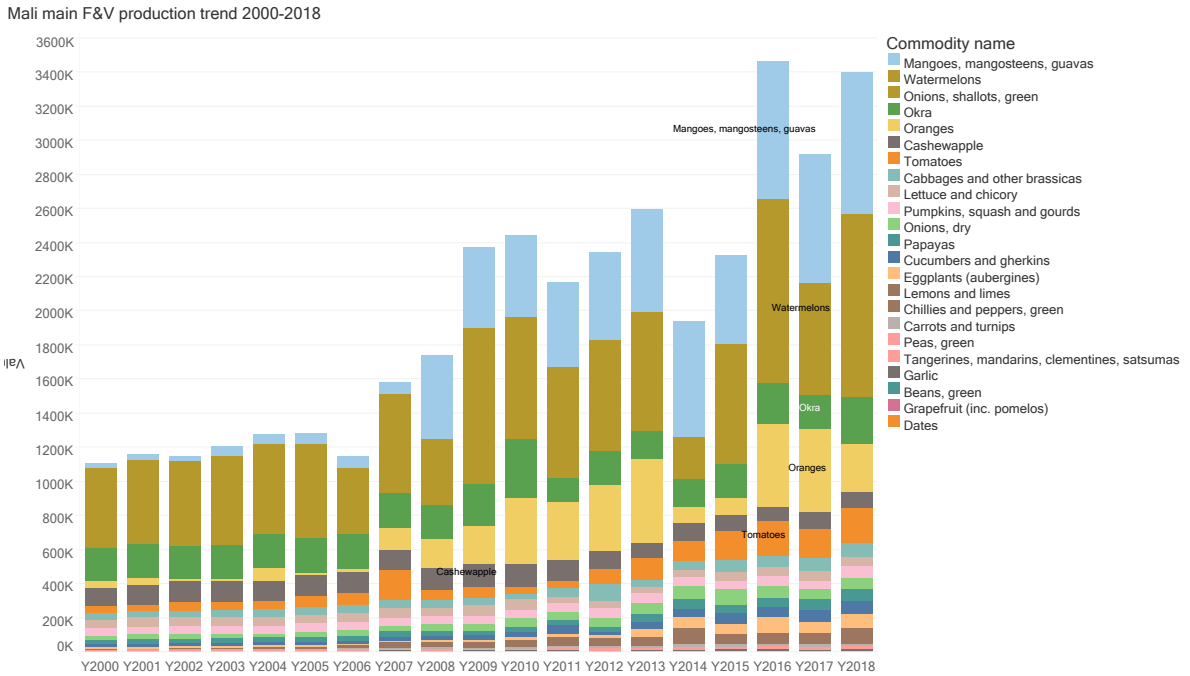
Cameroon main fruits and vegetables produced 2000-2018 in tonnes (FAOSTAT)



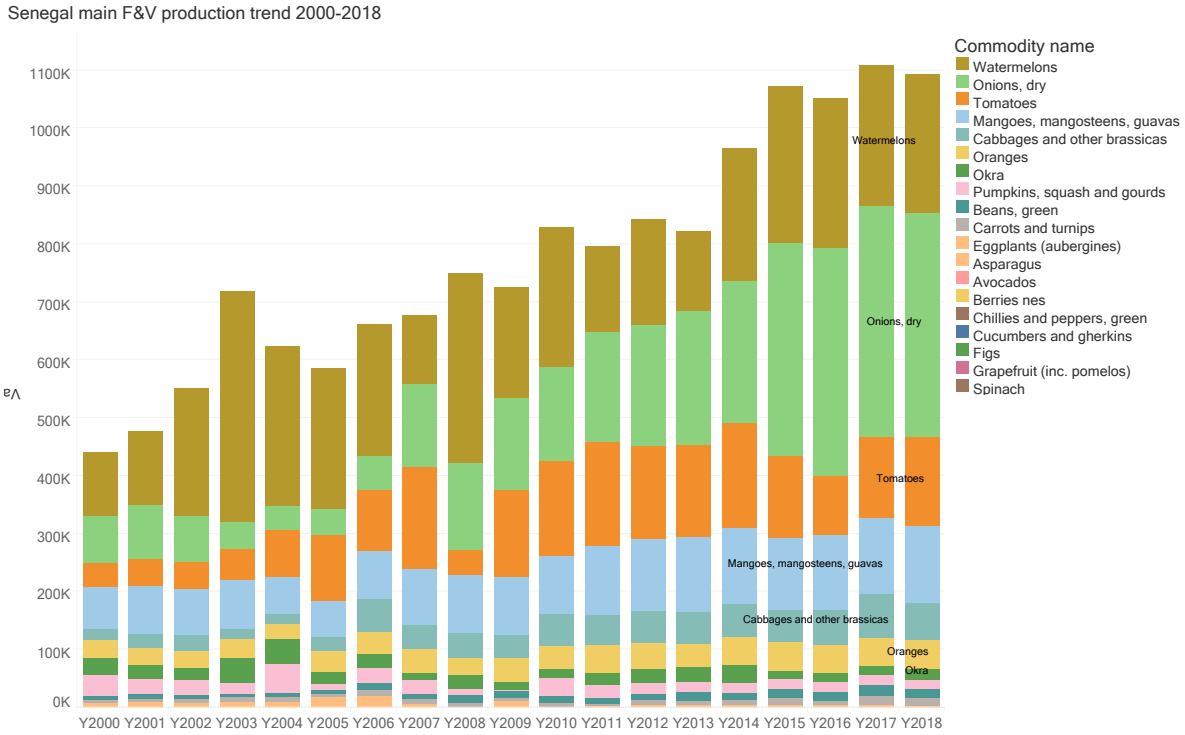
Ivory Coast main fruits and vegetables produced 2000-2018 in tonnes (FAOSTAT)



