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FRUITS AND VEGETABLES FOR HEALTHY DIETS: PRIORITIES FOR FOOD SYSTEM RESEARCH AND ACTION

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ABSTRACT

Fruits and vegetables are vital for healthy diets, but intake remains low for a majority of the global population. This paper reviews academic literature on food system issues, and opportunities for research and action, as an input into the 2021 UN Food Systems Summit in the context of the International Year of Fruits and Vegetables.

The paper summarises evidence underpinning food system actions to make fruits and vegetables more available, accessible and desirable through push (production and supply), pull (demand and activism) and policy (legislation and governance) mechanisms, with action options at macro (global and national) meso (institutional, city and community) and micro (household and individual) levels. It also suggests the need to recognise and address power disparities across food systems; and trade-offs among diet, livelihood and environmental food system outcomes.

We conclude that there is still a need to better understand the different ways that food systems can make fruits and vegetables available, affordable, accessible and desirable across places and over time – but that we know enough to accelerate action in support of fruit- and vegetable-rich food systems driving healthy diets for all.

WHY FRUITS AND VEGETABLES, WHY NOW?

Fruits and vegetables are vital for healthy diets, with broad consensus that a diverse diet containing a range of plant foods (and their associated nutrients, phytonutrients and fibre) is needed for health and wellbeing¹. Studies have suggested intake ranges of 300-600g per day (200-600g of vegetables and 100-300g of fruits) to meet different combinations of health and environmental goals²⁻⁴. The World Health Organisation (WHO) recommends adults to eat at least 400g of fruits and vegetables per day⁵, with national food-based dietary guidelines translating these into recommendations to eat multiple portions of a variety of fruits and vegetables each day for health⁶.

Despite this clear message, intake of fruits and vegetables remains low for a majority of the global population^{4, 7}. Low fruit and vegetable consumption is among the top-5 risk factors for poor health, with over 2 million deaths and 65 million Disability-Adjusted Life Years (DALYs) attributable to low intake of fruits, and 1.5 million deaths and 34 million DALYs attributable to low intake of vegetables globally each year, and particularly in low-

and middle-income countries⁴. Low consumption is a global problem affecting high- and low-income countries: only 7% of countries in Africa, 7% in the Americas, and 11% in Europe reach 240 g/day of vegetables on average⁷; and only 20% of individuals in low- and middle-income countries reach the recommendation of 5 servings of fruits and vegetables a day⁸. The mean global intake of vegetables is estimated to be around 190g/day and of fruits 81g/day; studies generally agree that parts of Africa and the Pacific Islands have the lowest fruit and vegetable consumption, and East Asia has the highest vegetable (but not fruit) consumption^{4, 7, 9}.

Changes in fruit and vegetable consumption are happening against a backdrop of the 'nutrition transition' from traditional foods to processed and ultra-processed foods that are high in energy, fat, sugar and salt but poor in other essential nutrients¹⁰. This transition also brings opportunities to diversify into healthy diets containing more fresh fruits and vegetables, though for some populations there is less opportunity than for others¹¹. Available literature does not suggest systematic differences in fruit and vegetable consumption between men and women in many contexts^{8, 9}, but it does highlight differences in consumption between rural and urban areas¹²⁻¹⁴, and between populations with different levels of education and national income⁸. These differences illustrate that there is an equity issue across populations in accessing fruits and vegetables¹⁵.

We now have good conceptual models for how food systems work to provide diets¹⁶. These help us to describe the structural and social constraints to fruit and vegetable consumption and to research how these play out in different contexts and for different populations. Below, we summarise what we know (and what we need to know) about how to address the issues above through a set of push (production and supply), pull (demand and activism) and policy (legislation and governance) actions. We conclude that there is still a need to better understand the different ways that food systems can make fruits and vegetables available, accessible, affordable and desirable for all people, across places and over time, to meet global recommendations – but that we know enough to accelerate action in support of healthy diets. The year 2021 is the UN International Year of Fruits and Vegetables, embedded in the middle of the Decade of Action on Nutrition. Now is the time to prioritise understanding and addressing these issues to enable fruit- and vegetable-rich food systems driving healthy diets for all.

