Investigating food environments and drivers of food acquisition in low- and middle-income countries: The case of peri-urban Hyderabad, Telangana, India

Christopher John Turner

Thesis submitted in accordance with the requirements for the degree of

Doctor of Philosophy

of the

University of London

SEPTEMBER 2019

Department of Population Health

Faculty of Epidemiology and Population Health

LONDON SCHOOL OF HYGIENE & TROPICAL MEDICINE

Funded by the London School of Hygiene and Tropical Medicine, Faculty of Epidemiology and Population Health Studentship 2015, and the London Centre for Integrative Research on Agriculture and Health.

Research group affiliations: London Centre for Integrative Research on Agriculture and Health (LCIRAH), Innovative Methods and Metrics for Agriculture and Nutrition Actions (IMMANA), Andhra Pradesh Children and Parents Study (APCAPS).

I Christopher John Turner, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Abstract

This thesis presents a body of work that deepens our knowledge and understanding of food environments and drivers of food acquisition practices in transitioning low- and middle-income country (LMIC) settings. It includes critical contributions to food environment theory, a systematic review of evidence from LMICs, the development, application, and evaluation of a novel qualitative geographical information systems (Q-GIS) methodological approach, and a qualitative investigation of the food environment and drivers of food acquisition in peri-urban Hyderabad, India.

The first article presents a new food environment definition, a globally applicable conceptual framework for food environment research, and maps methodological approaches. Critical perspectives suggest how existing knowledge and evidence may be leveraged to accelerate food environment research in LMICs, and key challenges and opportunities are identified.

The second article is the first systematic review of food environment research from LMICs. The review reveals the rapidly emerging body of literature from LMICs and provides a synthesis of the evidence base testing for associations between dimensions of food environment exposure and dietary, nutrition and health outcomes.

The third article presents the development, application and evaluation of a novel Q-GIS approach that features participatory photo mapping and follow-up graphic- and photo-elicitation interviews (*n*=22) designed to investigate food environments from an emic perspective. Results include participant's perceptions and experiences of documenting their FE as well as empirical data on the utility and feasibility of this approach.

The fourth article presents findings from in-depth interviews (*n*=18) and the Q-GIS approach (*n*=22) investigating complex, multi-scalar, and multifaceted drivers of food acquisition in two transitioning peri-urban villages in Hyderabad. Key drivers of food acquisition included: 1) food prices; 2) vendor and product properties, including freshness and quality, and adulteration and contamination; and 3) a sense of community and trust related to known people.

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Acknowledgements

I would like to start by thanking my supervisor, Suneetha Kadiyala, for her continued support, guidance and wisdom over the past four years. It has been a privilege to be your PhD candidate and I am eternally grateful for the time that you have dedicated to both my academic and personal development.

I would also like to thank my co-supervisor, Sanjay Kinra, for his support of my research within the Andhra Pradesh Children and Parents Study. In addition, I would also like to thank Bharati Kulkarni for acting as host supervisor during my time spent at the National Institute of Nutrition in Hyderabad, India. I could not have wished for a more accommodating host.

I would also like to thank my field team coordinator, Santhi Bhogadi, and the entire field team, including Amaravathi Mora, Niharika Muddepaka, Prasad Undrajavarapu, Sailaja M, Sandeep Kumar Gyara, Subhash Masapeta, Dr Srivalli Addanki and Srinivas Goud Avuladas. I cannot thank you all enough for your tireless work ethic throughout data collection, transcription and translation.

Finally, I would like to thank my wife, Anna, my daughter, Flora, and my entire family for being a constant source of inspiration and strength. I could not have reached this stage without your endless love, support, understanding, and patience!

Table of abbreviations

ANH-FEWG	Agriculture, Nutrition, and Health - Food Environment Working Group
APCAPS	Andhra Pradesh Children and Parents Study
BMI	Body Mass Index
BP	Blood Pressure
DALYs	Disability Affected Life Years
F	Female
FGD	Focus Group Discussion
GIS	Geographical Information Systems
GPS	Global Positioning Systems
HIC	High Income Countries
IDI	In-Depth Interview
IMMANA	Innovative Methods and Metrics for Agriculture and Nutrition Actions
INFORMAS	International Network for Food and Obesity/non-communicable diseases Research, Monitoring and Action Support
LMIC	Low- and Middle-Income Countries
M	Male
NCDs	Non-Communicable Diseases
PPM	Participatory Photo Mapping
PRISMA-ScR	Preferred Reporting Items for Systematic Reviews and Meta-Analyses – Extension for Scoping Reviews
Q-GIS	Qualitative Geographical Information Systems
UNICEF	United Nations Children's Fund

Scope

This thesis presents a body of work that deepens our knowledge and understanding of food environments and drivers of food acquisition practices in transitioning low- and middle-income country (LMIC) settings. It includes critical contributions to food environment theory, a systematic review of existing evidence from LMICs, the development, application, and appraisal of an emerging novel methodological approach, and empirical evidence of drivers of food acquisition and consumption practices in peri-urban Telangana, India.

This thesis is written by publication, with four standalone articles that collectively constitute a cohesive whole, linked by short sections of supporting material and additional information (Table 1). As such, there may be some instances of repetition between the chapters, particularly background information, although this has been kept to a minimum where possible. Published articles are included in their typeset format, whilst unpublished manuscripts are included in word processing format.

Outline

The introductory chapter starts by providing an overview of the global burden of malnutrition, followed by regional trends. An overview of the food systems research agenda is then documented, including the increasing interest in food environments, and more specifically, the recent attention allocated to food environments in LMICs. The rationale, research gaps, objectives, and associated research questions are then provided, followed by a description of the study setting, including dietary patterns and public health nutrition challenges in India, and the Andhra Pradesh Children and Parents Study (APCAPS).

Chapter 2 contains the first published article, a critical perspectives and theoretical-based paper that presents a globally applicable conceptual framework for food environment research and further provides suggested implications for action in LMICs.

Chapter 3 features the second published article, a systematic scoping review of food environment literature from LMICs. This review includes studies characterising food environments, and those testing for associations between aspects of food environments and dietary, nutrition and health outcomes.

Chapter 4 presents the third article, a methodology-based paper that documents the development, application and evaluation of a participatory qualitative geographical information systems (Q-GIS) approach designed to investigate food environments and drivers of food acquisition in Telangana, India.

Chapter 5 consists of the fourth article, a qualitative investigation of the food environment and drivers of food acquisition practices from a transitional peri-urban setting in Telangana, India. Multiple methods include in-depth interviews and a Q-GIS approach, featuring participatory photo mapping and follow up graphic- and photo-elicitation interviews.

Finally, in chapter six I hold a critical discussion where I reflect upon my contributions to the wider literature and present prospects for the continued refinement of food environment research.

Table 1. Overview of thesis chapters and publication status.

Chapter	Status
Chapter 1: Background	Unpublished, for thesis only
Chapter 2: Publication 1 – Concepts and critical perspectives for food environment research: A global framework with implications for action in low- and middle-income countries	Published in the journal Global Food Security. Citation: Turner C, Aggarwal A, Walls H, Herforth A, Drewnowski A, Coates J, Kalamatianou S, Kadiyala, S. Concepts and critical perspectives for food environment research: A global framework with implications for action in low- and middle-income countries. Global Food Security. 2018;18:93-101; doi: https://doi.org/10.1016/j.gfs.2018.08.003.
Chapter 3: Publication 2 – Food environment research in low- and middle-income countries: A systematic scoping review	Published in the journal Advances in Nutrition. Citation: Turner, C. Kalamatianou, S. Drewnowski, A., Kulkarni, B., Kinra, S., Kadiyala, S. Food environment research in low- and middle-income countries: A systematic scoping review. Advances in Nutrition. 2019; doi: https://doi.org/10.1093/advances/nmz031.
Chapter 4: Publication 3	Manuscript format
Chapter 5: Publication 4	Manuscript format
Chapter 6: Discussion	Unpublished, for thesis only
Chapter 7: Conclusion	Unpublished, for thesis only

1. Background

1.1. Introduction

Malnutrition in all its forms is unacceptably high across all regions of the world (1). Recent estimates by the High Level Panel of Experts on Food Security and Nutrition indicate that one in three people are malnourished globally (2). Poor diets and malnutrition are the leading causes of mortality and morbidity, and collectively represent one of the greatest public health challenges of our time (3, 4). Multiple forms of malnutrition include undernutrition, overweight, obesity and diet-related non-communicable diseases (NCDs) (5).

Maternal and child malnutrition have important consequences for survival, incidence of acute and chronic diseases, healthy development, and the economic productivity of individuals and societies (3). The 2018 Global Nutrition Report documents the challenges of maternal and child malnutrition. Whilst slow progress has been made with decreases in the global prevalence of underweight (BMI<18.5kg/m^2) among women aged 20-49, from 11.6% in 2000, to 9.7% in 2016; the global prevalence of overweight and obesity (BMI ≥25kg/m^2) among women aged 18 and over has increased rapidly from 31.7% to 39.2% for the same period. Modest progress has been made with reductions in the global prevalence of stunting among children under five years of age from 198.4 million (32.6%) in 2000, to 150.8 million (22.2%) in 2017, whilst overweight among children under five years of age has increased from 30.1 million (4.9%) to 38.3 million (5.6%) for the same period (1).

Regional trends indicate the prevalence of underweight (BMI<18.5kg/m^2) in adult women has decreased in Africa and Asia in the decades since 1980, although it still remains higher than 10%, whilst the prevalence of overweight and obesity (BMI ≥25kg/m^2) has increased in all regions, cumulatively reaching more than 40% in Africa by 2008 (3, 6, 7). Stunting prevalence among children under five years of age is estimated to have reduced among almost all of the United Nations less developed regions between 2000 and 2018, from 38% to 30% in Africa, 38.2% to 22.7% in Asia, and 16.7% to 9% for Latin America and the Caribbean, with the exception of Oceania, which has seen an increase from 36.8% to 38.2%. Overweight among children under five years of age has increased in most regions for the same period, from 4% to 5.2% in Asia, 6.6% to 7.5% for Latin America and the Caribbean, and 4.7% to 9.1% in

Oceania, with Africa maintaining around 5% (8).

1.2.Food systems and food environment research

Multidisciplinary research into food systems has gained momentum over the last decade in response to the need to improve diets and end malnutrition in all its forms. The global food system is comprised of the processes, actors, and institutions involved in keeping the global population fed, from farm to flush, including the production, harvesting, transformation, distribution, marketing, consumption and disposal of food (9-12). The Global Panel on Agriculture and Food Systems for Nutrition categorise the food system into four macro-level domains: agricultural production, market and trade systems, food transformation and consumer demand, and consumer purchasing power (13). Together, these food system domains and the diverse actors and institutions within them create complex food environments. Food environments have been defined in various ways. Swinburn et al., provided one of the first definitions in 2013, referring to the "collective physical, economic, policy and socio-cultural surroundings, opportunities and conditions that influence people's food and beverage choices and nutritional status" (14: p.2). More recent publications, such as the 2017 High Level Panel of Experts on Food Security and Nutrition report have built upon this definition to include a food systems perspective, as is evident in the following example: "the physical, economic, political and socio-cultural context in which consumers engage with the food system to acquire, prepare and consume food." (2: p.2). Public health researchers, funding donors, and policymakers alike have become increasingly interested in the influence of the food environment on dietary, nutrition, and health outcomes (15). This is made evident by the recent publication of a number of high-profile policy briefs and reports that feature food environment concepts (2, 10, 11, 16-18), highlighting the potential of food environment research to identify points of leverage for policies and interventions targeting improved diets, nutrition, and health. The following excerpts from a selection of these publications provide pertinent examples:

> *"Food and nutrition policies should, at a minimum, be supportive of food environments in which all people can access a high-quality diet." - The Global Panel on Agriculture and Food Systems for Nutrition (17: p.5).*

"A food environment framework is helpful in understanding the different dimensions of actions that need to be taken within food systems, as it looks at the various entry points from an environmental perspective." - The United Nations System Standing Committee on Nutrition (18: p.5).

"Policies and programmes focused on the food environment have been implemented worldwide, including approaches aimed to: improve access to nutritious and healthy foods in food deserts; provide healthy options in public establishments; and promote healthier diets through regulations and standards, taxes, subsidies, trade policies, labelling and advertising." - The High Level Panel of Experts on Food Security and Nutrition (2: p.6).

Historically, food environment research has developed over the past two decades in high income countries (HICs) in response to the high prevalence of overweight, obesity, and diet-related NCDs in these settings. Several systematic reviews have documented the empirical evidence base from HICs. On the whole, collective consensus surrounding the influence of the food environment on dietary and health outcomes has yet to be established, with a number of reviews finding modest evidence amongst adults (19, 20) and children (21), whilst others have reported equivocal findings (22, 23).

Food environment research in low- and middle-income countries (LMICs) remains nascent at present (24). However, researchers from diverse disciplines with a shared interest in public health nutrition in LMICs have been mobilising quickly around the groundswell of interest generated by the increasing prevalence of the double burden of malnutrition in these settings and the 2030 Agenda for Sustainable Development (25). Targets to end hunger (Target 2.1) and all forms of malnutrition (Target 2.2), and to reduce mortality from non-communicable diseases such as diabetes and cardiovascular disease (Target 3.4) have been particularly influential in catalysing interest in food environments and drivers of food acquisition in LMICs.

Food environments in LMICs are complex, dynamic and rapidly changing (13). The High Level Panel of Experts on Food Security and Nutrition identify five main categories of drivers of food system changes that influence diets and nutrition, including: biophysical and environmental; innovation, technology and infrastructure; political and economic; socio-cultural; and

demographic drivers (2). Food systems are generally considered to be converging across the world as processes of globalization, foreign investment, and trade create the deeper integration of markets resulting in the greater availability and diversity of foods in many LMIC settings (26-28). However, fundamental differences exist between food environments and food acquisiton practices in HICs and LMICs. A prime example is the dominance of formalised markets in HICs, whilst LMIC food environments feature both formal and informal markets. Another example is the ways in which consumers acquire food, with the vast majority of consumers in HICs purchasing food from formal market-based vendors, whilst many consumers in LMICs acquire foods on credit, through own production, or as payment for labor, in additon to purchases from formal and informal markets.

As of 2015, few publications had addressed the development and application of food environment research in LMICs. Authors such as Battersby and Crush provided intial insights in their discussion of the potential merits and challenges of applying a food deserts perspective in South Africa, with a view to providing a new lens through which to tackle urban food security (29, 30). However, beyond this pioneering work, there remained a need to develop, adapt, and contextualise key concepts, methods and metrics to the dynamic and complex food environments and public health nutrition challenges at hand in LMICs.

At this point it is important to note that whilst food environment research is in its infancy in LMICs, a wealth of literature on food systems and public health nutrition has been published in these settings, although there has been a historical tendency for research and institutions to be constrained by disciplinary silos (31). Recent years have seen a shift towards more integrated and interdisciplinary research, particularly at the nexus of agriculture, food systems, nutrition and health (32, 33).

Food environment research has the potential to address the black box within food systems research that exists between the food supply and consumer demand, by addressing how and why food environments mediate food acquisition and consumption. However, the kinds of in-depth situated knowledge and understanding about food environments and drivers of food acquisition in LMICs remains sparse. Knowledge and understanding about food environments and drivers of food acquisition and consumption will be key to the successful design and implementation of targeted public health policies to improve food environments so that

people have better opportunities to consume healthy diets (2, 13).

1.3.Rationale

The overarching goals of my research are to: a) contribute to the development of a globally applicable food environment definition and conceptual framework; b) conduct a systematic review and synthesis of the emerging body of food environment literature from LMICs; c) develop, implement and evaluate an emerging innovative participatory qualitative geographical information systems (Q-GIS) approach to investigate food environments and drivers of food acquisition; and d) to provide in-depth knowledge and understanding of the food environment and drivers of food acquisition in a transitional peri-urban setting in Telangana, India.

1.4.Research gaps, aims, and questions

My PhD research seeks to address four key research gaps, outlined below, each with a specific research aim and question designed to guide my critical contributions to the literature.

Theoretical-based gap

Food environment research spans well over a decade, with the majority of research articles published from HIC settings. Studies have predominantly focused on either the empirics of measuring and analysing food environments in relation to dietary and nutrition outcomes, or debates around measurement methods and tools (34, 35). A number of publications have identified the limited body of literature addressing theoretical aspects of food environment research and the determinants of food acquisition and consumption (36-39), whilst others have called for improved concepts and the alignment of theoretical perspectives with research methods and metrics to guide empirical research (38, 40). The omission of theoretical perspectives in many empirical food environment publications is striking.

Seminal theoretical contributions include the notion of the ‘community’ and ‘consumer’ food environments by Glanz et al. (41) in 2007, the ecological model presented by Story et al. (42) in 2008, and the conceptual framework by Swinburn et al. (14) in 2013 that identifies physical, economic, policy and socio-cultural aspects of food environments. Critically, there remains a

need to define what a food environment is, what key dimensions it includes, and how it might be conceptualised in relation to the wider food system. This research gap is particularly problematic when considering recent efforts to implement food environment research in LMIC settings, many of which are fundamentally different from HICs in terms of their food systems, food environments, and public health nutrition challenges. Whilst it is important to recognise the need to contextualise food environment research across diverse settings (43), a globally applicable framework is needed to guide research and provide a platform of consensus around how food environments are defined and conceptualised.

> ***Aim 1:*** To develop a food environment definition and globally applicable conceptual framework in collaboration with food environment experts.
>
> ***Research question 1:*** How can food environments be defined and conceptualised in a way that is globally applicable, how can existing knowledge and evidence from HICs be leveraged to accelerate food environment research in LMICs, and what are the main challenges and opportunities of doing so?

Literature review-based gap

Food environment research is gaining momentum in LMICs as researchers and policymakers seek to tackle the double burden of malnutrition. However, in the absence of a systematic review of the literature from these settings there is a critical need to synthesise the emerging body of evidence. This includes studies characterizing food environments and also those analysing associations between food environments and diets, nutrition and health outcomes. A comprehensive review of the rapidly evolving and diverse food environment literature from LMICs is needed to identify existing research gaps and inform the future development of the research agenda.

> ***Aim 2:*** To conduct a systematic scoping review and synthesis of the existing food environment literature from LMICs to date.
>
> ***Research question 2:*** Where has food environment research been undertaken in LMICs, how have food environments been conceptualized, which key domains and dimensions have been studied, which study designs, methods and measures have

been implemented, and what are the key findings regarding associations between food environment exposure and dietary, nutrition, and health outcomes?

Methodological-based gap

Food environment research to date has typically relied on quantitative, top-down approaches. Several publications have documented the various methods and metrics used to measure food environment exposure and dietary, nutrition and health outcomes in HICs. The majority of studies from these settings have utilised GIS mapping and market basket surveys to measure the local availability of food vendors, often in relation to dietary and nutrition indicators at the neighbourhood scale. Common limitations include the lack of robust standardised exposure measurement methods and metrics, and the diverse array of indicators used to assess dietary, nutrition, and health outcomes (15, 19-21, 23, 35, 38, 44, 45).

Recent calls have been made to investigate food environments and the determinants of diets from the individual emic perspective, in order to situate people within their environment (36, 38, 46) and account for the role of space and place in food acquisition and consumption (47). Consistent with this philosophy, authors have identified the need to address people's perceptions of their food environment to understand food acquisition and consumption patterns (19, 38, 39, 46).

Qualitative and mixed method approaches may provide more nuanced and comprehensive understanding about how people perceive and experience their environment in different ways, and account for the multiple contexts to which people are exposed in their everyday life (46, 48). A small number of pioneering studies have employed qualitative and mixed methods to describe and investigate food environments and how they drive food acquisition in LMICs. For example, studies in India have addressed community (24, 49), school (50-52), and household levels (53). Focus group discussions, in-depth interviews, and pile sorting exercises have been commonly used among these studies. Overall, within the published food environment literature to date, the kinds of qualitative research required to capture in-depth, emic perspectives and experiences of food acquisition and consumption practices as they occur as part of daily life remain scarce. Inspiration may be drawn here from wider

participatory public health research health grounded in geographical and sociological traditions. Participatory research methods have an established history across a broad range of research settings and topics of interest. Participatory approaches that enable consumers to collect primary data about their food acquisition practices as part of daily life and share their perceptions, tacit knowledge and understanding of food environments may be particularly useful in LMIC settings, where: 1) existing quantitative data and validated tools are scarce; 2) food environments are highly dynamic, featuring large variation throughout the diurnal cycle; 3) many vendors are difficult to survey due to their informal, un-registered, and often highly mobile nature; and 4) many consumers acquire and consume foods from diverse market and non-market-based sources as part of daily life.

> ***Aim 3:*** *To develop, implement and evaluate a novel methodological approach designed to capture people's emic interactions with their food environment in an LMIC setting.*

> ***Research question 3:*** *How can a qualitative geographical information systems approach and participatory visual methods be used to investigate the food environment and drivers of food acquisition in LMICs, and what are the strengths and limitations of a Q-GIS approach?*

Empirical-based gap

Whilst a growing body of literature is starting to emerge, few studies to date have investigated food environments and drivers of food choice in India despite mounting evidence of transitioning diets, the double burden of malnutrition, and the increasing prevalence of diet related NCDs (53-56). A small handful of recent studies provide a crucial point of departure for food environment research and drivers of food acquisition in both rural and urban contexts in India (24, 50-52, 57, 58). Findings from these ground-breaking studies allude to the complex and dynamic nature of food environments across India, and further research is required to understand rapidly evolving food environments and how they drive food acquisition across community, household and individual levels. No studies have explicitly focused on food environments in transitioning peri-urban settings in India to date. Given the rapid rates of urban development and expansion, processes of urbanisation and the transition towards more urban ways of life across many settings in India and other LMIC settings, there

is a need to gather empirical evidence from a diverse range of settings to better understand how people interact with their food environment to acquire and consume foods as part of daily life.

Aim 4: *To investigate the food environment and drivers of food acquisition practices in a peri-urban Indian setting, to understand perceptions and experiences of change in the food environment and food acquisition practices over the past decade, and to explore intra-household dynamics in relation to food acquisition, preparation and consumption practices.*

Research question 4**:** *How do people interact with their food environment to acquire foods as part of daily life in peri-urban villages in Telangana, India, what are the key drivers of food acquisition and consumption practices in this setting, what are people's perceptions and experiences of change regarding the food environment and food acquisition and consumption practices over the past decade, and are there any intra-household dynamics in relation to food acquisition and consumption?*

1.5.Study setting

The primary data collection for my research is set in a rapidly developing peri-urban setting on the outskirts of Hyderabad, Telangana, India. In the sections that follow I will provide an overview of dietary patterns and public health nutrition challenges in India, and introduce the Andhra Pradesh Children and Parents Study (APCAPS) to set the scene for my primary data collection.

Dietary patterns and public health nutrition challenges in India

Dietary patterns in India typically feature large regional variations, but can broadly be categorised into wheat-based patterns in the north and north-west, and rice-based patterns in the south (53, 59, 60). Typical Indian meals feature a staple grain accompanied with seasonal vegetables, and occasionally a pulse or lentil based dish (53).

Dietary patterns in India are transitioning, characterised most broadly by shifts away from cereals towards animal source foods and other products, and increases in the intake of calories, fat, sugar and salt (61-64). A recent national-level assessment of dietary trends in India between 1993 and 2012 by Tak et al. (59) found household diets to have diversified slowly but consistently throughout this period, with rural diets becoming more diverse than those in urban areas by 2011-2012. Evidence from this study suggests Indian diets have shifted away from cereals to higher levels of consumption of milk and edible oil, whilst progress on fruits, vegetables, meat and eggs has remained slow, especially in rural areas, and has not compensated for insufficient intakes of micronutrient-rich foods.

Malnutrition and dietary risks are estimated to be the leading risk factors contributing to disability-adjusted life-years (DALYs) in India (65). Trends over the past decade from the Global Burden of Disease study reveal the evolving character of the public health nutrition challenges at hand in India. Malnutrition has prevailed as the most important risk factor to DALYs amongst all ages in India between 2007 and 2017. Concurrently, dietary risks have risen from fourth to the second most prominent risk factor during these years, with a 34.9% increase in contribution to DALYs (65). The most recent estimates from the Global Burden of Disease study also attest to the public health nutrition challenges posed by the double burden

of malnutrition in India, with an estimated 1520 DALYs per 100 000 population lost in 2017 due to iron, zinc and vitamin A deficiencies, whilst 2703 DALYs per 100 000 population were lost due to high low-density lipoprotein cholesterol or BMI (66).

In summary, shifting diets, reduced levels of physical activity - especially among urban populations, and the rise of the double burden of malnutrition have led to suggestions over the past two decades that India, like many other LMICs (67), is experiencing the nutrition transition (62, 64, 68-71). However, recent work has cautioned the need to acknowledge the context specific nature of transitioning diets in India due to lacto-ovo-vegetarian diets and the limited consumption of meat driven by cultural preferences (60) and economic affordability (59).

Recent publications have outlined rural-urban distinctions in dietary patterns and NCD risks in India, with persistent energy and nutrient deficiencies identified within poorer, rural populations, and increasingly prevalent non-communicable diseases amongst urban dwellers (60). However, Marshall and Randhawa (72) note that there is little account of peri-urban areas within the literature to date as food consumption and nutrition data is divided into binary distinctions between rural and urban categories, neglecting the context specific challenges of transitional peri-urban zones.

The Andhra Pradesh Children and Parents Study (APCAPS)

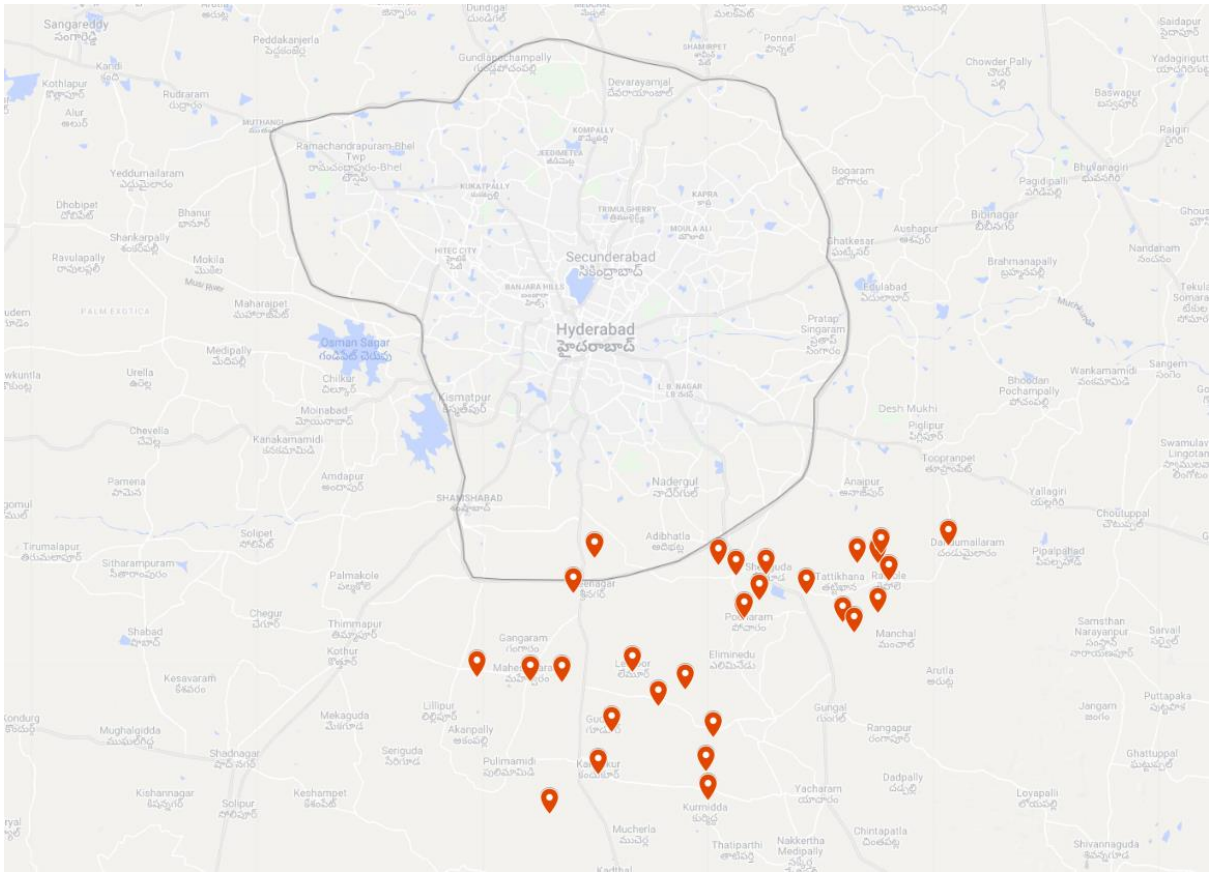
This research is framed within the APCAPS, located across 29 peri-urban sites on the outskirts of Hyderabad in the Ranga Reddy district of Telangana state (annexed from the north-western part of Andhra Pradesh state in 2014). The APCAPS was originally established in 1987 as a prospective intergenerational cohort designed to study the long-term effects of early-life undernutrition on risk of cardiovascular disease. Its aims were subsequently expanded to include trans-generational influences of other environmental and genetic factors on chronic diseases (73). In 2003-05, households from the original trial were re-traced and surveyed. Families with at least one child born during the trial period and still alive in 2003-05 constitute the prospective cohort (1815 families, 2601 index children). During 2011-13, all households (N=20,551) were surveyed and socio-demographic data on residents was collected (N=84,055).

The APCAPS study sites are located south of Hyderabad (Figure 1). A decade ago these places were considered rural villages. However, with the progressive urban sprawl of Hyderabad growing ever closer these places are now situated at the peri-urban fringe of the city and undergoing rapid developments; populations are growing, livelihoods are transitioning, the built environment is changing, land prices are increasing, and more people are using motorised transport (74). Nutritional and epidemiological transitions are also underway in this setting. Evidence from APCAPS has revealed a high prevalence of chronic diseases and risk factors amongst adults aged 30-84 years, including hypertension (BP > 140/90 mmHg: men 20%, women 13%); overweight (BMI ≥ 25 kg/m2: men 18%, women 24%); underweight (BMI < 18.5 kg/m2: men 31%, women 20%) (73).

Formative qualitative research suggests that the food environment is changing rapidly in this setting, with an increased availability of fast food outlets and more people acquiring and consuming foods from outside the home (57). However, perceptions of change regarding the availability and accessibility of various foods have been found to divide opinion within the community, and further research is required to understand the complex and multifaceted ways in which people acquire foods as part of daily life in this dynamic setting.

The APCAPS built environment was profiled in 2016 using a survey tool designed to document and survey non-residential places across the 28 APCAPS sites related to 1) food, tobacco and alcohol, 2) physical activity, 3) health, 4) education, and 5) advertising, transport and walkability. Data from the built environment survey is used in manuscripts three and four to describe the APCAPS built and food environment.

Figure 1) A map of the 29 APCAPS sites located in the peri-urban fringe of Hyderabad, India.



1.6.References: Introduction

1. Development Initiatives. Global Nutrition Report: Shining a light to spur action on nutrition. Bristol, UK: Development Initiatives, 2018.

2. High Level Panel of Experts on Food Security and Nutrition. Nutrition and food systems. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security. Rome: 2017.

3. Black RE, Victora CG, Walker SP, Bhutta ZA, Christian P, de Onis M, Ezzati M, Grantham-McGregor S, Katz J, Martorell R, et al. Maternal and child undernutrition and overweight in low-income and middle-income countries. Lancet. 2013;382(9890):427-51.

4. Development Initiatives. Global Nutrition Report 2017: Nourishing the SDGs. Bristol, UK: Development Initiatives, 2017.

5. World Health Organization – WHO. The double burden of malnutrition: Policy brief. Geneva: 2017.

6. Stevens GA, Singh GM, Lu Y, Danaei G, Lin JK, Finucane MM, Bahalim AN, McIntire RK, Gutierrez HR, Cowan M, et al. National, regional, and global trends in adult overweight and obesity prevalences. Popul Health Metr. 2012;10(1):22.

7. Finucane MM, Stevens GA, Cowan MJ, Danaei G, Lin JK, Paciorek CJ, Singh GM, Gutierrez HR, Lu Y, Bahalim AN, et al. National, regional, and global trends in body-mass index since 1980: systematic analysis of health examination surveys and epidemiological studies with 960 country-years and 9.1 million participants. Lancet. 2011;377(9765):557-67.

8. United Nations Childrens Fund - UNICEF, World Health Organisation - WHO, The World Bank Group. Levels and trends in child malnutrition. UNICEF, WHO, The World Bank Group, 2019.

9. Food and Agriculture Organisation of the United Nations. Influencing food environments for healthy diets. Rome: 2016a.

10. Global Panel on Agriculture and Food Systems for Nutrition – Global Panel. Food systems and diets: Facing the challenges of the 21st century. London, UK: Global Panel on Agriculture and Food Systems for Nutrition, 2016.

11. United Nations System Standing Committee on Nutrition – UNSCN. Investments for Healthy Food Systems, Implementing the Framework for Action of the Second International Conference on Nutrition, Executive Summary. United Nations System Standing Committee on Nutrition, 2016 September 2016. Report No.

12. Dangour AD, Mace G, Shankar B. Food systems, nutrition, health and the environment. The lancet Planetary Health. 2017;1(1):e8-e9.

13. Global Panel on Agriculture and Food Systems for Nutrition – Global Panel. Improving nutrition through enhanced food environments. Policy Brief London, UK: Global Panel on Agriculture and Food Systems for Nutrition, 2017.

14. Swinburn B, Sacks G, Vandevijvere S, Kumanyika S, Lobstein T, Neal B, Barquera S, Friel S, Hawkes C, Kelly B, et al. INFORMAS (International Network for Food and Obesity/non-communicable diseases Research, Monitoring and Action Support): overview and key principles. Obesity Reviews. 2013;14:1-12.

15. Lytle LA, Sokol RL. Measures of the food environment: A systematic review of the field, 2007-2015. Health & Place. 2017;44:18-34.

16. Global Panel on Agriculture and Food Systems for Nutrition – Global Panel. How can agriculture and food system policies improve nutrition? Technical Brief. London, UK: Global Panel on Agriculture and Food Systems for Nutrition, 2014.

17. Global Panel on Agriculture and Food Systems for Nutrition. Improving nutrition through enhanced food environments. Policy Brief London, UK: Global Panel on Agriculture and Food Systems for Nutrition, 2017.

18. United Nations System Standing Committee on Nutrition – UNSCN. Food environments: Where people meet the food system. 2019.

19. Caspi CE, Sorensen G, Subramanian SV, Kawachi I. The local food environment and diet: A systematic review. Health & Place. 2012;18(5):1172-87.

20. Gamba RJ, Schuchter J, Rutt C, Seto EY. Measuring the food environment and its effects on obesity in the United States: a systematic review of methods and results. J Community Health. 2015;40(3):464-75.

21. Engler-Stringer R, Le H, Gerrard A, Muhajarine N. The community and consumer food environment and children's diet: a systematic review. BMC Public Health. 2014;14:522.

22. Cetateanu A, Jones A. How can GPS technology help us better understand exposure to the food environment? A systematic review. SSM Popul Health. 2016;2:196-205.

23. Gustafson A, Hankins S, Jilcott S. Measures of the consumer food store environment: a systematic review of the evidence 2000-2011. J Community Health. 2012;37(4):897-911.

24. Gupta V, Downs SM, Ghosh-Jerath S, Lock K, Singh A. Unhealthy Fat in Street and Snack Foods in Low-Socioeconomic Settings in India: A Case Study of the Food Environments of Rural Villages and an Urban Slum. J Nutr Educ Behav. 2016;48(4):269-79 e1.

25. United Nations General Assembly – UNGA. Transforming our world: the 2030 Agenda for Sustainable Development. GA Res. 70/1. UN GAOR, 70th Session, Suppl. 49, U.N. Doc. A/RES/70/1. United Nations General Assembly, 2015.

26. De Haen H, Stamoulis K, Shetty P, Pingali P. The World Food Economy in the Twenty-first Century: Challenges for International Co-operation. Development Review Policy. 2003;21(5-6):683-96.

27. Kennedy G, Nantel G, Shetty P, Food and Agriculture Organization of the United Nations. Globalization of food systems in developing countries: impact on food security and nutrition. FAO Food Nutr Pap. 2004;83:1-300.

28. Reardon T, Timmer CP, Barrett CB, Berdegue J. The rise of supermarkets in Africa, Asia, and Latin America. American Journal of Agricultural Economics. 2003;85(5):1140-6.

29. Battersby J. Beyond the Food Desert: Finding Ways to Speak About Urban Food Security in South Africa. Geografiska Annaler Series B-Human Geography. 2012;94b(2):141-59.

30. Battersby J, Crush J. Africa's Urban Food Deserts. Urban Forum. 2014;25(2):143-51.

31. Kanter R, Augusto GF, Walls HL, Cuevas S, Flores-Martinez A, Morgan EH, Tak M, Picchioni F. 4th Annual Conference of the Leverhulme Centre for Integrative Research on Agriculture and Health (LCIRAH), Agri-food policy and governance for nutrition and health, London, 3-4 June 2014. Food Security. 2014;6(5):747-53.

32. Gillespie S, van der Bold M. Agriculture, Food Systems, and Nutrition: Meeting the Challenge. Global Challenges. 2017;1(3).

33. Picchioni F, Aurino E, Aleksandrowicz L, Bruce M, Chesterman S, Dominguez-Salas P, Gersten Z, Kalamatianou S, Turner C, Yates J. Roads to interdisciplinarity: working at the nexus among food systems, nutrition and health. Food Security. 2017;9(1).

34. Cummins S. Commentary: Investigating neighbourhood effects on health - Avoiding the 'local trap'. International Journal of Epidemiology. 2007;36(2):355-7.

35. Lucan S. Concerning limitations of food-environment research: a narrative review and commentary framed around obesity and diet-related diseases in youth. Journal of the Academy of Nutrition and Dietetics. 2015;115(2):205-12.

36. Brug J, Kremers SP, van Lenthe F, Ball K, Crawford D. Environmental determinants of healthy eating: in need of theory and evidence. Proceedings of the Nutrition Society. 2008;67(3):307-16.

37. Giskes K, Kamphuis CB, van Lenthe FJ, Kremers S, Droomers M, Brug J. A systematic review of associations between environmental factors, energy and fat intakes among adults: is there evidence for environments that encourage obesogenic dietary intakes? Public Health Nutr. 2007;10(10):1005-17.

38. Penney TL, Almiron-Roig E, Shearer C, McIsaac JL, Kirk SFL. Modifying the food environment for childhood obesity prevention: challenges and opportunities. Proceedings of the Nutrition Society. 2014;73(2):226-36.

39. Penney TL, Brown HE, Maguire ER, Kuhn I, Monsivais P. Local food environment interventions to improve healthy food choice in adults: a systematic review and realist synthesis protocol. BMJ Open. 2015;5(4):e007161.

