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ORIGINAL PAPER

Metrics to analyze and improve diets through food Systems in low and Middle Income Countries

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Abstract

Taking a food systems approach is a promising strategy for improving diets. Implementing such an approach would require the use of a comprehensive set of metrics to characterize food systems, set meaningful goals, track food system performance, and evaluate the impacts of food system interventions. Food system metrics are also useful to structure debates and communicate to policy makers and the general public. This paper provides an updated analytical framework of food systems and uses this to identify systematically relevant metrics and indicators based on data availability in low and middle income countries. We conclude that public data are relatively well available for food system drivers and outcomes, but not for all of the food system activities. With only minor additional investments, existing surveys could be extended to cover a large part of the required additional data. For some indicators, however, targeted data collection efforts are needed. As the list of indicators partly overlaps with the indicators for the Sustainable Development Goals (SGDs), part of the collected data could serve not only to describe and monitor food systems, but also to track progress towards attaining the SDGs.

Keywords Food systems · Metrics · Indicators · SDGs

1 Introduction

Improving diets features high on the global development agenda. A notable share of the world population faces at least one of the three forms of malnutrition—undernutrition, micronutrient malnutrition, or overweight and obesity (e.g. Padilla et al., 2015; IFPRI, 2016). While diets are rapidly changing, they are not necessarily improving (Pingali, 2007; Popkin, 2014). Dietary transitions typically imply increased consumption of animal fats, sugars, and processed foods (Hawkes et al., 2012; Imamura et al., 2015). To stimulate changes towards healthier diets, numerous policies, projects, and programs have been implemented (e.g. Fiorella et al., 2016; Allen and De Brauw, 2018). However, these interventions often narrowly focus on specific consumer groups or foods and rarely take a whole diet approach.

Recently, a growing literature has emphasized the importance of approaching diet improvement from a food systems perspective (e.g. Miller and Welch, 2013; Sundaram, 2014; Allen and Prosperi, 2016; Gustafson et al., 2016; Caron et al., 2018). Food systems shape diets and are characterized by multiple interactions, tradeoffs and feedback mechanisms. For example, food systems have been shown to put stress on the environment and its natural resource base by degrading soils, polluting and exhausting fresh water supplies, encroaching on forests, depleting wild fish stocks and reducing biodiversity (FAO, 2013; Prosperi et al., 2014; Westhoek et al., 2016). Consequently, dietary challenges will potentially be best addressed using analytical methods that aim at understanding complex systems (Popkin, 2014). In particular, adopting a food systems approach to diet improvement would facilitate the identification of leverage points for systemic changes, accounting for the full range of interactions, tradeoffs, and system dynamics (Ericksen, 2008; Foran et al., 2014; Dentoni et al., 2017).

Implementing such a food systems approach, however, would require the use of a comprehensive set of metrics. In the context of this paper, a food system metric is

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conceptualized as a system of relevant indicators that provide a tool for measurement, comparison or tracking system performance (Padilla et al., 2015). Food systems metrics are important to describe the current state of food systems, facilitate quantifying relationships needed for exploring causal mechanisms, set baselines against which to measure progress on key goals, evaluate impacts of system transitions and proposed changes, gauge efficacy of interventions, and ultimately facilitate the scaling up of successful interventions (Allen and Prosperi, 2014; Global Panel, 2015; McDermott et al., 2015; IFPRI, 2016). Food system metrics and indicators are also useful to structure high-level debates and communicate the complexity of the system as well as data from science to policy makers or the general public (Gustafson et al., 2016; Lehtonen et al., 2016). As such, they are instrumental to create awareness and improve transparency, beyond being used as monitoring and evaluation tools. Ideally, a common set of indicators could be used across countries and over time to allow comparison.

The aim of this paper is to synthesize existing knowledge and propose an integrated set of food systems metrics that can be readily applied to facilitate food system research and allow cross-case comparison. To ensure that the set of metrics is comprehensive, we base it on a conceptual framework delineating all key food systems components (Ericksen, 2008; Eakin et al., 2016). To allow practical applicability, we limit ourselves to indicators for which data is covered in datasets widely available for low and middle income countries (LMICs): Living Standards Measurement and related Surveys (LSMS), Demographic and Health Surveys (DHS), and publicly available sources of aggregate data, like FAOSTAT and the World Development Indicators. The metrics are thus defined, and can work best, at national and subnational scales. To link this discussion to the broader debate on sustainable development, we prioritize indicators present in the indicator compendium of the Sustainable Development Goals (SDGs). A recent analysis shows that at least 12 of the 17 Goals have strong linkages with food systems (Chaudhary et al., 2018), which illustrates the importance of food systems not only for diets but also for other development outcomes.

We illustrate our approach for four countries that provide relevant case studies for LMICs –Ethiopia, Bangladesh, Nigeria and Vietnam. These countries were chosen as they were recognized to provide a wide range of diet and (sub) national food systems contexts at various stages of food system transformation—from rural (Ethiopia) through mixed (Nigeria and Bangladesh) to urban (Vietnam) with increasing complexity, and urbanization. They are also expected to represent "typical" LMICs in terms of availability (or lack thereof) of national-level data.

There have been a few earlier attempts to develop a series of food system metrics. Notably, Gustafson et al. (2016) propose multidimensional indicators to quantitatively characterize the performance of food systems through seven metrics of sustainable nutrition security. Other recent efforts include Acharya et al. (2014) on assessing sustainable nutrition security, Prosperi et al. (2014) on a vulnerability assessment for the food system of the Mediterranean region, FAO's (2016) compendium of indicators for nutrition-sensitive agriculture, and Zurek et al. (2017) on the sustainability metrics for the European food system. While each of these studies emphasizes the importance of adopting a holistic perspective, none of them covers all dimensions and domains of the food system –see, however, Béné et al. (2019a). Many of the existing studies focus on food system outcomes, without always addressing activities and drivers. As a result, a comprehensive set of metrics to measure the entire food system continues to be a critical knowledge gap (Jones et al., 2013; Global Panel, 2015; McDermott et al., 2015).

Below, we first present a conceptual framework of the food system. Broadly, we distinguish three domains: food system drivers, activities, and outcomes. For each domain, we then propose a comprehensive set of metrics and underlying indicators. Focusing on the four case study countries, we select indicators based on data availability and presence in the SDG indicator compendium. We assess for which metrics data is covered in the relevant datasets and for which metrics additional data collection investments need to be made. We conclude with a discussion on the potential use of the data, the data gaps identified and a cost-effective, high-return strategy for filling those gaps.

2 A conceptual framework of the food system

Before considering how food systems can be measured, a clear understanding of the concept of "food system" is essential. Multiple perspectives are found in the literature. Nearly all contain some notion of a "food supply chain," highlighting a series of stages through which food materials are turned into final food products (e.g., Sobal et al., 1998; Grant, 2015), but they are characterized by different levels of recognition of the importance of feedback loops capturing the circular (rather than linear) nature of food systems. Based on elaborated discussions in the context of the CGIAR research Flagship "Food Systems for Healthier Diets", this paper defines food systems broadly as the full set of actors, resources, processes and activities that encompass the domains of food production, processing, distribution, consumption and food waste disposal, and the outcomes of these activities, including nutrition and health, socioeconomic wellbeing and environmental quality, as well as the feedbacks, tradeoffs and synergies between these outcomes.