POLICY FACTORS: POLITICAL POWER

The Green Revolution in the latter part of the 20th century transformed agriculture's ability to produce sufficient calories to feed the world, but the focus on grain crops through funding, research, extension and technology development limited supply of nutrient-dense fruits and vegetables both through losses of wild sources with the promotion of monocultures, and through policy and structural impediments that crowded out non-staple crops¹⁷. Today, the combined international public research budget for maize, wheat, rice, and starchy tubers is 30 times than for vegetables for instance¹⁸, and these incentives skew many of the technology and infrastructure drivers of food systems. This has fed into national food policies, which are normally focused on the production or import of staple crops (as a source of cheap calories) rather than diet quality through diversity of fresh foods (as a source of other essential nutrients)¹⁹. Following suit, food system data have focused largely on globally-tradable commodities, leading to a dearth of trustworthy and disaggregated data with which to track the production, price, trade or consumption of the diversity of fruits and vegetables²⁰ and global data are biased towards economically-relevant crops, often missing traditional fruits and vegetables and those produced non-commercially²¹. Research on food systems and diets often treats fruits and vegetables as a single food group, rather than looking at diversity within fruit and vegetable species, or amounts or variety consumed within the food group²², further limiting our knowledge on the specifics of issues or actions.

At the same time, large structural changes outside of the food system, such as globalization of supply chains and societies, and changing demographics and urbanisation, have shaped food regimes to prioritise foods that are non-perishable and globally tradable^{23, 24}, the very opposite of most fruits and vegetables whose perishability requires shorter food chains from farm to fork. Modern trade rules improve regulation on the safety of imported fruits and vegetables and may protect domestic production or improve supply of highly-traded commodities, but they also limit the ability of governments to protect public health policy space and institutional purchase of fresh foods²⁵ and tend to prioritise staple foods over fruits and vegetables while out-sourcing the environmental impacts of production to poor countries¹. In many contexts, the concentration of inputs, distribution and retail of foods, including fruits and vegetables, in the hands of a few large companies has shifted food system choices away from the livelihood interests of producers, the health interests of consumers, and the environmental interests of all²⁶.

These broad and sweeping changes are not without interruption: The COVID-19 pandemic and previous economic shocks and natural disasters have disrupted many aspects of food systems and diets over time²⁷⁻²⁹. Such disruptions particularly affect fruits and vegetables because of their specific labour, storage and transport requirements³⁰ with at least temporary impacts of different shocks documented on the livelihoods of fruit and vegetable producers and on fruit and vegetable prices and consumption^{28, 29, 31, 32}. These shocks have affected the diets and livelihoods of marginalised populations differently to those with economic or social power, further exacerbating inequity³³⁻³⁵.

Opportunities for research and action

Each of these big-picture policy and political drivers has created food system ‘lock-ins’³⁶ which have tended to steer away from pathways prioritising fruits and vegetables, and away from agronomic and food system paradigms – such as agroecology, a right to food, or food as a commons rather than a commodity³⁷⁻³⁹ – that might promote a return to more diverse production systems. Policy decisions can start with evidence: We need to know more about how different production and distribution systems, based in different social and political traditions, drive the availability and accessibility of fruits and vegetables in food systems, and how they weather shocks to provide healthy diets sustainably and equitably. But ultimately while data and evidence can reveal nuance in the issues and their solutions, food policy decisions are political (and ideally ethical) in reality, depending on priorities and tolerances of the actors involved in making those decisions⁴⁰. Bringing together people with a stake in food systems to debate and decide policy, explicitly recognising disparities in power among them in contributing to outcome and decisions, is likely to lead to the most context-specific and equitable policy in practice when done well⁴¹⁻⁴³.

A starting point for addressing the lack of fruits and vegetables in food system policy is ‘reverse thinking’, putting the dietary outcomes we want from food systems up-front in responsive food policy-making and legislation, and working towards incentivising systems that create these¹⁹. A difficulty in achieving this vision is that different actor coalitions frame food system issues and priorities differently according to their interests and beliefs, so there is no single narrative to work towards^{40, 44}, and coherent diet and food system policy will require policy sectors to work together in non-traditional ways⁴⁵. There is therefore a need to better understand how public and private decision-makers make food system choices and how other food system actors influence these, and implications for fruits and vegetables across food systems.