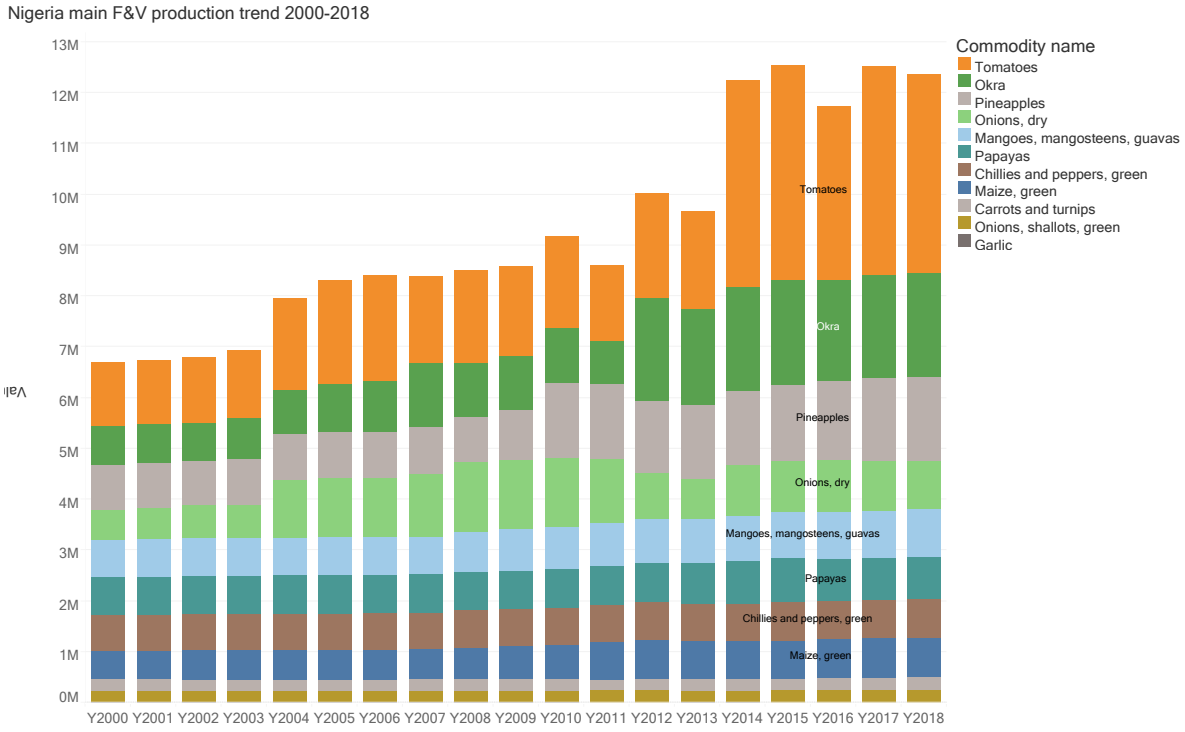
Ghana main fruits and vegetables produced 2000-2018 in tonnes (FAOSTAT)



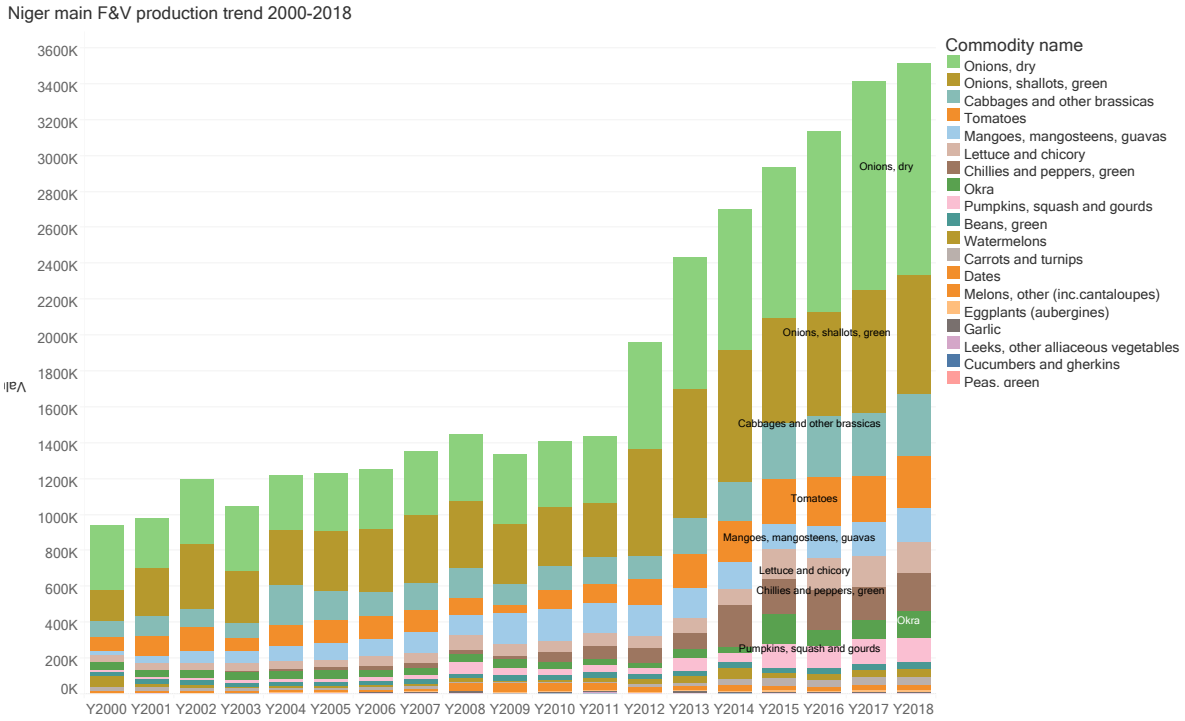
Mali main fruits and vegetables produced 2000-2018 in tonnes (FAOSTAT)



