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Enhancing fruit and vegetable consumption in low- and middle income countries through a food systems approach

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Executive summary

Based on extensive literature review, data analysis and in-depth country studies conducted in seven countries (i.e., Bangladesh, Burkina Faso, Ethiopia, India, Nepal, Nigeria and Tanzania), this brief highlights the main constraints, opportunities and leverage points to enhance food systems related to fruit and vegetable consumption, trade, processing and production.

Our key findings include:

- Fruit and vegetable consumption in low- and lower middle-income countries (LLMICs) is far below recommended intake levels, with serious consequences, and costs, for public health, and loss of economic activity in the agri-food sector. The challenge that we will be facing in the coming decades is not only to feed a growing population under a changing climate, but to enhance the nutritional content of diets by improving availability, access and acceptability of fruits and vegetables.
- Most fresh fruits and vegetables are supplied to domestic markets through what can be characterized as informal marketing channels. Such channels operate relatively effectively given the current enabling environment, but they are not efficient—as quality, cost and reduction of losses could be greatly improved. Enabling actors (i.e., sourcing agents, traders, transporters and retailers) operating in informal marketing channels is key to improve fruit and vegetable supply chains for domestic consumption.
- Current production quality, quantity, availability and affordability of fruits and vegetables for domestic consumption are insufficient to meet consumer demands. Profound food system transformations are needed to reverse these trends, especially in governance at the system and sub-system levels.
- Women involved at different stages of fruit and vegetable supply chains, and especially in production, face systemic barriers to controlling their time, resources and income. Addressing these barriers is a necessary step to addressing wider food systemic constraints.
- Investments in fruits and vegetable sectors must be considered as the next stage of an inclusive agriculture transformation; one that connects production and supply much more to consumer demand and preferences, diversifies the production and value generation base of domestic agri-food systems, and creates additional jobs, reduces risks, and shares value among critical actors more equally.

Our key recommendations are:

- Fruit and vegetable production systems located in peri-urban areas present the best opportunity to service expanding domestic markets. Integration of sub-systems located in more rural areas will require additional investments in irrigation infrastructure.
- To ensure women's equitable participation and inclusion, systemic barriers need to be addressed and overcome.
- A major shift is required by public and private research and development from a focus on (carbohydrate rich) staple crops to fruits and vegetables, and beyond improvements in tomatoes and onion germplasm to fruits and leafy vegetables.
- Interventions to promote fruits and vegetables must be adjusted to the prevailing conditions of informal marketing channels, enabling relevant actors operating in these economies. This includes increasing availability of 'risk capital' required to increase experimentation with incentives, measures and service provisions proven to be effective in their specific food systems contexts.

Introduction

The purpose of this policy brief is to provide policymakers, impact investors and other key stakeholders with insights on challenges and opportunities to further develop fruit and vegetable sub-systems to serve growing domestic demand, and, generate employment and economic activity. Enhancing fruit and vegetable value chains is also essential to reducing public health costs associated with the low consumption of healthy foods in low- and lower middle-income countries (LLMICs).

Based on extensive literature review, data analysis, and in-depth country studies conducted in seven countries (i.e., Bangladesh, Burkina Faso, Ethiopia, India, Nepal, Nigeria, and Tanzania), this brief highlights the main constraints, opportunities, and leverage points in the food sub-systems related to fruit and vegetable consumption, trade, processing and production. We conclude with an overview of the most critical issues to be addressed to achieve higher levels of nutritious fruit and vegetable consumption through improved supplies and production.

Background

Increasingly, LLMICs face the double burden of malnutrition, defined as the simultaneous manifestation of undernutrition[1], micronutrient deficiencies[2], and overweight and obesity[3] (Popkin et al., 2020). Globally, 1.9 billion adults are currently overweight or obese, while 462 million are underweight (WHO, 2021). In many LLMICs, the risk of overweight and obesity is greatest among higher-income, urban households, but it is also increasing in rural areas.

Poor diets play a major role in this malnutrition pandemic, and the current dietary shifts observed in LLMICs are moving in the wrong direction, with increasing intakes of (saturated) fat, sugar and salt (HLPE, 2017). Specifically, low vegetable and fruit consumption is a key contributor to malnutrition, as fruits and vegetables are key sources of vitamins, such as carotenoids and 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). Fruits and vegetables can therefore help to tackle the global malnutrition challenge.

To improve dietary patterns a shift from a focus solely on caloric-rich grains to more nutritious foods like fresh fruits and vegetables is required. Increasing food production to meet growing demands cannot be disassociated from the pressure that existing agricultural systems place on the environment (Lobell et al., 2008). As a result, increasing the production of fruits and vegetables must take place within these boundaries through sustainable intensification and shift in land use.

