

# Concepts and critical perspectives for food environment research: A global framework with implications for action in low- and middle-income countries

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## ABSTRACT

Malnutrition in all its forms currently affects one in three people globally and is considered one of the greatest public health challenges of our time. Low- and middle-income countries (LMICs) are increasingly facing a double burden of malnutrition that includes undernutrition, as well as increasing overweight, obesity and diet related non-communicable diseases. The role of food environments in shaping transitioning diets and the double burden of malnutrition in LMICs is increasingly gaining policy attention. However, food environment research to date has predominantly been undertaken in response to obesity and associated diet-related non-communicable diseases in high-income countries (HICs). Empirical research in LMICs is in its infancy. There is a need to create a cohesive research agenda to facilitate food environment research and inform action across the globe, particularly with regard to LMICs. In this paper, we address three fundamental questions: First, how can the food environment be defined and conceptualised in a way that captures the key dimensions that shape food acquisition and consumption globally? Second, how can existing knowledge and evidence from HICs be leveraged to accelerate food environment research in LMICs? Third, what are the main challenges and opportunities in doing so? We conduct a brief synthesis of the food environment literature in order to frame our critical perspectives, and introduce a new definition and conceptual framework that includes external and personal domains and dimensions within the wider food environment construct. We conclude with a discussion on the implications for future research in LMICs.

## 1. Introduction

Malnutrition in all its forms afflicts one in three people globally (High Level Panel of Experts on Food Security and Nutrition, 2017). It affects every country and is considered one of the greatest public health challenges of our time (Development Initiatives, 2017). High-income countries (HICs) are almost universally experiencing a very high burden of overweight, obesity and diet-related non-communicable diseases (NCDs) (Ng et al., 2014). In low- and middle-income countries (LMICs), populations are increasingly facing a double burden of malnutrition that includes undernutrition, as well as increasing overweight, obesity and diet-related NCDs (World Health Organisation, 2017). This double

burden of malnutrition often co-exists within communities, households and individuals (World Health Organization, 2017).

Globalization, economic development, technological advancement and shifts in agricultural systems have been rapidly transforming diets across the world in recent decades. Collectively, these factors have led to a transition away from the reliance on staple grains, legumes, vegetables and fruits to dietary patterns that include more processed foods, away-from-home foods, animal source foods, refined carbohydrates, edible oils and sugar-sweetened beverages (Popkin, 2015; Popkin et al., 2012). While these transitioning diets are being documented, there is limited research investigating how people interact with food sources to acquire foods as part of daily life. Accordingly, the role

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of food environments in shaping diets is increasingly gaining policy attention (Development Initiatives, 2017, High Level Panel of Experts on Food Security and Nutrition, 2017, Global Panel on Agriculture and Food Systems for Nutrition, 2017), set against the backdrop of the Sustainable Development Goal (SDG) 2 to end hunger, achieve food and nutrition security, improve nutrition, and promote sustainable agriculture (United Nations General Assembly, 2015). Such targets to ensure the year-round provision of safe, nutritious and sufficient food will require healthy food environments that cater for all (Food and Agriculture Organisation of the United Nations, 2016a). Improving knowledge and understanding about food environments, including the who, what, when, where, why and how of food acquisition and consumption, will be key to addressing malnutrition in all its forms.

The United Nations Decade of Action on Nutrition 2016–2025 (United Nations General Assembly, 2016) presents a key opportunity to improve food environments across the globe. Food environment research to date has primarily been undertaken in response to the rapid rise of obesity and associated diet-related NCDs in HICs. However, with critical refinement and adaptation of key concepts, methods and metrics, food environment research has the potential to provide an integrated approach to addressing malnutrition in all its forms in LMICs. A number of pioneering studies have broken new ground by investigating food environments in middle-income countries (Azeredo et al., 2016; Duran et al., 2016; Fernandes et al., 2017). Whilst a growing body of literature is starting to emerge, food environment research in LMICs remains in its infancy.

In this paper, we address several fundamental questions with the aim of creating a cohesive research agenda and facilitating robust empirical research to inform action, particularly in LMICs. First, how can the food environment be defined and conceptualised in a way that captures the key dimensions that shape food acquisition and consumption globally? Second, how can existing knowledge and evidence from HICs be leveraged to accelerate food environment research in LMICs? Third, what are the main challenges and opportunities in doing so?

Consideration of these questions is crucial in order to: 1) track rapidly evolving food environments across the globe, particularly in LMICs; 2) investigate relationships between components of the food environment and dietary, nutrition and health outcomes; and 3) identify appropriate policy entry points to facilitate healthier food environments that promote nutritious diets and improve public health outcomes. We present critical perspectives from the Agriculture, Nutrition and Health Academy Food Environment Working Group (ANH-FEWG) (Box 1), including a new food environment definition and conceptual framework applicable to global contexts. A brief synthesis of existing literature from HICs is provided to guide research in LMICs,

### Box 1

The Agriculture, Nutrition and Health Academy Food Environment Working Group: A brief overview.