40. Cummins S. Neighbourhood food environment and diet:Time for improved conceptual models? Preventive Medicine. 2007;44(3):196-7.

41. Glanz K, Sallis JF, Saelens BE, Frank LD. Nutrition Environment Measures Survey in stores (NEMS-S): development and evaluation. Am J Prev Med. 2007;32(4):282-9.

42. Story M, Kaphingst KM, Robinson-O'Brien R, Glanz K. Creating healthy food and eating environments: Policy and environmental approaches. Annual Review of Public Health. 2008;29:253-+.

43. Pomerleau J, Knai C, Foster C, Rutter H, Darmon N, Derflerova Brazdova Z, Hadziomeragic AF, Pekcan G, Pudule I, Robertson A, et al. Measuring the food and built environments in urban centres: reliability and validity of the EURO-PREVOB Community Questionnaire. Public Health. 2013;127(3):259-67.

44. Kirkpatrick SI, Reedy J, Butler EN, Dodd KW, Subar AF, Thompson FE, McKinnon RA. Dietary assessment in food environment research: a systematic review. Am J Prev Med. 2014;46(1):94-102.

45. Lytle LA. Measuring the food environment: state of the science. Am J Prev Med. 2009;36(4 Suppl):S134-44.

46. Chen X, Kwan MP. Contextual Uncertainties, Human Mobility, and Perceived Food Environment: The Uncertain Geographic Context Problem in Food Access Research. Am J Public Health. 2015;105(9):1734-7.

47. Pritchard B, Mackay H, Turner C. Special issue introduction: geographical perspectives on food and nutrition insecurity in the global South. Geographical Research. 2017;55(2):127-30.

48. Kwan MP. The Limits of the Neighborhood Effect: Contextual Uncertainties in Geographic, Environmental Health, and Social Science Research. Annals of the American Association of Geographers. 2018;108(6):1482-90.

49. Finzer LE, Ajay VS, Ali MK, Shivashankar R, Goenka S, Sharma P, Pillai DS, Khandelwal S, Tandon N, Reddy KS, et al. Fruit and Vegetable Purchasing Patterns and Preferences in South Delhi. Ecology of Food and Nutrition. 2013;52(1):1-20.

50. Maxfield A, Patil S, Cunningham SA. Globalization and Food Prestige among Indian Adolescents. Ecology of Food and Nutrition. 2016;55(4):341-64.

51. Rathi N, Riddell L, Worsley A. What influences urban Indian secondary school students' food consumption? - A qualitative study. Appetite. 2016;105:790-7.

52. Rathi N, Riddell L, Worsley A. Food environment and policies in private schools in Kolkata, India. Health Promotion International. 2017;32(2):340-50.

53. Bailey C, Garg V, Kapoor D, Wasser H, Prabhakaran D, Jaacks LM. Food Choice Drivers in the Context of the Nutrition Transition in Delhi, India. Journal of Nutrition Education and Behavior. 2018;50(7):675-86.

54. Ramachandran P, Kalaivani K. Nutrition Transition in India: Challenges in Achieving Global Targets. Proceedings of the Indian National Science Academy. 2018;84(4):pp. 821-33.

55. Ravishankar AK. Is India shouldering a double burden of malnutrition? Journal of Health Management. 2012;14(3).

56. Shetty P. Public health: India's diabetes time bomb. Nature. 2012;485(7398):S14-6.

57. Hayter AK, Jeffery R, Sharma C, Prost A, Kinra S. Community perceptions of health and chronic disease in South Indian rural transitional communities: a qualitative study. Glob Health Action. 2015;8:25946.

58. Patel O, Shahulhameed S, Shivashankar R, Tayyab M, Rahman A, Prabhakaran D, Tandon N, Jaacks LM. Association between full service and fast food restaurant density, dietary intake and overweight/obesity among adults in Delhi, India. Bmc Public Health. 2017;18.

59. Tak M, Shankar B, Kadiyala S. Dietary Transition in India: Temporal and Regional Trends, 1993 to 2012. Food and Nutrition Bulletin. 2019;40(2):254-70.

60. Joy EJ, Green R, Agrawal S, Aleksandrowicz L, Bowen L, Kinra S, Macdiarmid JI, Haines A, Dangour AD. Dietary patterns and non-communicable disease risk in Indian adults: secondary analysis of Indian Migration Study data. Public Health Nutr. 2017;20(11):1963-72.

61. Law C. Unintended consequence of trade on regional dietary patterns in rural India. World Development. 2019;113:277-93.

62. Misra A, Singhal N, Sivakumar B, Bhagat N, Jaiswal A, Khurana L. Nutrition transition in India: Secular trends in dietary intake and their relationship to diet-related non-communicable diseases. Journal of Diabetes. 2011;3(4):278-92.

63. Rao CHH. Declining demand for foodgrains in rural India - Causes and implications. Economic and Political Weekly. 2000;35(4):201-6.

64. Shetty PS. Nutrition transition in India. Public Health Nutrition. 2002;5(1a):175-82.

65. Institute for Health Metrics and Evaluation - IHME. India profile Seattle, WA: IHME, University of Washington; 2018 [cited 2019 30/08/19]. Available from: http://www.healthdata.org/India.

66. Institute for Health Metrics and Evaluation - IHME. Global Burden of Disease Database 2019 [cited 2019 30/08/19]. Available from: http://ghdx.healthdata.org/gbd-results-tool?params=gbd-api-2017-permalink/5da9be71c21eb5c160fe86ffe1938e54.

67. Popkin BM, Adair LS, Ng SW. Global nutrition transition and the pandemic of obesity in developing countries. Nutr Rev. 2012;70(1):3-21.

68. Griffiths P, Bentley ME. The dual burden of the nutrition transition for women in India: A comparison of the rural poor and the urban elite in Andhra Pradesh. Faseb Journal. 2001;15(5):A732-A.

69. Griffiths PL, Bentley ME. The nutrition transition is underway in India. Journal of Nutrition. 2001;131(10):2692-700.

70. Shaikh NI, Frediani JK, Ramakrishnan U, Patil SS, Yount KM, Martorell R, Narayan KMV, Cunningham SA. Development and evaluation of a Nutrition Transition-FFQ for adolescents in South India. Public Health Nutrition. 2017;20(7):1162-72.

71. Pingali P, Aiyar A, Abraham M, Rahman A. Diet Diversity and the Declining Importance of Staple Grains. Transforming Food Systems for a Rising India. Cham: Springer International Publishing; 2019. p. 73-91.

72. Marshall F, Randhawa P. India's peri-urban frontier: rural-urban transformations and food security. London: IIED, International Institute for Environment and Development, 2017.

73. Kinra S, Radha Krishna KV, Kuper H, Rameshwar Sarma KV, Prabhakaran P, Gupta V, Walia GK, Bhogadi S, Kulkarni B, Kumar A, et al. Cohort profile: Andhra Pradesh Children and Parents Study (APCAPS). Int J Epidemiol. 2014;43(5):1417-24.

74. Andhra Pradesh Children and Parents Study. Study site 2019 [cited 2019 31/08/19]. Available from: https://apcaps.lshtm.ac.uk/study-site/.

2. Publication 1: Concepts and critical perspectives for food environment research: A global framework with implications for action in low- and middle-income countries

2.1. Preamble to publication 1: Motivation for the article

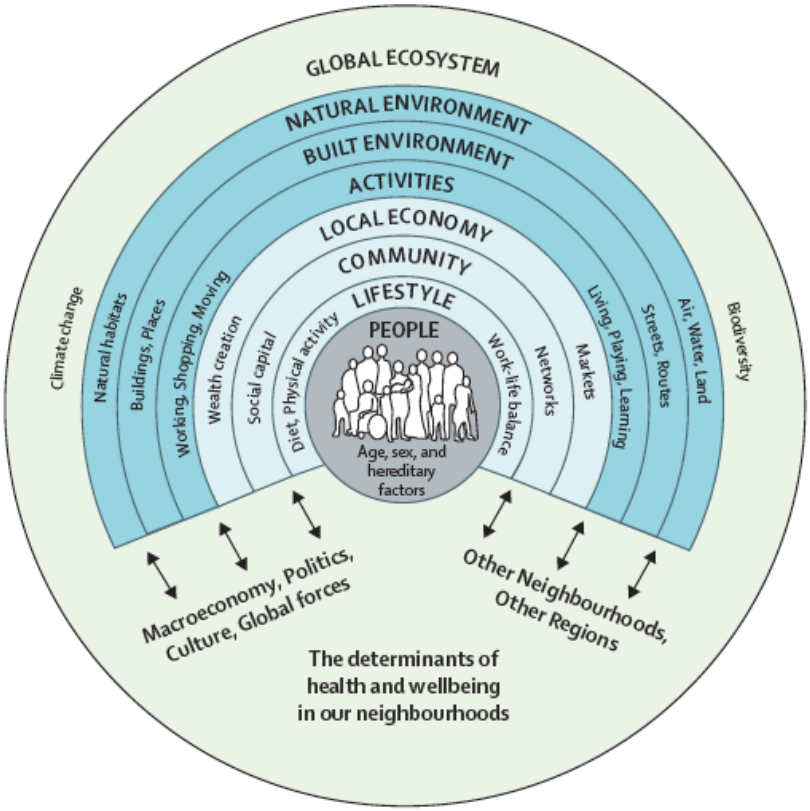
Publication one addresses the first research question:

1. *How can food environments be defined and conceptualised in a way that is globally applicable, how can existing knowledge and evidence from HICs be leveraged to accelerate food environment research in LMICs, and what are the main challenges and opportunities of doing so?*

Theoretical and conceptual research has received little attention within the food environment literature to date. A number of publications have acknowledged the need to develop theoretical concepts and frameworks (1-5). The development of a globally applicable framework may align theoretical perspectives with methods and metrics and harmonize empirical research.

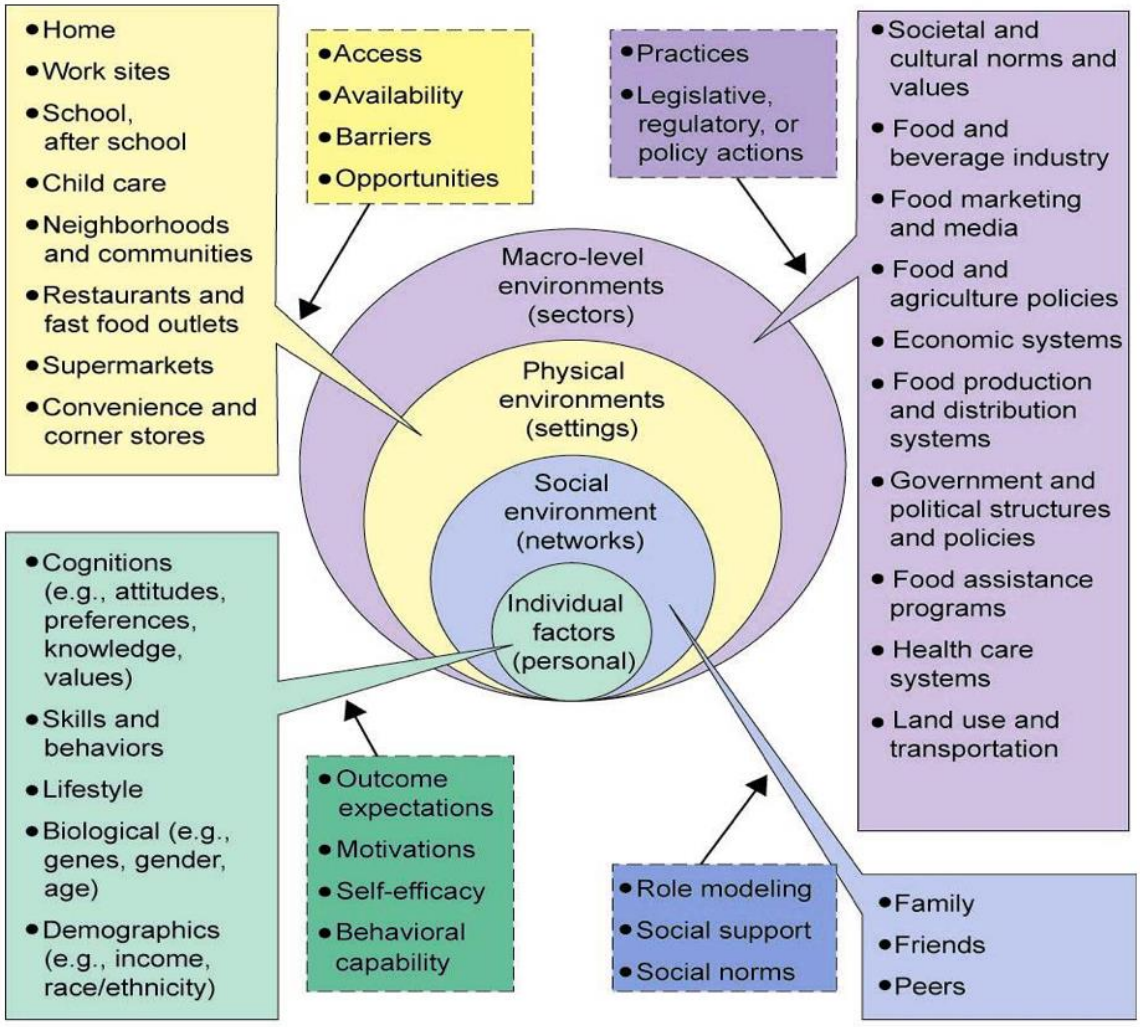
In the broadest sense, food environment research can be considered a specialised research strand within wider research investigating the influence of the built environment on health. Built environment research draws from socio-ecological model and the recognition of multi-scalar determinants of health and well-being within neighbourhoods (6). The conceptual framework by Rao et al. (6) outlines a series of multi-scalar determinants of health and well-being in neighbourhoods, from the individual scale up to the global ecosystem (Figure 2).

Figure 2. The determinants of health and well-being in neighbourhoods (6).



Adopting a similar approach, Story et al. (7) propose an ecological model, depicting the multiple influences on what people eat, such as individual factors, social environments, physical environments, and macro-level environments (Figure 3).

Figure 3. An ecological model depicting the multiple influences on what people eat (7).

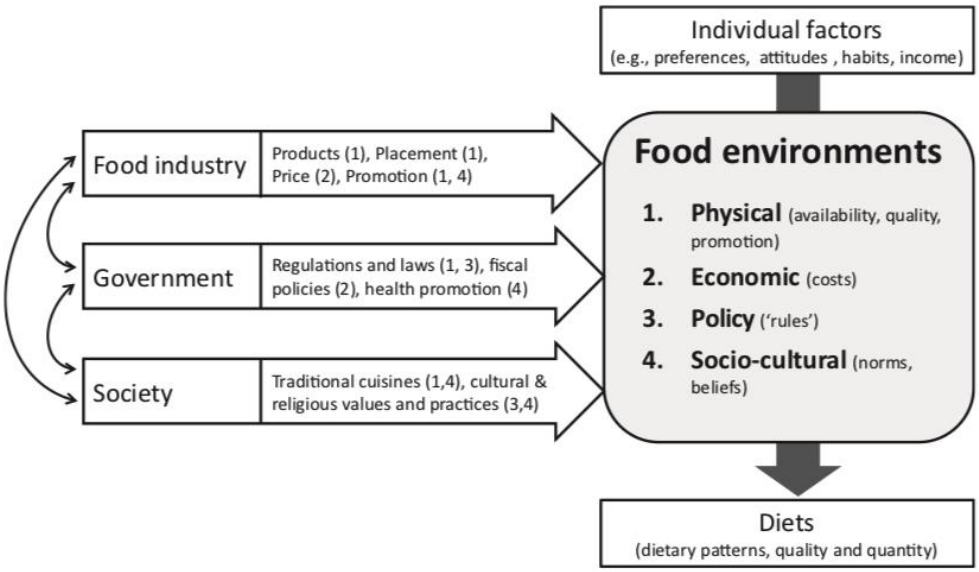


Although socio-ecological theory dictates that inter-related personal and environmental factors shape health outcomes, in practice, food environment research has tended to focus almost exclusively on the environmental side of this equation. Influential conceptual work by Glanz et al. (8) in 2007 described the food environment at the local neighbourhood scale, termed the 'community food environment', and the in-store scale, referred to as the 'consumer food environment'. This relatively early dichotomous conceptualization of the food environment has guided much of the empirical research that has followed seeking to

quantify the various types of food vendors available in local neighbourhoods, and the food products found within them that people may acquire and consume.

More recent contributions to the conceptual literature have sought to distil the key components of food environments considered to shape diets. For example, Swinburn et al. (9) define 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" (9: p2). Accordingly, the conceptual framework by Swinburn et al. (9) depicts physical, economic, policy and socio-cultural aspects of food environments, and further outlines a series of macro level influences such as the food industry, governments and society. Individual level factors are depicted as separate, ancillary influences (Figure 4).

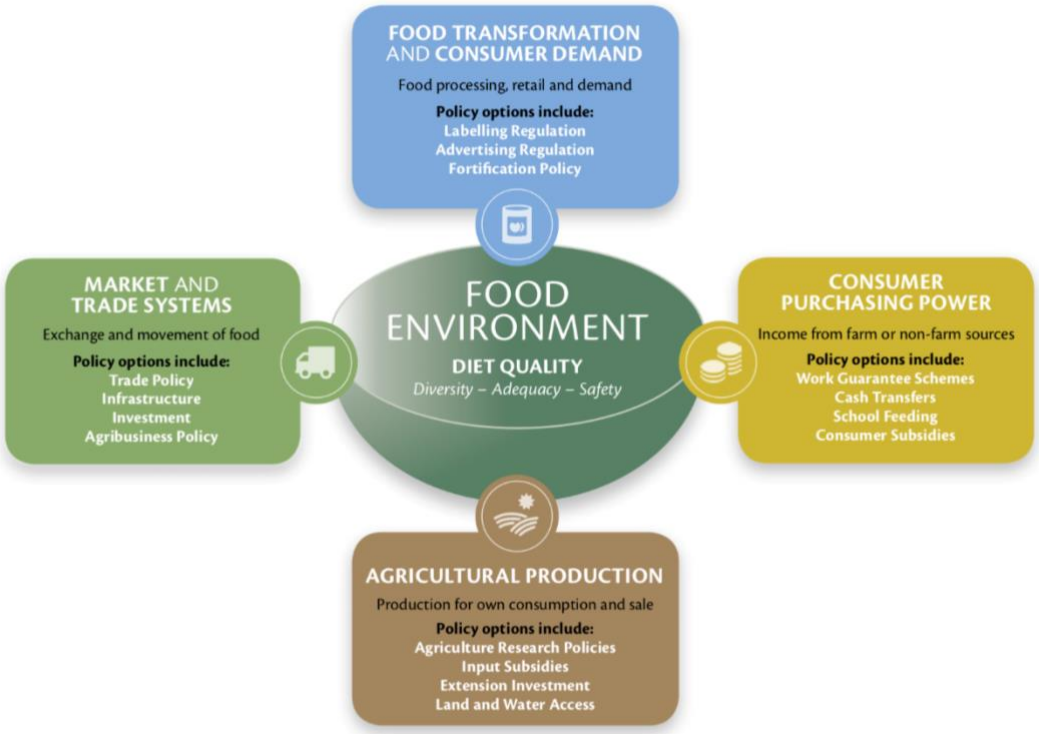
Figure 4) Food environments and their four main components (9)



Herforth and Ahmed (10) made a significant conceptual contribution to the literature in 2015 by defining key food environment dimensions, including food availability, affordability, desirability and convenience. The Food and Agricultural Organisation (11) and the Global Panel on Agriculture and Food Systems for Nutrition (12) subsequently contributed additional dimensions, such as the nutritional quality, price, labelling and promotion of foods. However, on the whole, conceptual frameworks have had a tendency to remain at the macro scale,

highlighting various food environment dimensions in relation to political, economic, cultural, biophysical and environmental drivers (13) or agricultural, food storage and transport, food transformation, and food retail subsystems (11, 12). The most recent Global Panel on Agriculture and Food Systems for Nutrition framework made a key contribution by positioning the food environment as a mediator between diet quality and wider food systems (Figure 5) (14).

Figure 5) Conceptual framework depicting links between diet quality and food systems (14).



Collectively, the theoretical and conceptual contributions above reflect the broad and all-encompassing scope of food environment research. However, there remains a critical need for specificity in order to define what the food environment is, what key dimensions it includes, how they relate to the socio-ecological model, and how the food environment might be conceptualised in relation to the wider food system. In addition, although food environment research has been gaining attention with regard to the public health nutrition research agenda in LMICs (13, 15, 16), there has been a distinct lack of conceptual thinking about how to contextualise concepts developed in HICs to LMIC settings. Empirical studies in LMICs to date have broadly sought to adapt methods and metrics from HICs with little regard

to the refinement of theoretical and conceptual underpinnings in relation to LMIC contexts. This is a significant research gap given the fundamental differences between food environments and food acquisition practices in HIC and LMIC settings, and the recognised need to contextualise food environment research to diverse settings (17).

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 was initiated by Suneetha Kadiyala. I led the working group, which brought together food environment experts to review and synthesise food environment definitions, key concepts, methods, metrics, and research gaps in order to provide a platform of consensus to guide and accelerate food environment research in LMICs. Six members participated in the working group on a voluntary basis (Helen Walls, Jennifer Coates, Corinna Hawkes, Adam Drewnowski, Anju Aggarwal, and Anna Herforth). Sofia Kalamatianou, a research assistant, contributed to the formative research activities.

I conducted a literature search of review articles and grey literature on food environments in February 2016. The inclusive search featured four databases; Medline, Econlit, Web of Science, Scopus. Search terms included 'food environments', 'methods' and 'metrics'. The resulting synthesis of review articles (n=18) informed bi-monthly ANH-FEWG meetings, where I discussed and evaluated definitions, key concepts, frameworks, methods and metrics with working group members, with critical consideration allocated to the potential for LMIC application. This formative phase paved the way for the iterative development of a new working definition and conceptual framework. I led process with critical inputs from the working group members.

During the development of the framework, the working group took the decision to focus our attention on the socio-ecological interactions between people and the food environment that shape food acquisition and consumption. Whilst we recognised the importance that political, economic, cultural, biophysical and environmental drivers play in forming the food environment and diets, nutrition and health, for the purposes of the framework, we decided to zoom in from these broader drivers to depict the food environment as the interface between consumers and the wider food system. In doing so, we sought to situate the food

environment concept within that of the wider food system and unpack the core socio-ecological dimensions of food environments related to external and personal domains. Our intention was to arrive at a coherent and comprehensive set of globally applicable dimensions that allow for the better characterization, measurement, and monitoring of food environments across diverse settings, and thus improve knowledge and understanding of the relationship between food environments and dietary, nutrition, and health outcomes. In this way, future context specific interventions may be better tailored to target key food environment dimensions within a given setting, and thereby create and sustain enabling food environments that improve dietary, nutrition and health outcomes.

I presented the emerging body of work 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 technical brief outlining evolving concepts was disseminated at the Agriculture, Nutrition and Health Academy Week 2017, in Kathmandu, Nepal (18). A short animation supporting this technical brief is available online (19).

Following consultations with several external experts including Jessica Fanzo and Marie Ruel, I developed the technical brief into a critical perspectives article with co-authors from the ANH-FEWG (Box 1). In addition to providing far more detailed, in-depth, and rigorous critical perspectives on food environments than was undertaken in the technical brief, the article included several key technical developments. These include: 1) the inclusion of an additional food source: 'wild and harvested foods', 2) an extensively revised structure and labelling of the conceptual framework to improve clarity and strengthen the 'interface' concept' - including the re-labelling of food system, food environment, external and personal domains, and food sources under the dimension availability.

Box 1: Author contributions to publication 1

Christopher Turner: Conceived the paper, led the working group discussions, conducted a review of reviews on food environment concepts, compiled and integrated critical feedback from group members, designed the conceptual frameworks and figures, led the writing process, compiled feedback and comments from co-authors on the manuscript, copy-edited the manuscript, finalised the manuscript for submission, responded to peer reviewers, amended the manuscript for publication and led the development of the animation.

Suneetha Kadiyala: Provided critical feedback on the initial paper concept, contributed to the scope and structure of the manuscript, and provided written critical feedback throughout the writing process.

Anju Aggarwal, Helen Walls, Anna Herforth, Adam Drewnowski, Jennifer Coates and Sofia Kalamatianou: Provided written critical feedback throughout the writing process.

2.2.References: Preamble to publication 1

1. Brug J, Kremers SP, van Lenthe F, Ball K, Crawford D. Environmental determinants of healthy eating: in need of theory and evidence. Proceedings of the Nutrition Society. 2008;67(3):307-16.

2. Giskes K, Kamphuis CB, van Lenthe FJ, Kremers S, Droomers M, Brug J. A systematic review of associations between environmental factors, energy and fat intakes among adults: is there evidence for environments that encourage obesogenic dietary intakes? Public Health Nutr. 2007;10(10):1005-17.

3. Penney TL, Almiron-Roig E, Shearer C, McIsaac JL, Kirk SFL. Modifying the food environment for childhood obesity prevention: challenges and opportunities. Proceedings of the Nutrition Society. 2014;73(2):226-36.

4. Penney TL, Brown HE, Maguire ER, Kuhn I, Monsivais P. Local food environment interventions to improve healthy food choice in adults: a systematic review and realist synthesis protocol. BMJ Open. 2015;5(4):e007161.

5. Story M, Giles-Corti B, Yaroch AL, Cummins S, Frank LD, Huang TTK, Lewis LB. Work Group IV: Future Directions for Measures of the Food and Physical Activity Environments. American Journal of Preventive Medicine. 2009;36(4):S182-S8.

6. Rao M, Prasad S, Adshead F, Tissera H. The built environment and health. Lancet. 2007;370(9593):1111-3.

7. Story M, Kaphingst KM, Robinson-O'Brien R, Glanz K. Creating healthy food and eating environments: Policy and environmental approaches. Annual Review of Public Health. 2008;29:253-+.

8. Glanz K, Sallis JF, Saelens BE, Frank LD. Nutrition Environment Measures Survey in stores (NEMS-S): development and evaluation. Am J Prev Med. 2007;32(4):282-9.

9. Swinburn B, Sacks G, Vandevijvere S, Kumanyika S, Lobstein T, Neal B, Barquera S, Friel S, Hawkes C, Kelly B, et al. INFORMAS (International Network for Food and Obesity/non-communicable diseases Research, Monitoring and Action Support): overview and key principles. Obesity Reviews. 2013;14:1-12.

10. Herforth A, Ahmed S. The food environment, its effects on dietary consumption, and potential for measurement within agriculture-nutrition interventions. Food Security. 2015;7(3):505-20.

11. Food and Agriculture Organisation of the United Nations – FAO. Influencing food environments for healthy diets. Rome: 2016.

12. Global Panel on Agriculture and Food Systems for Nutrition – Global Panel. Food systems and diets: Facing the challenges of the 21st century. London, UK: Global Panel on Agriculture and Food Systems for Nutrition, 2016.

13. High Level Panel of Experts on Food Security and Nutrition. Nutrition and food systems. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security. Rome: 2017.

14. Global Panel on Agriculture and Food Systems for Nutrition. Improving nutrition through enhanced food environments. Policy Brief London, UK: Global Panel on Agriculture and Food Systems for Nutrition, 2017.

15. Development Initiatives. Global Nutrition Report 2017: Nourishing the SDGs. Bristol, UK: Development Initiatives, 2017.

16. Global Panel on Agriculture and Food Systems for Nutrition – Global Panel. Improving nutrition through enhanced food environments. Policy Brief London, UK: Global Panel on Agriculture and Food Systems for Nutrition, 2017.

17. Pomerleau J, Knai C, Foster C, Rutter H, Darmon N, Derflerova Brazdova Z, Hadziomeragic AF, Pekcan G, Pudule I, Robertson A, et al. Measuring the food and built environments in urban centres: reliability and validity of the EURO-PREVOB Community Questionnaire. Public Health. 2013;127(3):259-67.

18. Turner C, Kadiyala S, Aggarwal A, Coates J, Drewnowski A, Hawkes C, Herforth A, Kalamatianou S, Walls H. Concepts and methods for food environment research in low and

middle-income countries. Technical Brief. London, UK: Agriculture Nutrition and Health Academy Food Environment Working Group (ANH-FEWG), Innovative Methods and Metrics for Agriculture and Nutrition Actions (IMMANA) programme; 2017.

19. Agriculture Nutrition and Health Academy Food Environments Working Group (ANH-FEWG). Food environment research: An introduction Agriculture Nutrition and Health Academy Food Environments Working Group (ANH-FEWG); 2018 [25/09/19]. Available from: https://www.youtube.com/watch?v=5cUaro1gUcI.

2.3.Research paper cover sheet: Publication 1

London School of Hygiene & Tropical Medicine
Keppel Street, London WC1E 7HT

T: +44 (0)20 7299 4646
F: +44 (0)20 7299 4656
www.lshtm.ac.uk

RESEARCH PAPER COVER SHEET

Please note that a cover sheet must be completed for each research paper included within a thesis.

SECTION A – Student Details

Student ID Number	1510864	**Title**	Mr
First Name(s)	Christopher		
Surname/Family Name	Turner		
Thesis Title	Investigating food environments and drivers of food acquisition in low- and middle-income countries: The case of peri-urban Hyderabad, Telangana, India		
Primary Supervisor	Dr Suneetha Kadiyala		

If the Research Paper has previously been published please complete Section B, if not please move to Section C.

SECTION B – Paper already published

Where was the work published?	Global Food Security		
When was the work published?	11/09/2018		
If the work was published prior to registration for your research degree, give a brief rationale for its inclusion	n/a		
Have you retained the copyright for the work?*	**Yes**	Was the work subject to academic peer review?	**Yes**

*If yes, please attach evidence of retention. If no, or if the work is being included in its published format, please attach evidence of permission from the copyright holder (publisher or other author) to include this work.

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Please list the paper's authors in the intended authorship order:	
Stage of publication	Choose an item.

SECTION D – Multi-authored work

For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)	Publication title: Concepts and critical perspectives for food environment research: A global framework with implications for action in low- and middle-income countries. Chris conceived the paper, lead the working group discussions, compiled and integrated critical feedback from group members, designed the conceptual frameworks, lead the writing process, compiled feedback and comments from co-authors on the manuscript, copy-edited the manuscript, finalised the manuscript for submission, responded to peer reviewers and amended the manuscript for publication.

SECTION E

Student Signature	[redacted]
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Supervisor Signature	[redacted]
Date	22/09/19

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Author: Christopher Turner,Anju Aggarwal,Helen Walls,Anna Herforth,Adam Drewnowski,Jennifer Coates,Sofia Kalamatianou,Suneetha Kadiyala

Publication: Global Food Security

Publisher: Elsevier

Date: September 2018

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2.5.Publication 1: Manuscript

Available online: https://www.sciencedirect.com/science/article/pii/S2211912418300154

Global Food Security 18 (2018) 93–101

Contents lists available at ScienceDirect

Global Food Security

journal homepage: www.elsevier.com/locate/gfs

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

Christopher Turner[a,*], Anju Aggarwal[b], Helen Walls[c], Anna Herforth[d], Adam Drewnowski[e], Jennifer Coates[f], Sofia Kalamatianou[a], Suneetha Kadiyala[a]

[a] London School of Hygiene and Tropical Medicine, Faculty of Epidemiology and Population Health, Department of Population Health, Keppel Street, London WC1E 7HT, United Kingdom
[b] University of Washington, Department of Epidemiology, Center for Public Health Nutrition, Box 353410, 327 Raitt Hall, Seattle, WA 98195, United States
[c] London School of Hygiene and Tropical Medicine, Faculty of Public Health and Policy, Department of Population Health, 15-17 Tavistock Place, London WC1H 9SH, United Kingdom
[d] Independent Consultant, New Haven, CT, United States
[e] University of Washington, Department of Nutritional Sciences, Center for Public Health Nutrition, Box 353410, Raitt Hall 305B, Seattle, WA 98195, United States
[f] Tufts University, Friedman School of Nutrition Science and Policy, 150 Harrison Avenue, Room 153, Boston, MA 02111, United States

ARTICLE INFO

Keywords:
Food environments
Low- and middle-income countries
Food security
Food acquisition
Double burden of malnutrition
Non-communicable diseases

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

* Corresponding author.
E-mail address: christopher.turner@lshtm.ac.uk (C. Turner).

https://doi.org/10.1016/j.gfs.2018.08.003

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, 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

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 lead 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)

(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

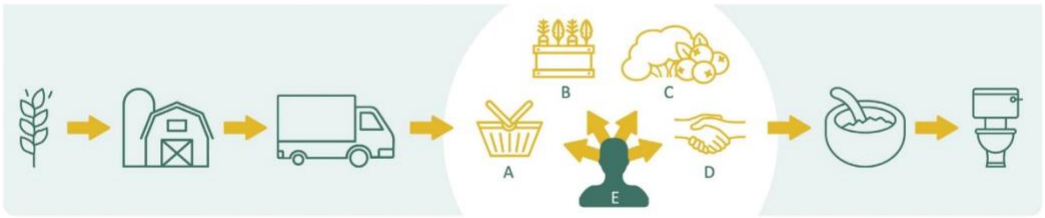

Fig. 1. Situating the food environment within the wider food system.The figure depicts the food system from 'farm to flush' (United Nations System Standing Committee on Nutrition, 2016). The white sphere highlights the food environment as the interface where people acquire foods from a range of sources, 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.

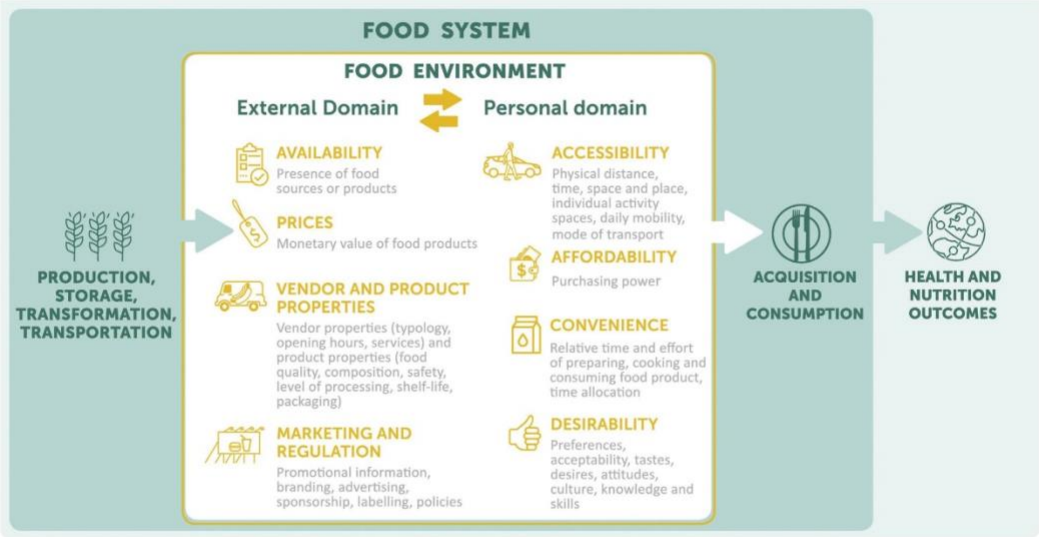

Fig. 2. Conceptual framework. The conceptual framework depicts the food environment as the interface within the wider food system. Key dimensions are mapped to external and personal domains. Interactions between these domains and dimensions shape people's food acquisition and consumption.

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 geo-tagged 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.

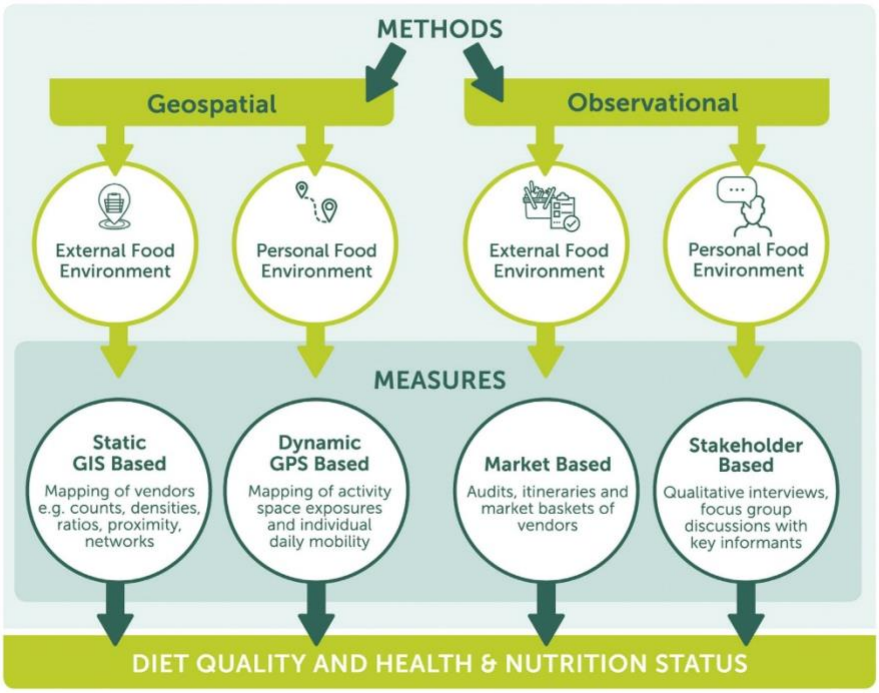

Fig. 3. Methodological framework. The methodological framework maps geospatial and observational approaches to the personal and external food environment domains, each with its own set of respective measures.

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 Penchansky and Thomas (1981), who described a multidimensional 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	**Formal markets:**	**Formal markets:**
	Relatively stable	Highly dynamic
	Supermarkets, fast food chains, farmers markets, restaurants, cafés, street foods	Increasing introduction of supermarkets and fast food chains
	Little seasonal variation in availability	**Informal markets:**
		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
Prices	Relatively stable prices	Highly volatile prices
	High premiums for speciality foods	Vulnerable to shocks and seasonality
		Ready to eat street foods relatively cheap
		Perishables expensive and/or volatile in price
Vendor and product properties	Brick & mortar vendors	Brick & mortar vendors, temporary roadside stalls, mobile traders.
	Increasingly 24/7 trading	Limited trading hours
	Online shopping/delivery	Increasingly offering online/delivery options
	High level of food packaging	Limited food packaging
	Cold storage	Increasing cold storage, but gaps in the cold chain
	Food safety regulations	Limited food safety regulations
		Potential to acquire food on credit
Marketing and regulation	Highly regulated with strict trading laws	Largely un-regulated
	High level of promotion, marketing campaigns, labelling, shelf information	Basic labelling and information on select products

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 socioeconomic 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.