Public investment in agriculture is shown to impact the growth of production through the private sector, but different types of investment produce different results for different foods in different contexts⁴⁶, so we need to know more about how specific investments such as in breeding, production subsidies, and extension support play out in food environments for different fruits and vegetables. Acknowledging the imbalance of power between food system actors, illustrated by disparities between budgets of processed food producers⁴⁷ and public investment in healthy foods such as fruits and vegetables¹⁸, is necessary in order to make transparent and health-positive policy, regulation and investment. Public policy shaping food environments – such as mandating vegetables in institutional meals (schools, workplaces, hospitals), setting incentives for healthy retail, and regulating food system actors⁴⁸⁻⁵⁰ – is seen to improve intakes in some contexts. Similarly, land rights are a key issue for sustainable food access and production⁵¹ and we need to know more about how these issues affect fruits and vegetables. For all of these analyses, better data and contextual knowledge on diverse fruits and vegetables in different systems is needed, particularly in low- and middle-income countries, to inform businesses, policy-makers, practitioners, workers and activists in making decisions within food systems.

PUSH FACTORS: PRODUCTION AND POST-HARVEST POWER

By the data we have, global fruit and vegetable production is insufficient to meet the WHO dietary recommendations and has been since global records began: in 1965 sufficient fruits and vegetables (≥ 400 g/day) were available for 17% of the global population, increasing to 55% in 2015⁵². Supply varies widely between contexts: in Africa, only 13% of countries have an adequate aggregate vegetable supply while in Asia 61% do⁷. This is despite the fact that fruits and vegetables are valuable: the annual farmgate value of global fruit and vegetable production is nearly \$1 trillion and exceeds the farmgate value of all food grains combined (US\$ 837 billion)⁵³. Most fruits and vegetables (about 92%) are not internationally traded, but still the international trade in fruits and vegetables was valued at US\$ 138 billion in 2018.

Fruit and vegetable production needs to increase particularly in regions with low consumption, together with accompanying measures to prevent losses, to provide enough for healthy diets⁵². Scaling production is not straightforward, as fruits and vegetables have specific attributes – in terms of seasonal and agro-climatic differences, labour and input needs, knowledge and expertise, and storage and distribution – that mean there are particular trade-offs to consider. While we can in theory produce healthy diets within

planetary boundaries², achieving national food-based dietary guidelines has been found to be incompatible with climate and environmental targets in a majority of 85 countries studied⁵⁴, and producing more fruits and vegetables may require more land, water and chemical inputs than producing staple foods in some contexts⁵⁵, with one third of all greenhouse gas emissions produced by the food system⁵⁶. Various studies show widespread misuse of agricultural chemicals, particularly on high-value vegetables, creating hazards for farm workers, consumers and the environment⁵⁷. Foodborne diseases caused by biological contamination of food are also an important threat to public health particularly in low- and middle-income countries, and fruits and vegetables are among the riskiest foods for biological hazards⁵⁸.

Seed or planting stock is a key input into fruit and vegetable production, though it is a contested area: Some see the introduction of (often proprietary) improved varieties of fruits and vegetables as necessary to transform the fruit and vegetable sector to one with increased volumes of regularly available quality products^{53, 59-61}. Others stress the importance of local or cultural seed-saving and exchange of planting material for conserving farmer independence, agricultural diversity and food sovereignty^{26, 62}, and debates about the primacy of breeders' rights or farmers' rights are ongoing⁶³⁻⁶⁵. Beyond inputs, labour requirements in fruit and vegetable production are considerably higher than in cereal production, with labour costs making up more than 50% of production costs depending on the food grown, related to more skilled and intensive field operations^{66, 67}. This is a positive for food system worker incomes, but extension services are often geared to staple crops, with little support for fruit and vegetable producers, limiting formal training opportunities⁶⁸. Beyond the farm, post-farmgate midstream employment in developing regions constitutes roughly 20% of rural employment^{69, 70}; it is assumed that many smallholders also engage in midstream fruit and vegetable chain operations, such as trade and processing, but fruit and vegetable value chains have not been a focus of this work so more knowledge is needed in this area.