The Agriculture, Nutrition and Health Academy Food Environment Working Group (ANH-FEWG) was established in 2016 as a work stream of the Innovative Methods and Metrics for Agriculture and Nutrition Actions (IMMANA) initiative. The working group brought together experts to review and synthesise food environment definitions, key concepts, methods, metrics, and research gaps, with the aim of providing a platform of consensus to guide and accelerate food environment research in LMICs.

A literature search of review articles and grey literature on food environments was conducted by two ANH-FEWG members in February 2016. The inclusive search used four databases; Medline, Econlit, Web of Science, Scopus. The search terms were ‘food environments’, ‘methods’ and ‘metrics’. The resulting synthesis of review articles (n = 18) informed bi-monthly ANH-FEWG meetings, whereby working group members discussed and evaluated definitions, key concepts, frameworks, methods and metrics with critical consideration to their LMIC application. This formative phase led to the iterative development of a new working definition and conceptual framework (Fig. 2).

The emerging body of work was presented for consultation at the Agriculture, Nutrition and Health Academy Week 2016, in Addis Abba, Ethiopia. Discussions with over 100 participants at the conference and further analysis of grey literature refined concepts further. A non-peer reviewed technical brief by Turner et al. (2017) outlining evolving concepts was disseminated at the Agriculture, Nutrition and Health Academy Week 2017, in Kathmandu, Nepal. A short animation supporting this technical brief can be found at (<https://www.youtube.com/watch?v=5cUaro1gUcI>)

leading into a discussion of the implications for action in LMIC settings.

## 2. How can we define and conceptualize food environments?

While it is beyond the scope of this paper to provide a comprehensive review of the literature, we present a brief synthesis of existing food environment definitions and concepts in order to frame our contributions and critical perspectives.

Food environment research builds on socio-ecological theory and the understanding that health-related behaviours are determined by inter-related personal and environmental factors (Brug et al., 2008; Rao et al., 2007). Pioneering conceptual work by Glanz et al. (2007) described the food environment at the local *neighborhood scale*, termed the ‘community food environment’, and the *in-store scale*, referred to as the ‘consumer food environment’. This conceptualization has guided much of the empirical research seeking to quantify the world that is ‘out there’ in terms of the various types of food sources and products that people may acquire and consume. However, beyond the ‘community’ and ‘consumer’ based concepts and broad notions of “any opportunity to obtain food” (Townshend and Lake, 2009:910), defining precisely what a food environment is and the critical components it entails has proven somewhat more challenging.

Swinburn et al. (2013) defined the food environment as the “collective physical, economic, policy and sociocultural surroundings, opportunities and conditions that influence people’s food and beverage choices and nutritional status” (Swinburn et al., 2013:2). The identification of structural drivers of food acquisition, consumption, and nutritional status is particularly useful in framing the wider concept. However, at an operational level there is a need to define a set of measurable dimensions to guide empirical research. Herforth and Ahmed (2015) provided an important contribution in this regard by pinpointing a range of key dimensions, including the “availability, affordability, convenience, and desirability of various foods.” (Herforth and Ahmed, 2015:506). Key publications by the Global Panel on Agriculture and Food Systems for Nutrition, (2016) and the Food and Agriculture Organisation of the United Nations, (2016a) built on this work, adding further dimensions and introducing the role of people’s daily lives and activities; “Food environments comprise the foods available to people in their surroundings as they go about their everyday lives and the nutritional quality, safety, price, convenience, labelling and promotion of these foods” (Food and Agriculture Organisation of the United Nations, 2016a:vii; Global Panel on Agriculture and Food Systems for Nutrition, 2016:83).

The Food and Agriculture Organisation of the United Nations, (2016a) also provided a critical contribution by framing the food environments as the ‘interface’ or ‘link’ between food systems and diets

(Food and Agriculture Organisation of the United Nations, 2016a:21). This concept is particularly valuable as it helps situate the food environment construct within the wider ‘farm to flush’ notion of the food system as it is defined by the United Nations System Standing Committee on Nutrition, (2016), helping to distinguish between these related concepts.

A key commonality amongst these existing definitions is the conceptualization of the food environment in terms of the spaces within which food acquisition occurs, and the series of market-based opportunities and constraints that influence people’s food acquisition and consumption. However, clear differences exist with regard to the articulation of dimensions. These differences likely reflect not only the diversity of food environments globally but also the wide array of academic disciplines undertaking research, each with their respective areas of interest and expertise (e.g. public health nutrition, economics, epidemiology, geography, sociology, urban planning). A number of publications have noted the need to harmonize definitions with theoretical concepts and measurable dimensions of food environments in order to guide empirical research (Caspi et al., 2012; Cobb et al., 2015; Penney et al., 2014).