Acknowledgements

This paper is the culmination of the Agriculture, Nutrition and Health Academy's Food Environment Working Group (ANH-FEWG) collaboration under the Innovative Methods and Metrics for Agriculture and Nutrition Actions (IMMANA) programme, funded with UK aid from the UK Government, United Kingdom (Grant number: 6682).

We would like to thank Corinna Hawkes for her critical inputs to the

Food Environment Working Group. We would also like to thank Jessica Fanzo and Marie Ruel for their constructive feedback with regard to the conceptual frameworks and perspectives included in this manuscript. In addition, we would also like to thank our workshop participants for engaging in dialogue around food environments, including the concepts presented in this manuscript.

References

Aggarwal, A., Cook, A.J., Jiao, J.F., Seguin, R.A., Moudon, A.V., Hurvitz, P.M., Drewnowski, A., 2014a. Access to supermarkets and fruit and vegetable consumption. Am. J. Public Health 104, 917–923.

Aggarwal, A., Monsivais, P., Cook, A.J., Drewnowski, A., 2014b. Positive attitude toward healthy eating predicts higher diet quality at all cost levels of supermarkets. J. Acad. Nutr. Diet. 114, 266–272.

Aggarwal, A., Rehm, C.D., Monsivais, P., Drewnowski, A., 2016. Importance of taste, nutrition, cost and convenience in relation to diet quality: evidence of nutrition resilience among US adults using National Health and Nutrition Examination Survey (NHANES) 2007–2010. Prev. Med. 90, 184–192.

Ahmed, S., Byker Shanks, C., 2017. Quality of vegetables based on total phenolic concentration is lower in more rural consumer food environments in a rural American state. Int J. Environ. Res Public Health 14.

Ahmed, S., Shanks, C.B., Smith, T., Shanks, J., 2018. Fruit and vegetable desirability is lower in more rural built food environments of Montana, USA using the produce desirability (ProDes) tool. Food Secur. 10, 169–182.

Andreyeva, T., Blumenthal, D.M., Schwartz, M.B., Long, M.W., Brownell, K.D., 2008. Availability and prices of foods across stores and neighborhoods: the case of New Haven, Connecticut. Health Aff. 27, 1381–1388.

Apparicio, P., Cloutier, M.S., Shearmur, R., 2007. The case of Montreal's missing food deserts: evaluation of accessibility to food supermarkets. Int. J. Health Geogr. 6.

Azeredo, C.M., De Rezende, L.F., Canella, D.S., Claro, R.M., Peres, M.F., Luiz Odo, C., Franca-Junior, I., Kinra, S., Hawkesworth, S., Levy, R.B., 2016. Food environments in schools and in the immediate vicinity are associated with unhealthy food consumption among Brazilian adolescents. Prev. Med. 88, 73–79.

Baker, P., Hawkes, C., Wingrove, K., Demaio, A.R., Parkhurst, J., Thow, A.M., Walls, H., 2018. What drives political commitment for nutrition? A review and framework synthesis to inform the United Nations Decade of Action on Nutrition. BMJ Glob. Health 3, e000485.

Battersby, J., 2012. Beyond the food desert: finding ways to speak about urban food security in South Africa. Geogr. Ann. Ser. B Human. Geogr. 94b, 141–159.

Battersby, J., Crush, J., 2014. Africa's urban food deserts. Urban Forum 25, 143–151.

Bell, S.L., Phoenix, C., Lovell, R., Wheeler, B.W., 2015. Using GPS and geo-narratives: a methodological approach for understanding and situating everyday green space encounters. Area 47, 88–96.

Black, C., Moon, G., Baird, J., 2014. Dietary inequalities: what is the evidence for the effect of the neighbourhood food environment? Health Place 27, 229–242.

Bodor, J.N., Rice, J.C., Farley, T.A., Swalm, C.M., Rose, D., 2010. The association between obesity and urban food environments. J. Urban Health 87, 771–781.

Brug, J., Kremers, S.P., VAN Lenthe, F., Ball, K., Crawford, D., 2008. Environmental determinants of healthy eating: in need of theory and evidence. Proc. Nutr. Soc. 67, 307–316.

Caspi, C.E., Sorensen, G., Subramanian, S.V., Kawachi, I., 2012. The local food environment and diet: a systematic review. Health Place 18, 1172–1187.

Cetateanu, A., Jones, A., 2016. How can GPS technology help us better understand exposure to the food environment? A systematic review. SSM Popul Health 2, 196–205.

Charreire, H., Casey, R., Salze, P., Simon, C., Chaix, B., Banos, A., Badariotti, D., Weber, C., Oppert, J.M., 2010. Measuring the food environment using geographical information systems: a methodological review. Public Health Nutr. 13, 1773–1785.

Cobb, L.K., Appel, L.J., Franco, M., Jones-Smith, J.C., Nur, A., Anderson, C.A., 2015. The relationship of the local food environment with obesity: a systematic review of methods, study quality, and results. Obesity 23, 1331–1344.

Development Initiatives 2017, 2017. Global Nutrition Report. Nourishing the SDGs. Development Initiatives, Bristol, UK.

Drewnowski, A., Aggarwal, A., Hurvitz, P.M., Monsivais, P., Moudon, A.V., 2012. Obesity and supermarket access: proximity or price? Am. J. Public Health 102, e74–e80.

Duran, A.C., De Almeida, S.L., Latorre MDO, R., Jaime, P.C., 2016. The role of the local retail food environment in fruit, vegetable and sugar-sweetened beverage consumption in Brazil. Public Health Nutr. 19, 1093–1102.

Duran, A.C., Lock, K., Latorre MDO, R., Jaime, P.C., 2015. Evaluating the use of in-store measures in retail food stores and restaurants in Brazil. Rev. Saude Publica 49.

Engler-Stringer, R., Le, H., Gerrard, A., Muhajarine, N., 2014. The community and consumer food environment and children's diet: a systematic review. BMC Public Health 14, 522.

Fernandes, M., Folson, G., Aurino, E., Gelli, A., 2017. A free lunch or a walk back home? The school food environment and dietary behaviours among children and adolescents in Ghana. Food Secur. 9, 1073–1090.

Food and Agriculture Organisation of the United Nations, 1983. World food security: a reappraisal of the concepts and approaches, Director general's report, Rome.

Food and Agriculture Organisation of the United Nations, 1996. Rome declaration on world food security and world food summit plan of action, World food summit, Rome.

Food and Agriculture Organisation of the United Nations, 2014. Growing greener cities in latin america and the caribbean: an FAO report on urban and peri-urban agriculture in the region, Rome.

Food and Agriculture Organisation of the United Nations, 2016a. Influencing food environments for healthy diets, Rome.

Food and Agriculture Organisation of the United Nations, 2016b. Compendium of indicators for nutrition-sensitive agriculture, Rome.

Franco, M., Diez Roux, A.V., Glass, T.A., Caballero, B., Brancati, F.L., 2008. Neighborhood characteristics and availability of healthy foods in Baltimore. Am. J. Prev. Med. 35, 561–567.

Gamba, R.J., Schuchter, J., Rutt, C., Seto, E.Y., 2015. Measuring the food environment and its effects on obesity in the United States: a systematic review of methods and results. J. Community Health 40, 464–475.

Gibson, D.M., 2011. The neighborhood food environment and adult weight status: estimates from longitudinal data. Am. J. Public Health 101, 71–78.

Glanz, K., Sallis, J.F., Saelens, B.E., Frank, L.D., 2007. Nutrition environment measures survey in stores (NEMS-S): development and evaluation. Am. J. Prev. Med. 32, 282–289.

Global Panel on Agriculture and Food Systems for Nutrition, 2014. How can Agriculture and Food System Policies Improve Nutrition? Technical Brief. Nutrition. Global Panel on Agriculture and Food Systems, London, UK.

Global Panel on Agriculture and Food Systems for Nutrition, 2016. Food Systems and Diets: Facing the Challenges of the 21st Century. Global Panel on Agriculture and Food Systems for Nutrition, London, UK.

Global Panel on Agriculture and Food Systems for Nutrition, 2017. Improving Nutrition Through Enhanced Food Environments. Policy Brief London. Global Panel on Agriculture and Food Systems for Nutrition, UK.

Gomez, M.I., Ricketts, K.D., 2013. Food value chain transformations in developing countries: selected hypotheses on nutritional implications. Food Policy 42, 139–150.

Gupta, V., Downs, S.M., Ghosh-Jerath, S., Lock, K., Singh, A., 2016. Unhealthy fat in street and snack foods in low-socioeconomic settings in India: a case study of the food environments of rural villages and an urban slum. J. Nutr. Educ. Behav. 48, 269–279 (e1).

Gustafson, A., Hankins, S., Jilcott, S., 2012. Measures of the consumer food store environment: a systematic review of the evidence 2000–2011. J. Community Health 37, 897–911.

Herforth, A., Ahmed, S., 2015. The food environment, its effects on dietary consumption, and potential for measurement within agriculture-nutrition interventions. Food Secur. 7, 505–520.

High Level Panel of Experts on Food Security and Nutrition, 2017. Nutrition and food systems. A report by the high level panel of experts on Food security and Nutrition of the Committee on world Food security, Rome.

Hosler, A.S., Rajulu, D.T., Fredrick, B.L., Ronsani, A.E., 2008. Assessing retail fruit and vegetable availability in urban and rural underserved communities. Prev. Chronic Dis. 5, A123.

Kanter, R., Alvey, J., Fuentes, D., Garcia, R., Bearup, R., Koeppel, L., Caplan, E., Chang, F., Chomitz, B., Solomons, N., 2014. The Nutrition environment measurement survey-stores in Guatemala: measurement performance between the standard (USA) and a modified version. FASEB J. 28.

Kanter, R., Walls, H.L., Tak, M., Roberts, F., Waage, J., 2015. A conceptual framework for understanding the impacts of agriculture and food system policies on nutrition and health. Food Secur. 7, 767–777.

Laraia, B.A., Siega-Riz, A.M., Kaufman, J.S., Jones, S.J., 2004. Proximity of supermarkets is positively associated with diet quality index for pregnancy. Prev. Med. 39, 869–875.

Lucan, S., 2015. Concerning limitations of food-environment research: a narrative review and commentary framed around obesity and diet-related diseases in youth. J. Acad. Nutr. Diet. 115, 205–212.

Lytle, L.A., 2009. Measuring the food environment: state of the science. Am. J. Prev. Med. 36, S134–S144.

Martins, P., Cremm, E., Leite, F., Maron, L., Scagliusi, F., Oliveira, M., 2013. Validation of an adapted version of the nutrition environment measurement tool for stores (NEMS-S) in an Urban Area of Brazil. J. Nutr. Educ. Behav. 45, 785–792.

Milton, S., Pliakas, T., Hawkesworth, S., Nanchahal, K., Grundy, C., Amuzu, A., Casas, J.P., Lock, K., 2015. A qualitative geographical information systems approach to explore how older people over 70 years interact with and define their neighbourhood environment. Health Place 36, 127–133.

Moore, L.V., Diez Roux, A.V., Nettleton, J.A., Jacobs, D.R., J.R., 2008. Associations of the local food environment with diet quality – a comparison of assessments based on surveys and geographic information systems: the multi-ethnic study of atherosclerosis. Am. J. Epidemiol. 167, 917–924.

Morland, K., Diez Roux, A.V., Wing, S., 2006. Supermarkets, other food stores, and obesity: the atherosclerosis risk in communities study. Am. J. Prev. Med. 30, 333–339.

Morland, K., Wing, S., Diez Roux, A., 2002. The contextual effect of the local food environment on residents' diets: the atherosclerosis risk in communities study. Am. J. Public Health 92, 1761–1767.

Ng, M., Fleming, T., Robinson, M., Thomson, B., Graetz, N., Margono, C., Mullany, E.C., Biryukov, S., Abbafati, C., Abera, S.F., Abraham, J.P., Abu-Rmeileh, N.M.E., Achoki, T., Albuhairan, F.S., Alemu, Z.A., Alfonso, R., Ali, M.K., Ali, R., Guzman, N.A., Ammar, W., Anwari, P., Banerjee, A., Barquera, S., Basu, S., Bennett, D.A., Bhutta, Z., Blore, J., Cabral, N., Nonato, I.C., Chang, J.C., Chowdhury, R., Courville, K.J., Criqui, M.H., Cundiff, D.K., Dabhadkar, K.C., Dandona, L., Davis, A., Dayama, A., Dharmaratne, S.D., Ding, E.L., Durrani, A.M., Esteghamati, A., Farzadfar, F., Fay, D.F.J., Feigin, V.L., Flaxman, A., Forouzanfar, M.H., Goto, A., Green, M.A., Gupta, R., Hafezi-Nejad, N., Hankey, G.J., Harewood, H.C., Havmoeller, R., Hay, S., Hernandez, L., Husseini, A., Idrisov, B.T., Ikeda, N., Islami, F., Jahangir, E., Jassal, S.K., Jee, S.H., Jeffreys, M., Jonas, J.B., Kabagambe, E.K., Khalifa, S.E.A.H., Kengne, A.P., Khader,

Y.S., Khang, Y.H., Kim, D., Kimokoti, R.W., Kinge, J.M., Kokubo, Y., Kosen, S., Kwan, G., Lai, T., Leinsalu, M., Li, Y.C., Liang, X.F., Liu, S.W., Logroscino, G., Lotufo, P.A., Lu, Y., Ma, J.X., Mainoo, N.K., Mensah, G.A., Merriman, T.R., Mokdad, A.H., Moschandreas, J., Naghavi, M., Naheed, A., Nand, D., Narayan, K.M.V., Nelson, E.L., Neuhouser, M.L., Nisar, M.I., Ohkubo, T., Oti, S.O., Pedroza, A., et al., 2014. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: a systematic analysis for the Global burden of disease study 2013. Lancet 384, 766–781.

Penchansky, R., Thomas, J.W., 1981. The concept of access: definition and relationship to consumer satisfaction. Med. Care 19, 127–140.

Penney, T.L., Almiron-Roig, E., Shearer, C., Mcisaac, J.L., Kirk, S.F.L., 2014. Modifying the food environment for childhood obesity prevention: challenges and opportunities. Proc. Nutr. Soc. 73, 226–236.

Pongutta, S., Chongwatpol, P., Tantayapirak, P., Vandevijvere, S., 2018. Declaration of nutrition information on and nutritional quality of Thai ready-to-eat packaged food products. Public Health Nutr. 21, 1409–1417.

Popkin, B.M., 2015. Nutrition Transition and the Global Diabetes Epidemic. Curr. Diab. Rep. 15, 64.

Popkin, B.M., Adair, L.S., Ng, S.W., 2012. Global nutrition transition and the pandemic of obesity in developing countries. Nutr. Rev. 70, 3–21.

Powell, L.M., Auld, M.C., Chaloupka, F.J., O'malley, P.M., Johnston, L.D., 2007. Associations between access to food stores and adolescent body mass index. Am. J. Prev. Med. 33, S301–S307.

Powell, L.M., Han, E., Chaloupka, F.J., 2010. Economic contextual factors, food consumption, and obesity among U.S. adolescents. J. Nutr. 140, 1175–1180.

Rao, M., Prasad, S., Adshead, F., Tissera, H., 2007. The built environment and health. Lancet 370, 1111–1113.

Rose, D., Richards, R., 2004. Food store access and household fruit and vegetable use among participants in the US food stamp program. Public Health Nutr. 7, 1081–1088.

Sharkey, J.R., Horel, S., 2008. Neighborhood socioeconomic deprivation and minority composition are associated with better potential spatial access to the ground-truthed food environment in a large rural area. J. Nutr. 138, 620–627.

Smoyer-Tomic, K.E., Spence, J.C., Amrhein, C., 2006. Food deserts in the prairies? Supermarket accessibility and neighborhood need in Edmonton, Canada. Prof. Geogr. 58, 307–326. Wiley. https://onlinelibrary.wiley.com/journal/14679272.

Swinburn, B., Sacks, G., Vandevijvere, S., Kumanyika, S., Lobstein, T., Neal, B., Barquera, S., Friel, S., Hawkes, C., Kelly, B., L'abbe, M., Lee, A., Ma, J., Macmullan, J., Mohan, S., Monteiro, C., Rayner, M., Sanders, D., Snowdon, W., Walker, C., Informas, 2013. INFORMAS (International network for food and obesity/non-communicable diseases research, monitoring and action support): overview and key principles. Obes. Rev. 14, 1–12.

Swinburn, B.A., Sacks, G., Hall, K.D., Mcpherson, K., Finegood, D.T., Moodie, M.L., Gortmaker, S.L., 2011. Obesity 1 the global obesity pandemic: shaped by global drivers and local environments. Lancet 378, 804–814.

Townshend, T., Lake, A.A., 2009. Obesogenic urban form: theory, policy and practice. Health Place 15, 909–916.

Turner, C., Kadiyala, S., Aggarwal, A., Coates, J., Drewnowski, A., Hawkes, C., Herforth, A., Kalamatianou, S., Walls, H., 2017. Concepts and Methods for Food Environment Research in Low and Middle-Income Countries, 1 ed. Agriculture, Nutrition and Health Academy Food Environment Working Group (ANH-FEWG), London, UK.

United Nations Children's Fund, 1990. Strategy for improved nutrition of children and women in developing countries, New York.

United Nations Children's Fund , 1998. The state of the world's children, New York.

United Nations General Assembly, 2015. Transforming our world: the 2030 agenda for sustainable development, United Nations General Assembly.

United Nations General Assembly, 2016. United Nations decade of action on nutrition (2016–2025). United Nations General Assembly.

United Nations System Standing Committee On Nutrition, 2016. Investments for Healthy Food Systems, Implementing the Framework for Action of the Second International Conference on Nutrition, Executive Summary. United Nations System Standing Committee on Nutrition.

Walls, H.L., Johnston, D., Mazalale, J., Chirwa, E.W., 2018. Why we are still failing to measure the nutrition transition. BMJ Glob. Health 3, e000657.

White, M., 2007. Food access and obesity. Obes. Rev. 8, 99–107.

World Health Organization, 2017. The double burden of malnutrition: Policy brief, Geneva.

2.6.Summary of appendices for Publication 1

None.

2.7.Contribution of Publication 1 to the thesis

This publication fills the theoretical research gap and the first aim of my thesis to develop a food environment definition and globally applicable conceptual framework in collaboration with food environment experts. The concepts and critical perspectives presented in this publication also provide the theoretical foundation for the rest of the thesis that follows. The socio-ecological theoretical approach, including the food environment conceptual framework, is used to frame each of the publications. In publication 2, the conceptual framework is used to structure the systematic review process, including data charting and reporting of food environment domains and dimensions.

In publication 3, the socio-ecological approach to the inquiry of food environments and the food environment conceptual framework provide the theoretical grounding for the design of the novel Q-GIS methodological approach. The framework is also used to structure the visual coding of photographic content, including the food environment dimensions photographed by participants.

In publication 4, the theoretical framework directs my primary data collection, informing the design of the topic guides. In addition, the framework and food environment dimensions are used to create a deductive coding framework in the initial stages of the qualitative analysis process. Finally, the framework provides structure to the reporting of results on the food environment and drivers of food acquisition practices in the APCAPS.

3. Publication 2: Food environment research in low- and middle-income countries: A systematic scoping review

3.1. Preamble to publication 2: Motivation for the article

Publication two addresses the second research question:

2. *Where has food environment research been undertaken in LMICs, how have food environments been conceptualized, which key domains and dimensions have been studied, which study designs, methods and measures have been implemented, and what are the key findings regarding associations between food environment exposure and dietary, nutrition, and health outcomes?*

Food environment research has been gaining momentum in LMICs over recent years, both in terms of policy recognition and research practice. However, in the absence of a systematic review of the literature, little is known about the state of science and the emerging body of evidence from these settings. This is a significant research gap given the origins of research in HICs and the fundamental differences in LMICs with regard to food environments, food acquisition and consumption patterns, and the public health nutrition challenges at hand. I conducted a systematic scoping review with the aim of addressing this gap by capturing the breadth and depth of peer-reviewed published food environment literature from LMICs, and mapping and synthesizing findings to inform evidence-based practice in LMICs (Box 1). More specifically, this systematic scoping review seeks to address the following questions in relation to LMICs: first, where has food environment research been undertaken? Second, how have food environments been conceptualized? Third, which key domains and dimensions of food environments have been studied? Fourth, which research designs, methods and measures have been used? Fifth, what are the key findings regarding associations between food environment exposures and dietary, nutrition, and health outcomes?

The literature supporting systematic scoping reviews has been growing in recent years due to the recognised need to synthesise knowledge from multi-disciplinary research. Systematic scoping reviews provide a salient approach to knowledge synthesis when a body of literature has yet to be reviewed, or is highly heterogeneous in nature featuring for example diverse

disciplines, research designs, and methodological approaches (1, 2). Systematic scoping review protocols have recently been developed to guide the implementation of this type of review. We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses – Extension for Scoping Reviews (PRISMA-ScR) checklist to ensure a robust and replicable process (2).

Box 1: Author contributions to publication 2

Christopher Turner: Conceived the paper, conducted the systematic search and screening, conducted data charting, analysis, and quality assessment, led the writing process, copy-edited the manuscript, finalised the manuscript for submission, responded to peer reviewers and amended the manuscript for publication.

Sofia Kalamatianou: Conducted the systematic search, screening, data charting, and provided critical feedback on the manuscript.

Adam Drewnowski, Bharati Kulkarni, Sanjay Kinra: Provided critical feedback on the manuscript.

Suneetha Kadiyala: Conducted quality assessments and provided critical feedback on the initial paper concept, the data charting, and the manuscript throughout the writing process.

3.2.References: Preamble to publication 2

1. Peters MD, Godfrey CM, Khalil H, McInerney P, Parker D, Soares CB. Guidance for conducting systematic scoping reviews. Int J Evid Based Healthc. 2015;13(3):141-6.

2. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, Moher D, Peters MDJ, Horsley T, Weeks L, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. Ann Intern Med. 2018;169(7):467-73.

3.3.Research paper cover sheet: Publication 2

London School of Hygiene & Tropical Medicine
Keppel Street, London WC1E 7HT

T: +44 (0)20 7299 4646
F: +44 (0)20 7299 4656
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First Name(s)	Christopher		
Surname/Family Name	Turner		
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Primary Supervisor	Dr Suneetha Kadiyala		

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For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)	Publication title: Food environment research in low- and middle-income countries: A systematic scoping review. Chris conceived the paper, conducted the systematic search and screening, conducted data charting, analysis, and quality assessment, led the writing process, copy-edited the manuscript, finalised the manuscript for submission, responded to peer reviewers and amended the manuscript for publication.

SECTION E

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Publication: Advances in Nutrition

Publisher: Oxford University Press

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3.5.Publication 2: Manuscript

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REVIEW

Food Environment Research in Low- and Middle-Income Countries: A Systematic Scoping Review

Christopher Turner,[1] Sofia Kalamatianou,[1] Adam Drewnowski,[2] Bharati Kulkarni,[3] Sanjay Kinra,[1] and Suneetha Kadiyala[1]

[1]London School of Hygiene and Tropical Medicine, Faculty of Epidemiology and Population Health, Department of Population Health, London, United Kingdom; [2]University of Washington, Department of Nutritional Sciences, Center for Public Health Nutrition, Seattle, WA; and [3]National Institute of Nutrition, Tarnaka, Hyderabad, Telangana, India

ABSTRACT

Food environment research is increasingly gaining prominence in low- and middle-income countries (LMICs). However, in the absence of a systematic review of the literature, little is known about the emerging body of evidence from these settings. This systematic scoping review aims to address this gap. A systematic search of 6 databases was conducted in December 2017 and retrieved 920 records. In total, 70 peer-reviewed articles met the eligibility criteria and were included. Collectively, articles spanned 22 LMICs, including upper-middle-income countries ($n = 49$, 70%) and lower-middle-income countries ($n = 18$, 26%). No articles included low-income countries. Articles featured quantitative ($n = 45$, 64%), qualitative ($n = 17$, 24%), and mixed-method designs ($n = 11$, 8%). Studies analyzed the food environment at national, community, school, and household scales. Twenty-three articles (55%) assessed associations between food environment exposures and outcomes of interest, including diets ($n = 14$), nutrition status ($n = 13$), and health ($n = 1$). Food availability was associated with dietary outcomes at the community and school scales across multiple LMICs, although associations varied by vendor type. Evidence regarding associations between the food environment and nutrition and health outcomes was inconclusive. The paucity of evidence from high-quality studies is a severe limitation, highlighting the critical need for improved study designs and standardized methods and metrics. Future food environment research must address low-income and lower-middle-income countries, and include the full spectrum of dietary, nutrition, and health outcomes. Improving the quality of food environment research will be critical to the design of feasible, appropriate, and effective interventions to improve public health nutrition in LMICs. *Adv Nutr* 2019;0:1–11.

Keywords: food environment, nutrition environment, obesogenic environment, food desert, low- and middle-income countries, double burden of malnutrition, food and nutrition security, diets, nutrition, health

Introduction

Food environment research is gaining prominence in low- and middle-income countries (LMICs) at the start of the UN Decade of Action on Nutrition 2016–2025 (1). Policymakers seeking to tackle global food and nutrition security and the double burden of malnutrition are increasingly turning their attention to the role that food environments play in shaping diets, nutrition, and health in these settings (2–4).

Food environments have been described as the interface where people interact with the wider food system to acquire and consume foods (5, 6). Recent conceptual work has sought to define external and personal food environment domains applicable to global settings (5) (**Figure 1**). The external domain features exogenous dimensions such as food availability, prices, vendor and product properties, and marketing and regulation, whereas the personal domain consists of individual-level dimensions, including food accessibility, affordability, convenience, and desirability. Improved knowledge and understanding of the

This research is funded by the Innovative Methods and Metrics for Agriculture and Nutrition Actions (IMMANA) program, funded with UK aid from the UK Government (grant 6682), the Leverhulme Centre for Integrated Research on Agriculture and Health, and the Department of Epidemiology and Population Health Studentship 2015, London School of Hygiene and Tropical Medicine, United Kingdom.
Author disclosures: CT, SK, AD, BK, S Kinra, and S Kadiyala, no conflicts of interest.
Supplemental Methods 1 and Supplemental Tables 1–5 are available from the "Supplementary data" link in the online posting of the article and from the same link in the online table of contents at https://academic.oup.com/advances/.
Address correspondence to CT (e-mail: christopher.turner@lshtm.ac.uk).
Abbreviations used: HIC, high-income country; LMIC, low- and middle-income country; NRCD, nutrition-related chronic disease; PRISMA-ScR, Preferred Reporting Items for Systematic Reviews and Meta-Analyses—Extension for Scoping Reviews; SDG, Sustainable Development Goal; SSB, sugar-sweetened beverage.

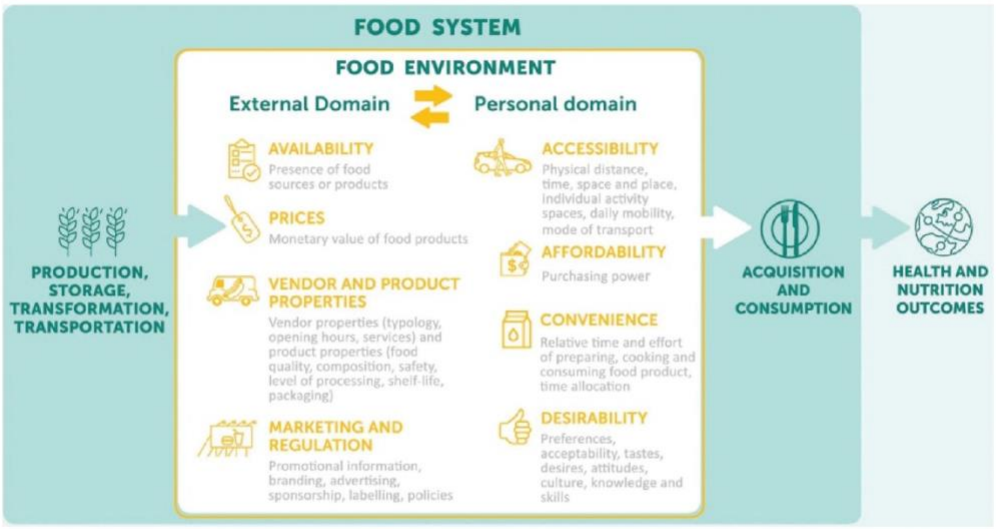


FIGURE 1 Conceptual framework. The conceptual framework depicts the food environment as the interface within the wider food system where people interact with food sources to acquire and consume foods. The external domain features exogenous dimensions such as food availability, prices, vendor and product properties, and marketing, and regulation, whereas the personal domain consists of dimensions relative to individuals, including food accessibility, affordability, convenience, and desirability. Complex interactions between these domains and dimensions shape food acquisition and consumption. (Reproduced from reference (5) with permission from Elsevier.)

interactions between these domains and dimensions are needed to address the double burden of malnutrition in LMICs, characterized by persistent undernutrition amongst women and children, as well as the increasing prevalence of overweight, obesity, and nutrition-related chronic diseases (NRCDs).

Food environment research has developed over recent decades within high-income countries (HICs) in response to the high prevalence of overweight, obesity, and NRCDs. Several systematic reviews have documented research methods and measures from HICs, as well as findings related to diet and nutrition outcomes (7–12). However, in the absence of a systematic review of the literature from LMICs, little is known about the state of science and the emerging body of evidence from these settings. This is a significant research gap given the fundamental differences between HICs and LMICs with regard to food systems, food environments, food acquisition and consumption practices, and public health nutrition challenges. This systematic scoping review aims to fill this gap by addressing 5 questions in relation to the literature from LMICs: *1*) Where has food environment research been undertaken? *2*) How have food environments been conceptualized? *3*) Which key domains and dimensions of food environments have been studied? *4*) Which study designs, methods, and measures have been implemented? *5*) What are the key findings regarding associations between food environment exposure and dietary, nutrition, and health outcomes? The synthesis of knowledge from this review is intended to mobilize a rigorous research agenda and inform evidence-based practice in LMICs, contributing towards Sustainable Development Goal (SDG) targets to end hunger (SDG Target 2.1) and all forms of malnutrition (SDG Target 2.2) (13).

Methods

Systematic scoping review

We undertook a systematic scoping review. This type of systematic review is recognized as a salient approach when synthesizing knowledge from a diverse body of literature that has yet to be reviewed (14, 15). We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses—Extension for Scoping Reviews (PRISMA-ScR) checklist and guidelines to ensure a robust and replicable process (15). The protocol is available upon request from the corresponding author.

Data collection

Search strategy.

We conducted a systematic search of the following 6 electronic databases for articles published between January 2000 and December 2017: Medline, Embase, Global Health, EconLit, Web of Science, and Scopus. Search terms included: "food environment," "nutrition environment," "obesogenic

environment," "food deserts," and "food swamps." These terms were informed by a priori knowledge and were intended to capture the breadth of the nomenclature used in food environment research. Our search strategy featured the search terms in conjunction with the 140 LMICs as defined by the World Bank for the year 2017 (16). The search strategy for Scopus is provided as an example (**Supplemental Methods 1**). No restrictions were set with regard to publication language. Scoping of results from an initial search with no date restrictions determined January 2000 to be an appropriate cut-off year, as no potentially relevant articles were identified prior to this date.

Inclusion criteria.

Original peer-reviewed published articles were considered for inclusion if they met the following criteria: *1*) included ≥1 of the search terms; *2*) included ≥1 LMIC; and *3*) described or assessed the food environment or its associations with diets, nutrition status, or health outcomes.

Exclusion criteria.

Articles were excluded if they fulfilled the following criteria: *1*) did not primarily assess the food environment or any of the key concepts; *2*) did not feature ≥1 LMIC; *3*) were not original peer-reviewed research articles; or *4*) did not contain sufficient evidence from a LMIC.

Data screening.

All records were screened independently by 2 of the authors according to the eligibility criteria. Title and abstract screening was followed by the retrieval and screening of full-text articles. The screening protocol was piloted on 6 articles to ensure consistency. Interrater agreement was high. Any disagreements were resolved through discussion between screening authors. Two articles in Spanish were screened by an additional reviewer fluent in the language.

Data charting.

Data charting was completed by 2 authors with a focus on study design, key concepts, food environment domains and dimensions (Figure 1), and any exposure, confounding, and outcome variables. Methods were categorized as either geospatial or observational (5). The data charting form was piloted on a random sample of 10 articles and refined following consultation with a third reviewer.

Quality assessment

Articles testing for associations between food environment exposure and dietary, nutrition or health outcomes were subjected to a quality assessment by 2 authors with the use of the National Heart Lung and Blood Institute checklists (17) or the Mixed-Methods Appraisal Tool (18) as appropriate. Observational notes were also taken with a focus on rigor when controlling for confounding. Quality was rated good, fair, or poor. Any discrepancies between reviewers were resolved through discussion.

Results

In total, 70 articles were included (**Figure 2**). An overview of key study characteristics is provided (**Supplemental Table 1**). Articles were published from 2009 to 2017, with the number of publications increasing per annum (**Figure 3**).

Where has food environment research been undertaken in LMICs?

The included studies spanned 22 LMICs. Forty-nine studies (70%) featured upper-middle-income countries, and 18 (26%) included lower-middle income countries. No studies were located in low-income countries. Three studies (4%) featured multiple countries from different income-level quartiles, 2 of which drew comparisons between upper-middle-income countries and HICs (19, 20), whilst 1 compared a lower-middle-income country with an HIC (21).

At the regional scale, Latin America and the Caribbean had the highest number of publications ($n = 31$), followed by East Asia and Pacific ($n = 17$), Sub-Saharan Africa ($n = 11$), South Asia ($n = 6$), and Europe and Central Asia ($n = 3$). Although Sub-Saharan Africa ranked third, South Africa dominated the continent with only 4 studies from elsewhere in the region. At the national scale, only 6 LMICs featured >2 studies: Brazil ($n = 16$), China ($n = 9$), Mexico ($n = 8$), South Africa ($n = 7$), India ($n = 6$), and Guatemala ($n = 5$) (**Figure 4**).

How have food environments been conceptualized in LMICs?

Sixty studies used a single key concept from our search terms or derivatives thereof, including "food environment" ($n = 48$), "obesogenic environment" ($n = 6$), "food desert" ($n = 4$), and "nutrition environment" ($n = 2$). Ten studies used various combinations of these key concepts. "Food swamp" was the only search term not used as a single stand-alone concept. Only 26 articles (37%) defined the key concept or concepts used to frame the study. Of these, the majority ($n = 21$) cited existing definitions, whilst 5 provided their own definition.

Which key domains and dimensions of food environments have been studied in LMICs?

The external food environment domain featured prominently, including dimensions of availability ($n = 63$), vendor and product properties ($n = 27$), prices ($n = 25$), and marketing and regulation ($n = 20$). The personal food environment domain has been addressed to a lesser extent through dimensions of accessibility ($n = 26$), desirability ($n = 21$), convenience ($n = 15$), and affordability ($n = 14$). Most studies (63%) included multiple food environment dimensions. However, only around half ($n = 33$, 47%) addressed dimensions from both the external and personal food environment domains. Of these, one-third ($n = 11$, 33%) focused exclusively on availability in combination with accessibility, the 2 most commonly studied dimensions from each respective domain. Although the external and personal food environment domains have broadly been included, few

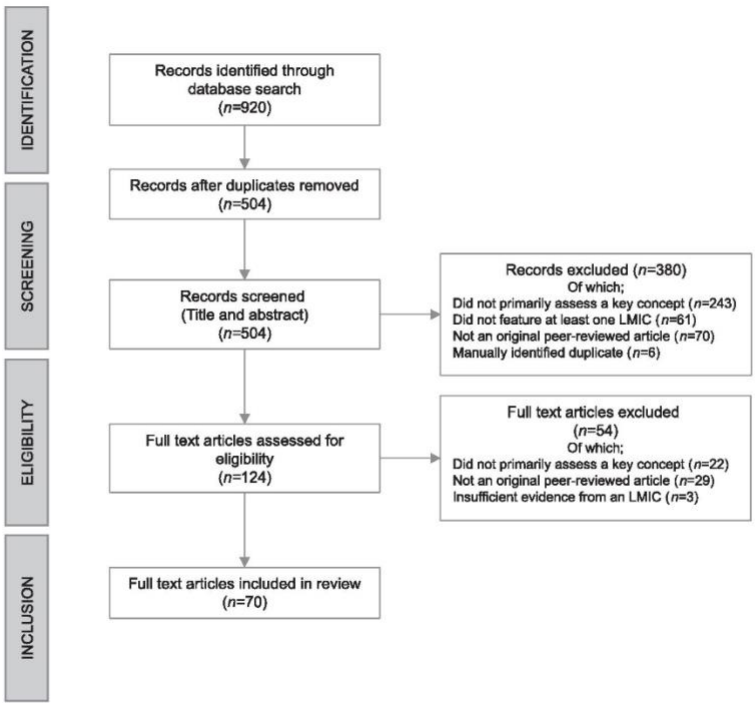


FIGURE 2 Search tree.

articles analyzed interactions between dimensions, either within or across domains.

Which study designs, methods, and measures have been implemented in LMICs?

Quantitative articles.

Forty-five articles (64%) used quantitative methods in isolation, either to describe or analyze the food environment, or test for associations with outcomes of interest. Amongst these articles, the vast majority (n = 39, 87%) featured cross-sectional study designs, whereas 3 used longitudinal data from the China Health Survey dataset (22–24), 2 used experimental designs (25, 26), and 1 implemented a modeling design (27). Quantitative articles featured a range of measurement methods, including market-based measures (n = 24), stakeholder-based measures (n = 17), and geographic information systems–based measures (n = 16) (**Supplemental Table 2**). The majority (n = 32) utilized 1 of these measurement methods in isolation, whereas 11 articles included 2 approaches, and 1 article included all 3. Four articles primarily focused on the adaptation and application of quantitative market-based survey tools from HICs (28–31).

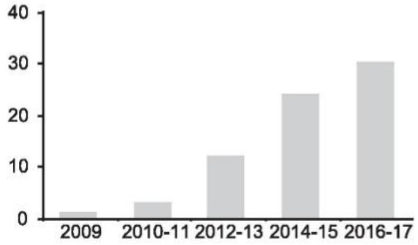


FIGURE 3 Publication year of included articles.

Qualitative articles.

Seventeen articles (24%) used qualitative stakeholder-based methods to investigate food environments. The majority (n = 10) featured a single method, such as semi-structured interviews (32–37), in-depth interviews (38), focus group discussions (21), and stakeholder workshops or dialog (39, 40). Seven articles used multiple qualitative methods (41–47).