Of food produced for human consumption, around a third by volume or a quarter by calories is either lost (before retail) or wasted (after purchase)⁷¹. Highly perishable fruits and vegetables have the highest rates of loss and waste, usually in the range of 40-50%^{72, 73}. Local production is therefore central, and in many contexts ultra-local home-based fruit and vegetable production and wild plant gathering are important strategies^{74, 75}, as are 'under-utilised' species and many traditional fruits and vegetables that are often left out of data, policy and extension^{76, 77}. Fruits and vegetables are particularly seasonal, which

can be an advantage in diverse systems where different foods become available at different times, or a challenge where there are gluts and shortages leading to price change over the year^{78, 79}.

Opportunities for research and action

Clearly, more availability of a variety of fruits and vegetables is needed for everyone to meet recommendations. This can be achieved through increased production, though there are trade-offs between environmental sustainability and providing for diets: Sustainable intensification using a wide range of approaches according to social, political and agro-ecological context to improve yields or protect against climate changes without environmental degradation has been suggested^{53, 80} though further understanding of the implications of different approaches to fruit and vegetable production is needed. Organic agriculture meets goals on a range of environmental factors, including reduced chemical contamination of diets, but it has weaknesses in terms of lower productivity and reduced yield stability⁸¹, and the subsidisation of chemical inputs makes it appear less profitable. Supporting the availability of planting material through formal (breeding and seed companies) and informal (seed saving and sharing networks) channels is important⁵³.

The economic value of fruits and vegetables is a strong incentive for their production, but much of this value is captured by large global firms rather than smallholders, despite over 80% of fruit and vegetables being grown on smallholder family farms (< 20 hectares) in LMICs⁶⁷. The smallholder nature of many fruit and vegetable producers and traders provides challenges and opportunities for vegetable supply⁸², and the complexity of systems of traders and the heterogeneity of smallholders and their support needs (particularly peri-urban vegetable producers or women, who may not be engaged in formal extension systems^{83, 84}) means that agricultural policy very often does not adequately support the twin goals of healthy food production and livelihood development⁸⁵. Aggregation or contract farming are commonly used to reduce transaction costs and risk, and to sell to modern channels such as supermarkets where demand for fruits and vegetables is growing^{86, 87}, though the impacts of commercialisation on the diets of commercial farmers themselves are mixed⁸⁸. Farmer extension needs to be strengthened⁵³ and we need more documented understanding of how informal sectors and formal small- and medium enterprises involved in fruit and vegetable processing, distribution and retail can deliver more on desired food system outcomes. These need further research to understand how they play out in fruit and vegetable systems.

Better availability can also be achieved by addressing food loss and waste: in low-income countries through addressing on-farm pests and diseases, pre-maturity harvesting due to climate shocks or seasonal gluts, and inappropriate post-harvest handling, transport and storage; and in middle/high-income countries addressing quality grading standards set by retailers⁷². Packaging of perishable fruits and vegetables can limit losses⁸⁹ but also contributes to environmental pollution and greenhouse gas emissions^{56, 90}. More understanding is needed of the production, processing and distribution options and trade-offs, and of food loss and waste, specifically for fruits and vegetables in different contexts.

Physical availability of food varies depending on functioning supply chains, whether short or long. Food deserts and swamps associated with poorer diets occur where there is a lack of available fresh foods for local purchase, and exist particularly in poorer urban areas⁹¹. Physical access is a key driver of purchase (and by extension, consumption), with lack of fresh food outlets making consumption of fresh produce harder⁹², and conversely living close to vegetable vendors making vegetable purchase more likely⁹³, suggesting that local access options are important in shaping diets.

PULL FACTORS: PEOPLE POWER

While availability of, and physical access to, sufficient fruits and vegetables is an important pre-requisite, there are other factors at the socio-economic and personal level that also impact their role in diets. Reviews of research suggest that in low-income countries similar determinants play a role in food choices as in high-income countries, at individual level (income, employment, education level, food knowledge, lifestyle, time), in the social environment (family and peer influence, cultural factors), and in the physical environment (food expenditure, lifestyle)⁹⁴.

Food prices interact with incomes to determine whether households can afford the components of a healthy diet, and fruits and vegetables, along with animal-source foods, are the most expensive element of a healthy diet by many metrics^{95, 96} comprising around 40% of the cost of a healthy diet⁹⁷, though these costs tend to vary with season⁷⁸. Fruits and vegetables are unaffordable for many, with 3 billion people unable to afford diverse healthy diets⁹⁷. Fruits and vegetables appear more affordable when comparing prices per micronutrient, where they are likely to be a relatively low-cost source of varied vitamins, minerals, and phytonutrients⁹⁸ – but this is not how most families choose their food.