### 2.1. ANH-FEWG definition and conceptual framework

Building on a report of the Food and Agriculture Organisation of the United Nations, (2016a), we describe the food environment as the interface where people interact with the wider food system to acquire and consume foods, as depicted in Fig. 1. The ‘interface’ concept and the focus on ‘interactions’ helps to ground the food environment construct in relation to people’s daily lives and activities that shape their diets. Political, economic and socio-cultural factors act as macro-level influences on the food environment and the wider food system (Baker et al., 2018; Swinburn et al., 2013).

Critically, we consider the food environment to include four types of food sources, namely; market-based food sources, own-production, wild harvested foods, and transfers – including gifts. The inclusion of both market and non-market-based food sources is an important distinction from existing conceptualizations of the food environment. Non-market-based food sources play a key role in food environments across many settings. However, they are especially important when considering food environments in LMICs. Traditional food environments, particularly in rural LMIC settings, are typically characterised by limited food availability and accessibility, with many people acquiring at least part of their food from own-production, as well as in-kind transfers and gifts (High Level Panel of Experts on Food Security and Nutrition, 2017). Non-market-based food sources may also be important in some urban food environments, for example in the form of urban agriculture (Food and Agriculture Organisation of The United Nations, 2014).

We draw from socio-ecological perspectives to identify two key domains within the wider food environment construct; the ‘external domain’ and the ‘personal domain’ (Fig. 2). Each domain includes an

expanded set of measurable dimensions. The *external* domain relates to the world of opportunities and constraints that are ‘out there’ within a given context, and includes dimensions such as food availability, prices, vendor and product properties, and marketing and regulation. The *personal* domain includes a set of individual level dimensions, including food accessibility, affordability, convenience and desirability. We consider continuous and complex interactions between these domains and dimensions to shape people’s food acquisition and consumption. Our proposed definition is as follows:

“The food environment is the interface that mediates people’s food acquisition and consumption within the wider food system. It encompasses external dimensions such as the availability, prices, vendor and product properties, and promotional information; and personal dimensions such as the accessibility, affordability, convenience and desirability of food sources and products”.

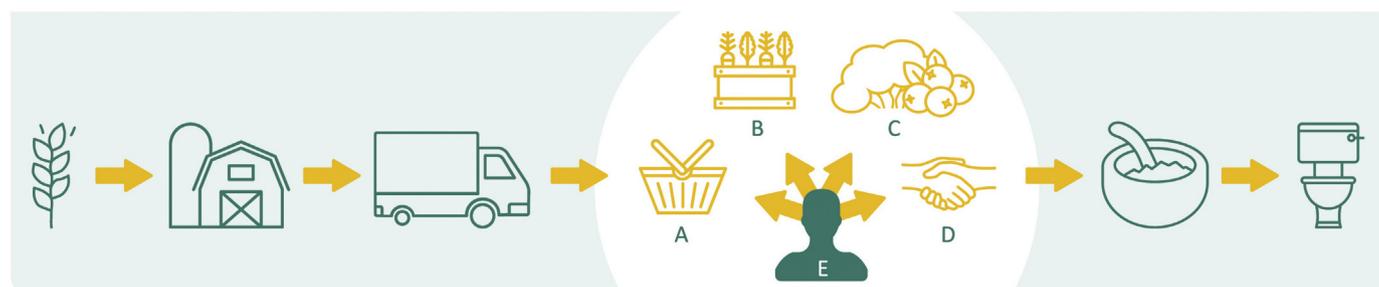
### 2.2. Key conceptual developments

This new conceptual framework provides four key globally relevant developments. First, it holds external and personal domains as central interacting tenets, providing epistemological and ontological links to underlying socio-ecological theory. The conceptualisation of the personal food environment domain answers repeated calls to allocate greater attention to individual level aspects that shape food acquisition and consumption (Black et al., 2014; Food and Agriculture Organisation of The United Nations, 2016a; Lytle, 2009; United Nations System Standing Committee on Nutrition, 2016). While previous frameworks by Swinburn et al. (2013) and Herforth and Ahmed (2015) have included personal factors, they have predominantly focused on external factors.

Second, this conceptual framework maps a comprehensive set of dimensions to each domain, distinguishing between external dimensions, such as availability, prices, vendor and product properties, and marketing and promotion; and personal dimensions, including accessibility, affordability, convenience, and desirability. Detailed distinctions between the full set of dimensions are provided in Table 1.

A key point to note is the differentiation of availability and accessibility. We draw from Charreire et al. (2010) and Caspi et al. (2012) in their delineation of these two dimensions. In our framework, availability refers to the presence (or absence) of a food source or product within a given context, whilst accessibility is relative to individuals and concerned with distance and time-based aspects, including transportation opportunities. Availability precedes accessibility, in that a food cannot be accessible to an individual if it is not available. Likewise, prices affect how an individual perceives affordability; vendor and product properties affect how an individual may perceive convenience; and marketing and regulation may affect the desirability of products to an individual.