Approach

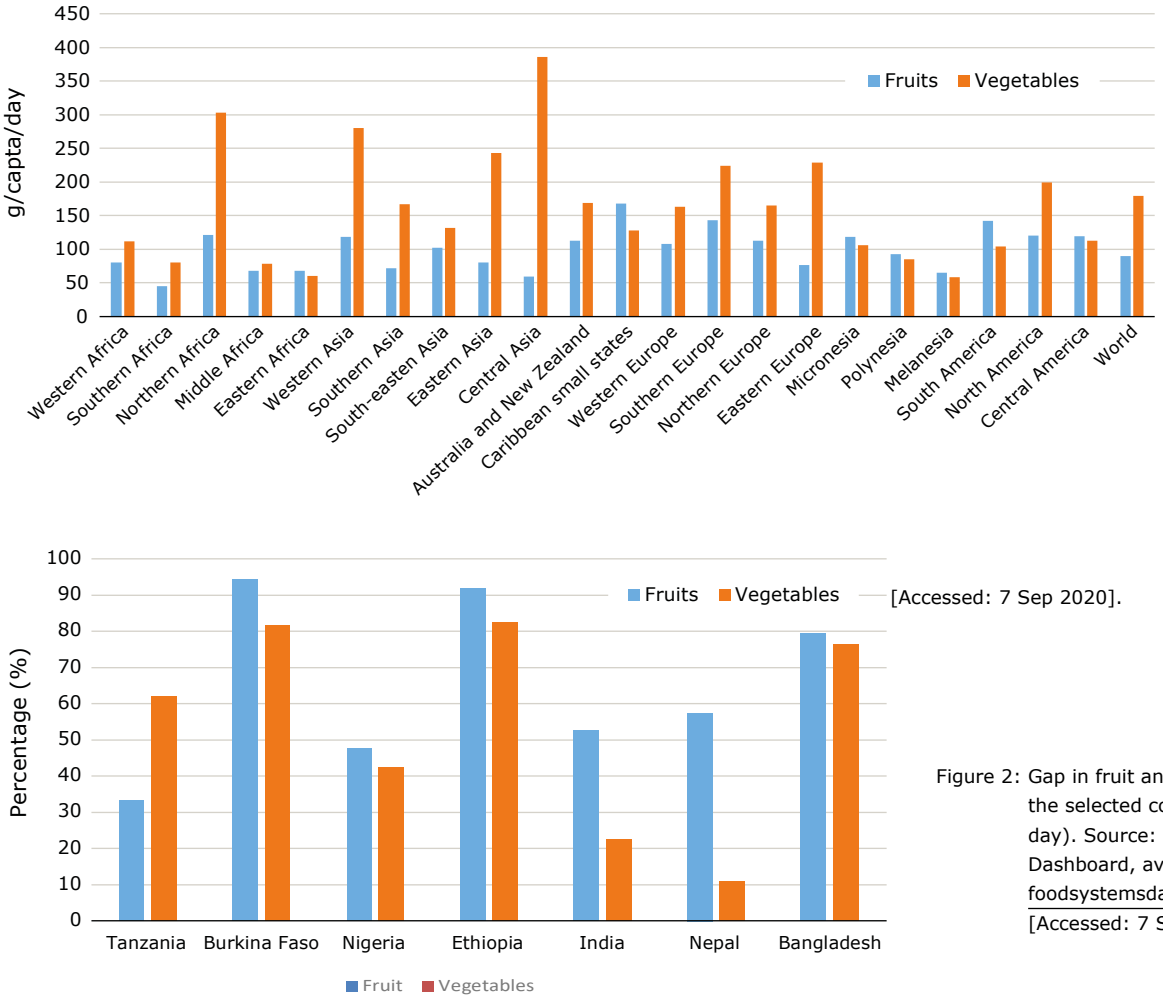
This brief is based on a scoping study[4] by an interdisciplinary team of WUR and national consultants on fruits and vegetables in LLMICs. The study was divided into two phases. The **first phase** analyzed fruit and vegetable trends across food systems globally and regionally (i.e., South Asia, East Africa and West Africa), and compared current production levels with existing domestic demand and dietary requirements. Also analyzed was how various food system drivers impact fruit and vegetable production, supply, demand and consumption. In the **second phase**, food system leverage points identified in the first phase were further studied in seven countries, namely, Bangladesh, Burkina Faso, Ethiopia, India, Nepal, Nigeria and Tanzania. This phase aimed to identify key barriers to consumption, drivers of change, incentives for enhanced production and supply, and innovative business models. Recommendations were made for investments that are needed to improve the fruit and vegetable sectors, whilst ensuring women's equitable inclusion through increased market opportunities and empowerment.