Beyond a certain income level, affordability is not a driving factor for everyone everywhere: While

an increase of fruit and vegetable consumption by income across geographical regions is confirmed in many studies, indicating that a low income is a barrier to fruit and vegetable consumption for some^{8, 99}, there is only a weak association between incomes and fruit and vegetable consumption, where on average (across 52 countries) 82% of the poorest quintile consume too few fruits and vegetables and 73% of the wealthiest quintile do¹². As incomes rise, the consumption of meat, dairy and ultra-processed foods rise much faster than that of vegetables, and vegetable purchase in some contexts changes little across income groups, hence vegetable consumption is relatively inelastic to income past a certain level¹³; though fruits may be more consumed at higher incomes. With little change in consumption of vegetables across income groups in some contexts¹⁰⁰, affordability is not the largest driver of consumption for all.

Even if vegetables are available, accessible and affordable, most people still do not consume large enough quantities¹², particularly if they are not considered an acceptable or desirable food choice, for instance due to food safety or contamination concerns, taste preferences, or cultural appropriateness¹⁰¹⁻¹⁰³. Low desirability of fruits and vegetables is particularly a problem among children and adolescents, with data across 73 countries showing that between 10-30% of students do not eat any vegetables at all in a quarter of these countries¹⁰⁴.

Opportunities for research and action

Addressing affordability of fruits and vegetables is key to creating an environment where all can access a healthy diet, and affordability can come from a combination of lower retail prices (through productivity improvements, reduced postharvest losses, or increased market efficiency for stable prices) and higher incomes (from inclusive economic growth and social safety nets)¹⁰⁵. Cheap food is not necessarily good for healthy diets, fair livelihoods or biodiverse environments, so a focus on raising people up through fair wages is important¹⁰⁶. Price subsidies of fruits and vegetables is a policy option that is popular with the public in some contexts¹⁰⁷, and there is evidence that price incentives to make fruits and vegetables more directly affordable have worked to increase consumption^{108, 109}. These affordability interventions where fruits and vegetables are largely purchased can be combined with promoting home and community production or facilitation of foraging where the context allows¹¹⁰⁻¹¹².

Alongside ability to afford fruits and vegetables, the challenge is to enhance consumer choice of and preference for these foods. There is clear evidence that focusing on education at all levels is a

key component for modifying behavioural changes in general¹¹³; and nutrition literacy, social norms for healthy eating, and self-efficacy are key components of health-related behaviour change¹¹⁴ – though we know less for fruits and vegetables in particular. Nutrition literacy programs generally target women, who are in many contexts custodians of household nutrition, but there may also be a need for community-targeted messages to change social norms¹¹⁵. Promoting traditional or under-utilised vegetables that are familiar was seen as a key policy option for healthy diets and environmental sustainability among an expert opinion Delphi panel¹¹⁶, and the latest generation of food-based dietary guidelines start to move in this direction – but these efforts should better consider cultural acceptability and may require promotional efforts to increase the willingness of consumer to shift their tastes to new or forgotten foods¹¹⁷. Food composition data is lacking for many indigenous species, limiting the opportunity to develop appropriate nutritional messaging and promote wider use^{118, 119}.

Beyond appeals to public health, better understanding is required of consumers' preferences and behaviours with respect to these foods and what kinds of incentives might promote more consumption in different contexts. Strategic placement of fruit and vegetables in retail outlets is found to have a moderately significant effect on increasing fruit or vegetable servings¹²⁰, and early exposure to fruits and vegetables through schools may shape future preferences for healthier diets¹²¹. Marketing is a key factor shaping desirability, but is consistently applied for 'hedonic' (processed) rather than 'healthy' (nutrient-dense) foods¹²². On marketing issues, much is known about high-income countries¹²³ but less about low- and middle-income contexts where these approaches (understanding market segments and speaking to issues of desirability, aspiration, emotion and imagination) can be adapted for fruits and vegetables¹²⁴.

FRUIT AND VEGETABLE FOOD SYSTEMS: WHAT NEXT?