The third contribution of this new approach is that it facilitates the



**Fig. 1.** Situating the food environment within the wider food system. The figure depicts the food system from ‘farm to flush’ (United Nations System Standing Committee on Nutrition, 2016). The white sphere highlights the food environment as the interface where people acquire foods from a range of sources, including; A) Market-based sources (formal and informal); B) Own production (urban, peri-urban, and rural); C) Wild harvested foods; and D) Food transfers – including gifts. Interactions with food sources are shaped by; E) Individual daily mobility.

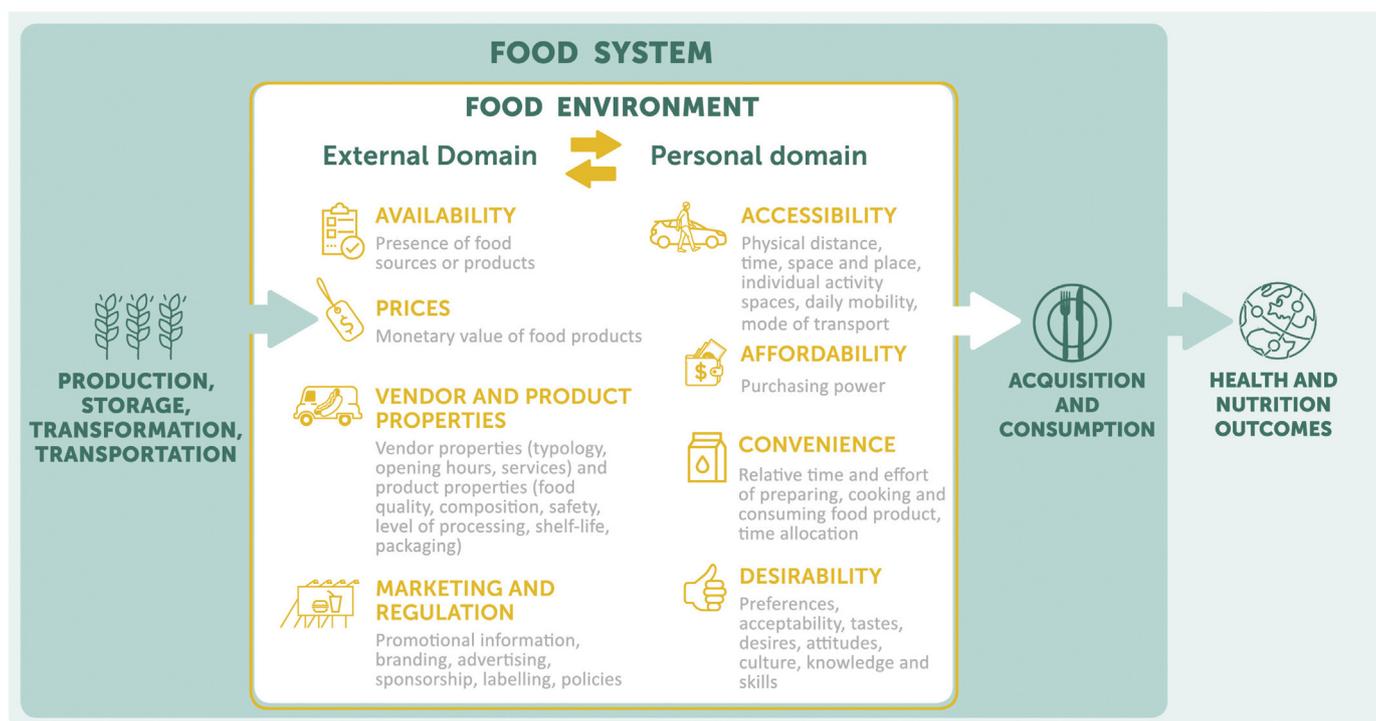


Fig. 2. Conceptual framework. The conceptual framework depicts the food environment as the interface within the wider food system. Key dimensions are mapped to external and personal domains. Interactions between these domains and dimensions shape people’s food acquisition and consumption.

alignment of the socio-ecological theory driven conceptual framework in Fig. 2 with methods and metrics, shown in Fig. 3. Mapping geospatial and observational approaches to personal and external food environment domains responds to the identified gap in linking food environment theory and concepts with methods and metrics (Caspi et al., 2012; Engler-Stringer et al., 2014; Penney et al., 2014). In doing so, we highlight the potential for the greater use of mixed methods to address the various domains and dimensions of food environments, echoing calls from the wider literature (Black et al., 2014; Lytle, 2009).

Geospatial approaches feature the collection and analysis of geotagged locational data, often within Geographical Information Systems

software. We distinguish between static approaches that are typically used to assess the external food environment (e.g. vendor density), and dynamic approaches that are increasingly being used to investigate the interaction between the personal and external food environment by tracking and mapping people’s daily mobility and activities. We use the term observational approaches with reference to methods that do not typically include geospatial analyses. We broadly categorise these as either market-based or stakeholder-based methods. Market-based approaches are commonly used to quantify the external food environment in terms of the availability and prices of foods by vendor typology within a given setting. Stakeholder-based approaches can employ a

Table 1  
Distinctions between interrelated food environment dimensions in greater detail.