Senegal main fruits and vegetables produced 2000-2018 in tonnes (FAOSTAT)



Nigeria main fruits and vegetables produced 2000-2018 in tonnes (FAOSTAT)



Niger main fruits and vegetables produced 2000-2018 in tonnes (FAOSTAT)

Appendix 16 Mapping harvested fruit and vegetable production

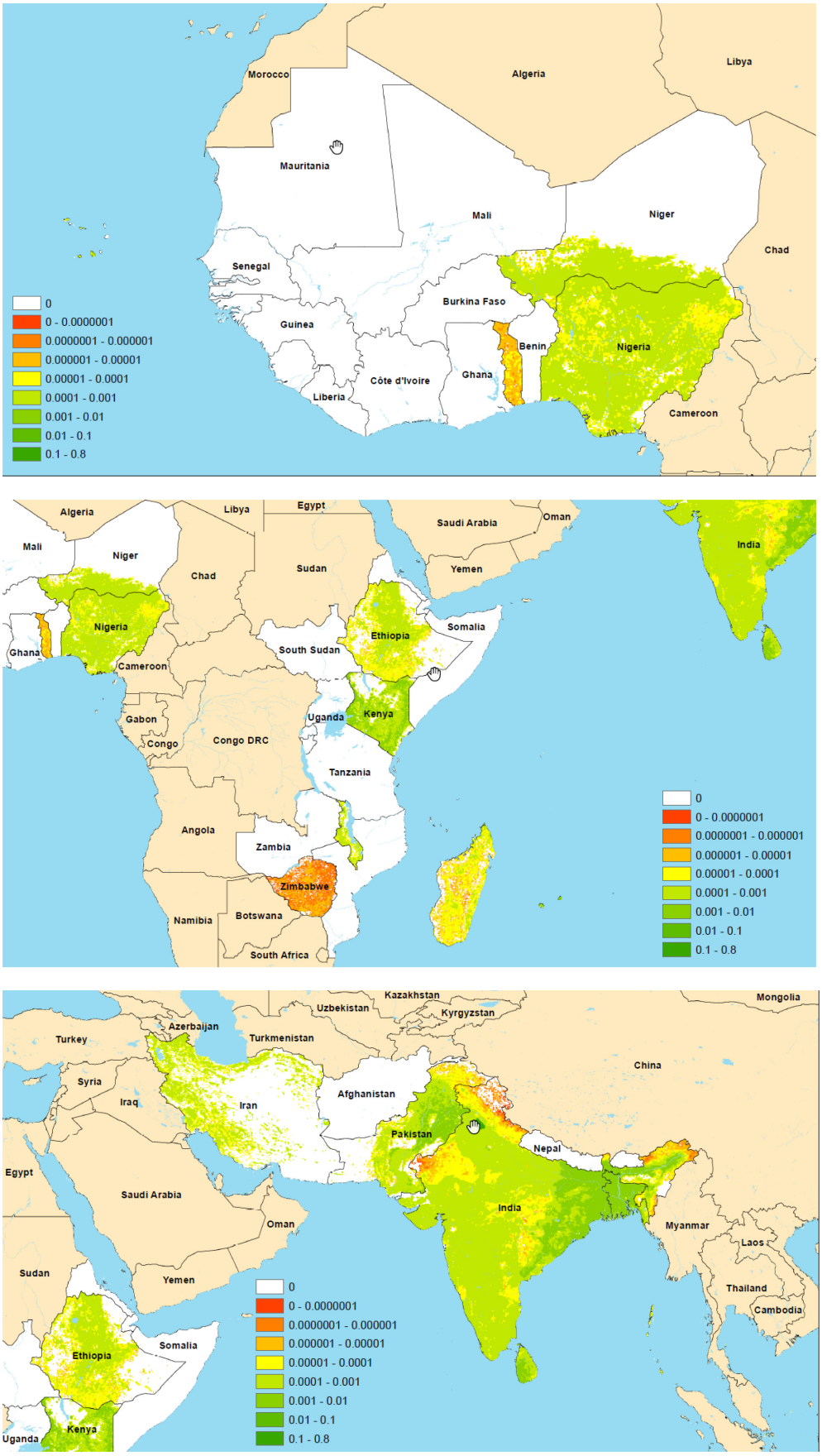
To map harvested areas of fruits and vegetables across the three regions, Western Africa, Eastern Africa and Southern Asia, we grouped fruit and vegetable crop types in five main groups according their nutritional value and potential health impact, according to a pers. comm. of I. Brouwer (Table 1).