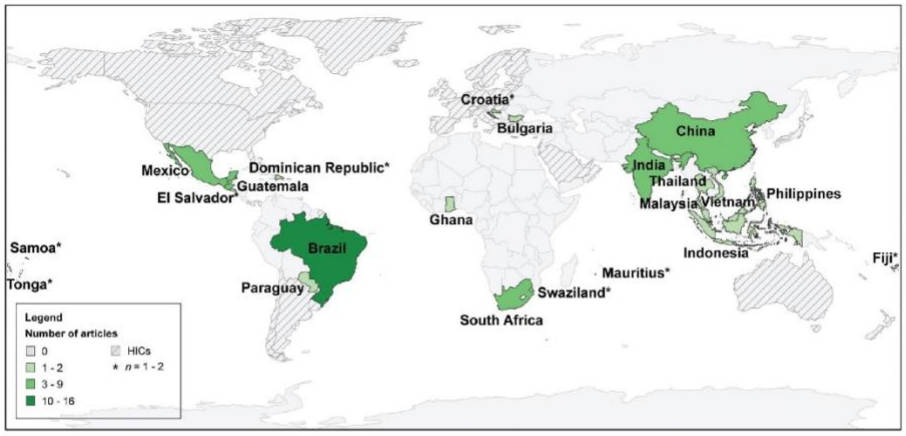


FIGURE 4 The geographic distribution of included articles across LMICs.

Mixed method articles.

Eight articles (11%) featured mixed methods. Measurement methods included stakeholder-based methods (n = 7), market-based methods (n = 6), and geographic information systems–based methods (n = 3). The majority of mixed-method articles combined ≥2 of these approaches (48–53). Mixed-method studies used similar methods and measures to those presented above.

Characterizing and analyzing food environments in LMICs

National scale.

Three articles addressed the influence of national scale policies on LMIC food environments. In Vietnam, significant increases in the availability of sugar-sweetened beverages (SSBs) were found following foreign direct investment and trade liberalization policies when compared with a control case, the Philippines (54). Qualitative articles garnered stakeholder perspectives on national scale policies in Thailand (34), and in the Pacific island states of Fiji and Tonga (39). Common themes included the need to modify the availability, accessibility, prices, and quality and marketing of healthy and unhealthy foods.

Community scale.

A number of articles characterized the availability of food sources and products at the community scale (45, 52, 53, 55–60). Evidence suggests that small- and medium-sized market-based vendors dominate across a number of LMIC settings (52, 58–60). Distinctions between formal and informal market-based vendors were identified. For example, in Cape Town, South Africa, a structural disconnect was found between the strategies of formal supermarkets and the needs of the poor, whereas informal vendors provided sources of cheaper, lower-quality foods available on credit (53). Nonmarket-based food sources were also found to be important in some settings. Examples include own production in Salvadorian communities vulnerable to food insecurity (45), and wild food harvesting in Brazilian rainforest cities (59).

Three articles from diverse settings found positive associations between levels of urbanization and the availability of market-based food vendors, such as fast-food restaurants, full-service restaurants, and supermarkets (23, 31, 60). Three articles applied a food desert perspective (49, 59, 61). In Brazil, food deserts characterized by insufficient availability and accessibility of healthy foods, particularly fruits and vegetables, were found to be widespread amongst urban communities (59). In Mexico, food swamps, rather than food deserts, typified by the inundation of unhealthy foods and drinks, were identified amongst low- and middle-income communities. In contrast, food oases were identified amongst high-income communities with limited availability of less-healthy options (49).

A number of qualitative and mixed-method articles from a range of communities described complex and contradictory perceptions and experiences of food environments. Common themes included the increasing availability and acceptance of cheap, convenient, tasty, and desirable ready-made "modern" foods, coupled with economic constraints limiting opportunities for healthier alternatives (32, 33, 45, 51). Multifaceted barriers to healthier diets were also identified in 2 studies of cross-border migrants in Cape Town, South Africa, and included an unfamiliar dependency on market-based food sources, discourse around inferior, unnatural, and unvaried food, and the fear of xenophobic violence restricting travel outside of local neighborhoods (46, 47).

School scale.
Quantitative evidence from multiple settings consistently found school food environments to be saturated with vendors selling unhealthy foods and beverages (62–68). The targeted marketing of SSBs to children was also evident (62, 64). Qualitative assessments supported the notion of readily available, affordable, and desirable unhealthy foods and beverages, whereas healthier options were found to be limited in many school settings (35, 36, 42, 43). Qualitative evidence from India also raised additional concerns around misleading marketing messages, food safety, and the importance of peer influence in school canteens (35, 36), as well as the role of food prestige placed upon non-traditional, foods from roadside vendors, restaurants, and small grocery stalls around schools (41).

School policies were found to be highly contested amongst a wide array of actors (36, 40, 43). For example, qualitative evidence from Mexico revealed divergent stakeholder perspectives on proposed policies to regulate the sale of unhealthy foods in schools, with consolidated support amongst academics, health professionals, citizens, and parents juxtaposed against food industry concerns surrounding a negative public image, loss of income, and reduced employment opportunities (40).

Household scale.
Evidence from multiple LMICs highlights a range of issues faced at the household scale, such as the role of traditional family structures and complex eating patterns in Brazil (19, 69), the perceived low efficacy of low-income mothers to provide their children with nutritious foods in Jakarta, Indonesia (38), and the targeted television marketing and promotion of unhealthy foods to children during school holidays in Malaysia (70).

Assessing associations between food environment exposures and diet, nutrition, and health outcomes in LMICs

Amongst the 42 quantitative and mixed-method articles, 23 (55%) sought to assess associations between food environment exposure and diet, nutrition, and health outcomes (**Supplemental Table 3**). Common food environment exposures included availability (vendor counts or densities) (n = 13), accessibility (distance to vendors or travel time) (n = 4), perceived availability (n = 2), food vendor choice (frequency of visits) (n = 2), and multicomponent indicators (n = 2) (20, 71). The majority of these analytical articles (n = 18, 78%) focused on a single type of outcome in isolation, whereas comparatively few (n = 5, 22%) included multiple types of outcomes. Overall, most analytical articles (n = 16, 70%) identified ≥1 significant association between food environment exposures and outcomes of interest. A synthesis of results related to dietary and nutrition outcomes is provided below. Only 1 study featured health outcomes in the form of doctor-diagnosed diseases (e.g., hypertension); however, no significant associations were found and the results are not reported in the text (72). On the whole, the quality of evidence from studies examining associations between food environment exposure and dietary, nutrition, and health outcomes was low, with 2 articles rated good (22, 73), 5 rated fair (25, 74–77), and 16 rated poor (20, 24, 26, 71, 72, 78–88) (**Supplemental Tables 4** and **5**). We therefore encourage the reader to exercise caution when interpreting results.

Dietary outcomes.
Fourteen articles included dietary outcomes. The majority of these articles (n = 11, 79%) reported ≥1 significant association between food environment exposure and dietary outcome. Most articles (n = 10) framed dietary outcomes in terms of the consumption of multiple food groups, although a few (n = 3) focused on a singular food group, and 1 featured dietary intake of kilocalories and macronutrients. Dietary diversity was used as a measure of dietary quality in 1 article (26).

Community scale. Cross-sectional evidence from multiple settings found the neighborhood availability of food vendors to be significantly associated with dietary consumption, although associations varied with vendor typology (22, 73, 87). Perceptions of food availability were also found to be significantly and positively associated with food acquisition and dietary outcomes amongst diverse Brazilian populations (76, 85). However, perceptions of other dimensions, such as proximity to vendors, food quality, or variety, were not found to be associated with fruit and vegetable intake amongst pregnant women in Ribeirao Preto City, Brazil (77).

School scale. Evidence from 2 randomzed controlled trials indicates the potential for supportive school food environments to improve adolescent diets. A school-based intervention in Mexico designed to improve the school food environment by reducing the availability of energy-dense foods and SSBs reported statistically significant reductions in the intake of non-recommended foods and beverages (25). In South Africa, a school-based intervention designed to increase the availability of healthier food options, provide nutrition education, and form school policies produced no significant effects on dietary diversity or the intake of fat and sugar between 2009 and 2011, although minor improvements in dietary diversity and restricted intake of sugar were reported (26). Cross-sectional evidence from Brazil found the availability of vendors selling unhealthy foods in and around schools to be significantly and positively associated with the regular intake of these foods amongst adolescents (83). In Guatemala, common correlates of SSB consumption included school type (public or private), sedentary behavior, frequency of purchasing lunch from school cafeterias, and frequency of purchasing snacks from vending machines (74). Cross-sectional evidence also highlighted the importance of other dimensions amongst adolescents, such as accessibility, with travel time to and from school found to be significantly and positively associated with purchasing food at or near schools in Ghana (75).

Nutrition outcomes.
Thirteen articles included nutrition outcomes. Of these, 6 (46%) found ≥1 significant association between food environment indicators and nutrition outcomes. BMI was used as the primary nutrition outcome amongst these articles, calculated with either measured (n = 9) or self-reported (n = 4) height and weight.

Community scale. Cross-sectional evidence from multiple settings identified significant associations between the availability (measured as density) of food vendors and BMI, although vendor type was found to have variable associations (86, 88). For example, a significant positive relationship was found between convenience stores and BMI in Ghana as hypothesized, whilst a significant negative relationship was found between out-of-home foods and BMI, the opposite to what was expected (86).

School scale. Evidence from a school-based randomized controlled trial in Mexico seeking to reduce the availability of energy-dense foods and SSBs found significant changes in BMI across intervention groups, although not always in the anticipated direction. Schools featuring a basic level of intervention (reliant on existing school resources) displayed increases in BMI, whereas plus-level intervention schools (provided with additional funding) and control schools showed reductions in BMI (25). Cross-sectional evidence from multiple settings also produced mixed findings. In Mexico, the availability of mobile vendors in and around schools was found to be significantly and positively associated with children's BMI, although significantly higher numbers of retail food sources around public schools produced no statistical difference on children's BMI when compared to private schools (84). A multinational study featuring Bulgarian schools (amongst others) found significant positive associations between the healthiness of the nutrition environments and the highest BMI-for-age z scores, contrary to the hypothesized expectation (20).

Discussion

The 70 articles included in this systematic scoping review constitute the rapidly emerging yet nascent body of food environment research from LMICs. Evidence from low-quality studies show that food availability is associated with dietary outcomes at both the community and school scales across multiple LMICs, although associations were found to vary by vendor type. Evidence regarding associations between food environment exposure and nutrition status is inconclusive at present, whilst evidence related to health outcomes is almost nonexistent.

The focus on outcomes related to overweight and obesity revealed in this review reflects a number of factors, including the increasing recognition of the nutrition transition that is underway across LMICs (89), the high proportion of upper-middle-income countries studied to date, many of which are arguably a considerable way along this trajectory (4), and also the development and adaptation of food environment research from HIC settings where these outcomes have typically taken precedence. However, the absence of attention to undernutrition is a striking omission within the literature. Food environment research in LMICs must seek to tackle the full spectrum of pressing public health nutrition challenges at hand (2–6), including undernutrition, overweight, obesity, and NRCDs. Research is urgently needed in lower-middle and low-income countries to track rapidly transitioning food environments and diets, and to identify the main pathways between food insecurity and multiple forms of malnutrition in these settings (90).

The lack of standardized food environment instruments and indicators identified in this review is broadly consistent with systematic reviews of the literature from HICs (7–11). Standardized instruments and indicators are needed to profile food environments across diverse LMIC settings and provide robust assessments of the influence of the food environment on transitioning diets, nutrition, and health. Deeper integration is needed between concepts, instruments, and indicators to improve the alignment between food environment exposures and outcomes of interest. The need to complement standardized dietary assessment instruments with ultraprocessed foods and out-of-home foods is increasingly being recognized (91), and such developments would benefit food environment research by harmonizing with data collection on the availability of these items.

The primary focus allocated to the external food environment domain and dimensions found in this review mirrors findings from HICs (7, 92). Although the personal food environment domain has featured less prominently, it has nevertheless received notable attention in LMICs. This is likely due to the increasing recognition of the need to understand lesser-studied dimensions such as affordability, desirability, and convenience (92, 93), the use of qualitative methods adept at capturing perceptions and experiences of such dimensions in understudied settings, and also the role that these dimensions play in food acquisition and consumption practices in LMICs. Going forward, food environment research must strive to improve understanding of the socio-ecological processes that shape food acquisition, diets, nutrition, and health (5). Establishing which dimensions are of particular importance across diverse LMIC settings and populations will be key. Mixed-methods studies are currently underutilized yet offer the opportunity for more comprehensive, multiscalar and nuanced assessments of food environments.

The paucity of evidence from high-quality analytical studies testing for associations between food environment exposures and dietary, nutrition, and health outcomes is a severe constraint at present. The current limited evidence base should not be interpreted as to diminish the importance of food environment exposure on diet, nutrition, and health outcomes in LMICs, but rather to emphasize the need to improve theoretical concepts, study designs, methods, and metrics to better capture, assess, and understand the socio-ecological interactions taking place.

Similar calls have previously been made amongst several reviews from HICs (7, 9–11, 92). Recommendations for future food environment research in LMICs are provided in **Box 1**.

Recommendations for food environment research in LMICs

(*1*) Research should seek to harmonize theoretical concepts with empirical research.
(*2*) Low-income countries and lower-middle-income countries should be considered a priority given the current paucity of studies from these settings and the pressing public health nutrition challenges at hand.
(*3*) Research should address the double burden of malnutrition, including undernutrition, overweight, obesity, and NRCDs.
(*4*) The development, testing and validation of standardized instruments and metrics to profile food environments should be prioritized to track transitioning diets across diverse settings in LMICs.
(*5*) Rigorous mixed-methods designs should be implemented to provide comprehensive assessments of external and personal food environment domains and dimensions.
(*6*) Research should apply robust longitudinal and experimental designs at multiple scales to assess the impact of interventions on diets, nutrition status, and health outcomes in LMICs.

Strengths and Limitations

This systematic scoping review is the first to focus exclusively on food environment research from LMICs. The strengths of this review include the use of the PRISMA-ScR guidelines to ensure a robust and replicable process, the use of 6 electronic databases to capture the breadth and depth of peer-reviewed publications, the inclusion of quantitative, qualitative, and mixed-methods articles, the use of the conceptual framework to guide the reporting and analysis, and the quality assessment of analytical articles. We acknowledge a number of limitations. First, in order to maintain the feasibility of this systematic scoping review we focused on the established food environment terminology. However, we recognize that there is a wealth of relevant research from wide-ranging disciplines that may not necessarily apply this nomenclature. For example, we acknowledge the following studies that address food environment dimensions in LMICs without referring to the wider construct (94, 95). Second, we conducted this systematic scoping review in adherence to the PRISMA-ScR guidelines with the aim of providing a comprehensive synthesis of the diverse food environment literature emerging from LMICs. The ability to synthesize disparate literature is a key strength of systematic scoping reviews. However, the inclusion of such a broad range of articles also limits the scope for the kinds of fine-grained analysis that other systematic review styles with a narrower aperture provide. Third, although we did not set any restrictions regarding publication language, our search terms were written in English, potentially excluding articles written in other languages. Fourth, our focus on peer-reviewed empirical articles excluded any potentially relevant gray-literature publications.

Conclusions

This systematic scoping review reveals the rapidly emerging body of food environment literature from LMICs. The included articles predominantly feature upper-middle-income countries and outcomes related to overweight and obesity. Going forward, food environment research must address low-income and lower-middle-income countries as a priority, and seek to include the full spectrum of diets, nutritional status, and health outcomes. The paucity of evidence from high-quality analytical studies indicates the urgent need to improve study designs, methods, and metrics to better capture external and personal food environment domains and dimensions. Improving the quality of food environment research will be critical to the design of feasible, appropriate, and effective interventions to improve public health nutrition in LMICs.

Acknowledgments

We thank Lauren Blake for her contributions to the screening of manuscripts written in Spanish. We also thank Helen Harris-Fry for her critical contributions to the quality assessment process. The authors' responsibilities were as follows—CT: conceived the paper, conducted the systematic search and screening, conducted data charting, analysis, and quality assessment, led the writing process, and finalized the manuscript for submission; S Kalamatianou: conducted the systematic search, screening, data charting, and provided critical feedback on the manuscript; AD, BK, S Kinra: provided critical feedback on the manuscript; S Kadiyala: conducted quality assessments and provided critical feedback on the initial paper concept, the data charting, and the manuscript throughout the writing process; and all authors: read and approved the final manuscript.

References

1. United Nations General Assembly. United Nations Decade of Action on Nutrition (2016–2025), GA Res 70/259, UN GAOR, 70th Session, Suppl 49, UN Doc A/RES/70/259. United Nations General Assembly; 2016.
2. Development Initiatives. Global nutrition report 2017: nourishing the SDGs. Bristol: Development Initiatives; 2017.
3. Global Panel on Agriculture and Food Systems for Nutrition. Improving nutrition through enhanced food environments. Policy Brief. London: Global Panel on Agriculture and Food Systems for Nutrition; 2017.
4. High Level Panel of Experts on Food Security and Nutrition. Nutrition and food systems. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security. Rome; 2017.
5. Turner C, Aggarwal A, Walls H, Herforth A, Drewnowski A, Coates J, Kalamatianou S, Kadiyala S. Concepts and critical perspectives for food environment research: a global framework with implications for

action in low- and middle-income countries. Global Food Security 2018;18:93–101.
6. Food and Agriculture Organization of the United Nations. Influencing food environments for healthy diets. Rome: FAO; 2016.
7. Caspi CE, Sorensen G, Subramanian SV, Kawachi I. The local food environment and diet: a systematic review. Health Place 2012;18(5):1172–87.
8. Cetateanu A, Jones A. How can GPS technology help us better understand exposure to the food environment? A systematic review. SSM Popul Health 2016;2:196–205.
9. Engler-Stringer R, Le H, Gerrard A, Muhajarine N. The community and consumer food environment and children's diet: a systematic review. BMC Public Health 2014;14:522.
10. Gamba RJ, Schuchter J, Rutt C, Seto EY. Measuring the food environment and its effects on obesity in the United States: a systematic review of methods and results. J Community Health 2015;40(3): 464–75.
11. Gustafson A, Hankins S, Jilcott S. Measures of the consumer food store environment: a systematic review of the evidence 2000–2011. J Community Health 2012;37(4):897–911.
12. Lytle LA, Sokol RL. Measures of the food environment: a systematic review of the field, 2007–2015. Health Place 2017;44: 18–34.
13. United Nations General Assembly, Transforming Our World: the 2030 agenda for sustainable development, GA Res 70/1, UN GAOR, 70th Session, Suppl 49, UN Doc A/RES/70/1, United Nations General Assembly, 2015.
14. Peters MD, Godfrey CM, Khalil H, McInerney P, Parker D, Soares CB. Guidance for conducting systematic scoping reviews. Int J Evid Based Healthc 2015;13(3):141–6.
15. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, Moher D, Peters MDJ, Horsley T, Weeks L, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): checklist and explanation. Ann Intern Med 2018;169(7):467–73.
16. World Bank. World Bank country and lending groups [Internet]. 2017. [cited 2017 Dec 1]. Available from: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups.
17. National Heart Lung and Blood Institute. Quality assessment tool for observational cohort and cross-sectional studies: US Department of Health and Human Services [Internet]. 2018 [accessed 2018 Apr 13]. Available from: https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools.
18. Pluye P, Robert E, Cargo M, Bartlett G, O'Cathain A, Griffiths F, Boardman F, Gagnon MP, Rousseau MC. Proposal: a mixed methods appraisal tool for systematic mixed studies reviews [Internet]. 2011 [accessed 2018 Apr 13]. Available from: http://mixedmethodsappraisaltoolpublic.pbworks.com.
19. Estima CCP, Bruening M, Hannan PJ, Alvarenga MS, Leal GVS, Philippi ST, Neumark-Sztainer D. A cross-cultural comparison of eating behaviors and home food environmental factors in adolescents from Sao Paulo (Brazil) and Saint Paul-Minneapolis (US). J Nutr Educ Behav 2014;46(5):370–5.
20. Wijnhoven TMA, van Raaij JMA, Sjoberg A, Eldin N, Yngve A, Kunesova M, Starc G, Rito AI, Duleva V, Hassapidou M, et al. WHO European Childhood Obesity Surveillance Initiative: school nutrition environment and body mass index in primary schools. Int J Environ Res Public Health 2014;11(11):11261–85.
21. Fuster M, Colón-Ramos U. Changing places, changing plates? A binational comparison of barriers and facilitators to healthful eating among Central American communities. J Immigr Minor Healt 2017;20(3):705–10.
22. Wang R, Shi L. Access to food outlets and children's nutritional intake in urban China: a difference-in-difference analysis. Ital J Pediatr 2012;38:30.
23. Wu Y, Xue H, Wang HJ, Su C, Du SF, Wang YF. The impact of urbanization on the community food environment in China. Asia Pac J Clin Nutr 2017;26(3):504–13.
24. Zhang J, Xue H, Cheng X, Wang ZH, Zhai FY, Wang YF, Wang HJ. Influence of proximities to food establishments on body mass index among children in China. Asia Pac J Clin Nutr 2016;25(1): 134–41.
25. Safdie M, Jennings-Aburto N, Lévesque L, Janssen I, Campirano-Núñez F, López-Olmedo N, Aburto T, Rivera JA. Impact of a school-based intervention program on obesity risk factors in Mexican children. Salud Publica Mex 2013;55(Suppl 3):S374–87.
26. Steyn NP, de Villiers A, Gwebushe N, Draper CE, Hill J, de Waal M, Dalais L, Abrahams Z, Lombard C, Lambert EV. Did HealthKick, a randomised controlled trial primary school nutrition intervention improve dietary quality of children in low-income settings in South Africa? BMC Public Health 2015;15:948.
27. Su SL, Li ZK, Xu MY, Cai ZL, Weng M. A geo-big data approach to intra-urban food deserts: transit-varying accessibility, social inequalities, and implications for urban planning. Habitat Int 2017;64: 22–40.
28. Duran AC, Lock K, Latorre MRDO, Jaime PC. Evaluating the use of in-store measures in retail food stores and restaurants in Brazil. Rev Saude Publica 2015;49:2–10.
29. Kanter R, Alvey J, Fuentes D. A novel mobile phone application to assess nutrition environment measures in low- and middle-income countries. Food Nutr Bull 2014;35(3):296–300.
30. Martins PA, Cremm EC, Leite FHM, Maron LR, Scagliusi FB, Oliveira MA. Validation of an adapted version of the Nutrition Environment Measurement Tool for Stores (NEMS-S) in an urban area of Brazil. J Nutr Educ Behav 2013;45(6):785–92.
31. Hua JN, Seto E, Li Y, Wang MC. Development and evaluation of a food environment survey in three urban environments of Kunming, China. BMC Public Health 2014;14:235.
32. Hardin J, Kwauk CT. Producing markets, producing people: local food, financial prosperity and health in Samoa. Food, Culture and Society 2015;18(3):519–39.
33. Kimoto R, Ronquillo D, Caamaño MC, Martinez G, Schubert L, Rosado JL, Garcia O, Long KZ. Food, eating and body image in the lives of low socioeconomic status rural Mexican women living in Queretaro State, Mexico. Health Place 2013;25:34–42.
34. Phulkerd S, Vandevijvere S, Lawrence M, Tangcharoensathien V, Sacks G. Level of implementation of best practice policies for creating healthy food environments: assessment by state and non-state actors in Thailand. Public Health Nutr 2017;20(3):381–90.
35. Rathi N, Riddell L, Worsley A. What influences urban Indian secondary school students' food consumption?—A qualitative study. Appetite 2016;105:790–7.
36. Rathi N, Riddell L, Worsley A. Food environment and policies in private schools in Kolkata, India. Health Promot Int 2017;32(2): 340–50.
37. Veeck A, Yu FG, Yu H, Veeck G, Gentry JW. Influences on food choices of urban Chinese teenagers. Young Consumers 2014;15(4): 296–311.
38. Kolopaking R, Bardosono S, Fahmida U. Maternal self-efficacy in the home food environment: a qualitative study among low-income mothers of nutritionally at-risk children in an urban area of Jakarta, Indonesia. J Nutr Educ Behav 2011;43(3):180–8.
39. Snowdon W, Lawrence M, Schultz J, Vivili P, Swinburn B. Evidence-informed process to identify policies that will promote a healthy food environment in the Pacific Islands. Public Health Nutr 2010;13(6): 886–92.
40. Monterrosa EC, Campirano F, Tolentino Mayo L, Frongillo EA, Hernandez Cordero S, Kaufer-Horwitz M, Rivera JA. Stakeholder perspectives on national policy for regulating the school food environment in Mexico. Health Policy Plan 2015;30(1):28–38.
41. Maxfield A, Patil S, Cunningham SA. Globalization and food prestige among Indian adolescents. Ecol Food Nutr 2016;55(4):341–64.
42. Pehlke EL, Letona P, Hurley K, Gittelsohn J. Guatemalan school food environment: impact on schoolchildren's risk of both undernutrition and overweight/obesity. Health Promot Int 2016;31(3): 542–50.

43. Pehlke EL, Letona P, Ramirez-Zea M, Gittelsohn J. Healthy casetas: a potential strategy to improve the food environment in low-income schools to reduce obesity in children in Guatemala City. Ecol Food Nutr 2016;55(3):324–38.
44. Smit W, de Lannoy A, Dover RVH, Lambert EV, Levitt N, Watson V. Making unhealthy places: the built environment and non-communicable diseases in Khayelitsha, Cape Town. Health Place 2016;39:196–203.
45. Fuster M, Messer E, Houser RF, Deman H, de Fulladolsa PP, Bermudez OI. Local notions of healthy eating and national dietary guidelines: a comparison in vulnerable Salvadoran communities. Food Foodways 2013;21(4):288–314.
46. Hunter-Adams J. Exploring perceptions of the food environment amongst Congolese, Somalis and Zimbabweans living in Cape Town. Int Migr 2017;55(4):78–87.
47. Hunter-Adams J, Rother HA. Pregnant in a foreign city: a qualitative analysis of diet and nutrition for cross-border migrant women in Cape Town, South Africa. Appetite 2016;103:403–10.
48. Barr S. Using mixed methods to describe a spatially dynamic food environment in rural Dominican Republic. Hum Ecol 2017;45(6): 845–51.
49. Bridle-Fitzpatrick S. Food deserts or food swamps? A mixed-methods study of local food environments in a Mexican city. Soc Sci Med 2015;142:202–13.
50. Chaudhari LS, Begay RC, Schulz LO. Fifteen years of change in the food environment in a rural Mexican community: the Maycoba project. Rural Remote Health 2013;13(3):2404.
51. Finzer LE, Ajay VS, Ali MK, Shivashankar R, Goenka S, Sharma P, Pillai DS, Khandelwal S, Tandon N, Reddy KS, et al. Fruit and vegetable purchasing patterns and preferences in South Delhi. Ecol Food Nutr 2013;52(1):1–20.
52. Gupta V, Downs SM, Ghosh-Jerath S, Lock K, Singh A. Unhealthy fat in street and snack foods in low-socioeconomic settings in India: a case study of the food environments of rural villages and an urban slum. J Nutr Educ Behav 2016;48(4):269–79.e1.
53. Peyton S, Moseley W, Battersby J. Implications of supermarket expansion on urban food security in Cape Town, South Africa. Afr Geogr Rev 2015;34(1):36–54.
54. Schram A, Labonte R, Baker P, Friel S, Reeves A, Stuckler D. The role of trade and investment liberalization in the sugar-sweetened carbonated beverages market: a natural experiment contrasting Vietnam and the Philippines. Global Health 2015;11:41.
55. Castro-Sánchez AE, Aparicio-Moreno CE, Ramos-Peña EG. The study of food environments as a strategy of social sustainability in the Mexican Northeast. Int J Sustain Policy Prac 2014;9(3):57–74.
56. Duran AC, Roux AVD, Latorre M, Jaime PC. Neighborhood socioeconomic characteristics and differences in the availability of healthy food stores and restaurants in Sao Paulo, Brazil. Health Place 2013;23:39–47.
57. Ivanova L, Trifonova J, Terziyska I. Study on some factors for healthy nutrition environment in restaurants in southwestern Bulgaria. Tourism and Hospitality Management. 2012;18(2): 259–66.
58. Costa BVD, Oliveira CD, Lopes AC. Food environment of fruits and vegetables in the territory of the Health Academy Program. Cad Saude Publica 2015;31:159–69.
59. Davies G, Frausin G, Parry L. Are there food deserts in rainforest cities? Ann Am Assoc Geogr 2017;107(4):794–811.
60. Liao CX, Tan YY, Wu CQ, Wang SF, Yu CQ, Cao WH, Gao WJ, Lv J, Li LM. City level of income and urbanization and availability of food stores and food service places in China. PLoS One. 2016;11(3): e0148745.
61. Cerovečki IG, Grünhagen M. "Food deserts" in urban districts: evidence from a transitional market and implications for macromarketing. J Macromarketing 2016;36(3):337–53.
62. Chacon V, Letona P, Villamor E, Barnoya J. Snack food advertising in stores around public schools in Guatemala. Crit Public Health 2015;25(3):291–8.
63. Faber M, Laurie S, Maduna M, Magudulela T, Muehlhoff E. Is the school food environment conducive to healthy eating in poorly resourced South African schools? Public Health Nutr 2014;17(6): 1214–23.
64. Moodley G, Christofides N, Norris SA, Achia T, Hofman KJ. Obesogenic environments: access to and advertising of sugar-sweetened beverages in Soweto, South Africa, 2013. Prev Chronic Dis 2015;12:140559.
65. Soltero EG, Ortiz Hernandez L, Jauregui E, Levesque L, Taylor JLY, Barquera S, Lee RE. Characterization of the school neighborhood food environment in three Mexican cities. Ecol Food Nutr 2017;56(2): 139–51.
66. Chan Sun M, Lalsing Y, Subratty AH. Primary school food environment in Mauritius. Nutr Food Sci 2009;39(3):251–9.
67. Pulz IS, Martins PA, Feldman C, Veiros MB. Are campus food environments healthy? A novel perspective for qualitatively evaluating the nutritional quality of food sold at foodservice facilities at a Brazilian university. Perspect Public Health 2017;137(2):122–35.
68. Wojcicki JM, Elwan D. Primary school nutrition and tuck shops in Hhoho, Swaziland. J Child Nutr Manage [Internet]. 2014, 38(1); [Accessed 2019 Feb 13]. Available from: https:/schoolnutrition.org/5–News-and-Publications/4–The-Journal-of-Child-Nutrition-and-Management/Spring-2014/Volume-38,-Issue-1,-Spring-2014—Wojcicki,-Elwan/).
69. Soares ALG, de Franca GVA, Goncalves H. Household food availability in Pelotas, Brazil: an approach to assess the obesogenic environment. Rev Nutr 2014;27(2):193–203.
70. Ng SH, Kelly B, Se CH, Chinna K, Sameeha MJ, Krishnasamy S, Ismail MN, Karupaiah T. Obesogenic television food advertising to children in Malaysia: sociocultural variations. Global Health Action 2015;8(1): 1–11.
71. Gartin M. Food deserts and nutritional risk in Paraguay. Am J Hum Biol 2012;24(3):296–301.
72. Kelly M, Seubsman SA, Banwell C, Dixon J, Sleigh A. Thailand's food retail transition: supermarket and fresh market effects on diet quality and health. Br Food J 2014;116(7):1180–93.
73. Duran AC, De Almeida SL, Latorre MDRD, Jaime PC. The role of the local retail food environment in fruit, vegetable and sugar-sweetened beverage consumption in Brazil. Public Health Nutr 2016;19(6):1093–102.
74. Godin KM, Chacon V, Barnoya J, Leatherdale ST. The school environment and sugar-sweetened beverage consumption among Guatemalan adolescents. Public Health Nutr 2017;20(16):2980–7.
75. Fernandes M, Folson G, Aurino E, Gelli A. A free lunch or a walk back home? The school food environment and dietary behaviours among children and adolescents in Ghana. Food Security 2017;9(5):1073–90.
76. Vedovato GM, Trude ACB, Kharmats AY, Martins PA. Degree of food processing of household acquisition patterns in a Brazilian urban area is related to food buying preferences and perceived food environment. Appetite 2015;87:296–302.
77. Zuccolotto DCC, Barbieri P, Sartorelli DS. Food environment and family support in relation to fruit and vegetable intake in pregnant women. Arch Latinoam Nutr 2015;65(4):216–24.
78. Anggraini R, Februhartanty J, Bardosono S, Khusun H, Worsley A. Food store choice among urban slum women is associated with consumption of energy-dense food. Asia Pac J Public Health 2016;28(5):458–68.
79. Mendes LL, Nogueira H, Padez C, Ferrao M, Velasquez-Melendez G. Individual and environmental factors associated for overweight in urban population of Brazil. BMC Public Health 2013;13:988.
80. Patel O, Shahulhameed S, Shivashankar R, Tayyab M, Rahman A, Prabhakaran D, Tandon N, Jaacks LM. Association between full service and fast food restaurant density, dietary intake and overweight/obesity among adults in Delhi, India. BMC Public Health 2017;18(1):36.
81. Velasquez-Melendez G, Mendes LL, Padez CMP. Built environment and social environment: associations with overweight and obesity in a sample of Brazilian adults. Cad Saude Publica 2013;29(10):1988–96.
82. Zhang XY, van der Lans I, Dagevos H. Impacts of fast food and the food retail environment on overweight and obesity in China: a

multilevel latent class cluster approach. Public Health Nutr 2012;15(1): 88–96.
83. Azeredo CM, de Rezende LF, Canella DS, Claro RM, Peres MF, Luiz Odo C, Franca-Junior I, Kinra S, Hawkesworth S, Levy RB. Food environments in schools and in the immediate vicinity are associated with unhealthy food consumption among Brazilian adolescents. Prev Med 2016;88:73–9.
84. Barrera LH, Rothenberg SJ, Barquera S, Cifuentes E. The toxic food environment around elementary schools and childhood obesity in Mexican cities. Am J Prev Med 2016;51(2):264–70.
85. Chor D, Cardoso LO, Nobre AA, Griep RH, Fonseca MDM, Giatti L, Bensenor I, Molina MDB, Aquino EML, Diez-Roux A, et al. Association between perceived neighbourhood characteristics, physical activity and diet quality: results of the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil). BMC Public Health 2016;16:751.
86. Dake FAA, Thompson AL, Ng SW, Agyei-Mensah S, Codjoe SNA. The local food environment and body mass index among the urban poor in Accra, Ghana. J Urban Health 2016;93(3):438–55.
87. Jaime PC, Duran AC, Sarti FM, Lock K. Investigating environmental determinants of diet, physical activity, and overweight among adults in Sao Paulo, Brazil. J Urban Health 2011;88(3):567–81.
88. Zhou M, Tan SK, Tao YH, Lu YZ, Zhang Z, Zhang L, Yan DP. Neighborhood socioeconomics, food environment and land use determinants of public health: isolating the relative importance for essential policy insights. Land Use Policy 2017;68:246–53.
89. Popkin BM. Nutrition transition and the global diabetes epidemic. Curr Diab Rep 2015;15(9):64.
90. Food and Agriculture Organization of the United Nations. The state of food security and nutrition in the world 2018: building climate resilience for food security and nutrition. Rome: FAO; 2018.
91. Walls HL, Johnston D, Mazalale J, Chirwa EW. Why we are still failing to measure the nutrition transition. BMJ Glob Health 2018;3(1):e000657.
92. Penney TL, Almiron-Roig E, Shearer C, McIsaac JL, Kirk SFL. Modifying the food environment for childhood obesity prevention: challenges and opportunities. Proc Nutr Soc 2014;73(2): 226–36.
93. Lytle LA. Measuring the food environment: state of the science. Am J Prev Med 2009;36(4 Suppl):S134–44.
94. Miller V, Yusuf S, Chow CK, Dehghan M, Corsi DJ, Lock K, Popkin B, Rangarajan S, Khatib R, Lear SA, et al. Availability, affordability, and consumption of fruits and vegetables in 18 countries across income levels: findings from the Prospective Urban Rural Epidemiology (PURE) study. Lancet Glob Health 2016;4(10):e695–703.
95. Yim A, Humphries D, Abuova G. Food, alcohol and cigarette availability and consumption in Almaty, Kazakstan: results and appraisal of a rapid assessment. Public Health Nutr 2003;6(8):791–800.

3.6.Summary of Appendix 1: Publication 2

Supplemental Material for this publication is included in Appendix 1 (Chapter 8), including:

- Supplemental Methods 1: Search strategy – Scopus.
- Supplemental Table 1: Key characteristics of all included articles (n=70).
- Supplemental Table 2: Quantitative articles - measurement methods and tools.
- Supplemental Table 3: A synthesis of results from articles assessing food environment exposure and diet, nutrition and health outcomes (n=23).
- Supplemental Table 4: Quality assessment - National Heart, Lung and Blood Institute checklists.
- Supplemental Table 5: Quality assessment – Mixed Methods Appraisal Tool.

3.7.Contribution of Publication 2 to the thesis

This publication addresses the literature review-based research gap, and the second aim of my thesis to conduct a systematic scoping review and synthesis of the existing food environment literature from LMICs. This publication also provides a critical contribution to my thesis by documenting the food environment research frontier in LMICs, including published articles from the year 2000 to December 2017. The review presents the geographical distribution of studies across countries, the various scales analysed, the methods and metrics used, and the evidence base from existing studies. In particular, this publication contributes definitive knowledge regarding the scope of the published food environment literature from India. Findings from this systematic scoping review reveal food environment research in India to have focused on the community level, including quantitative assessments of the availability of food vendors and products in Delhi (1-3), and the school level, including qualitative investigations of perceptions and experiences of the school food environment amongst adolescents in Kolkata (4, 5) and Vijaypura (6). In addition, findings make evident the lack of participatory research methods amongst food environment research in LMICs. I make strides to address this gap in the publications that follow.

3.8.References: Contributions of Publication 2 to the thesis

1. Finzer LE, Ajay VS, Ali MK, Shivashankar R, Goenka S, Sharma P, Pillai DS, Khandelwal S, Tandon N, Reddy KS, et al. Fruit and Vegetable Purchasing Patterns and Preferences in South Delhi. Ecology of Food and Nutrition. 2013;52(1):1-20.

2. Gupta V, Downs SM, Ghosh-Jerath S, Lock K, Singh A. Unhealthy Fat in Street and Snack Foods in Low-Socioeconomic Settings in India: A Case Study of the Food Environments of Rural Villages and an Urban Slum. J Nutr Educ Behav. 2016;48(4):269-79 e1.

3. Patel O, Shahulhameed S, Shivashankar R, Tayyab M, Rahman A, Prabhakaran D, Tandon N, Jaacks LM. Association between full service and fast food restaurant density, dietary intake and overweight/obesity among adults in Delhi, India. Bmc Public Health. 2017;18.

4. Rathi N, Riddell L, Worsley A. What influences urban Indian secondary school students' food consumption? - A qualitative study. Appetite. 2016;105:790-7.

5. Rathi N, Riddell L, Worsley A. Food environment and policies in private schools in Kolkata, India. Health Promotion International. 2017;32(2):340-50.

6. Maxfield A, Patil S, Cunningham SA. Globalization and Food Prestige among Indian Adolescents. Ecology of Food and Nutrition. 2016;55(4):341-64.