Dimensions	
‘Availability’ and ‘Accessibility’	The conceptual framework seeks to distinguish between ‘availability’ and ‘accessibility’, two commonly used dimensions that are often conflated within the literature. Availability refers to whether a vendor or product is present or not within a given context, and is included within the external food environment domain. Availability always precedes accessibility (i.e. a food cannot be accessible if it is not available). Accessibility is relative to individuals, and falls within the personal food environment domain. Accessibility is highly dynamic and can include distance, time, space and place, daily mobility, and modes of transport that collectively shape individual activity spaces.
‘Prices’ and ‘Affordability’	Prices refer to the cost of food products, and are included within the external food environment domain. Prices interact with individual purchasing power to determine affordability within the personal food environment domain. Prices and affordability are well established dimensions within food environment research. Prices and affordability are sensitive to fluctuations in food availability and accessibility.
‘Vendor and Product Properties’ and ‘Convenience’	Vendor and product properties refers to external food environment aspects such as the type of food vendors, opening hours, and services provided, as well as the intrinsic compositional assets of foods such as quality, safety, level of processing, shelf-life and packaging. Collectively, these structural aspects interact with individual factors such as time allocation and preparation facilities to determine convenience. Vendor and product properties feature prominently within food environment research. However, just how these aspects relate to personal convenience and desirability is an area where public research has yet to catch up with the private sector.
‘Marketing and Regulation’ and ‘Desirability’	Marketing and regulation fall within the external food environment and include promotional information, branding, advertising, sponsorship, labelling, and policy regulations pertaining to the sale of foods. Taken together, these aspects interact with people’s individual preferences, acceptability, tastes, desires, attitudes, culture, knowledge and skills to shape the desirability of food vendors and products, captured under the personal food environment domain. Whilst well established within other research disciplines, the influence of marketing and regulation on desirability has yet to feature prominently within food environment research.

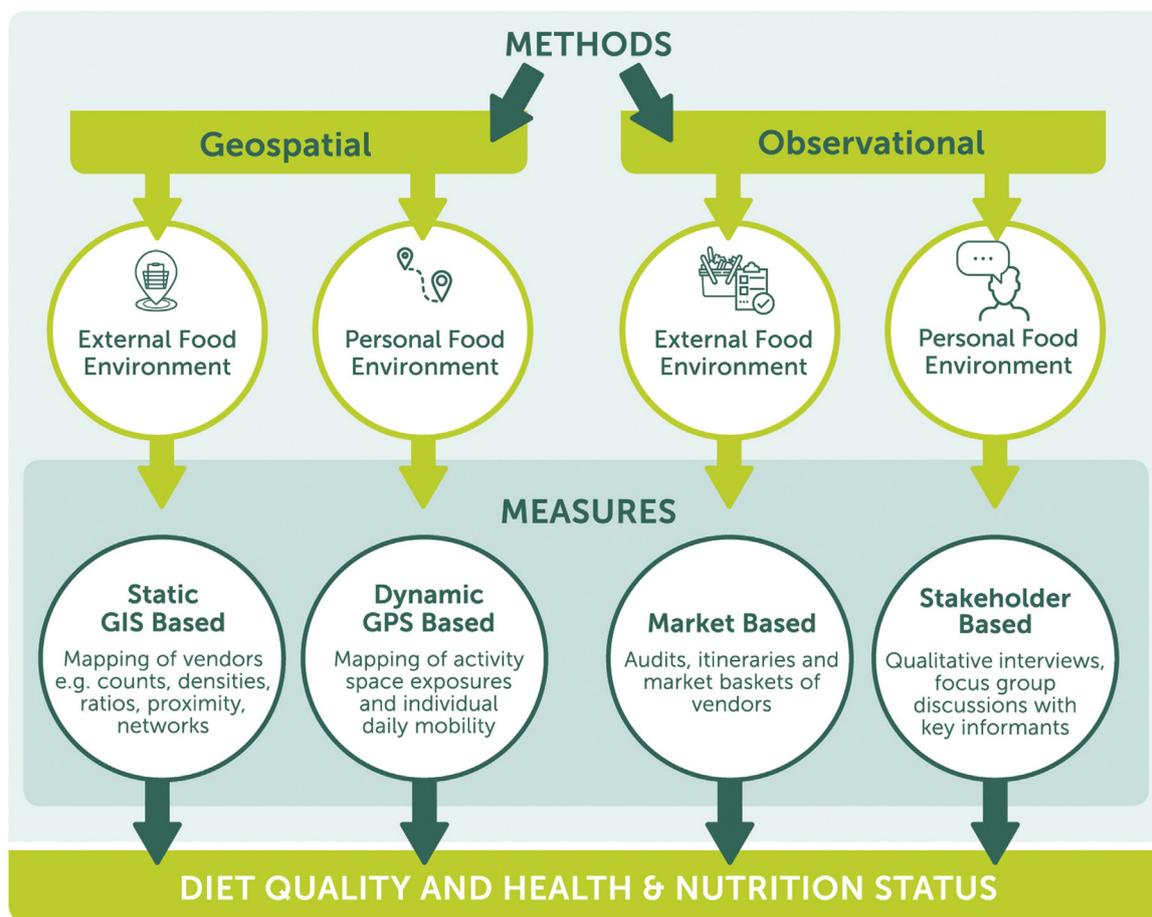


Fig. 3. Methodological framework. The methodological framework maps geospatial and observational approaches to the personal and external food environment domains, each with its own set of respective measures.