Subsequently, the harvested areas of these five main fruit and vegetable groups (as fraction of pixel area) around the year 2000 were mapped (Fig. 1 – 5; based on 5 arcmin resolution maps from http://www.earthstat.org/). The corresponding total harvested areas of the five fruit and vegetable groups in each country in Western Africa, Eastern Africa and Southern Asia are shown in Table 2.

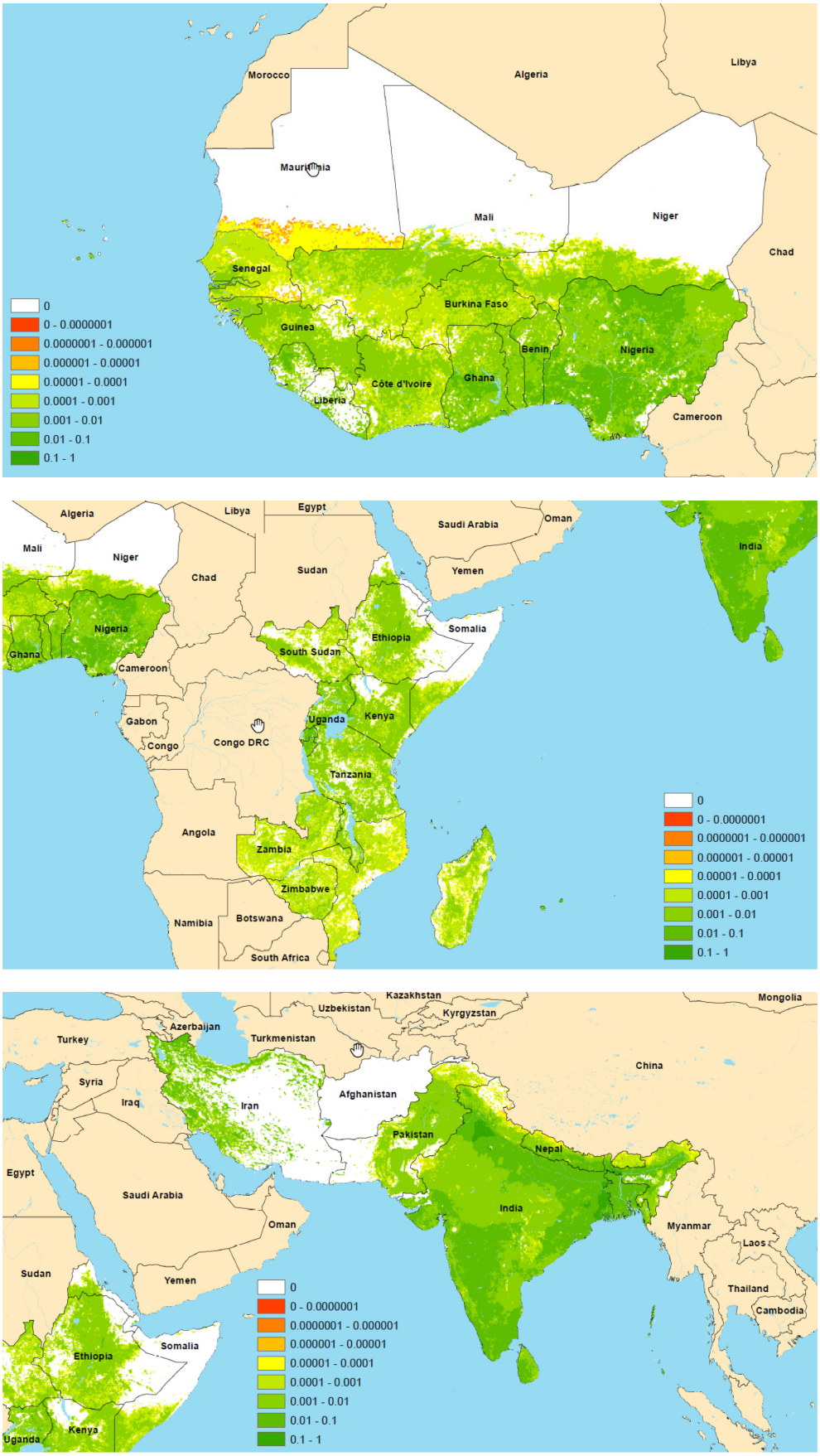
Grouping of fruits and vegetables in five functional nutrition groups.

GROUPS & CROPNAMES	GROUPS & CROPNAMES
GROUP 1 (Vegetables #1)	**GROUP 5 (Fruits #3)**
Cabbages and other brassicas	Apricots
Spinach	Sour cherries
Cauliflowers and broccoli	Cherries
Carrots and turnips	Peaches and nectarines
	Plums and sloes
GROUP 2 (Vegetables #2)	Stone fruit, nes [1)]
Artichokes	Strawberries
Asparagus	Raspberries
Lettuce and chicory	Gooseberries
Tomatoes	Currants
Pumpkins, squash and gourds	Blueberries
Cucumbers and gherkins	Cranberries
Eggplants (aubergines)	Berries nes[1)]
Chillies and peppers, green	Watermelons
Onions (incl. shallots), green	Other melons (incl. cantaloupes)
Onions, dry	Figs
Garlic	Avocados
Beans, green	Pineapples
Peas, green	Dates
Vegetables fresh nes [1)]	Persimmons
String beans	Cashewapple
Okra	Fruit, tropical fresh nes [1)]
Mushrooms and truffles	Fruit fresh nes [1)]
Chicory roots	
Legumenes	**GROUP 4 (Fruits #2)**
	Oranges
GROUP 3 (Fruits #1)	Tangerines, manderins, clem.
Mangoes, mangosteens, guavas	Lemons and limes
Papayas	Grapefruit (incl. pomelos)
	Citrus fruit, nes [1)]
	Apples
	Pears
	Quinces
	Grapes
	Kiwi fruit