Food systems are multifaceted and complex—with sociocultural, economic and environmental aspects (e.g., farming,

food access and equity, food sovereignty) (Pinstrup-Andersen et al., 2011). They involve multiple actors (food producers, food-chain actors, and consumers) operating within dynamic and interactive food environments, with many mechanisms at work across multiple scales and levels (Ericksen, 2008; Eakin et al., 2016; Caron et al., 2018; Turner et al., 2018). Food systems analysis must also consider the governance and political economy of food production, processing and consumption, sustainability of food systems, effects on health and well-being, and drivers of system change. A conceptual framework of the food system thus needs to portray different relationships, interactions, tradeoffs, feedback mechanisms and drivers of system changes that ultimately shape system outcomes across several levels.

Several food systems frameworks have been proposed in the literature (e.g. Sobal et al., 1998; Burchi et al., 2011). These frameworks tend to present the food system as a series of ordered and linear stages. While easily tractable and insightful, such a linear representation disregards complex interactions, synergies and feedbacks in the system. Importantly, many of these existing frameworks consider health or diet as the sole outcome of the system (e.g., Sobal et al., 1998; Burchi et al., 2011). Ericksen (2008) proposed a framework that recognizes the complex interactions, synergies and feedbacks, and thus presents a solid foundation for an appropriate conceptualization of food systems.

We largely follow this framework with two amendments (Fig. 1). First, given the focus of this paper on healthier diets, we separate the nutrition element from the broader concept of food security to create a new outcome category. We group the remaining elements of food security under socioeconomic wellbeing. In addition, we include food loss and waste management explicitly as an activity (Jurgilevich et al., 2016; Chaboud and Daviron, 2017). The resulting framework gives a schematic representation of food systems activities and their main outcomes along with system drivers. Food systems activities lie at the center and include food production, processing, distribution and marketing, consumption choices, and food loss and waste management. The key food systems outcomes relate to nutrition and health, socioeconomic wellbeing, and environmental quality. Finally, food systems drivers include biophysical, socioeconomic and natural factors that shape food system activities and outcomes.

Interactions within food systems are complex, and tradeoffs and synergies between various system outcomes must be considered to appropriately reflect the complexity of food systems and the difficulties to navigate between often competing goals (Béné et al. 2019b). For example, avoiding overconsumption and dietary changes, such as reducing the consumption of animal-sourced food and adopting diets with more plant-based products, serve not just dietary outcomes, but can also lead to improved environmental outcomes and reduced risk of diet-related non-communicable diseases (Tilman and Clark, 2014; van Dooren et al., 2014; Springmann et al., 2016). Yet, at the same time, recommendations to increase, say, the consumption of fruits and vegetables to promote healthier diets can raise questions about the potential consequences of expanding their production, such as increased irrigation water or farm labor, or increased use of pesticides with negative health outcomes (Wirsenius et al., 2010; Becker, 2017). Equally, reducing the consumption of animal-sourced food may negatively affect the livelihoods of livestock farmers. Further, tradeoffs can also exist between short-term gains and long-term costs of interventions. While all actors may agree that improved health and resource sustainability are positive long-term outcomes, present-day choices of consumers and businesses are still determined by costs, prices, convenience and cultural and social values, among other factors, all of which may not reflect good health or sustainable production practices (Nesheim et al., 2015). In sum, deciding among various intervention options can be challenging, and decision makers must possess the right tools for analyzing intended and unintended effects, including isolating underlying causes, understanding how to weigh various tradeoffs and taking advantage of synergies (Béné et al., 2019b).

3 Research methodology

We employed a series of processes for the selection of food systems metrics and corresponding indicators for different domains and dimensions of the food system. First, we reviewed the relevant literature and selected/amended a conceptual framework, with the aim of identifying key components of the food system. Second, we identified thematic categories of the food systems metrics and comprehensive sets of underlying indicators following a hierarchical approach based on this framework. We sought to be as comprehensive as possible capturing the various domains and dimensions of the food system in our metrics. Broadly, the identified metrics were grouped into three general thematic categories of metrics: 1) food systems drivers, 2) food systems activities, and 3) food systems outcomes. For each of these metrics categories, we further identified a coherent set of metrics components and corresponding indicators. Third, given the large number of potential indicators, there was a clear need for prioritization and standardization. We use two criteria: 1) data availability in at least one of the four countries; and 2) presence in the compendium of SDG indicators, which has a total of 230 indicators. Table 1 presents the SDGs and shows the overlap with our metrics. Please note that the SDG indicators are often less precise than our indicators, so that we used some expert judgment for matching.

Data availability is a critical dimension of metric construction if indicators are to be easily adopted. We therefore

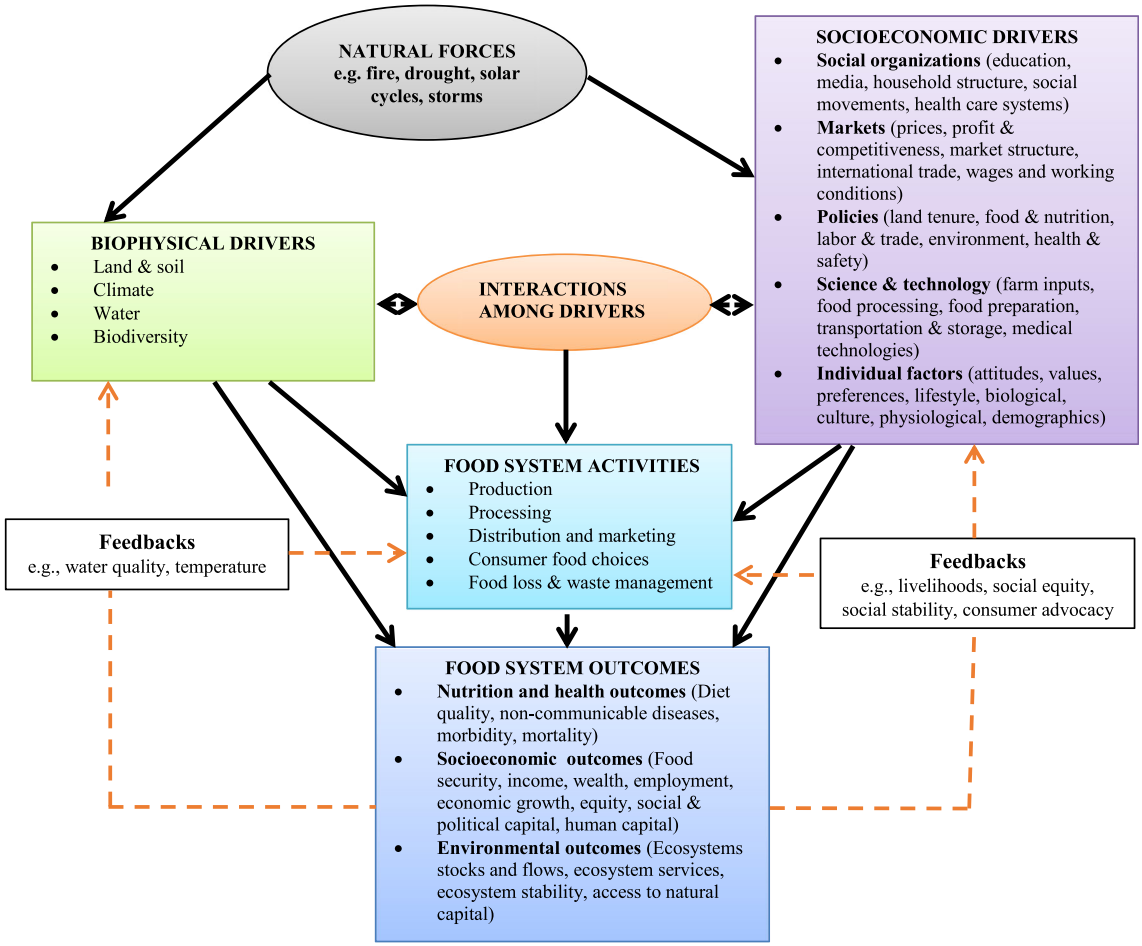

Fig. 1 A conceptual framework of the food system (adapted from Ericksen, 2008)