Based on these findings, we present the following five insights:

1 Fruit and vegetable consumption in LLMICs is well below recommended standards

Large differences in fruit and vegetable intake exist between regions (Figures 1 and 2).[5] Only Northern Africa and Central Asia meet the recommendation by the World Health Organization (WHO) of daily per capita intake 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, Eastern and Western Asia) show adequate average vegetable intake, with no region showing adequate fruit intake. In Africa (Western, Eastern and Southern sub-regions), South America, Polynesia and Melanesia, fruit and vegetable intake is very low. Regional disparities were also confirmed by Frank et al. (2019), showing that less than 35% of households in Central Asia and the Middle East, less than 20% in Eastern and Southern Asia, and less than 10% in the Caribbean, Latin America and Sub-Saharan Africa, consumed ≥400 g fruits and

1 Undernutrition is traditionally related to food insecurity and extreme poverty--usually expressed in wasting (low weight-for-height), stunting (low height-for-age), and underweight (low weight-for-age).
2 Micronutrient deficiencies refer to a lack of important vitamins and minerals.
3 The increase in overweight and obesity levels is related to food system changes that have made less nutritious food cheaper and more accessible, as well the decrease in physical activity due to major technological shifts in the workplace, home and transportation.
4 Funded by the Bill and Melinda Gates Foundation
5 Vegetables included in the analysis are 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 included in the analysis are fresh, frozen, cooked, canned, or dried fruits, excluding fruit juices and salted or pickled fruits.



[Accessed: 7 Sep 2020].

Figure 2: Gap in fruit and vegetable intake in the selected countries (g/capita/day). Source: Food Systems Dashboard, available at: https://foodsystemsdashboard.org/ [Accessed: 7 Sep 2020].

vegetables. The fruit and vegetable intake gap in the seven countries in phase 2 are very high (Burkina Faso, Ethiopia and Bangladesh) and high (Tanzania, Nigeria, India and Nepal), see Figure 2.

A healthy diet – defined according to the national food-based dietary guidelines and if guidelines were not available, according to the guidelines of a neighboring country – remains unaffordable for many (Herforth et al., 2020)safe, nutritious food to meet dietary needs and food preferences for an active and healthy life. In this study, the least-cost items available in local markets are identified to estimate the cost of three diet types: energy sufficient, nutrient adequate, and healthy (meeting food-based dietary guidelines. In our selected countries, more than 75% of the population cannot afford a healthy diet, with Burkina Faso and Nigeria showing the highest proportion (90% or above). Data shows that the average costs (US$) per person, per day, for a healthy diet ranged from US$2.62 in Tanzania to US$4.13 in Nepal (Table 1). Costs of the least expensive fruits and vegetables varied from US$0.86 in Tanzania to US$1.72 in Nepal, and between 30% and 42% of the cost of a healthy diet is accounted for by fruits and vegetables in the seven countries. In Ethiopia, for example, the affordability of fruits and vegetables was the major barrier to consumption, with the recommended intakes costing 11% of household income for the average Ethiopian, and 27% for the poorest households. This confirms that fruits and vegetables are more expensive compared to other food groups such as cereals, oils and fats, and drive a large part of the costs of a healthy diet. It was observed that, especially amongst low-income population groups, diets are dominated by cereals as these are cheaper (and other foods, including fruits and vegetables, are more expensive) and suppress the hunger feeling. However, cereals lack essential nutrients such as vitamins A and C, and do not exert protective properties against non-communicable diseases as fruits and vegetables do.

Data presented in the Food Systems Dashboard show that fruit and vegetable consumption increases as income grows, indicating that low-incomes constrain fruit and vegetable demand and actually become a barrier to achieving the recommended intake levels (Frank et al., 2019; Hall et al., 2009; Miller et al., 2016). However, data suggest that fruit and vegetable intake peaks at around 300 g per day, and does not increase despite further increases in income as observed in upper-middle and high-income countries (Figure 3). This suggests that

Table 1 Current situation regarding intake and costs of fruits and vegetables. Sources: Lancet's Global Burden of Disease (2017) and Anna Herforth and Aishwarya Venkat, personal communication. Based on an analysis in Herforth et al. (2020).