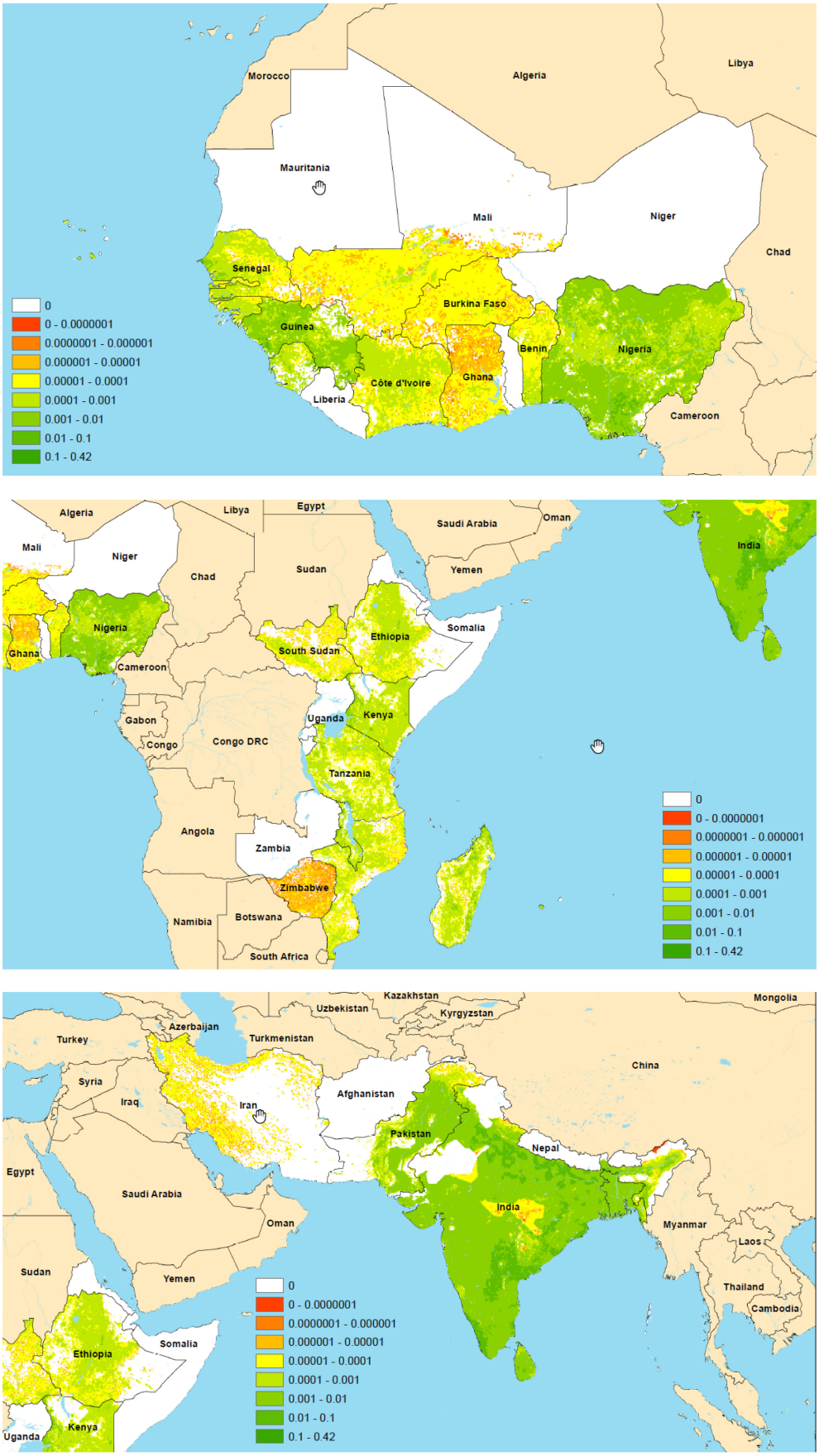
[1)] nes = not else specified.