4. Publication 3: Investigating food environments using a qualitative geographical information systems (Q-GIS) approach: A case study from Telangana, India

4.1. Preamble to publication 3: Motivation for the article

Publication three addresses the third research question:

3. *How can a qualitative geographical information systems approach and participatory visual methods be used to investigate the food environment and drivers of food acquisition in LMICs, and what are the strengths and limitations of a Q-GIS approach?*

Recent calls have been made within the field of environmental epidemiology and population health to implement people-based measures of exposure, in order to situate individuals within their wider environment and investigate the ways in which people perceive, experience, and respond to different contextual factors in different ways as part of daily life (1-4). Food environment research has also echoed these sentiments, largely in response to the limited evidence in support of associations between neighbourhood level exposure and individual diet, nutrition and health outcomes, and the recognised need to address the complex socio-ecological drivers and mediators of diets, nutrition and health (2, 5-8). Qualitative people-based measures of exposure have the potential to provide more nuanced and comprehensive knowledge and understanding of how people acquire and consume foods by accounting for the multiple contexts to which people are exposed as part of their daily activity spaces (3, 9). Geographical perspectives may be helpful here, as they are rooted in understanding how space and place interact with social and economic processes to shape various phenomenon of interest, and have a strong tradition of investigating *with* participants through participatory qualitative GIS methods such as community mapping (9-11). Inspiration may also be drawn from wider participatory public health research health such as 'photovoice' (12) that utilise participatory photography as a visual method to investigate community perspectives and experiences.

In order to investigate the food environment and drivers of food acquisition as part of daily life in the APCAPS, I have designed and implemented a qualitative multi-method approach,

complementing in-depth interviews with an innovative Q-GIS approach featuring participatory photo mapping (PPM) and follow-up graphic- and photo-elicitation interviews (Box 1). This methods paper presents the development and application of the novel Q-GIS approach, using a case study featuring two peri-urban villages in Telangana, India.

Box 1: Author contributions to publication 3

Christopher Turner: Conceived the paper, designed the research protocol, supervised data collection, conducted qualitative analysis, led the writing process, copy-edited the manuscript, finalised the manuscript, responded to feedback from co-authors and amended the manuscript for submission.

Santhi Bhogadi: Coordinated the field team during data collection. Provided technical feedback on fieldwork and data collection methods.

Bharati Kulkarni: Supervised data collection. Provided critical feedback on the manuscript.

Sanjay Kinra: Provided critical feedback on the manuscript.

Suneetha Kadiyala: Provided critical feedback on the manuscript throughout the writing process.

4.2.References: Preamble to publication 3

1. Bell SL, Phoenix C, Lovell R, Wheeler BW. Using GPS and geo-narratives: a methodological approach for understanding and situating everyday green space encounters. Area. 2015;47(1):88-96.

2. Chen X, Kwan MP. Contextual Uncertainties, Human Mobility, and Perceived Food Environment: The Uncertain Geographic Context Problem in Food Access Research. Am J Public Health. 2015;105(9):1734-7.

3. Kwan MP. The Limits of the Neighborhood Effect: Contextual Uncertainties in Geographic, Environmental Health, and Social Science Research. Annals of the American Association of Geographers. 2018;108(6):1482-90.

4. Milton S, Pliakas T, Hawkesworth S, Nanchahal K, Grundy C, Amuzu A, Casas JP, Lock K. A qualitative geographical information systems approach to explore how older people over

70 years interact with and define their neighbourhood environment. Health and Place. 2015;36:127-33.

5. Brug J, Kremers SP, van Lenthe F, Ball K, Crawford D. Environmental determinants of healthy eating: in need of theory and evidence. Proceedings of the Nutrition Society. 2008;67(3):307-16.

6. Lytle LA, Sokol RL. Measures of the food environment: A systematic review of the field, 2007-2015. Health & Place. 2017;44:18-34.

7. Penney TL, Almiron-Roig E, Shearer C, McIsaac JL, Kirk SFL. Modifying the food environment for childhood obesity prevention: challenges and opportunities. Proceedings of the Nutrition Society. 2014;73(2):226-36.

8. Turner C, Aggarwal A, Walls H, Herforth A, Drewnowski A, Coates J, Kalamatianou S, S. K. Concepts and critical perspectives for food environment research: A global framework with implications for action in low- and middle-income countries. Global Food Security. 2018;18:93-101.

9. Pritchard B, Mackay H, Turner C. Special issue introduction: geographical perspectives on food and nutrition insecurity in the global South. Geographical Research. 2017;55(2):127-30.

10. Corbett J, Rambaldi G. 'Representing our Reality': Geographic Information Technologies, Local Knowledge and Change. In: Cope M, Elwood S, editors. Qualitative GIS: Mixed Methods in Practice and Theory: Sage Books; 2009. p. 75.

11. Ahmed S, Haklay M, Allen A, Tacoli C, Simiyu E, Davila J. Participatory Mapping for Transformation: Multiple Visual Representation of Foodscapes and Environment in Informal Settings in Nairobi. In: Malleson N, Addis N, Durham H, Heppenstrall A, Lovelace R, Norman P, et al., editors. Proceedings of GIS Research UK (GISRUK). Leeds, UK.: GIS Research UK (GISRUK); 2015. p. 14-9.

12. Wang C, Burris MA. Photovoice: Concept, methodology, and use for participatory needs assessment. Health Education & Behavior. 1997;24(3):369-87.

4.3.Research paper cover sheet: Publication 3

London School of Hygiene & Tropical Medicine
Keppel Street, London WC1E 7HT

T: +44 (0)20 7299 4646
F: +44 (0)20 7299 4656
www.lshtm.ac.uk

RESEARCH PAPER COVER SHEET

Please note that a cover sheet must be completed for each research paper included within a thesis.

SECTION A – Student Details

Student ID Number	1510864	**Title**	Mr
First Name(s)	Christopher		
Surname/Family Name	Turner		
Thesis Title	Investigating food environments and drivers of food acquisition in low- and middle-income countries: The case of peri-urban Hyderabad, Telangana, India		
Primary Supervisor	Dr Suneetha Kadiyala		

If the Research Paper has previously been published please complete Section B, if not please move to Section C.

SECTION B – Paper already published

Where was the work published?			
When was the work published?			
If the work was published prior to registration for your research degree, give a brief rationale for its inclusion			
Have you retained the copyright for the work?*	Choose an item.	Was the work subject to academic peer review?	Choose an item.

*If yes, please attach evidence of retention. If no, or if the work is being included in its published format, please attach evidence of permission from the copyright holder (publisher or other author) to include this work.

SECTION C – Prepared for publication, but not yet published

Where is the work intended to be published?	International Journal of Qualitative Methods
Please list the paper's authors in the intended authorship order:	Turner, C.* Bhogadi, S. Kulkarni, B. Kinra, S., Kadiyala, S.
Stage of publication	**Not yet submitted**

SECTION D – Multi-authored work

For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)	Manuscript title:Investigating food environments using a qualitative geographical information systems (Q-GIS) approach: A case study from Telangana, India. Chris conceived the paper, designed the protocol, obtained ethical clearence, trained the field team, desinged the topic guides, conducted the pilot testing, managed the primary data collection, conducted data processing - including GIS mapping, writing of photo probes, and production of Q-GIS charts, conducted the data analysis - including coding of transcripts and photographs, led the writing process, copy-edited the manuscript, and finalised the manuscript for inclusion in the thesis.

SECTION E

Student Signature	[redacted]
Date	19/07/19

Supervisor Signature	[redacted]
Date	22/09/19

4.4.Publication 3: Manuscript

Investigating food environments using a qualitative geographical information systems (Q-GIS) approach: A case study from Telangana, India

Turner, C.[1*] Bhogadi, S.[2] Kulkarni, B[3] Kinra, S[1]. Kadiyala, S.[1]

[1] *London School of Hygiene and Tropical Medicine, Faculty of Epidemiology and Population Health, Department of Population Health, Keppel Street, London, WC1E 7HT, United Kingdom.*

[2] *Indian School of Business, Hyderabad, India*

[3] *National Institute of Nutrition, Hyderabad, India*

*Corresponding author: christopher.turner@lshtm.ac.uk

Abstract

This methods paper presents the development and application of a novel qualitative geographical information systems (Q-GIS) approach to investigating food environments and drivers of food choice, featuring participatory photo mapping (PPM) and follow-up graphic- and photo-elicitation interviews. A case study is used to illustrate the research design and implementation, featuring two urbanising villages in Telangana, India. Results include the feasibility and utility of the participatory photo mapping, as well as the follow-up graphic- and photo-elicitation interviews. We also present participant's perceptions and experiences of the Q-GIS approach throughout the research process, before discussing the strengths, limitations, and future prospects for the development of the Q-GIS approach within food environment research.

Introduction

Food environment research has been gaining prominence over the past decade as public health researchers seek to understand drivers of food acquisition that are shaping dietary and public health outcomes across the globe (1, 2). Food environments include the "collective physical, economic, policy and sociocultural surroundings, opportunities and conditions that influence people's food and beverage choices and nutritional status" (3: p.2). A recent globally applicable conceptual framework identified key domains and dimensions, including the external food environment and dimensions of food availability, prices, vendor and product properties, and marketing and regulation, and the personal food environment, including dimensions relative to individuals, such as accessibility, affordability, convenience and desirability (4) (Figure 1). Interactions between these domains and dimensions shape food acquisition and consumption practices, and contribute to nutrition and health outcomes.

Food environment research has developed in high income countries (HICs) over the past decade, however, public health researchers have increasingly sought to investigate food environments in low- and middle-income countries (LMICs) in recent years in response to rapidly transitioning diets and the emerging double burden of malnutrition that includes undernutrition, as well as increasing overweight, obesity and diet related non-communicable diseases. Several review articles have documented the broad range of methods and metrics implemented to measure various aspects of food environments, both in in HICs (1, 5-12) and LMICs (2). Quantitative methods feature prominently within the literature to date, with the majority of studies seeking to describe and analyse the food environment, often in terms of the availability of market-based food vendors, in relation to dietary, nutrition and health outcomes at the community or neighbourhood level. Quantitative methods and metrics can be broadly categorised into geographical information system (GIS) based approaches, featuring geospatial analysis techniques, and market-based survey approaches (4). A series of methodological limitations have been identified within the review literature from HIC settings, including a lack of robust standardised methods and metrics to measure food environment exposure, and the diverse array of indicators used to assess dietary, nutrition, and health outcomes (1, 5, 7-10, 12-14). In addition, known methodological limitations include the 'local trap' (15), 'neighbourhood effects' (16), the 'modifiable unit area problem'

and the 'uncertain geographic context problem' (17, 18), as well as a host of issues related to the collection of survey data in dynamic food environments, and the use of incomplete, inaccurate, or proxy-based secondary datasets (10, 11). These limitations have also been identified in the emerging body of quantitative research from LMICs, reflecting the adaptation of methods and metrics from HIC settings, and resulting in the paucity of high-quality evidence from analytical studies (2). Furthermore, many of the challenges outlined above facing quantitative food environment research are likely to be amplified in LMIC settings where: 1) existing quantitative data and validated tools are scarce; 2) food environments are highly dynamic, featuring large variation throughout the diurnal cycle; 3) many market-based vendors are difficult to survey due to their informal, un-registered, and often highly mobile nature; and 4) many consumers acquire and consume foods from diverse market and non-market-based sources as part of daily life.

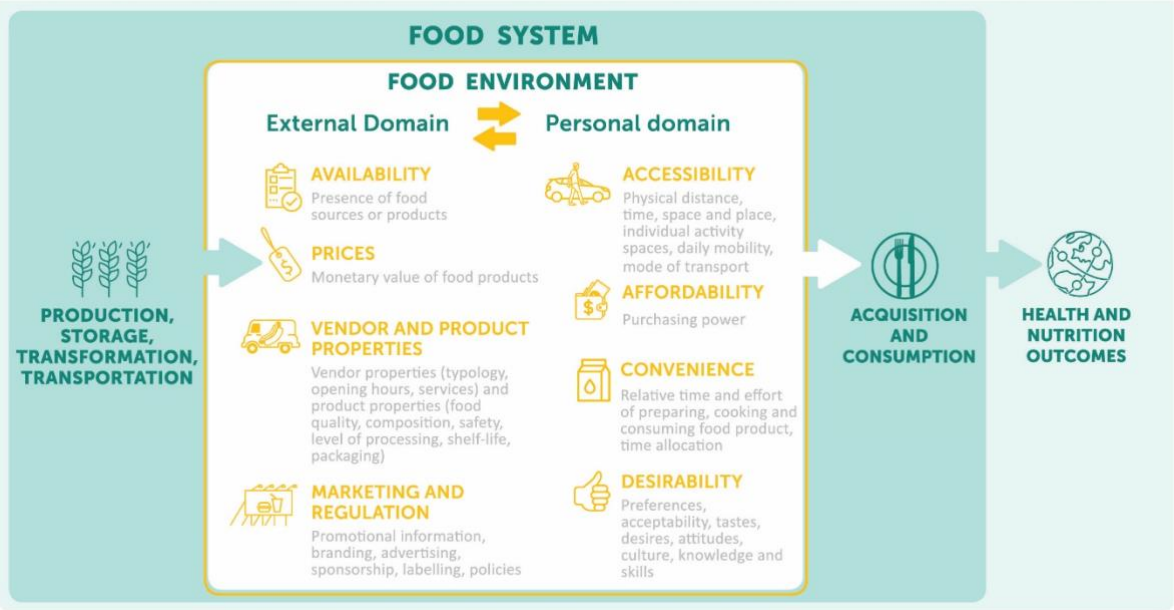
Recent calls have been made within public health-based research to expand research methods by introducing qualitative and mixed methods approaches, in order to obtain more nuanced, in-depth, and comprehensive forms of knowledge and understanding about how people perceive and respond to environmental exposures that occur as part of everyday life (16). Similar calls have been echoed with respect to food environment research in response to the dominance of quantitative approaches that have failed to account for the social processes and symbolic relationships between people and their environment (19), and the largely inconclusive body of evidence from the literature testing for associations between food environment exposure and dietary, nutrition and health outcomes. A number of articles have identified the need to investigate food environments and drivers of food acquisition using qualitative approaches to reveal individual, or emic, perspectives, and situate people's food acquisition practices within their food environment (4, 14, 17, 20). Consistent with this philosophy, there is increasing recognition of the need to understand people's perceptions of their food environment (4, 14, 17, 21), and to address the role that space and place play in food acquisition and consumption through the narrative practice of listening to contextualised lived experiences of voices from below (22).

Qualitative research investigating food environments and drivers of food choice in LMICs has predominantly drawn from methods such as in-depth interviews (23-28), semi-structured

interviews (29-36), and focus-group discussions (23-25, 27, 28, 37-39). However, on the basis of a recent systematic review of food environment research from LMICs (2) and wider reading of the drivers of food choice literature, the kinds of qualitative research required to gain emic perspectives and experiences of food acquisition and consumption framed within the wider spatial and temporal contexts of everyday life remain scarce. Inspiration may be drawn here from wider participatory public health research grounded in geographical and sociological traditions. Participatory research methods have an established history across a broad range of research settings and topics of interest, and have utilised various techniques including qualitative geographical information systems (Q-GIS) mapping (40-42) and visual-based techniques such as photo-elicitation, also known as photovoice (43). These approaches may be particularly useful in LMIC settings, enabling consumers to voice and visualise their contextualised perceptions, lived experiences, and tacit knowledge and understanding of food environments and drivers of food acquisition. Integrating participatory GIS and visual methods may also address the LMIC specific challenges outlined above by revealing embodied narratives of the spatial and temporal dynamics of food acquisition and consumption that occur as part of everyday life.

This methods paper presents a novel Q-GIS approach featuring participatory photo mapping (PPM) and follow-up graphic- and photo-elicitation interviews. We provide a short narrative synthesis review of Q-GIS and participatory visual research methods, including PPM and graphic- and photo-elicitation. A case study is subsequently used to illustrate the design and implementation of our research protocol, drawing from an investigation of the food environment and drivers of food acquisition in two urbanising villages in Telangana, India. We present an assessment of the feasibility and utility of our Q-GIS approach, including participatory photo mapping and the follow-up graphic- and photo-elicitation interviews. Participant's perceptions and experiences of the Q-GIS approach throughout the research process are presented, before we address the strengths and limitations of this approach, and discuss the future prospects for the development of our Q-GIS approach within food environment research.

Figure 1: A globally applicable food environment conceptual framework (4).



Literature synthesis

Qualitative Geographical Information Systems (Q-GIS)

Q-GIS emerged in the mid-1990s in response to critiques of the positivist epistemologies and quantitative traditions of GIS within the social and spatial sciences. GIS had, up until this point, focused almost exclusively on the measurement and analysis of geospatial data using spatial statistics (44). Q-GIS refers to the integration of qualitative forms of data and analysis into GIS, utilising multiple 'ways of knowing' in order to build representations and explanations of how spatial knowledge, patterns, relationships and interactions are produced, and with what social and or political impacts (44). Q-GIS enables critical thinking about the spatiality of social processes through narratives, perceptions and experiences garnered from everyday life (45). For example, a number of studies in HICs have integrated maps and interviews to provide contextualised insights into space and place-based aspects of health-related behaviours (41, 42).

Q-GIS approaches are often participatory in nature, enabling participants to collect data and engage in an interactive and reflective process of negotiating and representing local knowledge through diverse forms of media (46). Participatory forms of GIS have been found

to provide a particularly useful platform for the integration multiple sources of data such as maps, transcripts and statistics in innovative ways to create contextualized cartographic narratives grounded in everyday life (47). Participatory GIS projects have been used to map communities in the informal settlements of Nairobi, Kenya, engaging local residents in dialogue in order to explore how the types of food people eat are connected with the places where they live, work and walk (40, 48). Mapping in this way is considered to be both a process and a product, simultaneously consisting of and contributing to situated knowledge about interactions between consumers and food (40). Participatory GIS approaches have also been integrated with qualitative visual methodologies, such as participatory photo mapping (PPM). The PPM approach is rooted in social interpretivist theory which seeks to understand the ways in which people interpret and understand their environment, as well as the multi-faceted and often tacit aspects of lived experience (49). The integration of photos and maps provides the potential to unlock a nexus of locational, visual, and narrative forms of everyday knowledge about communities. For example, this approach has been successfully implemented in public health research in the United States to investigate the role of space and place in relation to community health and safety issues amongst adolescents, revealing narratives about food and nutrition amongst other issues (49).

Visual methods: Participatory photography and photo-elicitation

Visual methods such as participatory photography and photo-elicitation have been used in anthropology, sociology and health-based research across diverse settings to explore and emic perspectives of lived experiences (43, 50-52). Photo-elicitation consists of introducing photographs into the interview process to evoke information, feelings, and memories from the visual form of representation (52). A narrative review of photo-elicitation by Harper (52) traced the roots of the method back to a study of mental health in changing communities in Canada in the 1950s, where the inclusion of photographs in qualitative interviews was found to elicit more comprehensive interview transcripts and stimulate emotional statements related to lived experiences and daily life (51, 53, 54). A small and somewhat niche body of photo-elicitation research developed in the decades that followed, grouped around four main areas of sociological research, including social class, social organisation and family; community and historical ethnography; identity; and culture (52). Photo-elicitation was

rejuvenated in public health in the late 1990s through the development of photovoice, a community-based participatory action research strategy applied to women's health (43, 55). Recent publications have continued to build on the model of photo-elicitation as a salient participatory research approach in public health. For example, Coleman (50) recognised the utility of photo-elicitation as a socio-ecological approach for studies of health and well-being due to the ability of photo-elicitation techniques to reveal the interconnectedness between natural, built, social and symbolic environments and how these environments shape health beliefs, practices, and outcomes.

Expanding on the principles of photo-elicitation, visual methods such as graphic elicitation techniques complement the use of photographic data in interviews with a broader range of stimuli such as maps and drawings (56). These techniques have been found to help participants express complex or abstract ideas, opinions and reflections about research topics, generating more in-depth data than standard interviews alone (57). Graphic elicitation techniques have also been found to facilitate the triangulation of multiple data sources, supporting validity and reliability by helping to establish internal consistency of datasets and increasing the trustworthiness of the interpretation of data (57).

A number of published articles have implemented participatory visual methods to study a diverse range of research topics in LMICs. Examples include investigations of group dynamics and social capital amongst rural smallholder farmers in Mozambique (58), representations and use of natural resources among the Maasai in Tanzania (59), family lives and children's perspectives on climate change in India (60), and the phenomenon of the quarter life crisis on young adults in India (61). With specific regard to food-related visual research in LMICs, photo-elicitation has recently been used in sociological studies to examine the role of food in family relationships among obese adolescents in Brazil (62), and to investigate the 'food worlds' and eating behaviours of low socio-economic Chilean women (63). In addition, a small number of food environment projects featuring photovoice are currently ongoing such as the 'Dietary transitions in Ghanaian cities' project investigating the role of social and physical food environments shaping food and beverage choices (64-68). Another example is a pilot study of perceptions of the food environment among public school adolescents in Addis Ababa, Ethiopia (69).

An integrated Q-GIS approach: PPM and follow-up graphic- and photo-elicitation interviews

In this paper, we present a Q-GIS case study featuring PPM and follow-up graphic and photo-elicitation interviews about the food environment and drivers of food acquisition in peri-urban Hyderabad, India. The case study features men and women from 11 households (*n*=22) across two villages, and is part of a wider qualitative study of the food environment and drivers of food acquisition in the Andhra Pradesh Children and Parents Study (APCAPS). A full cohort profile outlining the development of the APCAPS has been published (70). The wider qualitative study also features in-depth interviews with men and women from an additional 9 households (*n*=18), however, all data presented in this article pertains to the Q-GIS data collection. For the wider qualitative study, we estimated that a total sample of 40 participants (20 Q-GIS participants and 20 in-depth interview participants) would yield sufficient data to achieve saturation, although we were prepared to sample additional participants if saturation was not reached. Additional participants were recruited in cases of attrition or where participants were not available at the time of data collection.

Recruitment of participants: We used the APCAPS 2012-2014 household survey census to select households with at least one adult male and female aged 18-65 registered at the residence from the two villages. Households were assigned a random number and sorted in rank order to provide a randomly generated household roster of eligible households for each village. Households were then randomly assigned to either in-depth interviews or the novel Q-GIS approach. Simple random sampling was used to prevent the purposive selection of familiar households from the wider cohort study that may be known to the field team and have built up a pre-existing rapport, and to give all households an equal chance of selection given the risk of participant burden within the wider multi-wave cohort study. We recruited participants sequentially from the household roster by calling the APCAPS index via telephone, as is standard practice within the wider APCAPS cohort study. During the call, the purpose of the study was explained and participants were invited to enrol in the study. Prospective households were subsequently visited by the field team at an agreed convenient time where the participant information sheets and consent forms were distributed. The index person and their spouse were recruited if they were willing to participate in the study

providing one male and one female from each household. Other household members were invited to participate in cases where the index person or their spouse were not willing or able to participate. Additional households were recruited in cases where no household members were willing or able to participate, and also in cases of attrition or deviance from the study protocol.

Development of the Q-GIS protocol

The literature synthesis presented above was used to inform the development of our integrated Q-GIS approach. We also consulted several visual method publications providing practical and ethical guidance when designing our protocol (71-73). The sections that follow detail the camera selection process, the development of the Q-GIS charts, field team training, and pilot testing process.

Camera selection

PPM requires the collection of geocoded photographs by participants. We considered a range of global positioning system (GPS) enabled camera devices including digital manual hand-held cameras, wearable automated cameras, and smartphone mobile devices.

Manual hand-held cameras: Manual hand-held disposable cameras have typically been used in participatory photography and photo-elicitation research (58, 74). Due to our geocoding requirements, we considered digital GPS-enabled manual hand-held cameras. However, we found the range of these devices available on the marketplace in 2016 to be limited, with a small number of devices on designed for specialist use in outdoor pursuits. The extensive feature set coupled with the high cost per unit and the high degree of technical knowledge required to operate these devices rendered them inappropriate for our study.

Wearable automated cameras: Wearable automated cameras are passive devices that capture photographs at pre-determined time intervals (Figure 2). Wearable automated cameras have been used in a small number of innovative public health studies. Examples include the documentation of opportunities for food and drink acquisition during journeys to and from school in the United Kingdom (75); the quantification of exposure to environmental

determinants of obesity such as television marketing amongst children in New Zealand (76), the objective audit of built environment features related to transport and mobility (77, 78), the evaluation of agri-nutrition interventions on women's time use and maternal and infant dietary practices (79), and the assessment of environmental exposure to air pollution in India (80).

Wearable automated camera devices are particularly useful at generating large datasets consisting of geotagged photographs and GPS tracks, allowing researchers to gain in-depth insights into the lived experience of participants. However, we considered these devices to have a number of limitations for our study. Firstly, the passive, automated nature of these units removes the conscious decision-making process that more traditional, manually operated cameras typically used in photo-elicitation research necessitate. Secondly, wearable automated camera devices typically collect large datasets consisting of thousands of photographs per participant, requiring the extensive processing and analysis of data by a team of researchers, which we considered to be beyond the scope of this PhD research. Thirdly, we found wearable automated cameras increasingly difficult to obtain in 2016, as the small number of start-up companies manufacturing these devices had either ceased operations or were in the process of being acquired by larger corporations. This was problematic given our need for multiple devices, the lack of technical support for any existing units available on the market, and the uncertain prospects of these devices. We therefore decided not to pursue wearable automated camera devices for our study.

Figure 2: A wearable automated camera

Smartphone mobile devices: Smartphone mobile devices and tablets are increasingly being used to collect primary research data. Pioneering studies have used smartphone mobile devices to capture automated images to improve dietary recall (81), as well as to administer quantitative food environment assessment tools via app-based platforms (82), and also to capture photographs in photo-elicitation studies (83).

We found budget smartphone devices to include the necessary specifications required to capture geotagged photographs for our study. In addition, smartphone devices had a number of additional benefits. First, the small ergonomic design and user-friendly interface of many mobile devices facilitates the ease of use and minimises the burden placed on participants when carrying the mobile device as part of daily life. Second, the global dissemination of mobile phone devices, including the increasing levels of mobile phone ownership and network coverage in LMICs makes these devices familiar across a range of settings (84). The familiarity of mobile devices reduces the level of participant training required, thereby lowering the potential barrier to participation associated with increasingly obsolete devices such as manual hand-held cameras, and novel devices such as wearable automate cameras. The use of mobile phones for community-based health reporting in participatory epidemiology has been documented in several articles, with projects spanning both HICs and LMICs (85, 86). Third, the phenomenon of mobile phone photography in the era of social media reduces the risk of arousing suspicion when capturing photographs during fieldwork due to the informal nature of this visual medium. Whilst mobile phone photography is commonplace in many settings today, other cameras such as manual hand-held cameras may

create a sense of intrusion. Fourth, the ability to pre-determine and lock the settings of the mobile device facilitates the optimisation of battery life. Fifth, the ability to customise the layout and appearance of the home-screen and lock-screen limits the potential for distractions and provides opportunities to display guiding instructions for the participants. Sixth, the ability to store information about the purpose of the study on the device provides a useful resource for participants in the event that any third party enquires about the study during data collection. Seventh, the mobile devices provide a free-of-charge line of contact between participant and the research team in the event of any technical difficulties or issues during data collection. Eighth, the ability to encrypt mobile devices with a personal pin code for each participant ensures data is protected in the event that a mobile device is lost or stolen during data collection.

We acquired 10 Samsung J2 mobile devices for data collection. This model was readily available and within budget at the time of data collection, with a cost of around £70 per unit at the time of procurement (Figure 3). The 2016 Samsung J2 specifications included a 5-inch display, an 8-megapixel rear camera, and 8GB of storage. We fitted each phone with a protective silicone case and provided the contact details of the field team coordinator on the inside of each case. A set-up protocol for the mobile devices was developed to ensure all devices were standardised and ready for use in the field.

Figure 3: A Samsung J2 smartphone device (2016 model)

Q-GIS Charts: Geo-narratives of food acquisition and consumption

The design of our Q-GIS charts was informed by several publications featuring cartographical visualisations of communities and individual mobility in relation to daily life, including activity space maps by Milton et al. (42), geo-narrative maps by Bell et al. (41), and grounded visualisations by Knigge and Cope (47). Our Q-GIS charts consisted of a single sheet of A1 chart paper with a GIS map depicting the numbered GPS points denoting the location of each included photograph, surrounded by the corresponding photographs placed around the edge of the map. We produced the maps and photographs in a physical paper-based format, rather than digital format, to provide a tangible focal point for the interview setting and to encourage the participants to engage critically with the visual materials and tell their narratives of food acquisition and consumption. It is important to note that the data collected and the visualisations presented in the Q-GIS charts were not intended to be an audit of the totality of each participant's food environment or an objective view of 'reality', but rather provide impetus for the elicitation of subjective geo-narratives of drivers of food acquisition and consumption. Thus, emphasis was placed on perceptions, values, meanings and socio-spatial relations attributable to the external and personal food environment domains, and how these socio-ecological dynamics are translated into food acquisition and consumption practices as part everyday life.

Field team training

Participatory training sessions were held with the field team prior to data collection, informed by established training manuals for field researchers (87). Sessions focused on qualitative skills and practical communication principles to ensure data quality, as well as food environment concepts, the research protocol, and data collection tools.

Specifically, qualitative skills training included sections on questioning techniques, probes, and interpretive summaries, as well as how to avoid common pitfalls such as closed or leading questions. In addition, interactive sessions where field team members practiced interviewing each other were undertaken, followed by a group discussion and question and answer session about the protocol.

Pilot testing

Pilot testing was conducted internally with a member of non-academic support staff from the National Institute of Nutrition in Hyderabad to provide proof of concept, test the various stages of the protocol, and assess the readiness of the field team prior to data collection. Pilot testing was successfully completed over a three-day period, and the mobile device including the GPS locational services and camera application were found to work without issues. Pilot testing also confirmed the capability of the device, and demonstrated the ability of the integrated camera to capture a high level of detail and clarity even in difficult high-contrast light conditions (Figure 4). No food vendors or third parties objected to the pilot participant taking photographs. Data from the pilot study was successfully downloaded, mapped and charted (Figure 5).

Figure 4: An example of a photograph taken during pilot testing.

Credit: Srinivas Goud Avuladas

Figure 5: A Q-GIS chart from pilot testing.

Data collection

Participant training

Participants received a brief training session following the completion of the recruitment process at each household. The field team demonstrated the basic functions of the Samsung J2 mobile phone device. Participants were shown how to take and delete photographs using the camera application. Participants were asked to photograph the façade of their household in order to practice using the device in a comfortable and familiar environment. This also allowed the field team to check that the device and GPS functionality was working correctly.

The sensitivity of visual methods was explained to the participants, who were requested to ask for oral consent from any third parties that they actively wished to feature as a focal point in their photographs. In addition, a brief descriptive text about the study and the contact details of the field team coordinator was included in the 'notes' application of the mobile, and also pasted onto the case of the device. We also provided small printed information cards for each participant, detailing the purpose of the study to aid explanation to any third party.

Participants were informed not to take any photographs in the event that they felt uncomfortable, or any third party displayed or expressed any concern or discomfort. At the end of the training session, each participant set up their own personal security pin code on their device, ensuring that its contents were encrypted and secure for the duration of data collection.

Participatory photo mapping (PPM)

Participants were tasked with taking photographs over three consecutive days. Data collection captured both weekdays and weekends. We encouraged participants to photograph the things that they consider to be important in shaping the foods that they eat, and to show how food fits into their daily life and activities. The following question was posed to guide participants:

> *"If I were to live with you, what would we eat, where would we get foods from, what would we see, what would we do, and who would we do it with?"*

Broad examples of the kinds of thematic content of interest were provided, such as buying, growing, preparing, cooking, and eating food. Participants were tasked with photographing any sources of food, including market vendors, own production (if any), or gifts from friends and/or family. Participants were also informed that they may wish to include non-food items, objects or activities that they consider important in shaping their food acquisition and consumption, for example work activities or travel. The background image, screensaver and lock screen on the mobile device displayed a brief set of guiding instructions (Box 1). Participants were instructed to show and distribute the information cards provided in the event that any third party should question the purpose of the data collection. The field team made regular visits each day to the field sites as part of the staggered data collection strategy,

and made a scheduled support call via telephone on the second day to check in on the participants and ensure data collection was running as planned.

Box 1: Guiding instructions displayed on the mobile device.

How does food fit into your daily life and activities?

Please take pictures of:

Buying, growing, preparing, cooking, and eating food

Food sources (stores, own production, or gifts)

Non-food items, objects or activities that you think are important in shaping the foods that you eat

Be creative, have fun, and take many pictures

There are no right or wrong pictures!

Data processing

The field team returned to each household to collect the mobile devices following the data collection period. Participants were requested to review their photographs on the mobile device and to select up to ten of their favourite or most important photographs for inclusion in the follow-up interview. This ensured that key photographs would not be left out of the follow-up interviews and also provided participants with photographs that they would feel confident and comfortable talking about. The lead author curated the photographs for inclusion and added any additional photographs of particular interest to complement those chosen by the participants. Participants' photographs were downloaded, printed, and numbered. The GPS data point for each photograph were mapped in ArcGIS software and labelled with the corresponding number. Maps were printed and pasted onto the chart paper along with the photographs. Probe sheets were written by the lead author for each interview with short questions related to the places shown on the map and any specific photographs of interest.

Follow-up in-depth interviews featuring graphic- and photo-elicitation techniques

Charts visualising the maps and photographs were used in conjunction with photo- and graphic-elicitation techniques in follow-up in-depth one-to-one interviews. Field team members worked in pairs to conduct the interviews, using the topic guide, probe sheet, and Q-GIS chart (Figure 5). Field notes were also taken on pre-prepared sheets detailing the duration of the interview, the location in which the interview took place, and any non-verbal cues or additional information that was shared but not audio-recorded. The majority of the interviews were undertaken in the participants' home at their convenience, often early in the morning before they had commenced their daily activities. Interviews were audio-recorded using the microphone application on the encrypted Samsung J2 mobile device.

Interviews started with an ice-breaker exercise whereby the Q-GIS chart was revealed and explained to the participant, including the map and photographs. To help participants to orientate themselves with the map, their village and house was indicated to them by the interviewers. The interviewers then re-affirmed the purpose of the interview using the following statement:

> *"We would like you to show and tell us, with the help of the map and the photographs that you took, how food fits into your daily life and activities."*

The topic guide consisted of four main sections (Supplemental Material 1). The first section addressed drivers of food acquisition practices. Participants were asked to explain how food acquisition fits into their daily routines and activities, using the photographs as visual aids. Participants were invited to talk about their favourite or most important photographs from the Q-GIS chart in the first instance. Probes focused on who; what; when; where; why; how often; and modes of transportation. Probes also addressed market sources, own production, and transfers – including gifts. To conclude section one, participants were asked to describe drivers of their food acquisition and consumption. Additional probes featured external and personal food environment dimensions from the conceptual framework (Figure 1). Participants were also asked whether any sources of food had been missed from the map and photographs.

Section two focused on perceptions and experiences of change in the food environment and food acquisition practices over the past decade. Probes again focused on external and personal food environment dimensions. Participants were also asked to detail any changes in their food acquisition practices during this time. To close section two, participants were invited to reflect upon their feelings towards their food environment, and were asked to identify any dimensions that they valued or would like to see change.

Section three addressed intra-household dynamics of food acquisition and consumption. Participants were asked to consider whom they regarded as the household food provider and decision maker surrounding food. In addition, participants were asked to detail the person who acquires food for the household, and were also asked to discuss roles and responsibilities regarding food preparation and cooking.

Section four addressed perceptions and experiences of the Q-GIS approach, including the participatory photography process and follow-up interview featuring graphic- and photo-elicitation techniques. Probes focused on the acceptability and feasibility of the mobile phone devices and graphic-elicitation techniques. Participants were invited to broadly describe their experiences of using the mobile device and camera application to document their food acquisition practices within their food environment as part of daily life. Participants were asked to discuss any feelings of discomfort while using the device or taking photographs, and whether they felt that they had changed or diverted from their usual activities due to their participation in the study. Probes encouraged participants to give examples of any such occasions. The participants were also asked if any third parties made enquiries or expressed concern about the study or their activities, and probe about the third-party reactions in such an event. Participants were asked whether they felt the maps and photographs represented their daily routines and interactions with their food environment. The interview closed by asking the participants consider their overall experiences of the study, including whether they felt they had changed or re-considered their food acquisition practices due to taking part. Direct observations of the graphic- and photo-elicitation interviews were conducted by the lead author, and written memos detailed the interview process. In addition, the field team made written notes about the physical location of the interview, the atmosphere, and any non-verbal communication from the participant.

Ethical considerations

This research was granted ethical approval by the Observational Ethics Committee of London School of Hygiene and Tropical Medicine (reference number: 12257) (Supplemental Material 2) and the Institutional Ethics Committee of the Indian Institute of Public Health, Hyderabad under the banner of the Public Health Foundation of India (reference number: IIPH/TRCIEC/092/2017) (Supplemental Material 3). Written informed consent was obtained from all participants prior to data collection (Supplemental Material 4). Due to the sensitive nature of the geocoded maps and photographs these data are private and confidential. All photographs in this manuscript are either taken by the lead author or the field team in the research setting and are indicative of the photos taken by the participants.

Analysis

Transcription and translation of the audio from the recorded interviews was conducted by the field team. Audio was first transcribed verbatim in Telugu and subsequently verified before being translated into English. Transcripts and the Q-GIS charts featuring each participant's maps and photographs were entered into NVivo12 software for analysis. Analysis featured triangulation and cross-examination of maps, photographs and interview transcripts. Thematic analysis was used to identify convergent themes related to the utility and acceptability of the Q-GIS approach. All photographs included in the follow-up interviews were subject to manual content coding by the lead author, drawing from the guidelines provided by Rose (88), focusing on what she terms the compositional modality of the image. Coding extracted descriptive information about the image content, collating data on the following categories: presence of a food source, including market-based formal, market-based informal, agricultural production, wild food harvesting, and transfers or gifts as outlined by Turner et al. (4); the food environment dimensions, derived from the conceptual framework (Figure 1); food vendor typology, as defined by the APCAPS built environment survey 2016; the presence of food items; the act of preparing or cooking food; the consumption of food; and the site of the photograph (in the home or elsewhere).

Findings

Characteristics of the sample

In total, eleven households participated in the Q-GIS study (*n*=22 participants) (Supplemental Material 5). The key socio-demographic characteristics of the participants are provided (Table 1). The average age of participants was 30 years (minimum 19 years, maximum 45 years). Almost all households owned a mobile phone (*n*=10; 91%).

Eight households (*n*=16 participants) successfully completed data collection as per the Q-GIS protocol, whilst three (*n*=6 participants) were missing GPS data due to deviations from the protocol and therefore participated in photo-elicitation interviews without maps.