	Tanzania	Burkina Faso	Nigeria	Ethiopia	India	Nepal	Bangladesh
Average daily per capita consumption of fruits and vegetables (g/day/person)	198	53	138	55	262	271	99
Average daily per capita consumption of fruits (g/day/person)	107	9	80	13	76	68	33
Average daily per capita consumption of vegetables (g/day/person)	91	44	138	42	186	214	57
Cost of a healthy diet (US$/person/day)	2.62	3.66	3.57	3.74	3.27	4.13	3.66
% of the cost of a healthy diet accounted for by fruits and vegetables	33	30	34	39	39	42	34
% of the population that cannot afford a healthy diet	85	90	91	84	78	76	75

income is an important determinant factor for fruit and vegetable consumption, but not the only one. Other factors like taste, convenience and consumer knowledge on fruit and vegetable are also of importance.

Macro-level studies do not show substantial differences in fruit and vegetable consumption between men and women, but regional and case studies find more mixed results (Micha et al., 2012). However, it was observed that women nearly always consumed slightly higher intakes of healthy foods (including fruits and vegetables) and lower amounts of less healthy foods (including processed meats). In addition, Frank et al. (2019) found no significant gender difference 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 WHO recommendations compared to men.

2 Informal fruit and vegetable supply chains are effective to deliver products to markets, but they are not efficient

Well-organized fruit and vegetable supply chains contribute to better allocation of scarce resources, with better distribution of economic benefits among stakeholders operating in different segments of the value chain. Our country studies indicate that informal fruit and vegetable marketing channels supply between 95-99% of traded volumes.

While these informal market channels are effective in supplying larger volumes to urban markets, they are not efficient, as these marketing channels have high post-harvest losses, high intermediation cost, low price and market data transmission, and low traceability and quality management. These factors combined exacerbate both sourcing and transaction risks faced by value chain actors, and increase prices paid by urban consumers. The biggest contributors to inefficiency in informal fruit and vegetable supply chains include farmers' dependency on traders, the high uncertainty levels on sales and prices, and lack of a standardized grading and weighing system. In addition to being inefficient, many fruit and vegetable value chains are unequitable in terms of sharing value and risks, with small-scale producers bearing price and sourcing risks. This is particularly observed for women actors in the supply chains.

Information and coordination costs increase are important transactions costs in the fruit and vegetable sector and increase with. Most fruits and vegetables are produced seasonally, often far away from consumer locations, which means that sourcing agents and traders play an important role in connecting farmers to markets. Sourcing agents and traders often choose to establish personal relationships with sellers and producers so that they have guaranteed access to, and a market for, the produce. Traders invest considerable resources into developing and maintaining these personal relationships. In all country studies, fruit and vegetable traders invest much time in obtaining market information and traveling to farmers to check potential supply quantity and quality; if the farmer has already sold to someone else, the trader cannot recuperate the investment. This problem increases when there are many traders and few farmers during the low season and the reverse is also often true; a fruit or vegetable farmer in remote locations may only be able to sell produce for a relatively low price during peak season since traders are not always in the vicinity.

Fruit and vegetable perishability adds to market uncertainty, as most products need to be traded and transported shortly after harvest—and in some cases, from remote locations with challenging infrastructure and constrained transport services. To avoid potential delays, farmers often sell to the first collector that offers a reasonable price. Traders have to set the highest possible sales price and the lowest sourcing price to cover risk of spoilage and price fluctuations, which impacts on consumers.

In informal markets, fruit and vegetable quality is generally graded by appearance, with no standardized quality grades. Weighing traded produce is rare, and inappropriate packing materials (e.g., basket, bags, sacks)