range of methods, including quantitative methods such as household or vendor surveys, and qualitative methods such as in-depth interviews.

The fourth significant contribution is the clarification of the use of the term “access”. This is particularly important given the various meanings the term carries within the diverse array of disciplines engaged in food environment research. The term ‘food access’ is often used as a multifaceted determinant of food acquisition (i.e. physical, social, economic access). It is also used as an outcome to signify the act of acquiring food. Authors such as Charreire et al. (2010) have problematized the term’s ambiguity. Its origins can be traced back to the work of Penschansky and Thomas (1981), who described a multi-dimensional conceptualisation of access, as well as the well-established definition of food security (Food and Agriculture Organisation of The United Nations, 1983, 1996) and the UNICEF Framework on the causes of malnutrition (United Nations Children’s Fund, 1990, 1998). In order to improve clarity, in our framework we use ‘access’ and ‘accessibility’ with exclusive reference to physical distance, time- and transport-based aspects relative to individuals. We use ‘prices’ and ‘affordability’ to capture economic aspects often referred to as “economic access” to food. Finally, we propose the use of ‘acquisition’ when referring to the outcome of obtaining food.

### 3. How can we leverage the existing knowledge and evidence from HICs to accelerate food environment research in LMICs?

The scoping of systematic review articles mentioned in Box 1 revealed modest evidence in support of the influence of the food environment on dietary and health outcomes, both amongst adults (Caspi et al., 2012; Gamba et al., 2015) and children (Engler-Stringer et al.,

2014), with the exception of two review articles that reported equivocal findings (Cetateanu and Jones, 2016; Gustafson et al., 2012). It has been suggested that the inconsistent evidence base not only reflects the wide range of food environment definitions, but also the strengths and limitations of primary and secondary data sources, the diversity of methodological approaches applied, the variety of dimensions and indicators measured, the heterogeneity of food vendors and categories studied, and the quality of studies themselves (Caspi et al., 2012; Engler-Stringer et al., 2014; Gamba et al., 2015).

Studies in HICs have predominantly sought to characterise food environments using quantitative approaches. A range of indicators have been used to measure dimensions of particularly food availability, accessibility, and prices (Penney et al., 2014). These indicators have typically been tested for associations with dietary, nutrition and health outcomes. *Availability* has been measured either in terms of presence or absence of food sources within a certain range around people’s home or work (Bodor et al., 2010; Gibson, 2011; Laraia et al., 2004; Morland et al., 2006, 2002; Powell et al., 2010; Rose and Richards, 2004); or food types within a supermarket or a convenience store by shelf space, and variety (Andreyeva et al., 2008; Franco et al., 2008; Hosler et al., 2008).

*Accessibility or physical proximity* to healthy foods is one of the most common dimensions that has been used in HICs to measure food environments. It is operationalised in terms of either density of food stores within certain buffer from home (Bodor et al., 2010; Moore et al., 2008; Powell et al., 2007; White, 2007), or street-network distance from home to the nearest food store (Apparicio et al., 2007; Sharkey and Horel, 2008; Smoyer-Tomic et al., 2006) vs. the primary food store shopped at (Aggarwal et al., 2014a; Drewnowski et al., 2012). Supermarkets have

**Table 2**  
Characterizing key differences in the external food environment domain between HICs and LMICs.

Dimension	HIC food environments	LMIC food environments
Availability	<b>Formal markets:</b> Relatively stable Supermarkets, fast food chains, farmers markets, restaurants, cafés, street foods Little seasonal variation in availability	<b>Formal markets:</b> Highly dynamic Increasing introduction of supermarkets and fast food chains  <b>Informal markets:</b> Street food vendors – including traditional and fast foods High seasonal variation in availability in perishable fresh products Own production – including rural, peri-urban, urban agriculture Highly volatile prices Vulnerable to shocks and seasonality Ready to eat street foods relatively cheap Perishables expensive and/or volatile in price
Prices	Relatively stable prices High premiums for speciality foods	Brick & mortar vendors, temporary roadside stalls, mobile traders. Limited trading hours Increasingly offering online/delivery options Limited food packaging Increasing cold storage, but gaps in the cold chain Limited food safety regulations Potential to acquire food on credit
Vendor and product properties	Brick & mortar vendors  Increasingly 24/7 trading Online shopping/delivery High level of food packaging Cold storage Food safety regulations	Largely un-regulated Basic labelling and information on select products
Marketing and regulation	Highly regulated with strict trading laws High level of promotion, marketing campaigns, labelling, shelf information	

often been used as the proxy for healthy foods, and contrasted with small convenience stores and fast food outlets as proxies for unhealthy foods. Food *prices* have been measured by either costing the market baskets of commonly used foods (Gustafson et al., 2012), or by ranking food stores by price of products sold (Drewnowski et al., 2012).