Table 1: Demographic and socio-economic characteristics of the Q-GIS sample.

Participant level data[1]			
Participants	***Total (n=19)***	***Patelguda (n=7)***	***Thummaloor (n=12)***
Male	11	4	7
Female	8	3	5
Mean age	30	27	32
Education level	***(n, %, [females])***	***(n, [females])***	***(n, [females])***
Illiterate	8 (42%) [5]	3 [2]	5 [3]
Literate	2 (11%) [1]	0 [0]	2 [1]
Primary school education	5 (26%) [2]	2 [1]	3 [1]
Secondary school education	4 (21%) [0]	2 [0]	2 [0]
Occupation	***(n, %, [females])***	***(n, [females])***	***(n, [females])***
At home doing housework	1 (5%) [1]	1 [1]	0 [0]
Unskilled manual labour	11 (58%) [6]	4 [2]	7 [0]
Semi-skilled manual labour	2 (11%) [1]	0 [0]	2 [1]
Skilled manual labour	3 (16%) [0]	2 [0]	1 [0]
Skilled non-manual labour	1 (5%) [0]	0 [0]	1 [0]
Student	1 (5%) [0]	0 [0]	1 [0]
Household level data			
Households	***Total (n=11)***	***Patelguda (n=4)***	***Thummaloor (n=7)***
Mean household asset score[2]	10	9	11
Select household assets[3]	***(n, %)***	***(n)***	***(n)***
Motorbike	4 (36%)	2	3
Bicycle	5 (45%	3	2
Agricultural land	4 (36%)	1	3

Electricity	11 (100%)	4	7
Water pump	6 (55%)	2	4
Kitchen	10 (91%)	3	7
Refrigerator	1 (9%)	0	1
Television	10 (91%)	3	7
Radio	4 (36%)	2	2
Mobile phone	10 (91%)	3	7

[1]Demographic and socio-economic data only available for 19 of the 22 Q-GIS participants as 3 of the female participants married into households after the completion of the 2012-14 household survey.

[2]APCAPS Household asset score consists of a 24-component ownership checklist (house; kitchen; radio; tv; fridge; telephone; cooler; washing machine; agricultural land; electricity; bicycle; two wheeler; four wheeler; motor; water pump; tractor; thresher; toilet; account; cart; sofa set; table; bed; mattress).

[3] Select assets related to food acquisition and consumption.

Recruitment process

Recruitment occurred over three phases. In phase one, four households were recruited from each of the two villages (n=16 participants). Three participants from separate households in Thummaloor experienced issues with PPM protocol adherence during data collection. Specifically, a case by case investigation revealed the following distinct deviations from the protocol: 1) the GPS locational services were actively turned off by the participant or another household member; 2) a household member other than the participant enrolled in the study took the majority of the photographs and turned off GPS locational services; 3) photographs were took from a single event yielding insufficient relevant data. A second phase was added in which a further three households were recruited to compensate for the issues in phase one. Amongst these, one household experienced issues with protocol adherence due to the incorrect set-up of the locational GPS settings by the field team, leading to a third phase and the recruitment of one additional household.

One household withdrew from the study following the PPM. Four participants were lacking GPS data due to deviation from the protocol and these cases were excluded from the reporting of the PPM GPS performance. Photo-elicitation interviews including photographs but without maps were conducted with these participants.

Participatory photography – photo content

In total, the twenty-two participants from eleven households captured a total of 1019 photographs. Participants took on average 46 photographs over their three-day PPM data collection period (minimum 8, maximum 109). Male participants collectively took 626 photographs (61%), whilst female participants took 393 (39%). All smartphone mobile devices were successfully returned following data collection, with no instances of damage, loss or theft.

One quarter of all photographs taken (n=257) were selected by participants for inclusion in the follow-up interviews, an average of 12 photographs per participant. The maps and photographs included in the follow-up interviews revealed how participants navigate their food environment throughout the diurnal cycle, reflecting the intricate spatial and temporal realities of food acquisition and consumption. Amongst the 257 photographs included in the follow-up interviews, around half (*n*=143; 56%) included an identifiable food source as per the manual visual coding completed by the lead author. Of these, agricultural production was most commonly photographed (*n*=47; 33%), followed by informal market-based vendors (*n*=43; 30%), formal market-based vendors (*n*=33; 23%), and wild food harvesting (*n*=20; 14%). In terms of market-based vendors, stationary street vendors, general stores, and mobile street vendors were among the most commonly photographed typologies by participants, respectively, whilst ready to eat vendors, other types of shop, and village markets were photographed considerably less (Table 2).

Table 2: Market-based vendors photographed by participants.

Market-based vendor typologies[1]	n, (%)
Stationary street vendor	24 (31%)
General store	19 (25%)
Mobile street vendor	17 (22%)
Ready-to-eat shop without seating, but with walls and roof	5 (6%)
Ready-to-eat shop with seating, walls and roof	5(6%)
Other shop with walls and roof	4 (5%)
Village market	3 (4%)
Total	**77 (100%)**

[1] *APCAPS built environment survey food related non-residential place (NRP) typologies.*

Manual visual coding of the descriptive image content revealed the key food environment dimensions captured in the photographs. External food environment dimensions were the most commonly captured, including food availability (i.e. presence of food source or item) (*n*=249; 97%), vendor and product properties (i.e. vendor type) (*n*=77; 29%), and marketing and regulation (i.e. branding) (n=20; 8%). The only personal food environment dimension to be captured was accessibility (i.e. mode of transport) (*n*=8; 3%). In addition to taking photographs of food sources and food acquisition practices, participants also documented other food related activities such as food preparation (*n*=45; 18%) and food consumption (*n*=46; 18%).

Participatory photography - Geocoding functionality (GPS)

In total, eighteen participants (82%) photographed their food environment without issue as per the Q-GIS protocol, accumulating 793 photographs. Amongst these, 648 photographs (82%) were successfully geocoded with a GPS reference point. None of the eighteen participants reported turning off the locational services on their devices during data collection, indicating weak or non-existent GPS signal to be the cause of the missing data for the remaining 145 (18%) photographs.

Participatory photography – participant's experiences

Overall, participants successfully photographed their food environment and drivers of food acquisition using the mobile device. Many participants found the participatory photography to be an engaging and enjoyable part of the research process:

> *"We liked to take [photos]…it was good and the photos came out very neat." (M, 240242, 38 years).*

> *"I have taken the pictures happily while working." (M, 240635, 45 years).*

> *"I took wholeheartedly and with enthusiasm. I took happily and in my own time […] I usually sit idle in my free time anyway so I used that time for this." (M, 240544, 35 years).*

All participants were able to conduct their daily lives and activities whilst successfully photographing their food environment without discomfort or inconvenience, as is demonstrated in the following excerpts:

> *"I took photos nicely with interest. There was no disturbance to my work. I took photos wherever I went. I did not waste my time in taking photos, when I saw, I took. I didn't have any difficulties." (M, 030088, 25 years).*

> *"Nothing. Nothing uncomfortable. As much I could I took the photos of food whatever I saw […] I had to speak to them [the food vendors] for 1 or 2 minutes, I explained it to them, that's all, other than that no difficulty." (M, 030062, 27 years).*

> *"We sowed paddy, I took photos of the paddy field, also while milking I clicked that, giving feed to buffalos, feeding grass, all those photos I took." (F, 240242, 36 years).*

> *"No difficulty. There was no difficulty for us. I brought the phone while doing my work and clicked the photos." (M, 030431, 35 years).*

The majority of participants explained how they were able to photograph their food environment and food acquisition practices using the mobile device without arousing suspicion among third parties such as food vendors or other consumers:

> *"No-one asked because everyone is using smart phones, no?! Everyone is taking selfies and all, no?! Like that they thought […] difficulty was not there." (M, 030625, 30 years).*

> *"I had the information card there, I thought I will show if someone asks but no one disturbed me. Nobody asked me why I was taking the photos." (M, 030088, 25 years).*

Almost all participants were granted permission to photograph their chosen subject on those occasions when they felt the need to ask. For example, a number of participants explained how they used the information card provided to inform and re-assure food vendors about the purpose of the data collection:

> *"They asked and I showed the card. They said 'If you want to take you can take'." (F, 030431, 25 years).*

> *"After they read …um…. the card, they didn't say anything. It says on that card that if they are not willing don't take photos. I said to them 'I will only take if you are willing'. They said, 'It's okay, it's your wish' and I clicked the photos from the two shops." (M, 030431, 35 years).*

A small number of participants acknowledged a degree of concern among some vendors, particularly 'outside food' vendors serving ready-to-eat foods. This anxiety among outside food vendors was attributed by participants to the known food safety risks and the sale of poor-quality foods. One participant explained:

> *"Other than natural foods, these tiffin centres, fast food centres, Haleem, all these, they prepare outside. If you go to any of those and take photos they will be frightened […] because they are not keeping quality food, they know that, [but] they said okay, they didn't object anywhere." (M, 030062, 27 years).*

Whilst most participants photographed food vendors without objection, one notable exception included a street vendor who requested that a participant refrain from photographing his drinks stall due to suspicion that he may be from the local authorities:

> *"One person asked, Sir. He asked 'Why are you taking photos like a food inspector? I said, 'They look good so I'm taking [photos], Sir.'" (M, 240544, 35 years).*

Although almost all participants were familiar with using mobile phone devices prior to start of the study, only two participants were familiar with using a smartphone with a touch screen interface. A small number of participants initially expressed some trepidation about using the smartphone device. However, following the in-field training session all participants were successfully able to use the smartphone device to photograph their food environment and food acquisition practices. A number of participants reflected on their experiences of using the smartphone device for the purpose of photographing their food environment:

> *"I thought of not taking the phone, I didn't understand. Madam [referring to a field team member] came and showed me how to take photos, and then I took them. After madam showed me, automatically I felt like taking. […] It came so quickly like that. Once I saw and I knew, like that, I wanted to take. I liked this!" (F, 030088, 20 years).*

> *"I did not understand at first when you said capture food items […] but yeah, after you guided me about how to use it [the mobile] I felt it was easy. If not I would not have taken the pictures." (M, 240253, 35 years).*

Some participants described how they learned to use the camera application through trial and error, adjusting the composition of the photographs to capture their intended subject: *"When I took the photo from close up the photo did not capture everything. That's why I took this photo from a long distance." (F, 240284, 25 years).* Participants also demonstrated their understanding of the sensitivity of visual methods, which had been emphasised during the in-field training sessions, and explained how they made attempts to avoid capturing third parties such as members of the public when photographing their food environment:

"There was no public there so I sat and took the photo. I took it from outside, I leant on the auto, moved to one side and took the photo. You see from this woman we will take onions, she will give nicely to us. I'm showing you." (M, 240284, 30 years).

Although all participants successfully captured photographs of their food environment, a small number of participants, particularly some women, felt upon reflection that they lacked the capability to use the mobile device to its full potential. For example, despite having captured 76 photographs, including a diverse range of food sources, one female participant explained:

"I have never used a big phone [smartphone] before, Madam. I'm used to small phones. I don't know how to switch it on and take photos. They [the field team] showed me but I don't know much. My husband also showed me, and then I took [photos], but I did not use it much you know, Madam." (F, 240544, 30 years).

We identified two instances from the interview transcripts where participants acknowledged that they had used both of the mobile devices allocated to their household by mistake. However, this was quickly rectified as participants were able to easily identify their own photographs from memory.

Finally, we identified an isolated case of a male participant who expressed his conflicted feelings regarding the use of the mobile device due to its perceived market value. He explained that whilst he enjoyed the experience and felt gratified by the display of trust placed upon him, he nevertheless felt anxious about carrying and using the mobile device:

"It is good using this phone…to use the phone is very nice. This big phone you have given us means you have so much trust in us, but we also felt tense. Not less than 5,000 rupees phone you gave us and went." (M, 030431, 35 years).

Follow-up graphic- and photo-elicitation interviews

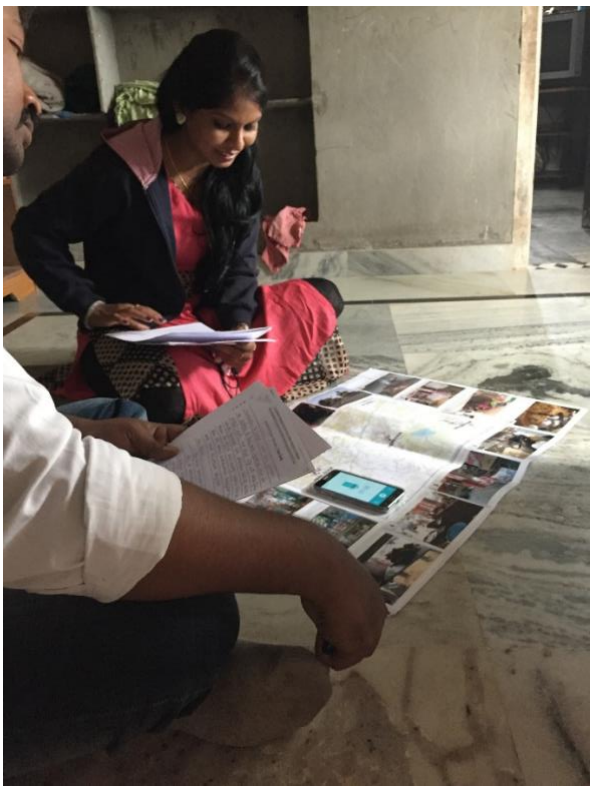
The majority of follow-up interviews lasted around one hour. The Q-GIS charts, including the maps and photographs, functioned as a central focal point for the interview process and were often placed on a table or on the floor between the two interviewers and the participant.

Working in pairs, the field team were able to use the topic guide, photograph probe sheet, and Q-GIS chart visualising the map and participant's photographs to facilitative the interview (Figure 6). Pre-prepared probe sheets for each photograph were found to be useful by the field team, providing an additional level of investigation and adding to the depth of discussion around each photograph.

Triangulation between the field notes, memos, and direct observations found participants to be engaged by the Q-GIS approach, and many were eager to see the Q-GIS charts, maps and photographs. The visual approach, consisting of several meetings between the participants and field team, was found to help foster a rapport between the researchers and the participants.

Whilst some participants were able to engage critically with the maps, photographs, and transcripts to describe their in-depth knowledge of their food environment, drawing from the visual stimuli to express their contextualised narratives, perceptions and lived experiences of food acquisition, others engaged less with these materials.

Figure 6: The field team conducting a graphic- and photo-elicitation interview.



This photograph shows two field team members working as a pair, utilising the Q-GIS chat, topic guide, and probe sheets to facilitate the interview. The participant is sitting just out of the shot to the right-hand side of the image. Oral consent was given by the participant to publish this photograph. Credit: Christopher Turner.

On the whole, participants broadly considered the maps and photographs to represent their food environment and daily food acquisition practices. We used additional probe questions to identify any key food sources, items, or activities that participants felt were not captured or represented in the maps or photographs. Whilst missed information was rare, some participants did note that they occasionally acquire foods from the city when running errands but had not done so during data collection period.

A number of participants shared their positive experiences with the Q-GIS approach, and demonstrated a degree of reflexivity when voicing their experiences of the participatory research process:

"I felt good, no difficulty. I liked it. Not only for me alone, but for any family food should be good. It doesn't matter if money is there or not but food should be good." (M, 030088, 25 years).

"Doing this inquiry about food is very good. By doing this, we got awareness about what kind of foods to take, and how to bring food, we learnt." (F, 030062, 27 years).

"When you asked me to take photos, I got some ideas, Sir. We should buy fresh items, we should eat fresh items. Little oil! We should take those that are a little healthy, this came into my mind, Sir." (M, 240544, 35 years).

"I am feeling good and happy. Now seeing this I am feeling even happier because I have taken all these photos, right? Like this, it is good…I am happy that I captured these photos." (M, 240635, 45 years).

The Q-GIS approach was found to elicit in-depth discussions around food acquisition practices, and there were many instances where the initial focal point of a particular photograph led on to deeper discussions around connected topics, that whilst relevant, were not captured during data collection. For example, when discussing a photograph of children eating snacks prepared at home, one female participant went on to discuss the school food environment and how her children consume snacks and sweets from the numerous vendors that surround her children's school:

"I took that photo. My daughter is eating [snacks] in the house […] As soon as I prepare, they will eat them. I took the photo when she was eating. We do not take anything from outside. If we want to eat anything I will make at home […] I will not let them take these [snacks] to school. Anywhere at school, shops are placed next to the school, is not it? They will eat chocolates at school but I did not take photo." (F, 030088, 20 years, Q-GIS).

Comparing male and female participants in our study, we generally found male participants to be more engaged and open to discussing their perceptions and experiences compared to the female participants.

Discussion

In this paper we present the development and application of a novel participatory Q-GIS approach, featuring PPM and follow-up interviews designed to capture emic perspectives and experiences of food environments and drivers of food acquisition practices. The case study broadly demonstrates the feasibility and utility of the Q-GIS approach, including PPM and follow-up graphic- and photo-elicitation interviews for food environment research in an LMIC setting.

Participants from two villages in peri-urban Hyderabad were successfully able to capture geotagged photographs of their food environment and drivers of food acquisition using the camera application of a smartphone device, collectively capturing over 1000 photographs. Participants engaged with enthusiasm in the participatory photography process, as has been found in previous studies using similar visual methods in both HICs (49) and LMICs (63, 74). The visual approach also built rapport between the researchers and the participants, supporting findings from the wider literature on visual methods (63, 89).

As was reported by Bell et al. (41), the use of geotagged data provided a visual representation of participant's daily activity spaces, accounting for temporal and spatial dynamics of everyday life. Triangulation between data sources, including the maps, photographs, and transcripts revealed a nexus of locational, visual, and narrative forms of everyday knowledge of the food environment and food acquisition and consumption practices in a similar manor to previous community-based health and place studies featuring PPM in HICs (49). We found this approach to provide a unique opportunity to investigate food environments from an emic perspective, in situ, providing insights into aspects related to the *who, what, when, where, why* and *how* of food acquisition and consumption.

Strengths of the Q-GIS approach for food environment research

The Q-GIS approach demonstrated in this case study provides a novel approach to capturing food environments and food acquisition practices from an individual, emic perspective. This participatory approach has a number of strengths. First, the participatory Q-GIS approach addresses calls within food environment research to align theoretical perspectives with

methods of data collection (14). We applied a socio-ecological lens, framing our approach, data collection tools and analysis around the food environment conceptual framework (Figure 1). The participatory approach was particularly well aligned with socio-ecological model, as has been identified by Coleman (50), as it enabled participants to document their interactions with their surrounding food environment. In addition, a number of publications have called for the need to capture individual level perceptions to fully understand the mechanisms driving food acquisition and consumption (14, 17, 20). The Q-GIS approach draws from participatory forms of mapping and photography that engage participants as co-creators of knowledge (40), giving resonance to what Pritchard et al. (22) refers to as voices from below.

Second, this emic approach enables the capture of data on diverse food sources, including formal and informal market-based vendors, agricultural production, and wild food harvesting, broadening the scope of food environment research beyond the traditional focus on market-based food sources. Similarly, it is possible to capture diverse vendor types, including those which are typically difficult to survey through more conventional survey approaches, such as informal street vendors and mobile vendors (11). Mobile vendors were among the most commonly photographed market-based vendors in our study and have been identified as important food sources in the wider literature from LMICs (90).

Third, participants in our study reported no hindrance to their daily activities and faced little resistance from food vendors when capturing photographs of their food environment, demonstrating the feasibility and utility of mobile devices for the collection of geotagged photographic data of food environments from an emic perspective, and supporting wider literature featuring the use of mobile phone devices for the collection of primary data in public health (85, 86) and food environment (82) research. Further the global dissemination of mobile devices across LMICs (84), and the popularity of mobile photography reported by participants in our study make these devices ideal for visual methods such as the Q-GIS approach presented, as well as similar approaches such as photovoice.

Fourth, the use of geotagged participatory photography to capture food acquisition and consumption practices has both spatial and temporal implications for food environment research. From a spatial perspective, collecting geotagged data on environmental exposure as it occurs, in situ, provides a new lens new lens through which to analyse the multifaceted

and multi-scalar drivers of diets that are not only constrained to local neighbourhoods, but more accurately grounded in individual activity spaces that play out across a range of settings from the household, to the neighbourhood and beyond. This new lens captures the ways that people navigate their food environment to acquire and consume food as part of daily life, and in doing so negates what Cummins (15) terms the 'local trap', a fundamental methodological limitation of much of the literature to date (17, 19, 91). From a temporal perspective, participatory photography facilitates the documentation of food acquisition and consumption practices as they occur, in 'real time', capturing what Chen and Kwan (17) refer to as the time-space sensitivity of food acquisition and other food-related activities. Participants in our study were able to photograph the food environment and food-related activities throughout the diurnal cycle, capturing the variable and dynamic nature of food environments and food acquisition practices in this peri-urban setting.

Limitations of the Q-GIS approach for food environment research

We acknowledge a number of limitations to the Q-GIS approach presented. First, this approach requires a significant amount of time and resources when compared to more conventional qualitative methods such as in-depth interviews. This limitation is consistent with assessments of participatory visual methods such as photo-elicitation (74, 92) and commentaries on geospatially tagged qualitative approaches (17). In our study, each household required a minimum of three pre-arranged visits, including an initial visit to recruit, conduct participant training, and commence data collection; a second to collect the mobile devices post data collection; and a third to conduct the follow-up interviews. In addition to these field-based activities, other desk-based activities included setting up the mobile devices as per the protocol prior to data collection, as well as downloading, processing, mapping and printing the photographs and Q-GIS charts for each participant, and writing photo probes for each of the photographs selected for inclusion in the follow-up interviews. This limits the potential to scale-up this kind of approach, although this is not typically a concern of qualitative research methodologies.

Second, we faced a series of ethical challenges. For example, a number of concerns were understandably raised by observational ethics committees regarding participant and third-party anonymity and confidentiality, particularly given the use of geocoded photography. A

number of articles have outlined similar challenges when designing and implementing visual methods (71, 73, 74, 83, 89). As a result of these concerns and pressing time constraints we modified our research protocol to stipulate that the maps and photographs would not be published, to safeguard the anonymity of the participants and third parties. To the knowledge of the author, this study was the first to propose visual methods to the respective ethics committees, which may partly explain their trepidation. Visual methods and tools are increasingly being used to enrich all stages of the qualitative research process, including data collection, analysis and dissemination (58). In our study, the maps and photographs were part of the participatory process and were particularly useful in engaging participants during data collection, and when triangulating data sources during the analysis stage. Descriptive data derived from manual visual coding of the photo content provides an indication of the types of subjects that participants photographed. However, the inclusion of participants' maps and photographs would have added an additional visual dimension to the results. We took the decision to withhold these data from publication given the concerns of the respective ethical committees on the basis that a responsibility of care is paramount to ethical research. Unfortunately, pressing time constraints limited the scope for further clarifications to ethics committees which may have permitted the ethical use of these data.

Third, whilst almost all participants in our study were able to photograph their food environment using the mobile device without hindrance from food vendors or third parties, it is possible that some food vendors may object to photographs being taken. However, we only found a small number of instances in this peri-urban setting in India where vendors expressed concerns about the purposes of the photography or refused grant them permission to take photographs.

Fourth, we generally found male participants to be more engaged throughout the participatory research process in our study, taking the majority of the photographs and also being more open to discussing their perceptions and experiences compared to the female participants. This mirrors findings from the participatory photography study by Gotschi et al. (58) amongst farmer groups in Mozambique, where male participants asserted their dominance over women with low levels of empowerment, limiting their participation in the study. We suggest a number of potential reasons that may have resulted in this finding. For

example, evidence from the Q-GIS charts suggests that female participants tended to have smaller activity spaces which may have reduced the number of subjects to photograph. In addition, low educational attainment amongst the majority of women may have reduced their ability to fully express their perceptions and experiences in the follow-up interviews, with only three women in our sample classified as either literate or having attained primary school education.

Prospects for the development of the Q-GIS approach

Going forward, researchers may seek to further develop and refine the in-depth Q-GIS approach presented. Drawing inspiration from the seminal participatory action research strategy photovoice by Wang (55), one suggestion for future research would be to complement our Q-GIS protocol with an additional community-based component. For example, participants could select a curated set of their photographs to include in a public photography exhibition, thereby creating a platform for open dialogue amongst participants and community members around the food environment and drivers of food acquisition, and providing a dissemination format for the photographic data, pending ethical clearance. Such a community event could also provide the opportunity for the attendees to create collaborative maps of their food environment, creating what Corbett and Rambaldi (46) refer to as an interactive and reflective process of negotiating and representing local knowledge to leverage change. Inspiration here may be taken from a number of recent studies that have featured visual methods along with community components, including the 'Dietary transitions in Ghanaian cities' project by Holdsworth (64), and the community mapping project by Ahmed et al. (48) in informal settlements in Nairobi, Kenya.

Conclusions

This paper presents the development and application of a novel Q-GIS approach, featuring PPM and follow-up graphic- and photo-elicitation interviews that may be used to investigate food environments and drivers of food acquisition practices. The case study from two villages in peri-urban Hyderabad, in Telangana, India, demonstrates the utility and feasibility of this approach for the capture emic perspectives and experiences of the food environment for in-depth qualitative food environment research. Participants were successfully able to capture

geotagged photographs their food environment and drivers of food acquisition using a budget smartphone over a three-day period. In conclusion, the Q-GIS approach presented provides a novel participatory approach that may be used to capture emic perceptions and experiences of food environments and drivers of food acquisition in LMICs. The protocol presented in this article features and number of strengths and limitations. Going forward, it is our hope that future studies may learn from our experiences and continue to develop and refine the protocol in order to realise the full potential of participatory visual methods within food environment research. Contextualised forms of in depth knowledge and understanding about food environments and drivers of food acquisition are urgently needed to inform the development of interventions and policies targeting healthier food environments in LMICs.

Acknowledgements

We would like to thank our field team coordinator, Santhi Bhogadi, and our field team members Amaravathi Mora, Niharika Muddepaka, Prasad Undrajavarapu, Sailaja M, Sandeep Kumar Gyara, Subhash Masapeta, Dr Srivalli Addanki and Srinivas Goud Avuladas for their knowledge, expertise, and tireless work ethic throughout data collection, transcription and translation. We would also like to thank Sofia Kalamatianou for her contributions, including setting up the NVivo server, discussing the coding framework, and conducting preliminary coding.

4.5.References: Publication 3

1. Lytle LA, Sokol RL. Measures of the food environment: A systematic review of the field, 2007-2015. Health & Place. 2017;44:18-34.

2. Turner C, Kalamatianou S, Drewnowski A, Kulkarni B, Kinra S, Kadiyala S. Food Environment Research in Low- and Middle-Income Countries: A Systematic Scoping Review. Adv Nutr. 2019.

3. Swinburn B, Sacks G, Vandevijvere S, Kumanyika S, Lobstein T, Neal B, Barquera S, Friel S, Hawkes C, Kelly B, et al. INFORMAS (International Network for Food and Obesity/non-communicable diseases Research, Monitoring and Action Support): overview and key principles. Obesity Reviews. 2013;14:1-12.

4. Turner C, Aggarwal A, Walls H, Herforth A, Drewnowski A, Coates J, Kalamatianou S, S. K. Concepts and critical perspectives for food environment research: A global framework with implications for action in low- and middle-income countries. Global Food Security. 2018;18:93-101.

5. Caspi CE, Sorensen G, Subramanian SV, Kawachi I. The local food environment and diet: A systematic review. Health & Place. 2012;18(5):1172-87.

6. Cetateanu A, Jones A. How can GPS technology help us better understand exposure to the food environment? A systematic review. SSM Popul Health. 2016;2:196-205.

7. Engler-Stringer R, Le H, Gerrard A, Muhajarine N. The community and consumer food environment and children's diet: a systematic review. BMC Public Health. 2014;14:522.

8. Gamba RJ, Schuchter J, Rutt C, Seto EY. Measuring the food environment and its effects on obesity in the United States: a systematic review of methods and results. J Community Health. 2015;40(3):464-75.

9. Gustafson A, Hankins S, Jilcott S. Measures of the consumer food store environment: a systematic review of the evidence 2000-2011. J Community Health. 2012;37(4):897-911.

10. Lucan S. Concerning limitations of food-environment research: a narrative review and commentary framed around obesity and diet-related diseases in youth. Journal of the Academy of Nutrition and Dietetics. 2015;115(2):205-12.

11. Lucan SC, Varona M, Maroko AR, Bumol J, Torrens L, Wylie-Rosett J. Assessing mobile food vendors (a.k.a. street food vendors)-methods, challenges, and lessons learned for future food-environment research. Public Health. 2013;127(8):766-76.

12. Lytle LA. Measuring the food environment: state of the science. Am J Prev Med. 2009;36(4 Suppl):S134-44.

13. Kirkpatrick SI, Reedy J, Butler EN, Dodd KW, Subar AF, Thompson FE, McKinnon RA. Dietary assessment in food environment research: a systematic review. Am J Prev Med. 2014;46(1):94-102.

14. Penney TL, Almiron-Roig E, Shearer C, McIsaac JL, Kirk SFL. Modifying the food environment for childhood obesity prevention: challenges and opportunities. Proceedings of the Nutrition Society. 2014;73(2):226-36.

15. Cummins S. Commentary: Investigating neighbourhood effects on health - Avoiding the 'local trap'. International Journal of Epidemiology. 2007;36(2):355-7.

16. Kwan MP. The Limits of the Neighborhood Effect: Contextual Uncertainties in Geographic, Environmental Health, and Social Science Research. Annals of the American Association of Geographers. 2018;108(6):1482-90.

17. Chen X, Kwan MP. Contextual Uncertainties, Human Mobility, and Perceived Food Environment: The Uncertain Geographic Context Problem in Food Access Research. Am J Public Health. 2015;105(9):1734-7.

18. Kwan MP. The Uncertain Geographic Context Problem. Annals of the Association of American Geographers. 2012;102(5):958-68.

19. Cummins S. Neighbourhood food environment and diet:Time for improved conceptual models? Preventive Medicine. 2007;44(3):196-7.

20. Brug J, Kremers SP, van Lenthe F, Ball K, Crawford D. Environmental determinants of healthy eating: in need of theory and evidence. Proceedings of the Nutrition Society. 2008;67(3):307-16.

21. Penney TL, Brown HE, Maguire ER, Kuhn I, Monsivais P. Local food environment interventions to improve healthy food choice in adults: a systematic review and realist synthesis protocol. BMJ Open. 2015;5(4):e007161.

22. Pritchard B, Mackay H, Turner C. Special issue introduction: geographical perspectives on food and nutrition insecurity in the global South. Geographical Research. 2017;55(2):127-30.

23. Daivadanam M, Wahlstrom R, Thankappan KR, Ravindran TK. Balancing expectations amidst limitations: the dynamics of food decision-making in rural Kerala. BMC Public Health. 2015;15:644.

24. Hunter-Adams J. Exploring Perceptions of the Food Environment Amongst Congolese, Somalis and Zimbabweans Living in Cape Town. International Migration. 2017;55(4):78-87.

25. Hunter-Adams J, Rother HA. Pregnant in a foreign city: A qualitative analysis of diet and nutrition for cross-border migrant women in Cape Town, South Africa. Appetite. 2016;103:403-10.

26. Kolopaking R, Bardosono S, Fahmida U. Maternal Self-efficacy in the Home Food Environment: A Qualitative Study among Low-income Mothers of Nutritionally At-risk Children in an Urban Area of Jakarta, Indonesia. Journal of Nutrition Education and Behavior. 2011;43(3):180-8.

27. Pehlke EL, Letona P, Hurley K, Gittelsohn J. Guatemalan school food environment: impact on schoolchildren's risk of both undernutrition and overweight/obesity. Health Promotion International. 2016;31(3):542-50.

28. Pehlke EL, Letona P, Ramirez-Zea M, Gittelsohn J. Healthy casetas: A potential strategy to improve the food environment in low-income schools to reduce obesity in children in Guatemala City. Ecology of Food and Nutrition. 2016;55(3):324-38.

29. Bailey C, Garg V, Kapoor D, Wasser H, Prabhakaran D, Jaacks LM. Food Choice Drivers in the Context of the Nutrition Transition in Delhi, India. Journal of Nutrition Education and Behavior. 2018;50(7):675-86.

30. Hardin J, Kwauk CT. Producing markets, producing people: Local food, financial prosperity and health in Samoa. Food, Culture and Society. 2015;18(3):519-39.

31. Kimoto R, Ronquillo D, Caamaño MC, Martinez G, Schubert L, Rosado JL, Garcia O, Long KZ. Food, eating and body image in the lives of low socioeconomic status rural Mexican women living in Queretaro State, Mexico. Health and Place. 2013;25:34-42.

32. Maxfield A, Patil S, Cunningham SA. Globalization and Food Prestige among Indian Adolescents. Ecology of Food and Nutrition. 2016;55(4):341-64.

33. Phulkerd S, Vandevijvere S, Lawrence M, Tangcharoensathien V, Sacks G. Level of implementation of best practice policies for creating healthy food environments: assessment by state and non-state actors in Thailand. Public Health Nutrition. 2017;20(3):381-90.

34. Rathi N, Riddell L, Worsley A. What influences urban Indian secondary school students' food consumption? - A qualitative study. Appetite. 2016;105:790-7.

35. Rathi N, Riddell L, Worsley A. Food environment and policies in private schools in Kolkata, India. Health Promotion International. 2017;32(2):340-50.

36. Veeck A, Yu FG, Yu H, Veeck G, Gentry JW. Influences on food choices of urban chinese teenagers. Young Consumers. 2014;15(4):296-311.

37. Fuster M, Colón-Ramos U. Changing Places, Changing Plates? A Binational Comparison of Barriers and Facilitators to Healthful Eating Among Central American Communities. Journal of Immigrant and Minority Health. 2017:1-6.

38. Fuster M, Messer E, Houser RF, Deman H, de Fulladolsa PP, Bermudez OI. Local Notions of Healthy Eating and National Dietary Guidelines: A Comparison in Vulnerable Salvadoran Communities. Food and Foodways. 2013;21(4):288-314.

39. Smit W, de Lannoy A, Dover RVH, Lambert EV, Levitt N, Watson V. Making unhealthy places: The built environment and non-communicable diseases in Khayelitsha, Cape Town. Health & Place. 2016;39:196-203.

40. Ahmed S, Haklay M, Allen A, Tacoli C, Simiyu E, Davila J. Participatory Mapping for Transformation: Multiple Visual Representation of Foodscapes and Environment in Informal Settings in Nairobi. In: Malleson N, Addis N, Durham H, Heppenstrall A, Lovelace R, Norman P, et al., editors. Proceedings of GIS Research UK (GISRUK). Leeds, UK.: GIS Research UK (GISRUK); 2015. p. 14-9.

41. Bell SL, Phoenix C, Lovell R, Wheeler BW. Using GPS and geo-narratives: a methodological approach for understanding and situating everyday green space encounters. Area. 2015;47(1):88-96.

42. Milton S, Pliakas T, Hawkesworth S, Nanchahal K, Grundy C, Amuzu A, Casas JP, Lock K. A qualitative geographical information systems approach to explore how older people over 70 years interact with and define their neighbourhood environment. Health and Place. 2015;36:127-33.

43. Wang C, Burris MA. Photovoice: Concept, methodology, and use for participatory needs assessment. Health Education & Behavior. 1997;24(3):369-87.

44. Cope M, Elwood S. Qualitative GIS: A mixed methods approach: Sage; 2009.

45. Kwan MP. From place-based to people-based exposure measures. Soc Sci Med. 2009;69(9):1311-3.

46. Corbett J, Rambaldi G. 'Representing our Reality': Geographic Information Technologies, Local Knowledge and Change. In: Cope M, Elwood S, editors. Qualitative GIS: Mixed Methods in Practice and Theory: Sage Books; 2009. p. 75.

47. Knigge L, Cope M. Grounded visualization: integrating the analysis of qualitative and quantitative data through grounded theory and visualization. Environment and Planning A. 2006;38(11):2021-37.

48. Ahmed S, Haklay M, Tacoli C, Githiri G, Davila J, Allen A, Fevre E. Participatory mapping and food-centred justice in informal settlements in Nairobi, Kenya. Geo-Geography and Environment. 2019;6(1).

49. Dennis SF, Gaulocher S, Carpiano RM, Brown D. Participatory photo mapping (PPM): Exploring an integrated method for health and place research with young people. Health & Place. 2009;15(2):466-73.

50. Coleman T. Photo elicitation as method: a participatory approach. In: Fenton N, Baxter J, editors. Practicing Qualitaitve Methods in Health Geographies. Geography of Health. 1 ed. New York, NY.: Routledge; 2016. p. 266.

51. Collier J. Visual Anthropology's Contributions to the Field of Anthropology. Visual Anthropology. 1987;1(1):37-46.

52. Harper D. Talking about pictures: a case for photo elicitation. Visual Studies. 2002;17(1).

53. Collier J. Photography in Anthropology: a report on two experiments. American Anthropologist. 1957;59:843-59.

54. Collier J. Visual Anthropology: Photography as a Research Method. New York, Holt.: Rineheart and Winston; 1967.

55. Wang CC. Photovoice: a participatory action research strategy applied to women's health. J Womens Health. 1999;8(2):185-92.

56. Crilly N, Blackwell A, Clarkson J. Graphic elicitation: using research diagrams as interview stimuli. Qualitaitve Research. 2006;6.

57. Copeland AJ, Agosto DE. Diagrams and Relational Maps: The Use of Graphic Elicitation Techniques with Interviewing for Data Collection, Analysis, and Display. International Journal of Qualitative Methods. 2012;11(5):513-33.

58. Gotschi E, Delve R, Freyer B. Participatory Photography as a Qualitative Approach to Obtain Insights into Farmer Groups. Field Methods. 2009;21(3):290-308.

59. Birgante E. The use of photo-elicitation in field research: Exploring Maasai representations and use of natural resources. EchoGeo. 2010;11.

60. Walker C. Photo elicitation as part of a multi method research design: Family lives and the environment in Andhra Pradesh, India. Sage Research Methods Online: Sage; 2014.

61. Duara R, Hugh-Jones S, Madill A. Photo-elicitation and time-lining to enhance the research interview: Exploring the quarterlife crisis of young adults in india and the united kingdom. Qualitative Research in Psychology. 2018(Pagination).

62. Ramalho JDM, Lachal J, Bucher-Maluschke JSNF, Moro MR, Revah-Levy A. A qualitative study of the role of food in family relationships: An insight into the families of Brazilian obese adolescents using photo elicitation. Appetite. 2016;96:539-45.

63. Patricia GE, Vizcarra M, Palomino AM, Valencia A, Iglesias L, Schwingel A. The photo-elicitation of food worlds: A study on the eating behaviors of low socioeconomic Chilean women. Appetite. 2017;111:96-104.

64. Holdsworth M. Dietary transitions in Ghanaian cities: Leveraging evidence for policy and intervention to prevent diet-related non-communicable diseases. University of Ghana, African Population and Health Research Center, The University of Sheffield, Loughborough University, University of Liverpool, Cirad, 2019.