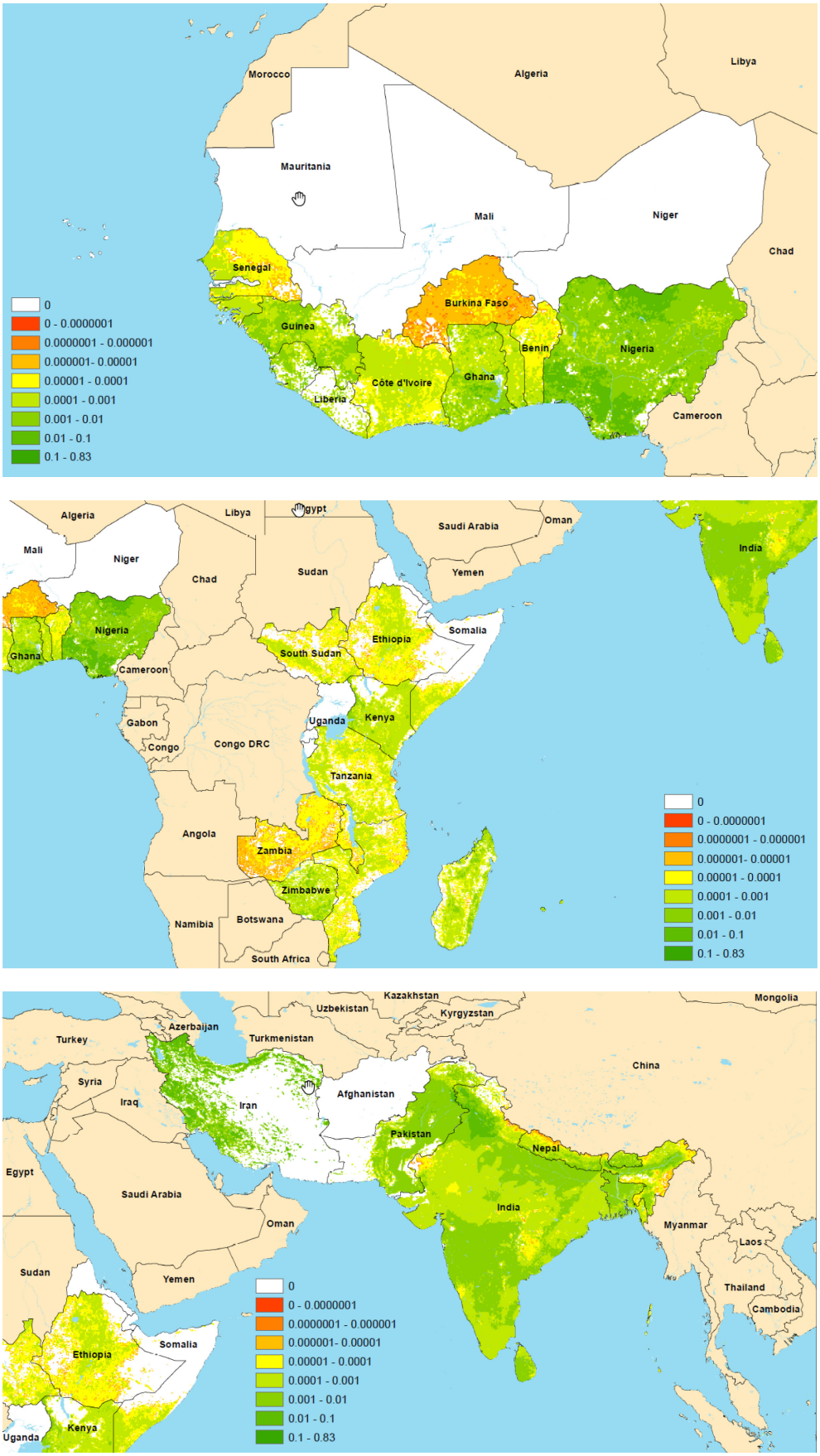
Harvested area of vegetables group #1 as fraction of pixel area around the year 2000



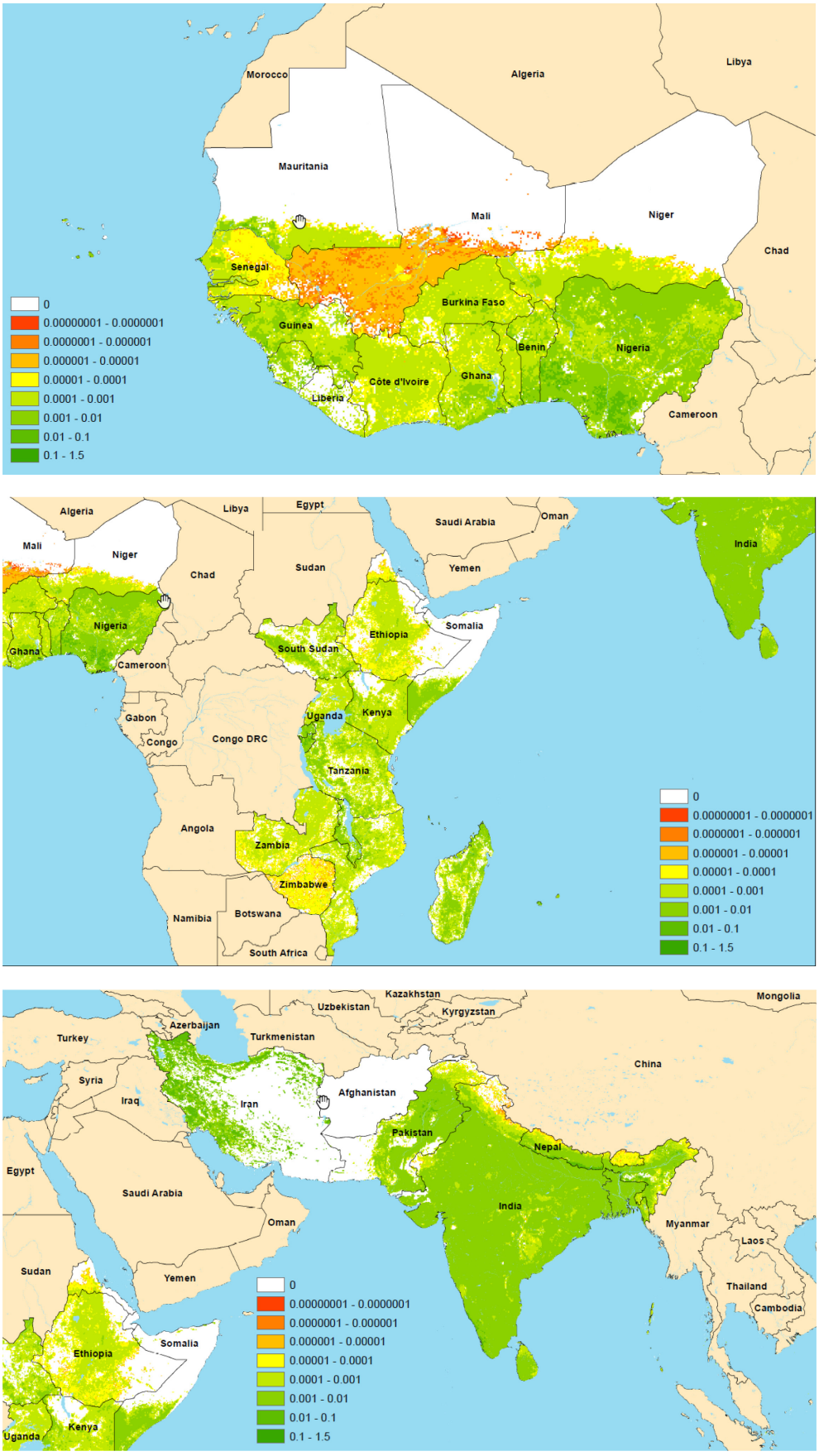
Harvested area of vegetables group #2 as fraction of pixel area around the year 2000