Studies comparing accessibility vs. price found that price level of products at the supermarket, rather than supermarket physical proximity, was found to be associated with higher fruit and vegetable intake (Aggarwal et al., 2014a) and lower prevalence of obesity (Drewnowski et al., 2012). The authors concluded that whilst improving physical access to food vendors may be one strategy to deal with public health challenges such as obesity; improving the affordability of healthy foods is another critical factor that must be addressed. Such findings emphasise that food environment research in LMICs must strive to determine the relative importance of availability, accessibility and prices on dietary, nutrition and health outcomes across a range of settings.

The role of *personal factors*, including desirability and preference towards convenience vs. healthy food remains relatively understudied (Penney et al., 2014). Aggarwal et al. (2014b) investigated individuals' food-related attitudes towards healthy foods vs. physical proximity to supermarkets in relation to diet quality. Prioritizing nutrition was found to be strongly associated with higher quality diets across all socio-economic strata. In addition, evidence from US national level data underscores the importance of positive food-related attitudes on diet quality (Aggarwal et al., 2016). Collectively, these findings suggest that personal perceptions might be stronger determinants of food acquisition, diets and health, than proximity, particularly among those with personal modes of motorised transport. The recent development of tools to assess the desirability of fruits and vegetables on the basis of sensory attributes also provides new impetus in this area (Ahmed and Byker Shanks, 2017; Ahmed et al., 2018).

The diverse body of food environment research from HICs yields a broad set of dimensions, methods and metrics that may be leveraged to guide future research in LMICs. The study of food environments is continually evolving as research seeks to address gaps in existing knowledge. It is noteworthy that whilst food environment research is increasingly seeking to complement external environmental drivers of diets and health with personal level dimensions (Penney et al., 2014); there is increasing advocacy within obesity-driven research to do the

opposite, namely to supplement individual-level strategies with structural built and food environment interventions (Swinburn et al., 2011). Rather than contradictory, that these two research agendas are recognising the need to address different domains re-affirms the notion that both structural and individual factors shape people's behaviours including food acquisition (and subsequent health outcomes), highlighting the need to address both external and personal domains and dimensions of the food environment. The frameworks presented in Figs. 2 and 3 provide a conceptual point of departure in this regard, and may be used to guide the development and implementation of food environment research, particularly in LMICs.

#### 4. What are the main challenges and opportunities for food environment research in LMICs?

##### 4.1. Main challenges

Food environments in LMICs present a series of significant challenges to empirical research. One of these challenges relates to the dynamic and complex nature of food environments in LMICs. Methods and metrics have largely been designed to capture the relatively stable, formalized and well documented food environments of HICs. Food environments in LMICs are often considerably more variable, changing throughout diurnal and seasonal cycles. Whilst global food system shifts may be considered to be homogenizing dimensions of the external food environment across many contexts through increased international trade, foreign direct investment, supermarketization, and the rise of 'big food', fundamental differences remain between HICs and LMICs. We highlight some key distinctions in availability, prices, vendor and product properties, and marketing and regulation in Table 2. Methods and metrics used in HICs need to be further developed and adapted to LMIC contexts. Furthermore, primary data collection must consider the rapidly changing nature of food environments in LMICs to capture, for example, changing diets in the context of shifts towards the greater consumption of highly processed food products and the 'nutrition transition' (Walls et al., 2018).

A second key challenge is the lack of coherent data on various dimensions of food environments in LMICs. Food environment research in HIC settings has often drawn, at least in part, from comprehensive

secondary datasets made available by governmental agencies, such as formal vendor registries kept by licensing authorities (Lucan, 2015). Detailed datasets containing geotagged information about vendors are likely to be limited if not non-existent in many LMICs. Similarly, policy information and documentation may not be as readily available in LMICs when compared to HICs (e.g. regulations regarding nutritional information on product labelling).

A third major challenge is the diverse range of food sources that exist in LMICs. Whereas food environment research in HICs has focused almost exclusively on market-based sources, studies in LMICs must consider the co-existence of formal and informal food markets, as well as non-market-based food sources such as own production, wild food harvesting, and food transfers – including gifts.