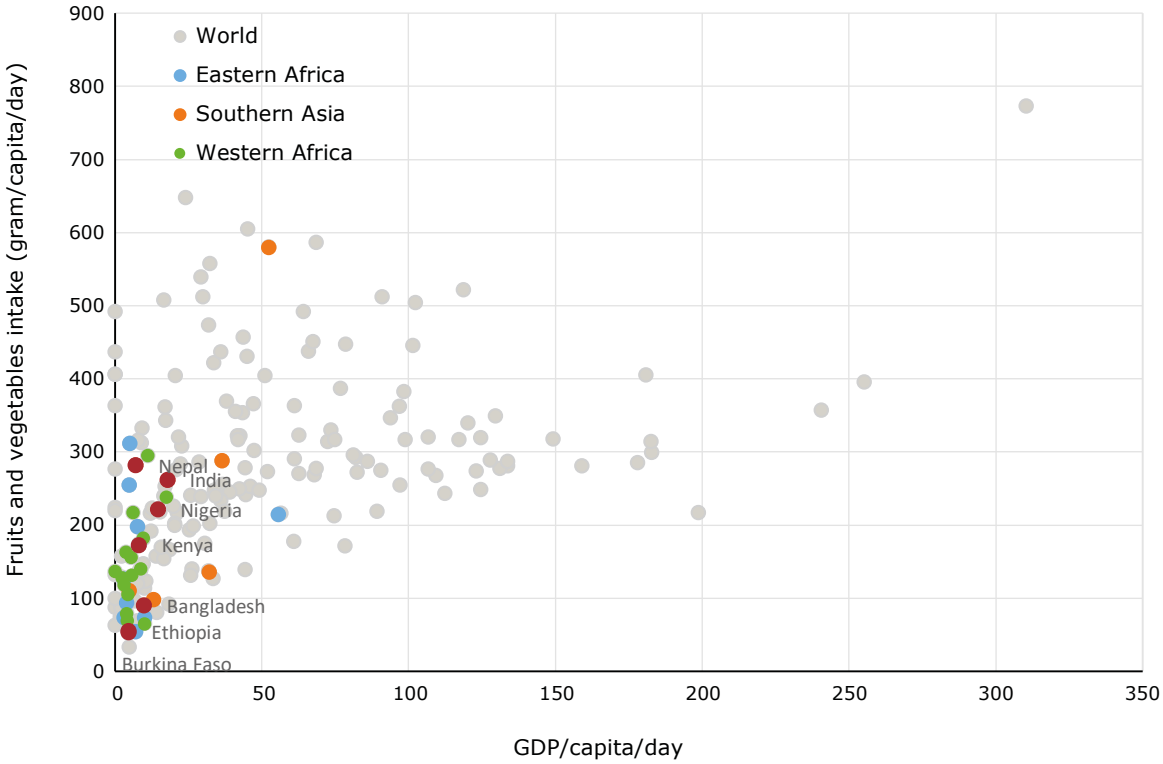


Figure 3: National data on 2017 fruit and vegetable intake against 2017 GDP in constant 2011 international US$ for the specific regions of Eastern Africa, Western Africa and Southern Asia
Source: Food Systems Dashboard, available at: http://www.foodsystemdashboard.org/ [Accessed: 7 September 2020] and FAOSTAT [Accessed: 7 September2020].

are used to transport produce. The lack of standardized packing, grading and weighing results in disputes and adds to transaction risk, resulting in higher consumer prices. For example, in Nigeria, poor quality tomatoes are often packed at the bottom of raffia baskets, while the best quality tomatoes are packed on top; traders anticipate these practices by farmers and so compensate accordingly. Improvements in governance of these markets and marketing channels is required to increase market facilitation services, improve quality and labor standards, and build trust among critical value chain actors—developing reinforcing loops that drive self-improvement.

Formal markets for fruit and vegetables are emerging in LLMICs. The rise in supermarkets, driven by urbanization and larger numbers of middle- and high-end consumers, benefit commercially-oriented farmers who are able to profit from stable markets and better prices. Formal markets often work with standards, registered businesses, and contracted arrangements (e.g., supplying supermarkets). In many countries, innovative short supply chains are emerging that bypass existing informal market actors to enter into direct business relationships with target urban consumers. For example, in India, women entrepreneurs create direct supply and home delivery chains between peri-urban vegetable producers and urban consumers.
National governments can do much more to support formal and informal fruit and vegetable value chains. Formally and informally traded fruits and vegetables are overly taxed as they transit to, and upon arrival to, markets, and midstream actors, notably wholesale traders, lack basic market information, specifically around consumer demand and consumer preferences. In contrast, informal retailers are often in direct contact with consumers, but there is little backward linkage of consumer information, which is why most fruit and vegetable chains are supply driven, and do not respond to changing consumer needs and preferences.

3 Current production levels are insufficient to meet consumer demand, with a potential growing gap if investments are not made

Despite encouraging trends in fruit and vegetable production, their production in LLMICs currently remains insufficient for healthy diets. In Africa, increases have been predominantly achieved through expansion of production areas, whilst in Asia, increases are achieved by higher productivity due to higher input use. Still, in both Asia and Africa, yield gaps of fruits and vegetables are very large (>80%), suggesting much scope to improve the production of current farming systems.

Smallholders in mixed-farming systems with or without irrigation produce 60-100% of fruits and vegetables. Access to irrigation is critical to increasing productivity,

but also to increase supply of nutrient-rich foods throughout the year, reduce dependency on erratic rainfall, and avoiding peak harvests at the end of the rainy season. While most fruit and vegetable farming systems studied are in remote, rural areas without access to irrigation, especially in sub-Saharan Africa, in contrast, about 40% of fruits and vegetables in India are produced by farmers with irrigation access.