65. Holdsworth M, Pradeilles R, Zotor F, Green G, Tandoh A, Klomegah S, Osei-Kwasi H, Bricas N, Griffiths P. How unhealthy food and beverages are embedded in everyday life in Ghanaian cities. Sixth BSA Sociology of Food Study Group Conference: Food Systems and Society - Re-imagining Food Systems, Sustainability, Futures and the Everyday; 24-25th June 2019; Monash University, Prato, Italy: BSA Publications Ltd; 2019.

66. Holdsworth M, Zotor F, Pradeilles R, Griffiths P, Green M, Mensah K, Akparibo R, Barnes A, Bricas N, Laar A. Dietary transitions in Ghanaian cities: using innovative methods to map the social and physical food environments that drive consumption of unhealthy foods and beverages, to identify contextually appropriate policies and interventions: the DFC dietary transitions in Ghana study. 3rd Agriculture, Nutrition and Health (ANH) Academy Week; 25-29th June, 2019; Accra, Ghana: Agriculture, Nutrition and Health Academy; 2018.

67. Pradeilles R, Laar A, Zotor F, Tandoh A, Klomegah S, Osei-Kwasi H, Bohr M, Green M, Bricas N, Holdsworth M, et al. Social and Physical Drivers of Food Choice: A participatory Photovoice Project in two Ghanaian Cities: a DFC Dietary Transitions in Ghana Study. 3rd Agriculture, Nutrition and Health (ANH) Academy Week; 24-28th June, 2018; Accra, Ghana: Agriculture, Nutrition and Health Academy; 2018.

68. Pradeilles R, Laar A, Zotor F, Tandoh A, Klomegah S, Osei-Kwasi H, Bohr M, Green M, Bricas N, Holdsworth M, et al. Social and Physical Drivers of Food Choice: A participatory Photovoice Project in two Ghanaian Cities: a DFC Dietary Transitions in Ghana Study. Sixth BSA Sociology of Food Study Group Conference: Food Systems and Society - Re-imagining Food Systems, Sustainability, Futures and the Everyday; 24-25th June 2019; Monash University, Prato, Italy: BSA Publications Ltd; 2019.

69. Trübswasser U. How do adolescents understand their food environment? A pilot study using Photovoice in urban Ethiopia. 4th Agriculture, Nutrition and Health Academy Week 2019; 24-28th June, 2019; Hyderabad, India. https://anh-academy.org/anh2019-programme: Agriculture, Nutrition and Health Academy; 2019.

70. Kinra S, Radha Krishna KV, Kuper H, Rameshwar Sarma KV, Prabhakaran P, Gupta V, Walia GK, Bhogadi S, Kulkarni B, Kumar A, et al. Cohort profile: Andhra Pradesh Children and Parents Study (APCAPS). Int J Epidemiol. 2014;43(5):1417-24.

71. Bugos E, Frasso R, FitzGerald E, True G, Adachi-Mejia AM, Cannuscio C. Practical guidance and ethical considerations for studies using photo-elicitation interviews. Prev Chronic Dis. 2014;11:E189.

72. Rose G. Visual Methodologies: An Introduction to the Interpretation of Visual Materials. 2nd Edition ed: Sage; 2007.

73. Wiles R, Prosser J, Bagnoli A, Clark A, Davies K, Holland S, Renold E. Visual Ethics: Ethical Issues in Visual Research. National Centre for Research Methods, 2008.

74. Meo AI. Picturing Students' Habitus: The Advantages and Limitations of Photo-Elicitation Interviewing in a Qualitative Study in the City of Buenos Aires. International Journal of Qualitative Methods. 2010;9(2):149-71.

75. Cowburn G, Matthews A, Doherty A, Hamilton A, Kelly P, Williams J, Foster C, Nelson M. Exploring the opportunities for food and drink purchasing and consumption by teenagers during their journeys between home and school: a feasibility study using a novel method. Public Health Nutr. 2016;19(1):93-103.

76. Barr M, Signal L, Jenkin G, Smith M. Capturing exposures: using automated cameras to document environmental determinants of obesity. Health Promot Int. 2015;30(1):56-63.

77. Kelly P, Doherty A, Berry E, Hodges S, Batterham AM, Foster C. Can we use digital life-log images to investigate active and sedentary travel behaviour? Results from a pilot study. Int J Behav Nutr Phys Act. 2011;8:44.

78. Oliver M, Doherty AR, Kelly P, Badland HM, Mavoa S, Shepherd J, Kerr J, Marshall S, Hamilton A, Foster C. Utility of passive photography to objectively audit built environment features of active transport journeys: an observational study. Int J Health Geogr. 2013;12:20.

79. Wellard K. Using Information Communication Technologies (ICTs) to understand the relationships between labour-saving agricultural innovations, women's time use and maternal and child nutrition outcomes London: Innovative Methods and Metrics for Agriculture and Nutrition Actions (IMMANA); 2016. Available from: https://immana.lcirah.ac.uk/node/589.

80. Tonne C, Salmon M, Sanchez M, Sreekanth V, Bhogadi S, Sambandam S, Balakrishnan K, Kinra S, Marshall JD. Integrated assessment of exposure to PM2.5 in South India and its relation with cardiovascular risk: Design of the CHAI observational cohort study. International Journal of Hygiene and Environmental Health. 2017;220(6):1081-8.

81. Arab L, Estrin D, Kim DH, Burke J, Goldman J. Feasibility testing of an automated image-capture method to aid dietary recall. European Journal of Clinical Nutrition. 2011;65(10):1156-62.

82. Kanter R, Alvey J, Fuentes D. A novel mobile phone application to assess nutrition environment measures in low- and middle-income countries. Food and Nutrition Bulletin. 2014;35(3):296-300.

83. Raby R, Lehmann W, Helleiner J, Easterbrook R. Reflections on Using Participant-Generated, Digital Photo-Elicitation in Research With Young Canadians About Their First Part-Time Jobs. International Journal of Qualitative Methods. 2018;17(1).

84. Greenleaf AR, Gibson DG, Khattar C, Labrique AB, Pariyo GW. Building the Evidence Base for Remote Data Collection in Low- and Middle-Income Countries: Comparing Reliability and Accuracy Across Survey Modalities. Journal of Medical Internet Research. 2017;19(5).

85. Freifeld CC, Chunara R, Mekaru SR, Chan EH, Kass-Hout T, Iacucci AA, Brownstein JS. Participatory Epidemiology: Use of Mobile Phones for Community-Based Health Reporting. Plos Medicine. 2010;7(12).

86. Pakhare A, Bali S, Kalra G. Use of mobile phones as research instrument for data collection. Indian Journal of Community Health. 2013;25(2):95-8.

87. Haaland A, Molyneux S, Marsh V, Mutemi W. Quality information in field research: Training manual on practical communication skills for field researchers and project personnel. Wellcome-KEMRI Research Programme and WHO/TDR: UNICEF, UNDP, World Bank, WHO, 2006.

88. Rose G. Visual Methodologies: An Introduction to the Interpretation of Visual Methods. First Edition ed. London: Sage; 2001.

89. Pain H. A Literature Review to Evaluate the Choice and Use of Visual Methods. International Journal of Qualitative Methods. 2012;11(4):303-19.

90. Battersby J, Crush J. The Making of Urban Food Deserts. In: Crush J, Battersby J, editors. Rapid Urbanization, Urban Food Deserts and Food Security in Africa. 1 ed. Switzerland: Springer International Publishing; 2016. p. 190.

91. Story M, Giles-Corti B, Yaroch AL, Cummins S, Frank LD, Huang TTK, Lewis LB. Work Group IV: Future Directions for Measures of the Food and Physical Activity Environments. American Journal of Preventive Medicine. 2009;36(4):S182-S8.

92. Sebastiao E, Galvez PAE, Bobitt J, Adamson BC, Schwingel A. Visual and participatory research techniques: photo-elicitation and its potential to better inform public health about physical activity and eating behavior in underserved populations. Journal of Public Health-Heidelberg. 2016;24(1):3-7.

4.6.Summary of Appendix 2: Publication 3

Supplemental Material for this publication is included in Appendix 2 (Chapter 8), including:

- Supplemental Material 1: Topic guide - In depth interviews.
- Supplemental Material 2: Ethical approval - Observational Ethics Committee, London School of Hygiene and Tropical Medicine.
- Supplemental Material 3: Ethical approval - Institutional Ethics Committee of the Indian Institute of Public Health under the banner of the Public Health Foundation India.
- Supplemental Material 4: CARE forms - Participant information sheets, consent forms.
- Supplemental Material 5: Flow chart - Recruitment of Q-GIS households by village.

4.7.Contribution of Publication 3 to the thesis

This publication addresses the methodological-based research gap identified in the introduction and my third research aim, to develop, implement and evaluate a novel methodological approach designed to capture people's emic interactions with their food environment in an LMIC setting. In addition, this publication provides comprehensive insights into the background, development and application of the Q-GIS approach, which constitutes around half of my primary data collection for publication 4 that follows.

5. Publication 4: Drivers of food acquisition practices in the peri-urban food environment of Hyderabad, India: A qualitative investigation

5.1. Preamble to publication 4: Motivation for the article

Publication four addresses the fourth research question:

4. *How do people interact with their food environment to acquire foods as part of daily life in peri-urban villages in Telangana, India, what are the key drivers of food acquisition and consumption practices in this setting, what are people's perceptions and experiences of change regarding the food environment and food acquisition and consumption practices over the past decade, and are there any intra-household dynamics in relation to food acquisition and consumption?*

Food environment research has been gaining prominence in LMICs, as is evidenced by my systematic scoping review which includes 70 articles from across 22 countries (1) (Publication 2). Whilst the body of food environment literature from LMICs has been rapidly growing in recent years, my systematic review featured only six studies located in India. Amongst these, five studies focused on urban food environments, including at the community level (2, 3) and school level (4-6), whilst one study addressed urban and rural food environments (7). Wider reading of the drivers of food choice literature also revealed two qualitative studies from urban settings in India (8, 9). No food environment studies have explicitly focused on transitioning peri-urban settings in India to date. In this multi-method qualitative publication, I aim to contribute to this research gap by investigating the food environment and drivers of food acquisition from two APCAPS villages in peri-urban Hyderabad, in Telangana (Box 1).

Urbanization, urban expansion, and shifts towards more urban ways of life have been suggested as influential in changing dietary patterns and transitions towards the consumption of generally unhealthy foods outside the home in LMICs, linked to consumer demand for pre-prepared, processed, and ultra-processed foods as a result of time constraints and the prioritization of income earning activities over food preparation (10-14). Preliminary evidence from the APCAPS suggests that urban expansion and the development of the built environment is well underway along with transitions towards more urban ways of life as the

city of Hyderabad expands ever closer to these peri-urban villages (15), making this setting a particularly salient location to investigate narratives of change in relation to the food environment and drivers of food acquisition and consumption as part of daily life.

Box 1: Author contributions to publication 4

Christopher Turner: Conceived the paper, designed the research protocol, supervised data collection, conducted qualitative analysis, led the writing process, copy-edited the manuscript, finalised the manuscript, responded to feedback from co-authors and amended the manuscript for submission.

Santhi Bhogadi: Coordinated the field team during data collection. Provided technical feedback on fieldwork and data collection methods.

Helen Walls, Shilpa Surendran, Sanjay Kinra: Provided critical feedback on the manuscript.

Bhrathi Kulkarni: Provided critical feedback on the manuscript, acted as host-supervisor for lead author during data collection.

Suneetha Kadiyala: Provided critical feedback on the manuscript throughout the writing process, including the structure and scope of the paper.

5.2.References: Preamble to publication 4

1. Turner C, Kalamatianou S, Drewnowski A, Kulkarni B, Kinra S, Kadiyala S. Food Environment Research in Low- and Middle-Income Countries: A Systematic Scoping Review. Adv Nutr. 2019.

2. Finzer LE, Ajay VS, Ali MK, Shivashankar R, Goenka S, Sharma P, Pillai DS, Khandelwal S, Tandon N, Reddy KS, et al. Fruit and Vegetable Purchasing Patterns and Preferences in South Delhi. Ecology of Food and Nutrition. 2013;52(1):1-20.

3. Patel O, Shahulhameed S, Shivashankar R, Tayyab M, Rahman A, Prabhakaran D, Tandon N, Jaacks LM. Association between full service and fast food restaurant density, dietary intake and overweight/obesity among adults in Delhi, India. Bmc Public Health. 2017;18.

4. Maxfield A, Patil S, Cunningham SA. Globalization and Food Prestige among Indian Adolescents. Ecology of Food and Nutrition. 2016;55(4):341-64.

5. Rathi N, Riddell L, Worsley A. What influences urban Indian secondary school students' food consumption? - A qualitative study. Appetite. 2016;105:790-7.

6. Rathi N, Riddell L, Worsley A. Food environment and policies in private schools in Kolkata, India. Health Promotion International. 2017;32(2):340-50.

7. Gupta V, Downs SM, Ghosh-Jerath S, Lock K, Singh A. Unhealthy Fat in Street and Snack Foods in Low-Socioeconomic Settings in India: A Case Study of the Food Environments of Rural Villages and an Urban Slum. J Nutr Educ Behav. 2016;48(4):269-79 e1.

8. Bailey C, Garg V, Kapoor D, Wasser H, Prabhakaran D, Jaacks LM. Food Choice Drivers in the Context of the Nutrition Transition in Delhi, India. Journal of Nutrition Education and Behavior. 2018;50(7):675-86.

9. Daivadanam M, Wahlstrom R, Thankappan KR, Ravindran TK. Balancing expectations amidst limitations: the dynamics of food decision-making in rural Kerala. BMC Public Health. 2015;15:644.

10. De Haen H, Stamoulis K, Shetty P, Pingali P. The World Food Economy in the Twenty-first Century: Challenges for International Co-operation. Development Review Policy. 2003;21(5-6):683-96.

11. Lindgren E, Harris F, Dangour AD, Gasparatos A, Hiramatsu M, Javadi F, Loken B, Murakami T, Scheelbeek P, Haines A. Sustainable food systems: a health perspective. Sustainability Science. 2018;13(6):1505-17.

12. Popkin BM, Adair LS, Ng SW. Global nutrition transition and the pandemic of obesity in developing countries. Nutr Rev. 2012;70(1):3-21.

13. Satterthwaite D, McGranahan G, Tacoli C. Urbanization and its implications for food and farming. Philosophical Transactions of the Royal Society B-Biological Sciences. 2010;365(1554):2809-20.

14. Pingali P, Aiyar A, Abraham M, Rahman A. Diet Diversity and the Declining Importance of Staple Grains. Transforming Food Systems for a Rising India. Cham: Springer International Publishing; 2019. p. 73-91.

15. Hayter AK, Jeffery R, Sharma C, Prost A, Kinra S. Community perceptions of health and chronic disease in South Indian rural transitional communities: a qualitative study. Glob Health Action. 2015;8:25946.

5.3.Research paper cover sheet: Publication 4

London School of Hygiene & Tropical Medicine
Keppel Street, London WC1E 7HT

T: +44 (0)20 7299 4646
F: +44 (0)20 7299 4656
www.lshtm.ac.uk

RESEARCH PAPER COVER SHEET

Please note that a cover sheet must be completed for each research paper included within a thesis.

SECTION A – Student Details

Student ID Number	1510864	**Title**	Mr
First Name(s)	Christopher		
Surname/Family Name	Turner		
Thesis Title	Investigating food environments and drivers of food acquisition in low- and middle-income countries: The case of peri-urban Hyderabad, Telangana, India		
Primary Supervisor	Dr Suneetha Kadiyala		

If the Research Paper has previously been published please complete Section B, if not please move to Section C.

SECTION B – Paper already published

Where was the work published?			
When was the work published?			
If the work was published prior to registration for your research degree, give a brief rationale for its inclusion			
Have you retained the copyright for the work?*	Choose an item.	Was the work subject to academic peer review?	Choose an item.

*If yes, please attach evidence of retention. If no, or if the work is being included in its published format, please attach evidence of permission from the copyright holder (publisher or other author) to include this work.

SECTION C – Prepared for publication, but not yet published

Where is the work intended to be published?	Public Health Nutrition
Please list the paper's authors in the intended authorship order:	Turner, C*., Bhogadi, S., Walls, H., Surendran, S., Kulkarni, B., Kinra., S., Kadiyala, S.
Stage of publication	**Not yet submitted**

SECTION D – Multi-authored work

For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)	Manuscript title: Drivers of food acqusition practices in the peri-urban food environment of Hyderabad, India: A qualitative investigation. Chris conceived the paper, designed the protocol, obtained ethical clearence, trained the field team, desinged the topic guides, conducted the pilot testing, managed the primary data collection, conducted data processing - including GIS mapping, writing of photo probes, and production of Q-GIS charts, conducted the data analysis - including coding of transcripts and photographs, led the writing process, copy-edited the manuscript, and finalised the manuscript for inclusion in the thesis.

SECTION E

Student Signature	[redacted]
Date	19/07/19

Supervisor Signature	[redacted]
Date	22/09/19

5.4.Publication 4: Manuscript

Drivers of food acquisition practices in the peri-urban food environment of Hyderabad, India: A qualitative investigation

Turner, C[1*]., Bhogadi, S[2]., Walls, H[1]., Surendran, S[3]., Kulkarni, B[4]., Kinra., S[5]., Kadiyala, S[1].

[1] *Department of Population Health, Faculty of Public Health and Policy, London School of Hygiene and Tropical Medicine, London, United Kingdom*

[2] *Indian School of Business, Hyderabad, India*

[3] *Department of Health Systems and Behavioural Sciences, Saw Swee Hock School of Public Health, National University of Singapore, Singapore*

[4] *National Institute of Nutrition, Hyderabad, India*

[5] *Department of Non-communicable Disease Epidemiology, Faculty of Epidemiology and Population Health, London School of Hygiene and Tropical Medicine, London, United Kingdom*

*Corresponding author: christopher.turner@lshtm.ac.uk

Abstract

Recent calls have been made to investigate food environments and improve knowledge and understanding of drivers of food acquisition in LMICs. This qualitative study aims to 1) investigate drivers of food acquisition in peri-urban Hyderabad; 2) understand perceptions and experiences of change in the food environment and food acquisition practices over the past decade; and 3) explore intra-household dynamics in relation to food acquisition, preparation, and consumption practices. We conducted primary data collection in two peri-urban sites, including in-depth interviews (*n*=18) and an innovative qualitative geographical information systems (Q-GIS) approach featuring participatory photo mapping and follow-up graphic- and photo-elicitation interviews (*n*=22). Secondary data from eight focus group discussions (FGDs) (*n*=94) in eight peri-urban sites corroborated findings related to fruits and

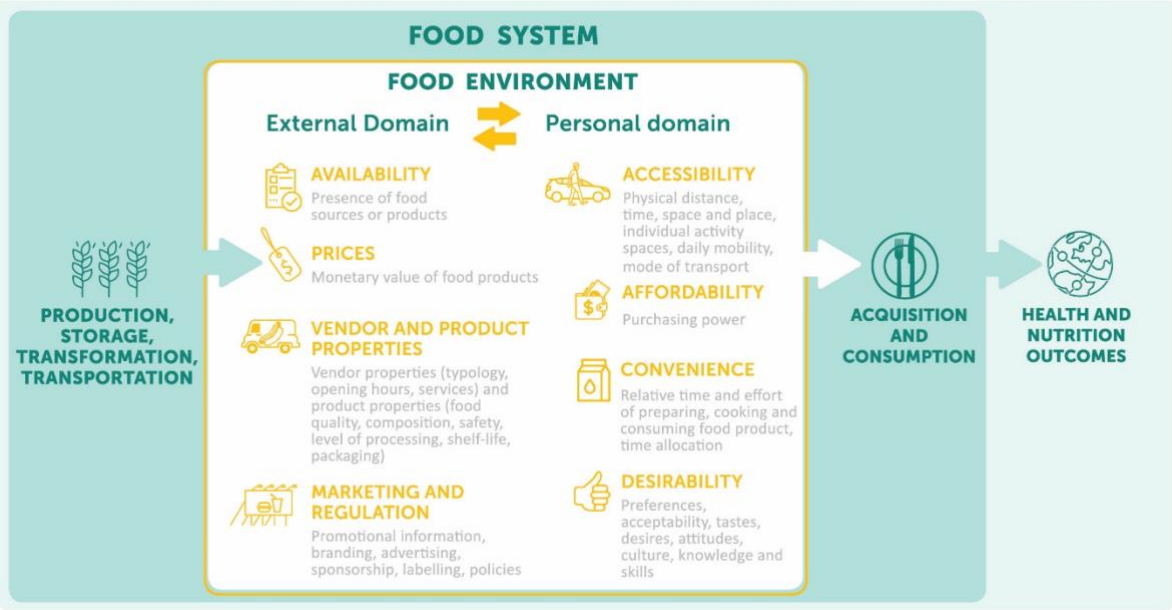
vegetables. We used deductive and inductive thematic analysis techniques in an iterative process, guided by our globally applicable food environment conceptual framework and the external and personal food environment domains and dimensions. Drivers of food acquisition practices were found to be diverse, complex, and multifaceted, and grouped around three primary themes: (1) Prices and affordability; (2) Vendor and product properties, with 2 sub-themes related to (a) quality and freshness, and (b) adulteration and contamination concerns; and (3) a sense of community and trust. Narratives of change included increasing availability of diverse foods, prices, adulteration and contamination, accessibility, and convenience, as well transitioning preferences and perceptions of the decreased tastiness of foods. Key themes at the intra-household scale included gendered dynamics of food acquisition and preparation, drivers of children's food acquisition and consumption, and perceptions and knowledge of diets, nutrition and health.

Introduction

Food systems and food environments are changing rapidly in low- and middle-income countries (LMICs), set against the backdrop of globalization, urbanization, economic development, technological advancement, and shifts in agricultural systems (1-3). Shifting dietary and lifestyle patterns are fuelling a nutrition transition (4, 5), resulting in an emerging double burden of malnutrition characterized by persistent undernutrition and the increasing prevalence of overweight, obesity, and diet-related non-communicable diseases (NCDs) (6).

Recent calls have been made to investigate food environments and improve knowledge and understanding of drivers of food acquisition in LMICs (1, 7, 8). Food environments form the series of physical, economic, socio-cultural, and policy opportunities, constraints and conditions that influence what people eat (9, 10). Food environment research is grounded in socio-ecological theory which dictates that health-related behaviours are determined by interactions between people and their surroundings (11). Recent efforts to harmonize key socio-ecological concepts into a globally applicable food environment framework outline the external food environment domain, featuring dimensions of food availability, price, vendor and product properties, and marketing and regulation; and the personal food environment domain, which includes food accessibility, affordability, convenience and desirability relative to individuals (12) (Figure 1). Public health researchers have acknowledged the need to understand the 'black box' of interactions and unknown mechanisms that link these domains and motivate dietary and health related behaviours (13). In parallel with these developments, there has been a resurgence of interest in drivers of food acquisition and the frequent, multifaceted, situational, dynamic and complex ways in which people acquire, prepare, and consume foods (14). This approach is grounded in the food choice process model developed by Furst et al. (15) that links life course events and experiences with personal influences that shape food behaviours.

Figure 1: A globally applicable food environment conceptual framework (12).



Food environment research has been gaining considerable momentum in LMICs. A recent systematic review revealed the rapidly emerging body of food environment literature spanning 22 LMICs (16). However, only a handful of studies to date have investigated food environments and drivers of food choice in India (Table 1). Three articles have sought to characterize the community-level availability of food vendors and products in Delhi. Of these, two found Indian-style full service restaurants, fast food restaurants, and street and snack food vendors to be key sources of unhealthy foods (17, 18), whilst street vendors and markets were found to be important nodes for fruit and vegetables (19). Three qualitative articles have focused on the school-level, addressing perceptions and experiences of the food environment amongst adolescents, highlighting concerns around food safety, marketing, and peer influence in Kolkata (20, 21) as well as prestige allocated to non-traditional fast foods amongst adolescents in Vijaypura (22). In addition, evidence from two qualitative articles investigating drivers of food choice in India found food prices, safety, and convenience to be important, as well as perceptions of health and the preferences of husbands and children (23, 24). Beyond these pioneering studies, there remains limited knowledge and understanding about food environments and drivers of food acquisition practices in India, particularly in rapidly developing peri-urban settings, as studies have predominantly focused on urban centres to date. A number of publications have called attention to the nutrition transition,

the double burden of malnutrition, and the increasing prevalence of diet-related NCDs in India (23, 25, 26). Malnutrition and dietary risks are estimated to be the leading risk factors contributing to disability-adjusted life-years (DALYs) in India, respectively (27). Trends over the past decade from the Global Burden of Disease study reveal the evolving character of the public health nutrition challenges at hand. Malnutrition prevailed as the most important risk factor to DALYs amongst all ages in India between 2007 and 2017. Concurrently, dietary risks have risen from fourth to the second most prominent risk factor to DALYs during these years, with a 34.9% increase in contribution to DALYs (27). The most recent estimates from the Global Burden of Disease study also attest to the public health nutrition challenges posed by the double burden of malnutrition in India, with an estimated 1520 disability-adjusted life-years per 100 000 population lost in 2017 due to iron, zinc and vitamin A deficiencies, whilst 2703 disability-adjusted life-years per 100 000 population were lost due to high low-density lipoprotein cholesterol or BMI (28). Given the challenges faced in India, there is a critical need to accelerate food environment research to investigate drivers of food acquisition.

Table 1: Key characteristics of studies investigating food environments and drivers of food choice in India, grouped by location.

Location	Author, year	Research focus[1]	Setting[2]	Article type[3]	Sample	Methods			Key results: food environment dimensions/drivers of food choice/themes
						GIS-based	Market-based	Stakeholder-based	
Delhi	Bailey et al., 2018	DFC	U	Qual	Thirty-eight women aged 20–35 years in Delhi, India.			✓	Family influence; cultural perceptions, including beliefs relating to: (a) outside food and less healthful food, (b) seasonality, and (c) hometown food; convenience, including: (a) decisions regarding procurement of food, (b) not having time to cook, resulting in eating out or purchasing premade foods, and (c) eating whatever is available at home or is left over from previous meals; habit, including: (a) subconscious decisions and (b) food roots.
Delhi	Finzer, 2013	FE	U	MM	Households (*n*=245) in South Delhi; Key informants (*n*=65)			✓	Street vendors and markets dominant source of fruits and vegetables in South Delhi. Affordability, not accessibility is the main barrier to increasing FV intake.
Delhi	Gupta, 2016	FE	U+R	MM	Street vendors (*n*=44) in three low-SES settings: two villages and one urban slum	✓	✓	✓	A variety of snacks were available, including unlabelled transparent packages and open glass jars. Mean fat content in snacks was 28.8 g per 100-g serving in rural settings and 29.6 g per 100-g serving in urban settings. Sampled oils contained high levels of saturated fats (25% to 69% total fatty acids) and trans fats (0.1% to 30% of total fatty acids).
Delhi	Patel, 2017	FE	U	Quant	Adults (*n*=5264) in 134 Census Enumeration Blocks in Delhi	✓			Availability: The most common full service and fast food restaurants were Indian savoury restaurants (57.2%). Participants in the highest tertile of full service and fast food restaurant density were less likely to consume fruit and vegetables and more likely to consume refined grains compared to participants in the lowest tertile after adjustment for age, household income, education and tobacco and alcohol use (both p <0.05).
Kerala	Daivadanam et al., 2015	DFC	R	Qual	Three focus group discussions (FGDs) and 17 individual interviews among 13 men and 40 women, between 23 and 75 years of age.			✓	'Counting and meeting the costs', including prices and affordability; 'Finding the balance', including food preferences of husband and children.
Kolkata	Rathi, 2016	FE; SFE	U	Qual	Students (*n*=15), parents (*n*=15), and principals (*n*=10) from ten secondary schools in Kolkata			✓	Influences on adolescent eating habits: Parent and peer influences, home and school food environments, and mass media.
Kolkata	Rathi, 2017	FE; SFE	U	Qual	52 Interviews, including adolescents aged 14–15 years (*n*=15), parents (*n*=15), teachers (*n*=12) and principals (*n*=10) from 10 private schools in Kolkata			✓	School food environment: Absence of written food policies, widespread supply of unhealthy foods; inadequate provision of healthy foods; misleading messages about food communicated by school authorities; lack of cleanliness in the school canteen; high cost of canteen food.
Vijapura	Maxfield, 2016	FE; SFE	U	Qual	Free listing included adolescents (*n*=29), 14 from a government school and 15 from a private school in Vijayapura city; Pile sorting included adolescents (*n*=65)			✓	Adolescents found non-traditional foods to be most prestigious; non-local foods, both from foreign countries and other regions of India, as well as foods eaten outside the home, were also considered prestigious.

[1] DFC, Drivers of food choice; FE, Food environment; SFE, School food environment

[2] U, Urban; R, Rural

[3] *Qual, Qualitative; Quan, Quantitative; MM, Mixed methods*

This qualitative study investigates the food environment and drivers of food acquisition in peri-urban Hyderabad, India. It is framed within a wider research project, the Andhra Pradesh Children and Parents Study (APCAPS), an inter-generational cohort study (N=7,000) located across 29 rapidly urbanising villages in peri-urban Hyderabad that seeks to understand the influence of environmental and genetic factors on chronic diseases in this setting (29). Empirical evidence from APCAPS has revealed a high prevalence of chronic diseases and risk factors amongst adults aged 30-84 years, including underweight (BMI < 18.5 kg/m2: men 31%, women 20%); overweight (BMI ≥ 25 kg/m2: men 18%, women 24%) and hypertension (BP > 140/90 mmHg: men 20%, women 13%) (29). Formative focus group discussions investigating perceptions health and chronic disease in this setting indicated concerns around the changing food environment and diets over the past decade (30). A comprehensive in-depth qualitative investigation is needed in order provide contextualised knowledge and understanding of perceptions and experiences of the food environment and drivers of food acquisition.

We implement a multi-scalar qualitative approach to address community, intra-household and individual level drivers of food acquisition and consumption. This approach is grounded in socio-ecological theory and the recognition of multi-scalar determinants of health-related behaviours (11, 31). We also apply a temporal lens to understand broader trends taking place in this transitional setting, focusing on narratives of change in the food environment and food acquisition practices. Retrospective qualitative approaches are rooted in ethnography and have enabled studies of food choice and the wider determinants of nutrition to move beyond merely reporting contemporary practices by exploring participants' memories and lived experiences of change, thereby aiding understanding of trajectories and turning points of dietary and nutrition related behaviours (32-34).

Specifically, this study aims to: 1) investigate drivers of food acquisition in peri-urban Hyderabad; 2) understand perceptions and experiences of change in the food environment and food acquisition practices over the past decade; and 3) explore intra-household dynamics in relation to food acquisition, preparation, and consumption practices. We draw from in-depth interviews (IDI's) and a novel qualitative geographical information systems (Q-GIS) approach, featuring participatory photo mapping (PPM) and follow-up graphic- and photo-

elicitation interviews. Findings are intended to improve understanding about how people perceive and experience drivers of food acquisition with a view to informing policies designed to improve the healthiness of food environments in peri-urban Indian settings. In addition, the sensitisation and qualitative validation of key food environment concepts from the conceptual framework (Figure 1) is intended to provide wider implications for food environment research across other LMIC settings.

Methodology

We implemented a multi-method qualitative methodology that included in-depth interviews and a Qualitative-Geographical Information Systems (Q-GIS) approach, featuring participatory photo mapping and follow-up graphic elicitation interviews. A detailed description of sampling, data collection, analysis, and ethical considerations is provided below.

Sampling

We purposively selected two peri-urban villages, Patelguda, featuring a high level of urbanicity, and Thummaloor, with a low level of urbanicity, in order to capture the range of peri-urban environments in this setting (Table 2).

Table 2: Descriptive characteristics of the study sites from the ACPAPS survey data.

Site	Population (APCAPS HH survey)	Urbanicity ranking (Multi-component scale 2013)[1]	Food vendor count (n)	Availability of food vendors by typology (n, %)[2]						
				Street vendor	Ready to eat shop with seating	General store	Other shop with walls and roof	Village market	Ration shop	Others
Patelguda	2745	High	36	2 (5%)	3 (8%)	19 (53%)	9 (25%)	0 (0%)	1 (3%)	2 (6%)
Thummaloor	2484	Low	30	1 (3%)	2 (7%)	14 (47%)	11 (37%)	1 (3%)	1 (3%)	0 (0%)

[1] APCAPS Multi-component urbanicity index 2013. The APCAPS urbanicity index 2013 was created by the wider APCAPS research project to provide an indication of each village's level of urbanicity, relative to the other 28 villages at that time point. Principal Component Analysis (PCA) was used to determine indicators that displayed a significant contribution to the construct of urbanicity. The 11 indicators were: Existence of post office, % of residents who own any type of phone, % of residents owning a two- or four-wheeler, Existence of Banks and Credit Coop Societies, % of residents working in skilled non-manual or professional roles, Existence of colleges, Existence of healthcare facilities, % of households with a private supply of water, % of households classified as "pucca", Night-time light intensity, % of residents who own a TV. Higher scores indicate higher urbanicity. PCA tertiles were compared to classifications obtained from a simple face validity study. Eight field-workers, all with several years of experience working in the APCAPS villages, were asked to rank all 29 villages based on their perception of each village's urbanicity. These eight rankings were combined to create urbanicity tertiles for all villages. The kappa statistic for agreement between these tertiles from face validity study and the PCA tertiles indicated a strong degree of agreement (0.86).

[2] Data collected as part of the 2016 APCAPS built environment survey.

We expected based on earlier studies that a sample 40 participants from 20 households, including one male and female from each household, would yield sufficient data to achieve thematic saturation in this in-depth, qualitative study (Figure 2). However, we were prepared to sample additional participants if saturation was not reached.

Figure 2: Study design.

We used the APCAPS 2012-2014 household survey census to select households with at least one adult male and female aged 18-65 registered at the residence from the two villages. Households were assigned a random number and sorted in rank order to provide a randomly generated household roster of eligible households for each village. Households were then randomly assigned to either IDIs or the novel Q-GIS approach. Simple random sampling was used to prevent the purposive selection of familiar households from the wider cohort study that may be known to the field team and have built up a pre-existing rapport, and to give all households an equal chance of selection given the risk of participant burden within the wider multi-wave cohort study. The APCAPS index person for each household was initially contacted via telephone as is standard practice within the wider cohort study. Households were called in sequential order from the household roster. The purpose of the study was explained and participants were invited to enrol in the study. Prospective households interested in enrolling on the basis of the phone call were subsequently visited by the field team at a convenient time where the participant information sheets and consent forms were distributed. The index person and their spouse were recruited if they were willing to participate in the study, providing one male and one female from each household. Other household members were invited to participate in cases where the index person or their spouse were not willing or able to participate. Additional households were recruited in cases where no household members were willing or able to participate, and also in cases of attrition or deviance from the study protocol.

Primary data

Primary data collection was conducted between June and August 2017 and consisted of IDIs and a Q-GIS approach, featuring participatory photo mapping and follow-up graphic- and photo-elicitation interviews. Data collection was designed and conducted in adherence to qualitative public health research guidelines (35, 36). The field team were recruited from the wider APCAPS research project. All field team members were fluent in both Telegu and English and possessed extensive local knowledge and fieldwork experience in APCAPS. Participatory training workshops were held with the field team prior to data collection, informed by established training manuals for field researchers (37). Workshops focused on qualitative skills and practical communication principles to ensure data quality. Specifically, training included sections on questioning techniques, probes, and interpretive summaries, as well as how to avoid common pitfalls such as closed questions, and leading questions. All interviews were conducted separately in private spaces, either within the household or in nearby community halls. Interviews were stopped when thematic saturation was reached. Interview audio was recorded using an encrypted Dictaphone device.

In depth interviews

IDIs were conducted with participants about their food acquisition practices, perceptions and experiences of change in their food environment over the past decade, and intra-household food acquisition, preparation and consumption. Topic guides and probes were developed by the lead author in English, and included food environment dimensions identified in the conceptual framework (Figure 1), as well as market-based food sources, own production, wild food harvesting, and gifts and transfers identified by Turner et al. (12) (Supplemental Material 1).

Following an initial consultation with the field team coordinator, topic guides were translated into Telugu by the field team. Pilot testing and group discussions with the field team refined the protocol and topic guides and ensured that the translated terminology was applicable within the local context. Each interview lasted between 40 and 60 minutes.

A qualitative Geographical Information Systems (Q-GIS) approach – Participatory photo mapping and follow-up graphic and photo-elicitation interviews

Q-GIS approaches feature the integration, analysis, and visualisation of geospatial and qualitative datasets. Q-GIS is grounded in narrative analysis, termed geo-narratives, that enable the critical thinking about the spatiality of social processes and lived experience (38, 39). Q-GIS has been used in a range of community development and planning projects in both HICs (40) and LMICs (41). Participatory forms of Q-GIS create an interactive and reflective process by placing participants at the centre of the research activities and allowing them to negotiate and represent local knowledge through multiple forms of media, including maps, transcripts, and drawings (41). Similarly, participatory visual-based methods such as photovoice have long been used in the social sciences to explore emic perspectives of lived experiences through the use of graphic- and photo-elicitation techniques (42-49). These techniques have been found to be particularly useful in exploring the interconnections between place and daily life, assisting understanding about socio-ecological interactions between natural, built, social and symbolic environments that shape health and well-being (42). They have also been successfully implemented in LMIC settings, helping to bridge cultural and relational voids between researchers and participants and reveal tacit forms of knowledge derived from everyday life (50, 51). Participatory photo mapping (PPM) combines participatory Q-GIS with visual approaches. This integrated approach features the analysis of a comprehensive set of images, narratives and other qualitative data produced by residents of participating communities, and has been applied in health and place research (52). These kinds of integrated participatory-based, geospatially informed qualitative approaches have the potential to provide in-depth contextualised knowledge and understanding about food environments and food acquisition practices in LMICs. Chen and Kwan (53) note the virtues of combining qualitative activity-based research with spatially and temporally tagged human mobility data in food environment research, in order to:

> *"…elucidate thoughts and feelings about purchasing and consuming foods and to document the nutrition environment in which foods are labelled, promoted, and priced as stimuli for changing individual perceptions [and] …provide an overarching*

understanding of how contextual influences shape people's choices for food as well as offer plausible evidence for food and nutrition policy intervention" (53: p.1736).

Few food environment studies have implemented such integrated qualitative methodologies to date. We designed a novel Q-GIS approach featuring two stages. In stage one, participants (n=22) were tasked with photographing their food environment and food acquisition, preparation and consumption practices over a three-day period using a GPS enabled mobile phone device. A brief training session on the functionality of the mobile device, the camera application, and ethical photographic principles was provided for participants. Guiding instructions provided on the background and screensaver of the mobile phone encouraged participants to take photographs of buying, growing, preparing, cooking and eating food, as well as any food sources, and also any non-food items, objects or activities considered to be important in shaping their diets. Data collection took place across weekdays and weekends to capture variation.