Market-based vendors provide the primary source of food for the majority of people across the globe. However, food environments in LMICs are particularly complex as they host a wide variety of market-based food sources that operate at multiple scales. Many settings feature market-based vendors that range from informal street vendors and wet markets, to more formalized shops, specialty stores, cooperatives, ration shops, restaurants, as well as national and multi-national supermarket chains. Collectively, these diverse typologies cater for a diverse selection of foods to a wide array of people, many of whom are increasingly experiencing constraints upon time and resources. Evidence suggests that vendors utilizing traditional value chains (such as wet market traders) supply high value foods such as fruits, vegetables and meats at lower prices compared to modern value chain vendors (such as supermarkets) (Gomez and Ricketts, 2013). It is therefore imperative to classify and capture the range of market-based vendor typologies that exist within LMIC food environments to better understand how they mediate foods to people across a variety of rural and urban settings.

Informal food vendors provide a key source of diverse foods in LMICs, especially amongst the poor (Battersby and Crush, 2014). In many settings, energy-dense nutrient-poor street and snack foods provide a readily available source of affordable, desirable and convenient calories (Gupta et al., 2016). These types of informal vendors are particularly challenging to document as they are often un-registered and highly mobile, capitalising on peak trading times in places where passing trade is busiest and consumers are hungry, thereby creating high spatial and temporal variability in the availability of foods.

Non-market-based food sources in LMICs include own production, wild food harvesting, and transfers – including gifts. Payment in food rather than cash is also commonplace in many settings. These alternative food sources necessitate a more holistic approach to understanding food environments than has often been undertaken in HICs.

#### 4.2. Key opportunities

Despite the challenges listed above, a number of exciting and innovative opportunities for food environment research in LMICs exist. Pioneering studies have modified, tested and implemented established tools from HICs to LMIC settings. Several studies have adapted the Nutrition Environment Measures Survey - Stores (NEMS-S) (Duran et al., 2015; Kanter et al., 2014; Martins et al., 2013). Others have used tools developed by the International Network for Food and Obesity/Non-communicable Diseases Research, Monitoring and Action Support (INFORMAS) to assess ready-to-eat food labelling (Pongutta et al., 2018). One potential opportunity is to complement market-based tools with existing household survey tools that include sections on own production and food transfers in order to provide more comprehensive assessments of food environments.

Qualitative food environment research remains underutilized yet has great potential, particularly in understudied settings such as LMICs. Qualitative approaches provide the opportunity to learn from lived experiences of food environments, and may reveal greater insights into issues such as which dimensions people perceive to be important in

shaping their food acquisition and consumption. Such knowledge is vital to the successful design, implementation and uptake of appropriate interventions and policies.

Mixed-methods research presents another opportunity. Integrating qualitative and quantitative approaches in mixed-method studies offers the potential to triangulate multiple data sources, further improving knowledge and understanding of people's interactions with their food environment. Approaches that combine participatory geographical information system (GIS) techniques with in-depth interviews have been used within the wider field of environmental epidemiology, providing in-depth contextualised knowledge and understanding about space- and place-based interactions in relation to daily life and health (Bell et al., 2015; Milton et al., 2015). Similar approaches may reveal the ways in which people navigate their food environment to acquire and consume foods in LMICs.

A key opportunity is to incorporate food environment research within wider food security and livelihood research taking place in LMICs. There is also considerable scope to harmonize research agendas, concepts, methods and metrics between these fields that share the common goal of promoting healthy diets and optimal nutrition. A useful point of departure would be to complement methods and metrics from food security research with food environment mapping techniques to provide a deeper understanding of the causes and effects of food insecurity (Battersby, 2012). Food environment research might also be linked with food value chain research in order to emphasise the role of both formal and informal markets and actors in mediating the acquisition of foods to people.

Improving food environment methods and metrics will be critical in developing the evidence base for agriculture-nutrition linkages, as well as for designing agriculture policies and programs to improve nutrition (Herforth and Ahmed, 2015). Recent frameworks depicting the links between agriculture and nutrition have featured the food environment prominently (Food and Agriculture Organisation of The United Nations, 2016b; Global Panel on Agriculture and Food Systems for Nutrition, 2014; Kanter et al., 2015). As these and Fig. 2 show, food environment research is needed to contextualise changes in agriculture and food systems with regard to food acquisition patterns, diets and nutrition.

## 5. Conclusion

A new research paradigm is required in order to better account for the socio-ecological interactions that determine food acquisition patterns, diets, nutrition and health outcomes across the globe. The food environment definition, conceptual frameworks and critical perspectives presented in this paper seek to accelerate a robust and coherent global research agenda to inform action. There is an urgent need to apply and test these new concepts across diverse settings, especially in LMICs. It is our hope that the articulation of the external and personal food environment domains and dimensions may guide mixed-methods empirical research. Furthermore, methods and metrics from HICs will need to be developed and adapted to food environments in LMICs, taking into account the key challenges and opportunities presented above. Improving knowledge and understanding of food acquisition and consumption practices is vital in order to inform the design of targeted interventions and policies that are able to facilitate healthier food environments, improve food and nutrition security, and tackle malnutrition in all its forms.

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