The brief review above has laid out evidence on the key food system issues for fruits and vegetables in healthy diets, and where available included evidence on actions to address these. From this summary, it is clear that we know on a broad scale the structural limitations to fruits and vegetables: Global and national challenges of increasing production and accessing quality growing material shared equitably; local issues of ensuring affordability and addressing perishability and enabling everyone everywhere to access fruits and vegetables; and social issues of valuing vegetables for their role in cuisines and for health. It is also clear that the precise issues and solutions to these vary by food system context and by population,

and that there are multiple potential routes towards solutions that sometimes clash on ideals. Food system actions to make fruits and vegetables more available, affordable, accessible and desirable through policy, push and pull mechanisms comprise various options working at macro (global and national) meso (institutional, city and community) and micro (household and individual) levels. Examples of actions from the review above are laid out in the table below.

It is unlikely that these are all the options available to orient food systems towards fruit- and vegetable-rich diets, but these are the options that appear in the academic literature, albeit with varying levels of evidence. In addition, there are two important over-arching considerations when considering action options: 1) Acknowledging that power shapes food systems, from concentration of economic and political power in a few global agri-food businesses, through to marginalisation of certain groups in societies from accessing healthy diets, so this needs to be considered in terms of both inclusive processes in deciding policies and actions and in assessing their equity impacts^{26, 125}. 2) There will be trade-offs among food system outcomes, so starting with a focus on healthy diets is important but understanding how food system decisions then impact fair livelihoods and sustainable environments is key¹²⁶. We do not yet know enough to formulate clear actions to address these trade-offs, but they need to be acknowledged and openly debated by those taking food system decisions.

Examples of pull, push and policy actions at different levels

	Macro (global and national)	Meso (institutional, city and community)	Micro (household and individual)
Policy	<ul style="list-style-type: none"> • R&D investment • Right to food legislation • Food safety regulation 	<ul style="list-style-type: none"> • Zoning and marketing regulation • Prioritising F&V in institutional food procurement plans 	<ul style="list-style-type: none"> • Protected foraging rights • Land rights
Push	<ul style="list-style-type: none"> • Production subsidies • Efficiency through breeding and technology • Support to diverse alternative production paradigms • Infrastructure development • Fair finance access 	<ul style="list-style-type: none"> • Quality F&V planting material (formal and informal systems) • Pre- and post-harvest practices and packaging • Improving market access, shortening food supply chains • F&V extension and training • Support to fresh food outlets 	<ul style="list-style-type: none"> • Home & community gardens
Pull	<ul style="list-style-type: none"> • Price subsidies • Social safety nets • Food-based dietary guidelines 	<ul style="list-style-type: none"> • F&V-rich institutional meals • Basic processing for preservation • Social marketing campaigns • Promotion of traditional F&V • F&V product placement in shops and canteens 	<ul style="list-style-type: none"> • Nutrition literacy campaigns • School gardens and learning for shaping preferences

These actions are likely to be foundational to creating food systems change towards enabling fruit- and vegetable-rich diets. Each of these actions will not change diets when implemented alone, however; rather packages of actions need to address particular limitations to fruit and vegetable consumption. These need to be considered in context, in light of an understanding of food system issues and bottlenecks limiting healthy diets in different places and for different people. It is likely that the best way to start is to bring together diverse groups of people interested in these issues at the different levels, to understand the issues and options from different perspectives and together prioritise which actions should be undertaken first in their own context. This is not easy, given inherent power disparities among interested parties, but with care and inclusion a strategy, policy or plan can be made to move towards enabling fruit and vegetable-rich food systems.

To guide better action, we need more evidence and understanding. We know a lot about a small fraction of the fruit and vegetable species of

which we are aware, and very little about the rest; we know there are disparities in diets in different contexts, but less how to address the political, social and equity determinants of who gets to eat fruits and vegetables; we know much about the technical production and market aspects of fruits and vegetables, but less about bottlenecks in bringing these to low- and middle-income countries; and we don't know enough about how these things change with context or over time. Work drawing on different academic traditions, including valuing traditional and tacit knowledge, is needed to join the dots. Food systems enabling fruits and vegetables in healthy diets are not only a technical issue, but bring up very real political, social and ethical questions that societies will have to address, alongside a reliance on evidence. Having these conversations through the lens of equity, to address the needs of both winners and losers of food systems change, will be a vital part of the UNFSS process towards enabling fruit and vegetable-rich food systems for healthy diets for all.

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