In home gardens, mostly managed by women, surplus fruits and vegetables are marketed at local rural markets. Lack of market proximity is a particular challenge for women who are often constrained in their mobility due to safety issues., In more commercial-oriented mixed-farming systems, male and female farmers combine production of various fruits and vegetables with multiple on- and off-farm activities. In Ethiopia and Tanzania, larger, export-oriented fruit and vegetable farms have been established, often with foreign capital and management. However, although piloted on a large scale during the past decade, the successes of small-scale commercial fruit and vegetable farming engaged in contract-farming, as set up by a 'mother company', have remained scarce.

Smallholder home gardens lack the opportunity to scale production and contribute to the increasing demand for fruits and vegetables required to feed populations, especially in urban centers. Yet, as the goal of increasing rural consumption of fruits and vegetables is also important, attention must be given to enhancing the variety of these crops in home gardens.

The large number of semi-commercial mixed-farming systems are good entry points to increase supply of fruits and vegetables. Overall, fruit and vegetable productivity in these mixed-farming systems is low with large yield gaps. The use of quality inputs and optimizing input use to increase productivity is a first step to narrowing the yield gap. Nevertheless, realizing productivity increases requires specialized knowledge and skill building because fruit and vegetable production exposes farmers and farmers' groups to challenges, including controlling new pests and diseases, joint irrigation scheme management, proper harvesting techniques and handling, and engaging in new marketing channels.

The most promising opportunity for improving the supply of, notably highly perishable, fruits and vegetables is represented by peri-urban smallholders. A study by Karg et al. (2016) shows that more than 30% of all food available in Ouagadougou, Burkina Faso, is produced within 50 km of the center. In Tamale, Ghana, this amount was produced within only 30 km of the town center (Karg et al., 2016). Many of the peri-urban farmers often start from an impoverished background, limiting their access to capital and suitable land. Yet, because of their interest in specialization of fruit and vegetable cropping, and support from informal networks, the number of peri-urban farmers is increasing rapidly, despite lack of formal support or a conducive environment.

However, no matter the system, due attention should be given to trade-offs, sustainability, and food safety issues. For example, increased water use for irrigated fruit and vegetable production potentially conflicts with other ecosystem services such as the provision of drinking water and biodiversity, while food safety and environmental risks may rise with increased use of agrochemicals to protect crops from pests and diseases, as already observed in various reports from LLMICs (Kapeleka et al., 2020; Loha et al., 2020; Mengistie et al., 2017).

4 Women are key to supplying consumers with more and better fruits and vegetables

Women are predominantly involved at the base of fruit and vegetable supply chains in rural, and mostly informal, contexts. There are examples of women leaders higher up specific supply chains in marketing—more so in West Africa, though they can be found in all countries studied—but they are the exception. More typically, women play an equal role to men in fruit and vegetable production, or a greater role than men in managing home gardens.

Opportunities for women to capture a higher share of revenue, and in the process increase their agency and influence dietary patterns at the household level, must blend with social norms and economic interventions. Purely economic interventions have as great a chance of having a negative impact. Time is a major constraint for women, so interventions that reduce or redistribute their existing daily work are necessary.

Mobility is a second constraint due to lack of time and/or socio-cultural norms which make it unacceptable for women to travel further afield unaccompanied by a male chaperone. Limited mobility can be circumnavigated through establishing (women-led) aggregation points for drop-off of produce. Informal and formal producer groups (e.g., cooperatives) that are exclusive to women or positively bias their membership, and that are located closer to women's homes, can address mobility as well as provide additional support such as access to market information, savings and training.

For women with greater access to education and other resources that provide more independence, support in formal markets, including access to finance, assets and market information, can be of benefit. Whilst these women are unfortunately a minority, they are

nevertheless important to both supporting and promoting (through events, awards, speaking opportunities, etc.) the position of women in fruit and vegetable supply chains. Such role models contribute to changing the face of agriculture and agribusiness—from one traditionally run by men, to the correct image that just as many women as men are involved—and so for which access to resources and opportunities should be equal.

Greater control over production and income by women correlates with increased food intake (quantity), but not necessarily with improved diets (quality), as both women and men require improved education and access to seeds and other inputs to grow or purchase fruits and vegetables that provide healthy diets. Interventions that focus on women's empowerment to improve diets must therefore explicitly raise awareness of healthy diets (tailored to the cultural context). More broadly, interventions that focus on women should always involve men to promote equal decision-making opportunities in the household.

5 Food system transformation is needed to increase fruit and vegetable consumption

Interventions to increase fruit and vegetable intake require clear consumer segmentation and targeting of the main intake drivers for each consumer segment. This is a critical prerequisite for promoting effective interventions to achieve higher fruit and vegetable consumption, because different consumer segments respond to different incentives. Segmentation could be done along income lines, but also along other criteria such as age, workplace, and level of education. Behavior change communication to adjust social norms about gender and women's empowerment should also be integral to all interventions.