identified widely available reliable open data sources to draw upon. At the micro-level, these surveys include the LSMS and the DHS. The LSMS and the DHS are representative at the national level. A wide range of topics are covered in these surveys, including household information, farm-related information, crop and livestock production details, agricultural extension services, household food consumption and income sources, among other variables. The LSMS surveys have a good quality rural and urban areas, enabling the surveys to provide reliable comparative analysis for rural and urban areas. Micro-level datasets are particularly useful, as these allow determining indicator values for subsystems or subpopulations and following indicator values throughout the system based on geographic location, food system activity, income, sex, age, race, ethnicity, migratory status, or other characteristics. At a higher (macro) level, aggregate data can be found in databases such as FAOSTAT, the World Development Indicators, AQUASTAT and the World Animal Protection dataset. Those aggregate datasets are also useful as they usually include more ready-to-use indicators. Summaries of these different datasets are provided in the Supplementary Materials. Data on regulatory bodies and other relevant institutions are available on their own websites.

The four case study countries have a good availability of common data sources. All four have a DHS and Ethiopia, Nigeria and Vietnam have a LSMS. For Bangladesh, we use the BIHS, which is similar to the LSMS but only covers rural areas. For key socio-economic characteristics of the individual countries, please refer to Table 2.

4 Food systems metrics

4.1 Metrics for food systems drivers

Understanding drivers of food system changes and transformations is important to assess potential policy or technological options to affect food system actors' decisions and behaviors, and ultimately shape outcomes of food systems (Grant, 2015; McDermott et al., 2015; Béné et al. 2019c). The framework (Fig. 1) broadly describes two types of drivers: biophysical and socioeconomic drivers. Biophysical drivers include environmental changes that affect food system activities and

Table 1 Sustainable Development Indicators

	Sustainable Development Goal	Food system metric with similar indicators
1	No Poverty	Socioeconomic outcomes
2	Zero Hunger	Diet, nutrition and health outcomes, environmental outcomes, food production
3	Good Health and Well-being	Diet, nutrition and health outcomes
4	Quality Education	
5	Gender Equality	Socioeconomic outcomes
6	Clean Water and Sanitation	Diet, nutrition and health outcomes, socioeconomic outcomes, environmental outcomes, food loss and waste
7	Affordable and Clean Energy	Socioeconomic outcomes
8	Decent Work and Economic Growth	Socioeconomic drivers, socioeconomic outcomes
9	Industry, Innovation and Infrastructure	Environmental outcomes, socioeconomic drivers, food production, food processing, food distribution and marketing
10	Reduced Inequality	Socioeconomic outcomes
11	Sustainable Cities and Communities	
12	Responsible Consumption and Production	Food loss and waste, environmental outcomes
13	Climate Action	
14	Life Below Water	Environmental outcomes
15	Life on Land	Environmental outcomes
16	Peace, Justice, and Strong Institutions	
17	Partnerships to achieve the Goal	Food marketing

outcomes through impacts on the quality and availability, notably climate change, deforestation, soil erosion, and reduced pollinators and ground water for irrigation. On the other hand, socioeconomic drivers comprise a wide range of social and institutional factors, including market forces, social organizations, science and technology, policies, and consumer preferences and norms, which also shape the ways in which food systems evolved and operate (Nesheim et al., 2015; Béné et al. 2019c). To combine these concepts, several indicators that capture essential drivers of food systems, mostly available from FAOSTAT can be identified. Table 3 shows that only a limited number of them is part of the SDG indicators. Data on drivers at subnational level is not available.

4.2 Metrics for measuring food system activities

Food system activities form the core of the system. The principal activities of the food system encompass food production, processing, distribution and marketing, consumption, and food loss and waste management. Metrics for food system activities largely reflect economic measures and are important to assess the economic performance of the systems.

4.2.1 Food production

Food production is the principal determinant of food availability in most economies (Ericksen, 2008). It includes all

Table 2 Selected sociodemographic features of the study countries

Variables	Bangladesh	Ethiopia	Nigeria	Vietnam
Total population	159,685,424	106,399,924	190,873,244	94,600,648
Share urban	37%	20%	50%	36%
Per capita income (US$)	1492	720	1969	2342
Stunting	36.1%	40.4%	32.9%	19.4%
Wasting	14.3%	8.7%	7.9%	5.7%
Underweight	32.6%	25.2%	19.8%	12.1%
Child overweight	1.4%	2.6%	1.8%	4.6%

Note: Nutrition outcomes for children under five in 2014 (WHO database) and other sociodemographic variables in 2017 (FAOSTAT)

Table 3 Indicators for the drivers of food systems

Metric components	Indicators	Description	Data source	Bangladesh	Ethiopia	Nigeria	Vietnam	Present in SDG indicators
Biophysical drivers	Climate change	The change in average temperature of a specific area (location) over time.	FAOSTAT	A	A	A	A	No
	Deforestation rate	The average annual rate at which natural forest area is permanently converted to other uses, including shifting cultivation, permanent agriculture, ranching, settlements, and infrastructure development.	FAOSTAT	A	A	A	A	No
	Soil erosion	Tons of topsoil lost per year due to erosion	FAOSTAT	A	A	A	A	No
Socioeconomic drivers	Economic development	The level of GDP and/or growth rate of GDP per capita of a country (region)	FAOSTAT	A	A	A	A	Yes
	Technological change	The annual per capita public and private expenditure on R&D in the food production and processing sector	-	NA	NA	NA	NA	Yes
	Population dynamics	Population growth rate and associated demographic changes, like shares of the young, working age, and old age	FAOSTAT	A	A	A	A	No
	Food price trends	Developments of aggregated and disaggregated (e.g., producer vs. consumer price indices, or nutritious vs. less nutritious food price indices) food prices over time or volatility in food prices over time.	FAOSTAT	A	A	NA	A	No
	Consumer organizations[1]	Number of consumer organizations that are active and present at a national/regional level	National consumer associations	A	A	A	A	No
	Urbanization	Change in the percentage of the total population who reside in urban areas	FAOSTAT	A	A	A	A	No
	Public policy	Indicators measuring the presence of public policies and programs (farm, health and safety, labor and trade, environment and energy policies) that have direct implications for activities and organizations of food systems	Government web sites	A	A	A	A	No