Harvested area of fruits group #1 as fraction of pixel area around the year 2000



Harvested area of fruits group #2 as fraction of pixel area around the year 2000



Harvested area of fruits group #3 as fraction of pixel area around the year 2000

Appendix 17 Two most important fruits and vegetables

Total annually harvested areas (in 1,000 ha) of each group around the year 2000 per country (aggregated from the gridded maps)

Country	REGION	VEG1	VEG2	FRUIT1	FRUIT2	FRUIT3	SUM_all
Cabo Verde	WA	0	0	0	0	1	1
Gambia	WA	0	2	0	0	1	3
Guinea-Bissau	WA	0	5	1	1	2	8
Mauritania	WA	0	1	0	0	11	12
Liberia	WA	0	12	0	2	2	15
Senegal	WA	0	9	6	2	7	23
Togo	WA	0	27	0	2	3	32
Burkina Faso	WA	0	24	1	0	9	34
Mali	WA	0	46	2	0	0	48
Sierra Leone	WA	0	30	3	9	8	51
Niger	WA	14	30	0	0	9	53
Cote d'Ivoire	WA	0	37	4	5	9	55
Benin	WA	0	69	2	2	18	90
Guinea	WA	0	53	44	32	22	151
Ghana	WA	0	142	1	43	21	206
Nigeria	WA	24	921	180	611	282	2,018
Total	**Total WA**	**38**	**1,408**	**244**	**709**	**405**	**2,800**
Seychelles	EA	0	0	0	0	0	0
Djibouti	EA	0	1	0	0	0	1
Comoros	EA	0	1	0	0	1	1
Mauritius	EA	1	5	0	0	0	6
Eritrea	EA	0	12	0	0	0	12
Reunion	EA	1	7	0	1	5	14
Zimbabwe	EA	0	19	0	18	1	39
Burundi	EA	0	23	0	0	18	41
Rwanda	EA	0	35	0	0	10	45
Malawi	EA	2	21	5	0	23	51
Zambia	EA	0	38	0	1	15	53
Mozambique	EA	0	22	8	6	27	63
Somalia	EA	0	18	0	2	42	63
South Sudan	EA	0	46	3	4	34	87
Uganda	EA	0	90	0	0	7	97
Madagascar	EA	2	41	18	22	73	157
Ethiopia	EA	12	169	17	6	16	220
Kenya	EA	48	102	22	23	28	223
Tanzania	EA	0	168	18	10	56	251
Total	**Total EA**	**66**	**818**	**91**	**93**	**356**	**1,424**
Maldives	SA	0	0	0	0	0	0
Afghanistan	SA	0	0	0	0	0	0
Bhutan	SA	0	2	0	9	0	11
Sri Lanka	SA	6	69	27	11	15	129
Nepal	SA	0	154	0	11	47	212
Bangladesh	SA	28	264	59	14	83	448
Pakistan	SA	33	268	98	260	262	922
Iran	SA	12	382	1	648	636	1,679
India	SA	535	5,130	1,525	547	1,134	8,871
Total	**Total SA**	**614**	**6,269**	**1,710**	**1,500**	**2,177**	**12,272**

Appendix 18 Cost structure vegetable production

Based on data sets from Tanzania and Ethiopia, the share of input costs in the total production costs has been calculated of 16 different vegetable crops (de Putter et al., 2012; Everaarts et al., 2015). The costs in both studies were subdivided into costs for planting material, labor requirements, fertilizers, crop protection and other costs, the latter including fuel for irrigation pumps, stakes, trellising, etc. In the Ethiopia data all labor costs were considered, including used family labor that was valued against market prices. In the Tanzania data 89% of the labor was hired and valued as cost. The other 11% was provided by family members and not considered as cost, which implies that the share of the real labor costs were higher than shown in the Table below.