Income improvement, rather than a reduction in retail prices, is likely to lead to a greater increase in the consumption of fruit and, to a certain extent, vegetables, for low-income consumers. Fruit demands seem to be more elastic compared to demand for vegetables. Investments should focus on supporting and diversifying income-generating activities for the poor, and on targeted social protection policies which support healthy diets, specifically fruit and vegetable intake (for example, through vouchers for nutritious foods and healthy school or workplace meals).

Middle-class consumers respond more to investments that enhance convenience, such as providing fresh foods at workplaces, and fruits and vegetables that are pre-cleaned or cut. More promising is the informal market, which can increase the fruits and vegetables on offer in street foods, provide home delivery, and increase convenience value by chopping vegetables, for example. Investments into the industrial processing of fruits and vegetables have been found to have limited contribution to improving healthy diets.

Interventions should prioritize nutritious fruits and vegetables, such as dark green leafy vegetables, red, orange or yellow (vitamin A rich) vegetables, and cruciferous vegetables, and shy away from tomatoes and onions which do not contain these important elements. Nutrient-rich fruit and vegetable crops need more attention from public and private research and development (R&D), and extension services, in anticipation of increasing consumer demands.

However, we still know very little about the consumption of indigenous (collected) fruits and vegetables, their role in diets, and their potential to fill the intake gap. Moreover, fruits are often lumped into a generic food group with vegetables, but they possess distinct features, have a different place in dietary patterns, and need different investments to increase consumption. Increasing fruit intake will lead to a greater impact on population health, as fruits have a higher propensity for reducing health risks compared to vegetables. Cultural prejudices that link vegetables to poverty can, in fact, reduce their consumption when household incomes start to rise, replacing the vegetables (originally found in diets) rather than staples with meat. Similarly, due to high costs and cultural prejudice, fruits, which are often consumed as snacks, may require less adaptation of dietary patterns, and may increase the potential impact of fruit investments on intake compared to vegetables. Such investments are likely to benefit all consumer segments above two years of age.

Evidence of the extent of biological hazards and pesticide residues for fruits and vegetables in different contexts should be further explored and communicated, as these are increasing problems and concerns for consumer health. Food safety institutions generally lack capacity and resources to carry out such investigation. More analysis of effective interventions to enhance the functioning of these institutions is also needed prior to making investments in the fruit and vegetable sus-system.

Consumers are rarely included in discussions on food system transformation for healthier diets. Ways to strengthen consumer agency to address food safety and diet quality issues should be identified. There are a limited number of institutions representing consumers, although examples of consumer movements are emerging and increased investments in the fruit and vegetable sus-system can result in more awareness of the benefits of fruit and vegetable intake among consumers, lobbying and agency, but this pathway should be further tested and evaluated.
Informal retailers are most aware of consumer preferences, so investments with the purpose of improving backward and forward information flows in fruit and

vegetable supply chains must start with the relationship between retailers and wholesalers. Retailers, from street vendors and corner shops to convenience stores, can be instrumental in improving fruit and vegetable accessibility and quality. If mobilized in public campaigning and raising awareness and provided with investments, they can have significant positive impacts.

Additional retail sector investment impacts for food system outcomes include income generation and employment creation. Investments in informal economies require different intervention models compared to those in formal economies. As the latter are directed through formal institutions, these will not reach informal target groups. This study highlights a lack of understanding of how to mobilize and transform informal institutions, and their organization and governance, to increase supply chain efficiencies that result in lower consumer prices. Given the proportional importance of informal fruit and vegetable chains—often covering over 90% of the supply to domestic consumers—well-targeted investments have potentially high impacts on the volumes and quality of supplies, as well as other food system outcomes, such as employment, income and economic inclusion of women.

Interventions to increase fruit and vegetable affordability to consumers must reduce transaction costs and risks in the supply chain. Opportunities to reduce transaction risks include investments in infrastructure, market information systems, and logistics such as cold storage. Opportunities to reduce supply chain losses include improved pest and disease control, harvesting techniques, and better packaging and handling.

Interventions to increase fruit and vegetable production require producer segmentation: those that are able to make a step towards commercialization and those that are not. Entrepreneurial ambitions among fruit and vegetable producers are prerequisites for investing in skills and know-how development, input supply and marketing. Such investments contribute to specialization processes, and higher and more sustainable fruit and vegetable production. In countries with poor infrastructure, peri-urban farming systems offer more opportunities to increase production and quality of more perishable fruits and vegetables compared to remote, mixed-farming systems. Peri-urban farming systems also offer better opportunities for women's involvement in production and trade, as risks of harassment when taking produce to distant markets are limited. To reach remote, rural consumers, interventions should not only focus on increasing productivity, but also on diversifying the production of fruit and vegetable crops and crop varieties. This will contribute to securing and improving household dietary diversity.