Notes: A = Publicly available and NA = Currently not available; LSMS: This involves integrated household surveys that from part of the LSMS program or similar surveys.[1] Consumers Association of Bangladesh, Ethiopian Consumers Protection Association, Consumer Awareness Organization for Nigeria, Vietnam Standards and Consumers Association

activities involved in the production of raw food materials, harvesting, raising livestock and activities related to fisheries. A (food) production system is characterized by its use of inputs (both natural resources and technologically improved varieties), productivity, and output levels. Relevant food production metrics should measure input utilization, productivity, and output levels in a given geographic area over a specific time period. Table 4 shows that sufficient information is available in the LSMS and FAOSTAT to generate a consistent set of indicators for these variables, though not equally complete for all four countries considered in this study. Notably, data about the use of high yielding varieties and biofortified seeds is collected in only two out of the four countries. Table 1 shows, however, that on the other hand, the SDGs make limited reference to food production: indicators are limited to the use of improved seeds and breeds and organic farming. Data on the latter is not routinely collected in the LSMS.

4.2.2 Food processing

Food processing consists of all processes that modify the original nature, content and/or appearance of the raw materials, including transforming it into more elaborated food products, as well as packaging and labelling (Ericksen, 2008; Ingram, 2009). These processes can substantially alter, reduce or improve the nutritional value, appearance, storage life, safety and content of the raw food materials (Miller and Welch, 2013). Food processing can also considerably reduce the time and energy required for home food preparation. The analysis (Table 5) shows that while data is available on the size of

Table 4 Indicators of the food production metric

Metric components	Indicators	Description	Data source	Bangladesh	Ethiopia	Nigeria	Vietnam	Present in SDG indicators
Inputs	High Yielding Varieties Seeds	Quantity of high yield hybrid seed varieties used per hectare of arable land	LSMS	A	NA	A	NA	Yes
	Biofortified seeds	Quantity of biofortified seeds used per hectare of arable land	LSMS	NA	A	A	NA	Yes
	Improved breeds	Total number of improved breeds	LSMS	A	A	A	A	Yes
	Number of organic farms	Total number of farms engaged in organic production weighted by land area	-	NA	NA	NA	NA	Yes
	Fertilizer use per unit of land	Quantity of fertilizer used per hectare of arable land	LSMS	A	A	A	A	No
	Agricultural water withdrawal	Annual quantity of self-supplied water withdrawal for irrigation, livestock and aquaculture purposes	AQUASTAT	NA	A	NA	NA	No
	Crop land	Percentage of cultivable land used for crop production in hectares	FAOSTAT	A	A	A	A	No
	Livestock statistics	Per capita number of cattle, shoats, and other animal food sources, like chickens	FAOSTAT	NA	A	A	A	No
Productivity	Agriculture factor productivity	Average yields of cereals and pulses; agricultural labor productivity; land productivity; total factor productivity (TFP)	LSMS/FAOSTAT	A	A	A	A	No
	Yield gaps for key staple crops	Measure of how close each country is to achieving their potential in production	FAOSTAT	A	A	A	A	No
	Agricultural R&D	Public expenditure on agricultural R&D in percentage of GDP	FAOSTAT	A	A	A	A	No
Output	Crop output	Physical quantity or value of each main crop produced in a given geographic area.	LSMS/FAOSTAT	A	A	A	A	No
	Animal food products	The total quantity or value of each animal food product (dairy products, meat, fish and egg)	LSMS/FAOSTAT	A	A	A	A	No

Notes: A = Publicly available and NA = Currently not available; LSMS: This involves integrated household surveys that from part of the LSMS program or similar surveys

the processing industry in the LSMS (local industry only), this information does not reveal much about the nature of the transformations and their impact on food quality, with the exception of the number of foods that are commonly fortified. Likewise, the SDGs only refer to the number of small and medium enterprises operating in the food sector in a country or region.

4.2.3 Food distribution and marketing

A well-functioning food distribution and marketing system is an integral component of the food system activities, and involves transporting, storing and marketing food products to consumers (Ingram, 2009). Food distribution consists of several facilities and actors, including wholesalers, brokers, food warehouses, logistics and other distribution channels. The performance of the distribution and marketing sector is strongly determined by transportation and infrastructure availability, storage facilities, cold chains and the organizational structure of markets. Table 6 shows that at the present time, data on these processes is limited, leading to a small set of available indicators with partial coverage. The SDG indicators include road density and competitiveness (of the food sector) in the world market, which could serve as proxies, though very rough, for transportation and marketing. FAOSTAT and the World Development Indicators both include data on competitiveness. Information about storage capacity is included in the LSMS survey for Bangladesh and to a limited extent Ethiopia and Nigeria, but not for Vietnam, where the data only cover the storage of harvests by farmers. Hence, good metrics for food distribution and marketing are quite incomplete (Table 6).

Table 5 Indicators of the food processing metric

Indicators	Description	Data source	Bangladesh	Ethiopia	Nigeria	Vietnam	Present in SDG indicators
Small & medium enterprises in the food sector	Number of small and medium enterprises operating in the food sector in a country or region	LSMS	A	NA	A	A	Yes
Food processing industry	Numbers of food processing firms and manufacturers, dairy processors, and slaughterhouses and meat processors in a country or region	LSMS	A	A	A	A	No
Value added in the food industry	The economic value added of the food processing sector as a percentage of the total food value	-	NA	NA	NA	NA	No
Fortified food	Number of commonly consumed foods that are fortified in a country or region	LSMS	A	A	A	A	No

Notes: A = Publicly available and NA = Currently not available; LSMS: This involves integrated household surveys that from part of the LSMS program or similar surveys

4.2.4 Consumption

Food consumption is a key outcome of food systems, closely related to food utilization and individual or collective health outcomes. Food consumption can be thought of as including decisions about what to purchase as well as food preparation and eating habits, along with actual food intakes. According to Just and Gabrielyan (2016), understanding food consumption behavior can (i) help to link nutrition demand with economic value to create business opportunities, and (ii) open opportunities to minimize threats that might be presented by transition processes of the food system. Income levels, tastes, preferences, social values, health status, socioeconomic status, ease of

Table 6 Indicators of the food distribution and marketing metric

Metric components	Indicators	Description	Data source	Bangladesh	Ethiopia	Nigeria	Vietnam	Present in SDG indicators
Transportation	Road density	Road density is the ratio of the length of the country's total road network to the country's land area. The road network includes all roads in the country: motorways, highways, main or national roads, secondary or regional roads, and other urban and rural roads.	–	NA	NA	NA	NA	Yes
Food marketing	Competitiveness in trade[1]	The share of food exports in the total gross value of exports of a country/region to the world market, which indicates competitiveness of the food sector in the world market compared to other products in the country/region	FAOSTAT; World Bank	A	A	A	A	Yes
Storage	Food warehousing	Number and capacity of food storage warehouses available in a region	LSMS	A	NA	NA	NA	No
	Cold storage	The total volume of both public and private cold storage facilities available for warehousing and transporting of perishable food products (like meats, fish and fruits/vegetables) in a country or region	LSMS	A	NA	NA	NA	No
	Contingency food storage[2]	An indicator for the presence of a contingency community food storage facility in a given region	LSMS	A	A	A	NA	No

Notes: A = Publicly available and NA = Currently not available; LSMS: This involves integrated household surveys that from part of the LSMS program or similar surveys. [1] FAOSTAT: data on export of food products and World Bank: data on total export; [2] Data on how much of the harvest is stored for Ethiopia and Nigeria

access to food and commercial advertising and prices are among the main factors that drive the type and nutrient quality of consumers' food choices (Ericksen, 2008; Nesheim et al., 2015). Food consumption behavior metrics should include indicators capturing capacity – including consumers' economic resources, nutrition knowledge and consumer advocacy. The analysis (Table 7) shows that while the SDG indicators do not explicitly refer to the capacity to consume, the LSMS cover food expenditures, time availability for food preparation (though not in Nigeria), nutrition knowledge (Bangladesh only) and government food and safety net policies. Similarly, the SDGs do not include consumer advocacy, but data on consumer associations are available on the web. As diets are also key outcomes, we will discuss diet indicators in the outcome section.