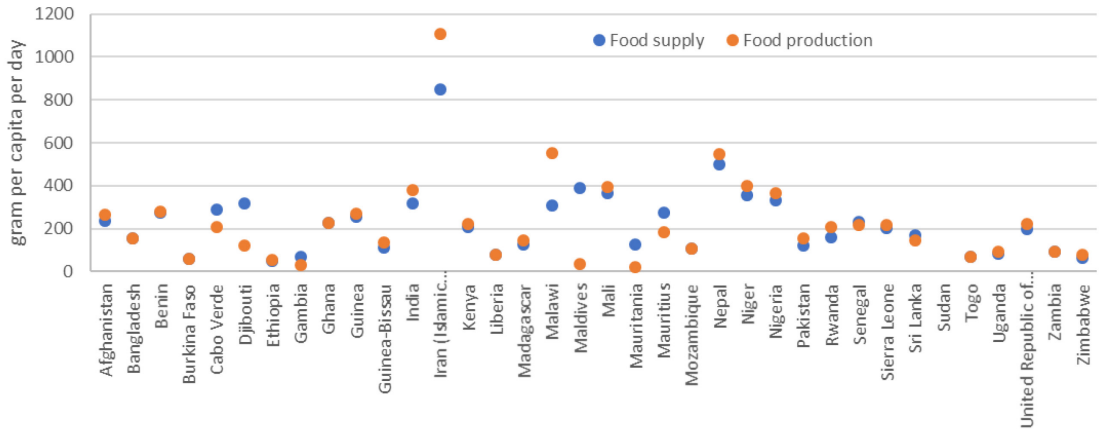
Although the data set is limited to two countries and few data of various crop types, the overall picture is clear: labor requirements are the largest cost component. In addition, the data illustrates the specific management needs of some crops that shows up in the cost structure. For example, the 'other costs' include irrigation costs (in Ethiopia) and stakes in tomato (in Tanzania). Costs of planting material differs among vegetable types depending on the type of starting material, i.e. seeds or (purchased) transplants. Furthermore, consequences of higher input use as presented in the Ethiopia data is visible: relatively lower costs for labor, but higher costs for crop protection and other costs compared to the Tanzania data.

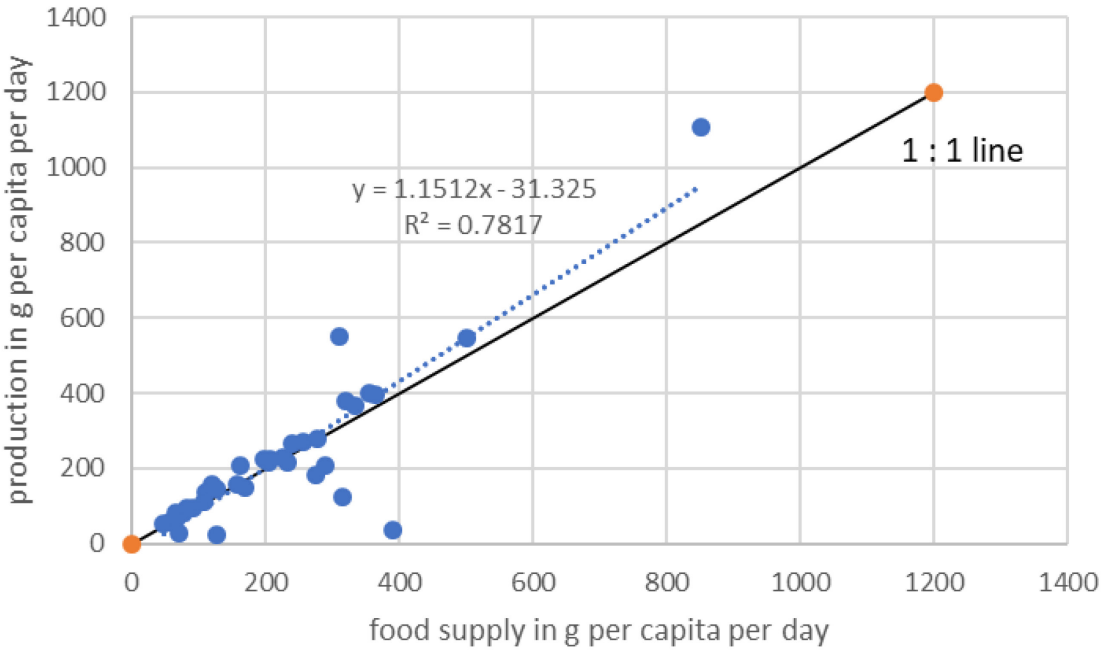
Percentage of costs for planting material, labor, fertilizers, crop protection and other costs for vegetable production in Tanzania and Ethiopia. Source: Everaarts and De Putter 2015; Putter et al. 2012

	n	Planting material	labor	fertilizers	crop protection	Other
Tanzania:						
Carrot	7	11	56	18	7	9
Lettuce	1	5	48	23	7	17
Ethiopian mustard	3	22	56	15	6	1
Kale (Sukuma wiki)	7	4	69	19	4	3
Cauliflower	1	26	45	22	7	0
Cabbage	11	20	44	24	8	4
Broccoli	1	21	37	29	1	11
Chinese cabbage	2	34	28	16	6	17
Cucumber	2	16	46	13	7	19
Onion	2	21	56	13	5	4
Okra	1	15	67	13	5	0
African eggplant	4	6	65	18	7	5
Tomato - Staked	6	5	62	13	10	11
Tomato - Non-staked	6	3	64	17	12	4
Eggplant	1	2	70	17	11	0
African nightshade	1	5	78	10	4	3
Ethiopia:						
onion	17	12	40	16	15	17
tomato	20	4	34	14	19	29
Average:		13	54	18	8	9

Appendix 19 Food production- supply relationships

The figures below show the relationships between food production and food supply data from FAOSTAT.





Appendix 20 References used in the appendices

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