To date, private R&D, notably in India, has focused on breeding of commercial crop varieties, such as tomatoes and onions, but these have very limited nutritional value. In Africa, there are very few private breeding programs and commercial seed companies mainly use varieties developed in Asia. In most countries, there is very limited public R&D and almost no breeding of fruit and vegetable varieties. Supplying consumers with a greater diversity of fruit and vegetable varieties will require major changes in public and private R&D, and a refocusing of knowledge development and resource allocation on nutrition-rich crops; this will require considerable investment.

Conclusions: What will trigger food system transformations?

Investments in fruits and vegetable sectors must be considered as the next stage of an inclusive agriculture transformation; one that connects production and supply much more to consumer demand and preferences, diversifies the production and value generation base of domestic agri-food systems, and creates additional income and jobs, reduces risks, and shares value among critical actors more equally.

A starting point for such transformation is 'reverse thinking'—putting the dietary outcomes requested from food systems upfront in responsive food policymaking, legislation, investments, and interventions, and working towards incentivizing systems that create these outcomes. Applying reverse thinking is key to achieving desired food system outcomes, such as enhanced food and nutrition security.

When starting from consumer needs, investments should prioritize the production, supply and promotion of more nutritious, safe fruits and vegetables, such as dark green leafy vegetables, red, orange or yellow fruits and vegetables, and cruciferous vegetables. These priorities can be achieved by focusing on the respective drivers and leverage points of changes in food systems. An example is increasing access to fruits and vegetables by reducing production and supply seasonality through irrigation in the off-season and better storage. Another example of an opportunity to achieve systemic changes is investing in peri-urban food systems to enhance the volume, diversity and quality of supplies to urban consumers, which also positively impacts women's economic opportunities. And,

if the goal is enhancing rural food and nutrition security, it is recommended to invest in diversifying fruit and vegetable production in home gardens of remote, mixed-farming systems.

All food system transformations come with synergies and trade-offs, whereby not all outcomes can be met or benefits equally distributed among stakeholder segments. Interventions may have a positive impact on, for example, smallholder production and income, while having a negative impact on the environment. Fruit and vegetable production can be sustainably intensified, but at the cost of women's labor force. Or consumer fruit and vegetable prices may be reduced at the expense of income generated by small retailers. What is critical in well-designed, embedded food system transformations is that these trade-offs are well understood prior to introducing interventions. Such forecasting and scenario analysis will equip decision-makers with insights on the plausible impacts of interventions, and opportunities to mitigate negative impacts.

Although foreign-owned export companies producing and trading fruits and vegetables may contribute to economic benefits through employment creation and tax revenues, their impact on domestic fruit and vegetable supply chains and consumption is very limited. We have not found convincing evidence that assumed trickle-down effects, such as widespread adoption of improved seeds, production practices or infrastructure, is taking place by producers, traders or processors for domestic markets. Yet, due to increasing populations and urbanization trends in LLMICs, domestic and regional demands for fruits and vegetables are increasing fast and projections forecast great supply deficiencies to satisfy these growing demands. Investments in the areas suggested in this policy paper are therefore urgently needed.

Investment in fruit and vegetable sectors will impact consumption, supply and production, but different types of investment produce different results for different foods in different contexts. We need to know more about how specific investments, such as nudging consumers towards healthy diets, improving supply efficiency, or improving producer access to irrigation, will play out in food systems for different fruits and vegetables. Because of the many 'unknowns', 'risk capital' is needed in terms of putting investments where conventional investors see too many risks. An example is providing financial services to women who have no legally acknowledged collateral. Philanthropic and impact investments can take on that role as 'risk capital' as they may not yield high financial returns, or meet long bureaucratic protocols or political agendas. Providing proof of concept studies will catalyze further investments by public or private sectors, and upscaling of an approach.

To conclude, enhancing fruit and vegetable consumption, supply and production in LLMICs will require non-conventional approaches and investments. Reverse thinking, adjusting interventions to the realities of the informal economies, shifting investments away from onions and tomatoes towards green leavy vegetables and other highly nutritious fruits and vegetables, focusing on women empowerment and inclusion, and avoiding damaging the environment will require bold decisions and collective efforts by all key stakeholders. Walking this pathway into the unknown can be challenging, but also very rewarding for the many people who will thus obtain access to nutritious foods and income-generating opportunities.

Literature

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