Table 7 Indicators of the food consumption behavior metric

Metric components	Indicators	Description	Data source	Bangladesh	Ethiopia	Nigeria	Vietnam	Present in SDG indicators
Capacity	Expenditure on food	Value of household food expenditures	LSMS	A	A	A	A	No
	Time available for food preparation[1]	Average time available for household food preparation in a day	LSMS	A	A	NA	A	No
	Consumer food knowledge[2]	Percentage of consumers who know basic nutrition information (healthy food, food safety etc.)	LSMS	A	NA	NA	NA	No
	National consumer nutrition literacy	Binary indicator that shows whether national food-based dietary guidelines for a balanced and nutritious diet are published or not	FAO	A	NA	A	A	No
	Income stream diversity	Percentage of households with more than one income source	LSMS	A	A	A	A	No
	Policy environment for stability[3]	Indicators measuring governmental commitment to ensure the continuity of the proper functioning of the food system in the event of adverse shocks and trends. •Presence of emergency response plans/safety net programs: Measures the presence of public programs to intervene, when needed, to facilitate access to food by providing an additional income to vulnerable people. •Presence of disaster recovery plans: the presence of mechanisms and allocation of resources for disaster prevention and recovery (e.g., presence of monitoring mechanisms for changing climate conditions and particular natural hazard risks, such as drought) •Existence of a policy plan for overweight/obesity: indicator whether or not a country has a fat tax that is placed upon fattening food to discourage unhealthy diets and offset the economic costs of obesity.	Government web sites	A	A	A	A	Yes (DRR)
Advocacy	Consumer organizations[4]	Number of consumer organizations that are active and present at a national or regional level	National consumer associations	A	A	A	A	No

Notes: A = Publicly available and NA = Currently not available; LSMS: This involves integrated household surveys that from part of the LSMS program or similar surveys. [1] Available for women's time, and time available for housework for Vietnam; [2] Nutritional knowledge of respondent mothers; [3] Only data available on presence of social safety net programs and [4] Consumers Association of Bangladesh, Ethiopian Consumers Protection Association, Consumer Awareness Organization for Nigeria, Vietnam Standards and Consumers Association

4.2.5 Food loss and waste management

Food losses and waste play a key role in affecting global food and nutrition security by directly reducing the total food available for consumption and by indirectly increasing natural resource use (FAO, 2013). Food losses can occur along the value chain, but most food waste is recognized to occur after consumers purchase it (FAO, 2013; Lipinski et al., 2013). Pre-consumer food losses are thought to be more prevalent in the food systems of developing countries (e.g. Delgado et al., 2017), and post-consumer food waste is considered to be higher in high-income countries (FAO, 2013; Gustafson et al., 2016). However, the extent and impact of food losses in developed countries should not be underestimated. While some stated that food loss or waste can be optimal in an economic sense (Bellemare et al., 2017) and recent rigorous evidence demonstrates that the rates of food loss and waste claimed by FAO (2011) are likely substantially overstated (Delgado et al., 2017; Ambler et al., 2018), food loss and waste management may constitute an important tool for improving food security and decreasing the pressure on food production (IFPRI, 2016; Jurgilevich et al., 2016).

Table 8 shows that data availability on those issues is limited, and the food loss and waste indicators from the SDGs and the data available do not overlap. While the SDGs propose to record the total percentage of food lost or wasted and the percentage of food waste that is recycled, data are only available on food losses at farm level. Note also that data collection methods used so far are not considered to be of high quality (Delgado et al., 2017). In measuring food loss, Delgado et al. (2017) emphasize the need to identify where food loss occurs in the food system along the various stage of the value chain and causes of food loss. They propose alternative methodologies that aim to reduce food loss measurement error and that allow to account for both quantitative and qualitative losses from the pre-harvest stage through product distribution, as well as discretionary losses among the processing, large distribution, and retail sectors.

4.3 Metrics for measuring food system outcomes

An optimized food system would meet consumers' food quality and safety demands, promote economic and sociocultural wellbeing of communities, reduce the pressure on aquatic and terrestrial ecosystems, and increase ecosystems capacity to respond to changes and shocks (Hinrichs, 2014; IPES, 2015, Béné et al., 2019b). Impacts of investments and food system interventions can be assessed more adequately when food system outcomes are measured well. In the present case, food system outcomes were classified into three categories: (i) diet, nutrition and health outcomes, (ii) socioeconomic outcomes, and (iii) environmental outcomes.

4.3.1 Metrics for dietary, nutrition, and health outcomes

Nutrition and health are among the most important food systems outcomes (Burchi et al., 2011; Padilla et al., 2015; Lartey et al. 2018). Health and nutrition status can be assessed using anthropometric measures, such as body-mass index for adults, stunting prevalence among children under 5 years old, or disease-related measures, such as anemia or the prevalence of diet-related non-communicable diseases, which are all available in the datasets that were reviewed here. These indicators are listed in Table 9 along with their degree of availability. Interestingly, while anthropometric data are available at microlevel as well as macrolevel, the availablity of disease-related measures is limited.

Diets provide a key link between the food system and health and nutrition status, as varied diets are essential to support individual physical and mental health. We focus on diet indicators that quantify two key attributes—diet quality and adequacy. Diet quality describes how well an individual's diet conforms to dietary recommendations that are often reflected in food based dietary guidelines (Alkerwi, 2014). The most commonly used assessment tool for dietary quality is the dietary diversity score. It refers to the consumption of a variety of desirable foods or food groups, reflecting both nutrient sufficiency (when measured at individual level) and economic ability to access a variety of foods (when measured at

Table 8 Indicators of the food loss and waste metric

Indicators	Description	Data source	Bangladesh	Ethiopia	Nigeria	Vietnam	Present in SDG indicators
Percentage of food waste recycled	Percentage of the total food waste that is recycled to recover resources and/or to minimize negative environmental effects of the waste	–	NA	NA	NA	NA	Yes
Food lost and wasted in the food system	Percentage of total food lost and wasted in the food system from food production to consumption	–	NA	NA	NA	NA	Yes
Food lost at farm level[1]	Percentage of food lost at farm level	LSMS	A	A	A	NA	No

Notes: A = Publicly available and NA = Currently not available; LSMS: This involves integrated household surveys that from part of the LSMS program or similar surveys. [1] Wastage of agriculture production for Bangladesh, quantity of production lost after harvest for Ethiopia and Nigeria

Table 9 Indicators of the diet, nutrition and health outcomes metric

Metric components	Indicators	Description	Data source	Bangladesh	Ethiopia	Nigeria	Vietnam	Present in SDG indicators
Diet quality	Food variety score	Simple count of the different food items consumed by household members or an individual over a given recall period (usually 24 h.).	LSMS	A	A	A	A	No
	Dietary diversity score	Measure of the number of unique food groups consumed by household members or an individual over a reference recall period.	LSMS	A	A	A	A	No
	Fruit and vegetable consumption	Average daily number of servings of fruits and vegetables at individual and/or household level	LSMS	A	A	A	A	No
	Healthy eating index[1]	Indicator of diet quality that measures conformance to food based dietary guidelines at individual and/or household level	LSMS; FAO (Dietary guidelines)	A	A	A	A	Yes
	Consumption of ultra-processed foods	Consumption of processed meats, saturated fat, cholesterol, sodium and added sugar, which are viewed as nutrients of public health concern at individual and/or household level.	LSMS	A	A	A	A	No
Diet adequacy	Nutrient Rich Food (NRF) Index	Unweighted sum of percentage daily values (DVs) for 9 nutrients to encourage (protein; fiber; vitamins A, C, and E; calcium; iron; potassium; and magnesium), minus the sum of percentage maximum recommended values (MRVs) for 3 nutrients to limit limited (saturated fat, added sugar, and sodium), calculated per reference amount and capped at 100% DV (Drewnowski, 2010).	LSMS	A	A	A	A	Yes
	Population share with adequate nutrients	100 minus the percentage of the population with dietary intakes of specified nutrients below the Estimated Average Requirement (EAR).	LSMS	A	A	A	A	Yes
	Mean probability of adequacy (MPA)	Average of probability of adequacy (PA) of essential nutrients, calculated based on nutrient requirement distributions (EAR) and inter- and intra-individual variation in intake. The MPA is calculated as the sum of the PAs for all evaluated nutrients, divided by the number of nutrients evaluated and expressed as a percentage. Alternatively, MPA can be computed as the percentage of population below the EAR of a certain nutrient.	LSMS	A	A	A	A	Yes
Food safety	Access to safe potable water	The percentage of the population with access to safe potable water.	LSMS	A	A	A	A	Yes

Table 9 (continued)

Metric components	Indicators	Description	Data source	Bangladesh	Ethiopia	Nigeria	Vietnam	Present in SDG indicators
	Food safety regulatory agency[2]	An indicator for whether a country has a regulatory agency or body to ensure the safety and health of food	National food safety authorities	A	A	A	A	No
	Incidence of food borne diseases	An indicator for proportion of population affected by foodborne diseases, including enteric (intestinal) diseases, chemicals and toxins, and parasitic diseases	LSMS	A	A	A	A	No
Health and nutrition status	Height-for-age	Prevalence of stunting (low height-for-age, <−2z-score) in children under 5 years of age	DHS, FAOSTAT	A	A	A	A	Yes
	Weight-for-height	Prevalence of wasting (low weight-for-height, <−2z-score) in children under 5 years of age	DHS, FAOSTAT	A	A	A	A	Yes
	Prevalence of dietary-related non--communicable diseases	Indicator of the number of dietary-related non--communicable disease affected adult persons at a given time. It is measured as the ratio of number of cases of dietary-related non--communicable diseases in the population during a given period of time to number of persons in that population at same time.	-	NA	NA	NA	NA	Yes
	Prevalence of anemia	The percentage of the population or subgroups of the population (e.g., children, women, etc.) affected by anemia at given period of time.	DHS, FAOSTAT	A	A	A	A	Yes
	Body mass index (BMI)	Indicator of appropriateness of the ratio of weight to height squared that is used to define and screen for thinness (<18.5), overweight (>25) and obesity (>30) for women and according to age for children.	LSMS, DHS	A	A	A	A	No
	Prevalence of low birth weight	The percentage of newborns that weigh less than 2.5 kg out of the total number of live births in the five (or two) years preceding the point of measurement in time.	FAOSTAT	A	NA	NA	A	No

Notes: A = Publicly available and NA = Currently not available; LSMS: This involves integrated household surveys that from part of the LSMS program or similar surveys. [1] Bangladesh: http://www.fao.org/3/a-as880e.pdf; Ethiopia: http://extwprlegs1.fao.org/docs/pdf/eth157047.pdf; Nigeria: http://www.fao.org/3/a-as841e.pdf; and Vietnam: http://www.fao.org/3/a-as980o.pdf; [2] Bangladesh Food Safety Authority, Food, Medicine and Health Care Administration and Control Authority of Ethiopia, National Agency for Food and Drug Administration and Control for Nigeria, and for Vietnam, three different ministries: the Ministry of Health (MOH), the Ministry of Agriculture and Rural Development (MARD), and the Ministry of Industry and Trade (MOIT) are responsible for managing and implementing the Law on Food Safety (LoFS)

household level) (FAO, 2010; Global Panel, 2015). Maintaining diet quality involves both enhancing the role of healthy foods, such as fruits and vegetables, while limiting the consumption of unhealthy foods or food groups, such as ultra-processed foods. Diet adequacy refers to the sufficient—not too little but also not too much—intake of energy and essential nutrients needed to fulfill nutritional requirements for optimal health appropriate to age, sex, disease status and physical activity for a healthy life (Castro-Quezada et al., 2014). Typically, the requirement for a given nutrient is defined as a lower (for heathy nutrients) or higher (for unhealthy nutrients) bound. Diet adequacy is assessed based on the

comparison between the (estimated) nutrient requirement and the intake of a certain individual or population (Castro-Quezada et al., 2014). Table 9 shows that the LSMS-type surveys, which typically include a seven day recall of food consumption, thus allows the construction of several household level diet quality and adequacy indicators.

Food safety is another key factor affecting nutrition and health outcomes of food systems. It includes all hazards and risks that make food consumption harmful or potentially harmful to the health of consumers. The primary focus of food safety efforts is the reduction of health hazards and risks related to microbial and food-borne pathogens (Hoffmann and Harder, 2012). Key indicators are the incidence of food borne diseases and toxins, and access to safe potable water—both available in the LSMS (Table 9)—and the presence of national regulatory agencies (available on the internet).

4.3.2 Metrics for socioeconomic outcomes

While dietary outcomes are the focus of this paper, other food system outcomes need due consideration. Food systems are the largest employer in LMICs (Chaudhary et al., 2018) and have the potential to be both economically viable and inclusive. Inclusive food systems could in turn provide sustainable livelihoods in the different sectors of the system, particularly for vulnerable groups like smallholders and women. In theory, food systems can also provide equitable access to food, thus improving global food security. Indicators for socioeconomic outcomes of food systems include measures of the economic and social wellbeing of the various players in the food system activities, including considerations of food security, gender equality, child labor and animal health and welfare. As detailed in Table 10, several indicators for measuring food systems' socioeconomic outcomes are present in the publicly available data.

4.3.3 Metrics for environmental outcomes

Food systems are also critically linked to the biophysical environment, which is a key source of crucial inputs (land, water, biodiversity and fossil fuels) and an important recipient of the waste stream and byproducts (Nesheim et al., 2015). Food systems can have significant environmental footprints (Prosperi et al., 2016; IPES 2016). Major environmental impacts of food systems include water pollution and depletion, soil degradation, desertification, biodiversity loss, and greenhouse gas (GHG) emissions contributing to climate change (Ericksen, 2008; Ingram, 2011; Vermeulen et al., 2012; FAO, 2011; Gustafson et al., 2016; Westhoek et al., 2016). Thus, sustainable food systems would be expected to achieve good nutrition and socioeconomic outcomes, while keeping the environmental impacts low enough so as not to transgress the planetary boundaries of biophysical processes and further destabilize environmental systems (Steffen et al., 2015; Béné et al. 2019a). Suitable indicators for environmental outcomes of the food system should therefore monitor changes in environmental conditions as reflected in the extent of resource consumption, biodiversity, harmful emissions, and natural resource management. Table 11 shows that aggregate information is available from AQUASTAT and FAOSTAT. Some indictors are also available at micro-level through LSMS-type surveys. Overall, data availability is good, at least at the national level.

5 Discussion and conclusion

Using a "food system approach" to find ways to improve diets has become a key area of interest among policy makers and researchers. The approach appears particularly relevant for studying dietary changes, as diets are complex outcomes of food systems, involving feedback loops at multiple levels across multiple scales (Cash et al., 2006). However, for the approach to gain practical relevance, it is important to rely on a more comprehensive set of ready-to-use metrics and indicators that can characterize food systems, set meaningful policy goals, track progress, and evaluate potential impacts of innovations and interventions. Current metrics mostly focus on food system outcomes and do not cover all components of the food system.

The information from a comprehensive set of food system metrics could be used by decision-makers to identify leverage points for intervention and investments at both sub-national and national levels. More concretely, data on food system metrics can serve as input in policy discussions and, together with foresight analysis, feed into participatory scenario analysis to discuss trade-offs and synergies (Rutten et al., 2018). Food system metrics can also help in the identification of important policy knowledge questions. For example, food system indicators were used in an interactive process with key stakeholders in Ethiopia. The aim of this process was to characterize the food system and to develop priority research questions to support operationalizing food systems approaches to improve diets (Gebru et al., 2018). The resulting discussion paper is currently used by the National Information Platforms for Nutrition (NIPN) to help policymakers develop their knowledge questions further.

A subset of indicators could be used to develop food system countries profiles, allowing some rapid characterization of countries, comparative analyses across countries or even regions, and benchmarking and monitoring at global level, all of which would be extremely useful for both national and international decision-makers. Food system metrics can also help further the discussion between experts from diverse disciplines and backgrounds. This discussion is often frustrated by framing within distinctive disciplinary narratives (Bene

Table 10 Indicators of the socioeconomic outcomes metric

Metric components	Indicators	Description	Data source	Bangladesh	Ethiopia	Nigeria	Vietnam	Present in SDG indicators
Food security	Household food security	Percentage of households that are food secure based on the household food insecurity access scale (HFIAS), an index of three key domains of household access to food—perceptions of insufficient quantity of food, perceptions of inadequate quality of food and uncertainty about whether the food budget or supply is adequate enough to meet the household's basic requirements.	LSMS/ FAOSTAT	A	A	A	A	Yes
Food affordability and availability	Poverty Index	The proportion of the population living below the "poverty line", often defined as PPP $1.90 per person per day threshold.	LSMS	A	A	A	A	Yes
	Income (in)equality in a country or region[1]	Gini coefficient for distribution of income, which has a value of 0 for the case of perfect income equality and 1 for the case of all income earned by a single individual.	World Bank	A	A	A	A	Yes
	Food affordability	The share of average annual income spent on food (total food expenditure/total income)	LSMS	A	A	A	A	No
	Food stressed households	Percentage of households dedicating more than 70% of their consumption expenditures to food purchase	LSMS	A	A	A	A	No
	Distance to supermarkets	Estimated average distance to three nearest supermarkets (an indicator of the choices available to consumers and the level of competition among stores)	LSMS	A	A	NA	A	No
	Access to market	Percentage of households with access to more than one market for food purchases	LSMS	A	A	A	A	No
	Healthy food basket cost index	Consists of a basket of food items selected to meet adequate nutritional requirements at the lowest cost, and observations of the costs of the basket over time to assess trends in affordability. The index would monitor the affordability of a nutritionally adequate diet.	LSMS	A	A	A	A	No
	Food consumer price index (FCPI)	Price index (preferably disaggregated nutritious vs. less nutritious) based on the average prices of cereals, fruit, vegetables, fish and meat	LSMS/ FAOSTAT	A	A	A	A	No
Food utilization	Access to power	Percentage of households with access to electricity for cooking	LSMS	A	A	A	A	Yes
	Access to water	Percentage of households with access to safe drinking water	LSMS	A	A	A	A	Yes

Table 10 (continued)

Metric components	Indicators	Description	Data source	Bangladesh	Ethiopia	Nigeria	Vietnam	Present in SDG indicators
	Food cooling facility	Percentage of households possessing enhanced refrigeration systems	LSMS	A	A	A	A	No
Socioeconomic welfare	Farm wage	Average wage paid to farmworkers in a country or region	LSMS	A	A	A	A	Yes
	Food sector wage	Average wage paid to food service, grocery and processing workers in a country or region	LSMS	A	A	A	A	Yes
	Child labor in the food system	The percentage of children (ILO convention ages 6–17) who are employed in the different food system sectors.	LSMS	A	A	A	A	Yes
	Tenure security	Extent of smallholders' tenure security	LSMS	A	A	A	A	Yes
	Gender equality[2]	a) Women's empowerment in agriculture index (WEAI): Index measuring women's empowerment in five relevant domains (role in production, resources ownership, income generation, leadership role and time allocation) of women in their households (Alkire et al. 2013)	LSMS/ DHS	A	A	A	A	Yes
		b) The Global Gender Gap Index (GGGI): an index measuring the extent of gender disparity based on four indicators—economic participation and opportunity, educational attainment, health and survival, and political empowerment (Gustafson et al., 2016).	LSMS/ DHS	A	A	A	A	Yes
	Household income	Average household income of households who make their livelihood from food system activities	LSMS	A	A	A	A	No
	Animal health and welfare[3]	a) Animal health and welfare legal framework: an indicator for whether a country has put in place the basic legal frameworks needed to protect animal health and welfare; b) Animal Protection Index (API): ranking of countries based on their commitment to animal protection, which gives letter grades to ranked countries ranging from a high of "A" to a low of "G" (World Society for the Protection of Animals).	World Animal Protection	NA	A	A	A	No

Notes: A = Publicly available and NA = Currently not available; LSMS: This involves integrated household surveys that from part of the LSMS program or similar surveys.[1] https://data.worldbank.org/indicator/SI.POV.GINI?locations=BD-ET-NG-VN; [2] For Ethiopia and Nigeria, decisions made by husband or wife or both in household decisions; [3] https://api.worldanimalprotection.org/#

Table 11 Indicators of the environmental outcomes metric

Metric components	Indicators	Description	Data source	Bangladesh	Ethiopia	Nigeria	Vietnam	Present in SDG indicators
Resource consumption	Capture fish consumption	Percentage of total seafood production accounted for by capture fishery	LSMS	A	NA	A	A	Yes
	Net freshwater withdrawals	Total annual food system net freshwater withdrawals from aquifers (m^3 freshwater consumption per year) in a country or region.	AQUASTAT	NA	A	NA	NA	Yes
	Water productivity in agriculture	The value of agricultural production divided by the volume of water withdrawn for agriculture (does not take into account the use of rainfall)	AQUASTAT	NA	A	NA	NA	No
	Land use	Total annual food system land use (m^2 per year), regardless of the purpose of the land use (cultivation, grazing, etc.).	FAOSTAT	A	A	A	A	No
	Non-renewable energy use	Total annual agricultural non-renewable energy use (Megajoules (MJ) per year).	FAOSTAT	A	A	A	A	No
	Agricultural water withdrawal	Annual quantity of self-supplied water withdrawal for irrigation, livestock and aquaculture purposes.	FAOSTAT	A	A	NA	A	No
	Agricultural irrigated land	Agricultural land purposely provided with water, including land irrigated by controlled flooding, as a percentage of total agricultural land.	LSMS	A	A	A	A	No
Biodiversity	Biodiversity loss	Plant and/or animal species that are near to extinct or endangered to extinction	FAOSTAT	A	A	A	A	Yes
	Crop varieties	Number of crops accounted for top 75% of the total land cultivated in a region or a country	FAOSTAT	A	A	A	A	No
	Species diversity	The diversity of species of crops and animals living in agricultural, forestry and fisheries ecosystems	FAOSTAT	A	A	A	A	No
Emissions	Greenhouse gas (GHG) emissions	Total annual food system GHG emissions (kg CO_2 equivalent per year: CO_2, CH_4, N_2O) in a country or region.	FAOSTAT	A	A	A	A	Yes
Resource management	Water infrastructure maintenance[1]	Frequency of control and maintenance work on water system (e.g., dams)	LSMS	A	A	A	A	Yes
	Soil conservation	Percentage of farmer producers implementing soil conservation measures	LSMS	NA	A	A	NA	Yes

Notes: A = Directly available and NA = Currently not available; LSMS: This involves integrated household surveys that from part of the LSMS program or similar surveys.[1] Irrigation (channel maintenance) per hour costs are available

et al., 2019b). Concrete data on a broad set of food system metrics can help identify these narratives and test whether they are supported by or not conflicting with the data.

In this paper, we propose a comprehensive set of metrics that can enable the measurement of food systems across all relevant domains and dimensions. Building on previous work, we present a conceptual framework of food systems and use it to systematically identify relevant metrics and indicators based on data availability in LMICS. To assure the practical applicability of the metrics and allow for inter-country comparisons, we select indicators present in datasets that are available in LMICS. We prioritize indicators that overlap with the SDG indicators, although the latter do not cover all aspects of the food system. We apply our approach to four countries. This allows us not only to show commonalities in data availability, but also reveals differences between similar datasets.

Key datasets are the LSMS and FAOSTAT, and for health and nutrition indicators, the DHS. While the existence of ready-to-use aggregate indicators from datasets like FAOSTAT is helpful for quick scans of some aspects of food systems, the availability of raw micro-level data from the LSMS has other advantages. The four study countries are large countries with high diversity in terms of agroecology, geography, rural-urban gradients, population, and multiple food sub-systems (Gebru et al., 2018; Raneri et al., 2019). As such, data collected at national scale tend to mask spatial and sectoral differences coming from these diversities within the countries. In addition, many indicators, such as food safety, diet diversity, and food losses and waste, can in theory be measured at local or sub-group scale and traced throughout the food system. Micro-level datasets allow doing so, thus potentially providing information about distributional implications and leverage points for interventions.

Key advantages of the LSMS and DHS are that they are nationally representative and available for multiple countries. The latter, however, does not automatically mean that the metrics are comparable between countries. Statistical capacities are dire in many LMICs, particularly in Africa (Jerven, 2013). The surveys used for data collection in the different countries were designed and conducted by various actors. For example, the LSMS surveys in Ethiopia and Nigeria were supported by the World Bank. The Bangladesh Integrated Household Survey (BIHS) was conducted by the International Food Policy Research Institute (IFPRI) under the auspices of the Feed the Future (FTF) program. The other national-level surveys were conducted by the statistical authorities or relevant ministries of the respective countries. The surveys were not conducted in standardized and harmonized ways, and there are likely to be inconsistency in guidelines for the data collection, which can impair the comparability of the metrics across the countries. The datasets across the different countries also vary in terms of quality and their coverage in the rural-urban gradient. For example, the BIHS covers rural areas only, while the other data sets cover both rural and urban areas. In addition, not all selected indicators are available for all countries. With these considerations, the metrics based on these datasets remain greatly important to support evidence-based decision making in the food systems of the respective countries.

We find that public data are available on food system drivers and outcomes, and on some of the activities, notably production and consumption. Data on food processing, food distribution and marketing, and food loss and waste appear less complete and thus require additional data collection efforts. With such data limitations, it would be difficult to carry out food system analyses that adequately address the complexity and trade-offs/synergies of the food system using the metrics currently available. Specifically, there is a risk that food system activities with missing data would largely be ignored in policy analyses and discussions, which could result in missing appropriate problem solutions or causing unwanted side effects.

Improving the accuracy and usefulness of food systems metrics requires setting widely accepted norms and standards for data collection, collecting data for important metrics which are not often covered in traditional surveys, systematic analysis and synthesis of existing datasets, promoting the principle of open data access, and improving capacity to analyse and use data at all levels. To increase their relevance for policy and practice, food system metrics should allow disaggregated analyses at multiple levels across different scales, including different social groups, regions and local levels. Data on seasonal patterns and their impact on food consumption, and on nutritional intake of macro- and micronutrients across time and space (within- and between-countries) are likely to be important for policymakers and practitioners.

With only minor additional investments, LSMS-type surveys could be extended to cover much of the required data. When individual indicators are not available for all countries, and this can easily be solved by including the relevant questions in the follow-up surveys for the relevant countries. In next data collection efforts, new modules could be added. In contrast to household surveys under the LSMS program, the community questionnaire of the Bangladesh Integrated Household Survey (BIHS) covers information on quality and accessibility of the road network, food warehousing and cold storage, all of which could be included in LSMS surveys relatively easily. The BIHS survey also includes valuable questions on nutrition knowledge in the household questionnaire. Food processing is a relatively new concern with limited coverage in all current surveys. The food expenditures sections contain only highly aggregate categories for processed foods that are less suitable for assessing their contribution to diets and nutrition. Some careful recategorization could solve this problem. The consumption questionnaire could also be extended to include food waste at the consumer level.

For some indicators lacking data, such as food losses in the value chain and food distribution indicators with above-local relevance, targeted data collection efforts are needed. As there is overlap with the SDG indicators, part of the collected data could serve a dual purpose: both improving the description and monitoring of food systems, and to track progress towards attaining the SDGs.

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