In stage two, each participant's geocoded photographs were downloaded, mapped and printed on chart paper. Charts visualizing the maps and photographs were used as visual stimulus in conjunction with photo- and graphic elicitation techniques in follow-up one to one interviews with participants. The topic guide included the same sections as the in-depth interview guide, with an additional section on the feasibility and experiences of the Q-GIS approach and PPM to enable an appraisal of the protocol and methodology. Additional probes were included to facilitate photo-elicitation techniques, and specific questions and probes were also included for each photograph. Q-GIS interviews lasted around one hour.

Secondary data

We corroborated our key themes and findings related to drivers of fruits and vegetable acquisition and consumption with secondary data from eight focus group discussions (FGDs) (*n*=94) conducted across 8 APCAPS sites. These additional focus groups were conducted as part of the wider APCAPS project in 2018 with the aim of identifying pathways to improve fruit and vegetable consumption. Secondary data on household and individual level socio-demographics was obtained from the 2012-2014 APCAPS Household Survey, whilst

descriptive data on the external food environment was taken from the 2016 APCAPS Built Environment Survey.

Data analysis

Transcription and translation of the audio from the recorded interviews was conducted by the field team. Audio was first transcribed verbatim in Telugu and subsequently verified before being translated into English. Transcripts and the Q-GIS charts featuring each participant's maps and photographs were entered into NVivo12 software for analysis. We applied a multi-scalar analytical lens, seeking to address what Green and Thorogood (35) refer to as both realist questions about *'what is going on'*, as well as interpretative questions related to the *'perceptions and experiences'* of the participants themselves. In other words, we not only sought to establish how people acquire foods as part of daily life, but also to reveal critical subjective reflections about which food environment dimensions are important by allowing participants to *'speak for themselves'.* Our roles as researchers were what Green and Thorogood (35) call dual, in the sense that we aimed to reflect the complexity of food acquisition practices whilst presenting the underlying structures that make sense of that complexity; simultaneously 'telling the story' from the participant's point of view, whilst 'unpacking the story' in relation to the food environment theoretical framework (Figure 1). To achieve this, we sought to present the emic accounts of participants to voice their worldview, whilst triangulating these accounts with theoretical concepts to provide etic abstractions and explanations about food acquisition and consumption practices.

Negotiating these multiple scales of analysis required both deductive and inductive thematic analysis techniques in an iterative process. Deductive techniques were used in the early stages of analysis and included coding the data according to the a-priori external and personal domains and dimensions of the food environment conceptual framework (Figure 1). Inductive techniques were subsequently introduced as the analytical process developed, generating new themes and codes. Inductive coding drew from elements of grounded theory such as open coding, the writing of detailed memos, and the identification of deviant cases within the data. Open coding allowed the analysis to move beyond descriptive accounts of the data towards more in-depth, 'thick' analyses. Particular attention was given to identifying in-vivo

codes, defined as the ways in which people categorise their social worlds (35). Each code was clearly defined and kept mutually exclusive to improve reproducibility.

All translated transcripts were read and reviewed in English by the lead author. A sample of 4 transcripts were co-coded with the aid of a research assistant, followed by the blind coding of a further 2 transcripts which returned a high level of inter-coder agreement (86%). Discrepancies were resolved through discussion, and the coding framework was amended accordingly.

All photographs included in the Q-GIS charts were coded manually by the lead author according to the image content, collating data on the food source, vendor typology, food environment dimensions, and presence of food items, preparing or cooking food, consumption of food, and location.

Comparison between the empirical data (including themes, photographs, and maps) and theoretical constructs from the food environment conceptual framework (Figure 1) was used to sensitise key concepts and build conceptual generalisability, framed by Green and Thorogood (35) as ways of thinking about or 'making sense' of the world that might inform our understanding of similar contexts. Building conceptual generalisability is recognized as a key strength and cornerstone of qualitative research in under-researched topics or settings (35), and is particularly salient to our study given the recent publication of the conceptual framework (Figure 1) and the nascent state of food environment research in LMICs, especially in peri-urban Indian settings. In addition, this analytical process facilitated the identification of any existing gaps within the framework.

Reporting of results was guided by established recommendations for reporting qualitative research, including the 21 item Standards for Reporting Qualitative Research guideline (54), and the 10-question checklist devised by the Critical Appraisal Skills Programme (55).

Ethical considerations

This research was granted ethical approval by the Observational Ethics Committee of the London School of Hygiene and Tropical Medicine (reference number: 12257) (Supplemental

Material 2), and the Institutional Ethics Committee of the Indian Institute of Public Health, Hyderabad under the banner of the Public Health Foundation of India (reference number: IIPH/TRCIEC/092/2017) (Supplemental Material 3). Written informed consent was obtained from all participants prior to data collection (Supplemental Material 4). All participants were reimbursed with a small nominal fee as compensation for their time commitments to the study. Due to the sensitive nature of the geocoded maps and photographs these data are private and confidential. All photographs in this manuscript are either taken by the lead author or the field team in the research setting and are indicative of the photos taken by the participants.

Results

Participant characteristics

In total, 40 participants took part in the study, including 20 men and 20 women (Supplemental Material 5). We conducted 18 IDIs, 16 Q-GIS interviews, and 6 photo-elicitation interviews. Photo-elicitation interviews were undertaken in cases where Q-GIS participants had missing GPS data to deviance from the protocol.

The mean age of participants was 31 years (Table 3). Amongst the participants for which socio-demographic data was available from the APCPAS Household Survey 2012-2014 (n=36), the most common occupations included unskilled manual labour (n=14; 39%), homemaker (n=8; 22%), semi-skilled manual labour (n=7; 19%), and skilled manual labour (n=5; 14%). Around half (n=19; 53%) of the participants were educated at primary or secondary school level, whilst more than a third (n=13; 36%) were illiterate, and a few (n=4; 11%) were literate with no formal education.

At the household level, 14 of the 20 households included in the study (70%) reported being eligible for subsidized food rations through the Public Distribution System that is means tested based on household income at the Below Poverty Line, which was set in 2016 at Rs. 27,000 per annum (56). The mean household asset score was 11.

Table 3: Demographic and socio-economic characteristics of the sample.

Participant level data[1]			
Participants	***Total (n=36)***	***Patelguda (n=17)***	***Thummaloor (n=19)***
Male	20	9	11
Female	16	8	8
Mean age	31	34	28
Education level	***(n, %, [females])***	***(n, %, [females])***	***(n, %, [females])***
Illiterate	13 (36%) [9]	6 (36%) [4]	7 (37%) [5]
Literate	4 (11%) [3]	2 (12%) [2]	2 (11%) [1]
Primary school education	9 (25%) [3]	6 (35%) [2]	3 (16%) [1]
Secondary school education	10 (28%) [1]	3 (18%) [0]	7 (37%) [1]
Occupation	***(n, %, [females])***	***(n, %, [females])***	***(n, %, [females])***
At home doing housework	8 (22%) [7]	6 (36%) [5]	2 (11%) [2]
Unskilled manual labour	14 (39%) [6]	5 (29%) [2]	9 (47%) [2]
Semi-skilled manual labour	7 (19%) [3]	3 (18%) [1]	4 (21%) [1]
Skilled manual labour	5 (14%) [0]	3 (18%) [0]	2 (11%) [0]
Skilled non-manual labour	1 (3%) [0]	0	1 (5%) [0]
Student	1 (3%) [0]	0	1 (5%) [0]
Household level data			
Households	***Total (n=20)***	***Patelguda (n=9)***	***Thummaloor (n=11)***
Mean household asset score[2]	11	10	11
Select household assets[3]	***(n, %)***	***(n, %)***	***(n, %)***
Motorbike	8 (40%)	2 (22%)	6 (55%)
Bicycle	7 (35%)	5 (56%)	2 (18%)
Agricultural land	6 (30%)	2 (22%)	4 (36%)
Electricity	20 (100%)	9 (100%)	11 (100%)
Water pump	11 (55%)	4 (44%)	7 (64%)
Kitchen	19 (95%)	8 (89%)	11 (100%)
Refrigerator	2 (10%)	1 (11%)	1 (9%)
Television	18 (90%)	7 (78%)	11 (100%)
Radio	9 (45%)	6 (67%)	3 (33%)
Mobile phone	18 (90%)	8 (89%)	10 (91%)

[1]Demographic and socio-economic data only available for 36 of the 40 participants as 4 of the female participants married into households after the completion of the 2012-14 household survey.

[2]APCAPS Household asset score consists of a 24-component ownership checklist (house; kitchen; radio; tv; fridge; telephone; cooler; washing machine; agricultural land; electricity; bicycle; two wheeler; four wheeler; motor; water pump; tractor; thresher; toilet; account; cart; sofa set; table; bed; mattress).

[3]Select assets related to food acquisition and consumption.

Food acquisition practices

Triangulation of the transcripts, maps, and photographs revealed how participants navigate their food environment to acquire foods as part of their daily lives. Activity spaces spanned a range of peri-urban and urban areas, with key nodes of food acquisition including local villages, mandal headquarters (the central administrative village of the sub-district), and the city of Hyderabad. Overall, the majority of participants described weekly grocery shopping trips to their nearby mandal headquarter markets (Photo 1) located 3-5km away from their villages. These weekly trips were interspersed with daily visits to small local general stores (Photo 2) for what were termed 'emergency' purchases of perishable items and the 'habitual' daily acquisition and consumption of snacks, sweets and beverages: *"In the village we get small things, like if things such as milk packets, biscuit packets are finished, but mostly we don't bring from the village." (F, 240391, 20 years, IDI).* Acquisition from urban areas was typically linked with work related travel. There were no discernible differences in food acquisition practices in terms of food sources utilized or foods acquired and consumed between residents from the two villages, despite the disparate levels of urbanicity.

Photo 1: A fruit and vegetable market in an APCAPS mandal headquarters.

Credit: Christopher Turner.

Photo 2: A typical small local general store in an APCAPS village.

Credit: Christopher Turner.

Food sources

Participants were found to acquire foods from diverse sources as part of daily life in this transitional peri-urban setting, including market-based sources, agricultural production, wild food harvesting, and transfers (Table 4). In total, Q-GIS participants took over 1000 photographs. Amongst the mapped photographs included in the interviews (n=267), around half (55%) included a food source. Of these, agricultural production was most commonly photographed (33%), followed by informal market-based vendors (30%), formal market-based vendors (22%), and wild food harvesting (13%).

Table 4: Commonly discussed food sources amongst participants.

Food source	Description
Market-based sources:	Market-based sources included formal and informal vendors in the villages, nearby mandal Headquarters, and urban areas. Commonly discussed formal vendors included weekly markets, traditional small brick and mortar shops in villages (also known as general stores), and ready-to-eat shops (also known as hotels and restaurants). Informal vendors were predominantly found to be street vendors, and included stationary vendors (including heap vendors and those with a temporary structure) and mobile vendors (such as door to door salespeople or motorbikes or autorickshaw vendors).
Agricultural sources:	Agricultural sources included own production in local fields, home gardens in and around residential plots, and the farm gates of local producers.
Wild food harvesting:	Wild food harvesting sources included seasonal fruits and nuts, often harvested from in and around the villages as a leisure activity.
Transfers:	Transfer sources included ration shops provided through the Government run Public Distribution System, payment for labour (often agricultural labour), and gifts from neighbours, friends and visiting relatives.

Types of foods

Perishable vegetables, staple grains, and pulses were consistently the most commonly discussed food types across the transcripts, and were almost always the first foods mentioned when participants were asked to describe their routine food acquisition practices. Participants regularly ascribed importance to the daily consumption of these foods: *"Pulses, vegetables, and rice are compulsory, they should be there, they are important because they are the foods that we eat daily, no?!" (M, 240391, 22 years, IDI)*. Snacks, sweets and sweet and sugary beverages were found to be commonly acquired and consumed, although these items were typically only mentioned when probed by the interview team. For example, one male participant revealed his regular consumption of snacks when probed about a photograph he had taken: *"whenever I go to the shop I keep eating, I like them […] when I'm in the village I eat many times, snacks in the afternoon." (M, 240233, 19 years, Q-GIS).* Animal source foods such as milk and eggs were commonly consumed, whilst meat was reported by almost all participants as a 'special food' consumed only at weekends and on festive occasions: *"On that day [Sunday], we will get mutton and chicken. We will work all week and on Sunday the children are also home, right? That's why we bring those." (F, 240284, 25 years, Q-GIS)*. Fruits were generally the least commonly discussed food type, and when probed were almost always considered to be foods for children.

Almost all participants made unprompted distinctions between homemade foods (prepared at home by the family), such as vegetable curries and dal, and outside foods (ready to eat foods prepared outside), such as samosas, tiffin (a term for a light snack or meal) and other street foods. Homemade foods were preferred over outside foods. Strong cultural and culinary traditions of cooking at home were often expressed by female participants. For example, one female participant *"I have never bought ready-made items. Now many such things are available in the shops but I prefer preparing with my own hands." (F, 030236, 30 years, IDI)*, whilst another explained how home cooking was learnt during childhood and continues to be a habitual part of family life:

> *"We should cook at home, should eat freshly at home. Even now it's the same […] from childhood I cooked at home and it became a habit […] we never even thought why like that. Habit in the family. I eat only at the house, I don't even drink tea outside." (F, 030445, 46 years, IDI).*

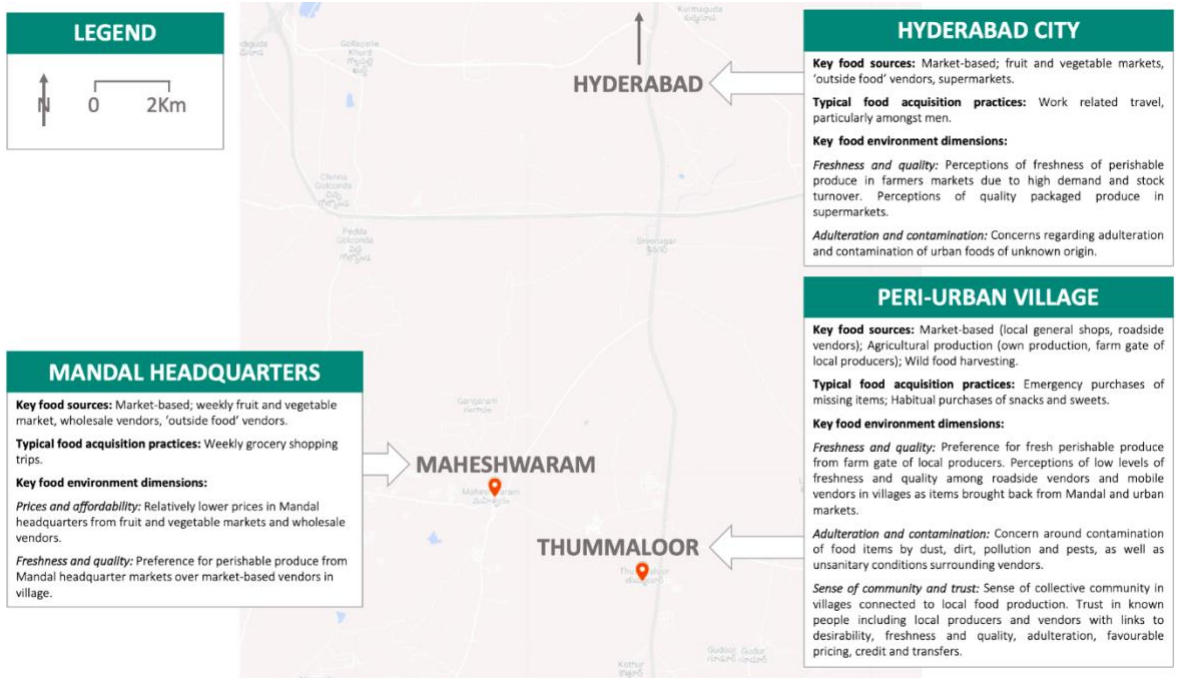
Drivers of food acquisition practices

Drivers of food acquisition practices were found to be diverse, complex, and multifaceted, with considerable variation according to food and vendor types, as well as individual perceptions and experiences. However, three primary drivers of food acquisition emerged: (1) Prices and affordability; (2) Vendor and product properties, with 2 sub-themes related to (a) freshness and quality, and (b) adulteration and contamination concerns; and (3) A sense of community and trust (Table 5). The key food environment nodes and drivers of food acquisition collectively identified by participants from Thummaloor are mapped to give an impression of the geography of the food environment and food acquisition practices in this peri-urban setting (Figure 3).

Table 5: Key themes related to drivers of food acquisition practices.

Themes	Sub themes (if applicable)	Detail
Prices and affordability		Relatively lower prices in mandal headquarters Relatively higher prices in villages Affordability of bulk purchases Affordability of spoiled perishable items
Vendor and product properties	Freshness and quality	Preference for fresh perishable produce from farm gate of local producers, and mandal headquarter fruit and vegetable markets Spoilage associated with transportation and storage Packaged vs unpackaged foods Low freshness and quality of perishable produce from roadside vendors and mobile vendors
	Adulteration and contamination concerns	Point of production: Use of pesticides, fertilizers, chemicals and medicines Point of transformation: Adulteration of raw produce; preparation of ready-to-eat outside foods Point of transportation: Contamination of produce by dust, dirt, pollution and pests Point of sale: Contamination of produce by dust, dirt, pollution and pests
Sense of community and trust		Sense of community in villages connected to local food production The role of known people, including local producers and vendors on: Desirability; Freshness and quality; Adulteration and contamination; Favourable prices; Credit; Transfers

Figure 3: Key nodes and characteristics of the food environment for Thummaloor.



Theme 1: Prices and affordability

Prices were considered to be a key driver of food acquisition practices. Almost all participants noted differences between smaller and larger peri-urban sites, and also different types of vendors. Mandal Headquarter villages located between 3-5km from the study sites were

considered to be a key source of foods, primarily due to the comparatively lower prices offered by wholesale vendors and weekly markets. One participant contrasted between prices in his village and the nearby mandal headquarters:

> *"Yes, there are differences. If we go to the headquarters to buy anything like pulses, salt, and sugar, whatever we bring from there we get that at less cost, like 5 to 10 rupees we can save." (M, 240253, 35 years, Q-GIS).*

Participants also told how the practice of buying groceries, vegetables and pulses 'for the week' from wholesale and market vendors in their local mandal headquarters was motivated by the relatively lower prices of bulk purchases:

> *"Maheshwaram is bigger as it's a mandal headquarters. Foods are available conveniently and we buy enough to be sufficient for a week. Going there for vegetables is beneficial as the price will be a little less […] two to three rupees less." (M, 240274, 30 years, IDI).*

> *"We go to the weekly market every Friday in Maheshwarem [mandal headquarters]. We also go to the wholesale shop as we get items a lower cost, so we bring 5kg or 10kg boxes of pulses and oil from there to last for a week or two." (M, 240635, 45 years, Q-GIS).*

The practice of purchasing stale perishable items such as vegetables at reduced prices in the days following the weekly markets was also evident, suggesting that price and affordability take precedence over freshness and quality, particularly amongst poor consumers in this setting (Box 1). Price was also perceived by some participants to be more important than other dimensions such as accessibility, exhibited by the willingness to travel to purchase at reduced prices: *"If you go a long distance it will be because the prices are lower. No matter how far, we will go and get from those shops*." *(F, 240253, 32 years, Q-GIS).*

In contrast to mandal headquarters, local market-based shop vendors in the villages were perceived to capitalize on their readily available and accessible nature and high level of convenience, targeting emergency purchases by local residents and charging higher prices for food items that were often considered to be of lower freshness and quality: *"If we want*

something in an emergency it costs more here in our village, but we don't get good ones. Sometimes we decide to wait while we go to Maheshwarem [mandal headquarters]" (M, 240635, 45 years, Q-GIS).

Box 1: Case study: Price takes precedence over freshness and quality.

Many participants considered price to be the most important driver of their food acquisition practices. In this excerpt, a participant living in a household with an income below the poverty line reveals how price and affordability interact with freshness and quality when purchasing vegetables from his local mandal headquarter market. When asked why he purchases as the mandal headquarters rather than from vendors in his village, price is the first dimension that comes to mind, followed by freshness. However, when probed further, he goes on to explain that whilst he looks for freshness and quality, price takes ultimately takes precedence:

> *"I: Why do you buy vegetables at Maheshwaram instead of buying here in the village?*
>
> *P: The price will be lower... it will be nice… they sell fresh vegetables for lower rate in Maheshwaram*
>
> *I: What do you look for when you buy vegetables? Do you see if it is fresh or do you see about the price?*
>
> *P: I will look for the lowest price. I will also see if it is good, look a little for freshness, but if the price is more I will not take them. I will only buy the low price items." (M, 240274, 30 years, IDI).*

The primacy of price over freshness and quality is also evidenced later in the interview when he describes the practice of purchasing spoiled vegetables from the mandal headquarters in the days following markets due to their reduced price:

> *"P: not only on the market day that is Friday, they also sell vegetables there on other days [at the mandal headquarters] […] the next day they also they sell […] a little less price… a little spoiled, more matured, we get them for a reduced price." (M, 240274, 30 years, IDI).*

This case study is typical of many accounts from our data of the primacy of price over other food environment dimensions amongst low-income consumers in this setting. Further, this case study also reveals how people navigate the spatial and temporal dynamics of their food environment as part of daily life to capitalize on interactions between external food environment dimensions.

Theme 2: Vendor and Product Properties

Freshness and quality: Perceptions of freshness and quality were considered to be key drivers of food acquisition amongst the majority of participants, particularly in relation to perishable items such as vegetables and milk. Perceptions varied by food sources. For example, many participants expressed their practice of acquiring fresh vegetables from known local producers, directly from the farm gate:

> *"We don't know when they [market vendors] take their produce and put them out. It's not fresh, that's why we do not want to take them. If we go to the garden [local fields] they will be fresh so we bring from there." (F, 240635, 38 years, Q-GIS).*

Regarding market-based vendors, weekly markets located within villages and nearby mandal headquarters were widely considered to provide the freshest source of quality perishable items. Participants noted the freshness of perishable items sold by known local producers in weekly mandal headquarter markets, as these items were *"cut in the morning and sold in the evening" (F, 240635, 38 years, Q-GIS),* thereby avoiding the spoilage associated with longer periods of transportation and storage. Urban fruit and vegetable vendors in Hyderabad city were preferred by a small number of participants due to perceptions of increased freshness of perishable produce as a result of higher levels of demand and stock turnover compared to peri-urban areas.

Roadside 'heap' vendors located in the villages were generally considered to provide low quality items, often those that had not been sold in mandal headquarter or urban markets and had subsequently been brought back to the villages and exposed to the elements along the way (Photo 3). One participant explained: *"In the village they keep in small heaps, it will not be good here, that's why we bring from the weekly market." (F, 240391, 20 years, IDI).* Roadside heap vendors were the most commonly photographed of the market-based vendors by Q-GIS participants (n=26; 33%), with many citing concerns about the freshness and quality of perishable produce when asked to explain their choice of subject: *"Fruits, pomegranates, applies, and bananas, they keep them outside. We don't buy from there […] sometimes the fruits are not that fresh." (M, 240651, 21 years, Q-GIS).* Similarly, mobile vendors selling items such as vegetables, grains, fruits and biscuits in the villages were also perceived as purveyors of low quality food products, and were commonly avoided by participants despite recognition of their low prices. The importance of freshness and quality of perishable items was also reflected in grassroots attempts to intervene in the food environment by residents (Box 2).

Photo 3: A roadside 'heap' vendor selling perishable fruits and vegetables in an APCAPS village.

Credit: Christopher Turner.

Perceptions of packaged versus unpackaged food items were found to be complex. For example, some participants preferred unpackaged products, such as unpasteurised milk acquired directly from local producers, which was prized for its freshness, and contrasted with packaged alternatives perceived to be less healthy: "*Buffalo milk will be fresh, Sir! Trust…we don't have trust in packet milk […] it's not healthy for the children" (M, 240391, 22 years, IDI).* Others, on the other hand, expressed contradictory narratives highlighting the complex nature of perceptions of food safety in the community:

> *"We buy milk packets from the shop right here. We don't take from those [local producers] in the village, they adulterate the milk by mixing it with water, that's why we get from that shop, but there may be adulteration in the packets too!" (F, 240274, 25 years, IDI).*

Whilst supermarkets were only discussed on occasion by participants in our study, one participant described his positive perceptions of packaged items from supermarkets in urban areas, telling of recommendations he had received from his educated friends in the city

advocating supermarket shopping: *"go nicely to that shop and take there, it will be available in packed form, it will be good." (M, 240544, 35 years, Q-GIS).*

Box 2: Case study: A grassroots intervention to improve the quality and freshness of perishable foods in the local food environment.

Freshness and quality were considered to be of prime importance among the majority of participants. Many participants voiced negative perceptions of the freshness and quality of perishable produce from market-based roadside and shop vendors in the villages. The commonly held narrative was that local agricultural producers and traders were typically transporting their freshest and highest quality produce directly to larger mandal headquarters and urban markets, whilst local village vendors were stocked with lower quality leftover items that had been brought back from mandal and urban markets having not been sold.

This case study reveals how a number of local residents from Thummaloor collectively mobilised to intervene in their local food environment in efforts to improve the quality and freshness of perishable produce. The excerpt below features a low-income consumer describing how he and other residents from his community opened up dialogue with local vendors, encouraging them to retain a portion of their freshest, high quality produce to sell in the villages:

> *"P: now… kowai, ladies finger, tomatoes, leafy vegetables […] earlier like 4-5 years back they used to keep the remaining leftover ones here. They took the good ones to the city, and they used to keep those leftover things here, Madam. Once like 2, 3 people, we went to ask them why they are keeping spoiled vegetables here when they can keep fresh ones here instead and take more money…So since we questioned them… like 4 years ago… since then they have started to keep 5 rupee bunches or 6 rupee bunches, when earlier they used to keep 1 rupee bunches…*
>
> *I: Okay, now you are getting quality vegetables?*
>
> *P: We told them, sell good quality vegetables, even if you charge more money we are ready to buy….like ….so nobody bought vegetables from the village previously… when we stopped buying they planned to sell quality ones at a higher price, I mean…so that people will buy, Madam." (M, 240253, 35 years, Q-GIS).*

This case study example provides evidence of the importance of freshness and quality in this setting, and further showcases the willingness of some consumers to pay for freshness and quality, contradicting the general narrative regarding the primary importance of price, and highlighting the complex and multifaceted nature of drivers of food acquisition. Further, this case study identifies a salient pathway that interventions may target to improve the freshness and quality of perishable items within peri-urban village food environments in this setting.

Adulteration and contamination: The majority of participants considered the adulteration of foods as a primary concern driving food acquisition practices. Participants identified range of adulteration and contamination sources, spanning the food system from the point of production, to transformation, transportation and acquisition. At the point of production, many participants identified the increasing use of 'fertilizers', 'pesticides', 'chemicals', 'medicines', and 'drugs' in agricultural processes related to both horticulture and livestock. Participants voiced their concerns regarding the perceived detrimental effects of these additives, not only to the taste of foods but also their nutrition and health. At the point of transformation, the adulteration of raw food items such as rice, oil and milk was a key concern

(Box 3), as was the preparation of ready to eat outside foods. Anxieties were manifested in sentiments of distrust with regard to unknown actors and hidden processes in the transformation, transportation, and storage of foods. For example, one participant described how she avoids perishable produce from roadside heap vendors in her village due to unknown processes associated with the production and distribution of their produce: "*we don't take them because we don't know when they were plucked or how they were transported and kept." (F, 240391, 20 years, IDI)*. As was identified with regard to freshness and quality above, many participants stated that they prefer to acquire foods from the farm gate of local producers in their community rather than unknown market-based vendors which were often associated with unknown levels of food safety. One participant explained:

> *"The wholesale shops don't know what they are getting in the bags, they don't know whether it's plastic rice or normal rice! We know those who cultivate rice so we will mostly buy from farmers rather than from wholesale shops." (M, 240417, 26 years, IDI).*

Others raised concerns about the contamination of foods. Contamination concerns were identified at the point of acquisition, grounded in both participant's tangible experiences of food vendors, and hidden processes related to storage and transportation of produce on route to market. Participants were particularly concerned about informal vendors, including unsanitary surrounding conditions, the exposure of raw food items to the open elements, including dust, dirt and pollution from passing vehicles (Photo 4), and also contamination by pests such as flies and mosquitoes. One participant explained:

> "*The food now is just waste. [In the village] they keep heaps in the evening at 4 or 5pm in the middle of the road. Vehicles drive past and dust will fall on them. There will be flies on the heaps and the surrounding areas are not good." (M, 240391, 22 years, IDI).*

Photo 4: Roadside preparation of chicken in an APCAPS village.

Credit: Christopher Turner.

Box 3: Case study: Modifying food acquisition practices due to adulteration concerns.

Adulteration and contamination concerns were key drivers of food acquisition amongst the majority of participants. In the excerpt below, a participant reveals how he has modified his food acquisition practices by opting to cultivate rice for his own consumption, due to experiences of adulteration at the point of transformation in the local rice mill and subsequent undesirable sensory attributes and perceived dietary health risks of adulterated rice:

> *"Now I'm not buying in the rice mill, they ask me why I'm not buying there. In the mill, they mix ten types of rice. There are ten types of paddy. One type of rice will be like gum when cooked, one type of rice will cook good. So, the rice mill people will buy the gummy paddy for a lower price, and buy the good paddy for a higher price, and they mix both types and sell. That's why when we cook it one grain will be cooked and one grain is not cooked. That affects man. We eat and cultivate that's why I'm saying it affects man […] Now I'm cultivating rice, first I'm putting the bag, ploughing, cultivating, so that nothing is there." (M, 030431, 35 years, Q-GIS).*

This case study reveals how food adulteration concerns are modifying food acquisition practices in this setting leading some consumers to avoid market-based food sources in efforts to mitigate against dietary health risks by producing their own food. This case contradicts wider trends of shifts away from agricultural production in this setting, highlighting how interactions between food environment dimensions such as vendor and product properties and desirability create complex and multi-layered food acquisition practices.

Theme 3: Sense of community and trust

Sentiments of trust and loyalty related to 'known people' were embedded throughout participant's accounts, and were closely connected with desirability and vendor and product properties, including aspects of freshness, quality, adulteration and contamination:

> *"We always bring from there. While eating we feel good, no?! If we go to another shop we don't know what they will give us. Always we go there and we like what they are giving us, in that only good food will be there. We are living healthy, no? That's why we are bringing from there." (F, 240391, 20 years, IDI).*

> *"We bring chicken from the village, there's a chicken shop there. He gives with trust, even if we send the children, he gives good things, that's why we only take from there." (F, 240284, 25 years, Q-GIS).*

There was also strong evidence of a collective sense of community and trust in relation to the local agricultural production of perishable items in and around the villages. Participants explained how this sense of community and trust shaped their food acquisition practices, and juxtaposed their willingness to consume local produce grown by known people with engrained sentiments of scepticism and distrust in relation to foods from unknown sources, such as 'foods from the city' (Box 4). One participant explained:

> *"Those that come from the city, we don't know from where they come, we don't have an idea. They could grow near Musi river or somewhere near their house. We cannot buy those. If we want to buy leafy vegetables we should buy from known people, from our neighbours, those who cultivate them, from them we bring." (M, 240417, 26 years, IDI).*

These sentiments of trust were grounded in interpersonal relationships and intricate tacit forms of knowledge about local vendors and their sourcing of produce. For example, leading on from the above quotation, the participant described how he was particularly careful to avoid those vendors who had travelled to the city in the early morning to complement their locally grown produce with items procured from urban markets.

In addition, a sense of collective community was also evident within the villages. This sense of community was often voiced and portrayed vividly through narratives and imagery of food production. For example, when discussing a photograph of the milking of buffalos by local farmers, one participant explained how she sends her children daily for fresh milk in her village:

> *"We know them, they are our village people, Madam. Fresh buffalo milk will be good, pure milk, right? That's why we bring from those people. Packaged milk will not be that good, powder gets mixed into it" (F, 240544, 30 years, Q-GIS).*

Others expressed a broader sense of collective ownership of the local food production of 'good food', which was closely connected to the tangible nature of agricultural practices and notions of 'good health'. One participant explained:

> *"We cultivate with our own hands so the food will be good for us […] if the food is good it will also be good for the children and for us too, our health will be good. Instead of outside food, our own cultivated crop will be good, no?! That's why we eat like that." (F, 240391, 20 years, IDI).*

Similar sentiments of trust and loyalty were also expressed with regard to consumption of ready to eat outside foods. Whilst many participants reported avoiding eating outside foods due to adulteration and contamination concerns, the role of known people and trust was pivotal in shaping decision making on those occasions when outside foods were consumed: *"We mostly don't bring outside food. If we go outside and want to eat anything then we will go to a known place where we always go." (F, 240391, 20 years, IDI).*

Sentiments of trust and loyalty to known vendors were also influential in shaping personal food environment dimensions such as affordability, both in relation to favourably reduced prices, *"they are our known people, so they don't charge the maximum, 2 to 3 Rs less" (M, 240391, 22 years, IDI),* and also the practice of acquiring food on credit. A number of participants explained the importance of interpersonal relationships with known market-based vendors with regard to the practice of acquiring food on credit:

"There are known people and unknown people, but if we go to the shop of a known person we go with trust […] Oh, so many shops are there, but I mostly go to that one because they will give to us on credit. If we don't have money, still they will give to us reasonably. They are known people to me." (M, 030088, 25 years, Q-GIS).

The role of known people was also found to be important with regard to transfers and gifts within the community, and also amongst relatives and friends. One female participant stated: *"today, if we are starving, some lady will send food. It is like that in our village. We support each other." (030445, 46 years, IDI)*. In another example, one male farmer explained how he benefits from the exchange of produce with friends at the local mandal headquarter market:

"We have some known people and if we ask them to give, they will give […] it is a friendship, they will give what they have, and we will give what we have […] we will take for free." (M, 240274, 30 years, IDI).

A small number of participants also discussed the collaborative home gardening of perishable vegetables on empty plots and open spaces during the rainy season, and linked this practice with food transfers and gifts between friends and neighbours.

Box 4: Case study: Buying with trust and confidence from 'known people'.

A sense of community and trust was key in shaping food acquisition practices. One pathway through which this was manifested was via interactions with the personal food environment dimension of desirability. Many participants described their desire, or 'willingness', to acquire and consume foods sourced from their network of trusted 'known people' and friends. These sentiments of desirability were often juxtaposed with their inherent distrust in of 'outside' produce from unknown sources, as is evidenced in the excerpt below:

"I will get from my friend's farms, they will be fresh and suitable. We bring them when we go to the fields. Coriander, mint, tomato, bottle guard, other vegetables, we will eat them willingly, we will eat well, Sir. We will eat willingly from those that are bought from the gardens and plucked by ourselves, rather than those bought outside. We will have at least 5% feeling that this is from outside for those that are bought outside, Sir. Even though it is tasty we will have the feeling that it is from outside, it's a conviction, we won't eat 100 % confidently. When we buy from our friend's fields we will have full confidence about what will be in it, it's like that." (M, 240544, 35 years, Q-GIS).

This case study highlights how sentiments of trust and loyalty interact with desirability to shape food acquisition and consumption practices. In addition, it also reveals the multifaceted nature of desirability, and how intangible socially driven sentiments of trust and confidence mediate individual-level sensory properties such as 'good taste' to determine food acquisition practices.

Perceptions and experiences of change in the food environment and food acquisition practices over the past decade

We identified six key themes related to perceptions and experiences of change in the food environment and food acquisition practices, including external food environment dimensions of: (1) availability, including (a) increasing availability of outside foods, and (b) loss of own production; (2) increasing prices; (3) vendor and product properties, increasing adulteration and contamination; and personal food environment dimensions of: (4) increasing accessibility; (5) convenience, including (a) shifts in cooking fuel, and (b) increased time constraints; and (6) desirability, comprised of (a) perceptions of decreasing tastiness of foods, and (b) shifting preferences (Table 6). These themes were all closely linked with broader processes and conditions related to urban development and agricultural transformation in this transitional peri-urban setting.

Table 6: Key themes related to perceptions and experiences of change in the food environment and food acquisition practices over the past decade.

Themes	*Sub themes (if applicable)*	*Detail*
Availability	Increasing availability of diverse food types	Increasing availability of cooked ready to eat outside foods and recent addition of weekly fruit and vegetable market in Patelguda
	Loss of own production	Loss of own production due to transitions from agricultural livelihoods to other forms of wage labour
Prices	Increasing prices	Increasing prices due to declining local production and transport costs for local vendors to source from urban areas.
Vendor and Product Properties	Increasing adulteration	Point of Production: increasing fertilizer and pesticide use Point of transformation: increasing adulteration
Accessibility	Increasing accessibility	Private modes of transport: increased use of motorbikes Public modes of transport: increased provision of bus services
Convenience	Increasing convenience	Shifts in cooking fuel from wood burning stoves to LPG burning stoves, reduced time constraints associated with cooking Increasing time constraints driving 'outside food' consumption
Desirability	Decreasing tastiness of foods	Due to increased use of chemicals and fertilizers Due to shifts in cooking fuel from wood burning stoves to LPG

Availability

Increasing availability of diverse food types: Participants identified the increase in availability of more diverse kinds of foods. In particular, links were made between the increasing availability of ready to eat outside foods such as fried rice, noodles, and tiffin, and transitioning diets within this setting (Photo 5):

"Everything that we eat has changed. Previously these mirchi, bajjis, fried rice and noodles that we eat were not available. It's only recently we saw all these items." (F, 030088, 20 years, Q-GIS).

"Tiffin is available in front of the shop here, before tiffin used to be sold outside of the village, but now they also came here. They supply the whole village daily between 6am and 8am. We bring on alternate days, whenever we feel like eating it […] previously people from outside the village people used to come roaming on vehicles, and it was only seldom that we used to take. Now they came to the shop, and the children also go there, so we go and bring from there and eat." (M, 030625, 30 years, Q-GIS).

Photo 5: An 'outside food' street vendor preparing chat in Hyderabad.

Credit: Christopher Turner.

Many participants from Patelguda also noted the importance of the recent addition of a weekly fruit and vegetable market in their village, which had served to increase the availability of perishable produce, providing some evidence of the decentralisation of markets from mandal headquarters to smaller villages in this setting (Photo 6). One participant explained:

"At that time [in the past], farmers went to the city to sell their products. But now markets have come up here in the village, and whatever they grow in their fields like

tomatoes and brinjal, they are selling here in the weekly market." (F, 030236, 30 years, IDI).

Photo 6: A weekly fruit and vegetable market in an APCAPS village.

Loss of own production: Others revealed how transitioning livelihood strategies, the sale of agricultural land, and more urban ways of life were driving increasing reliance on market-based foods as "*those who cultivate have become less, and those who eat have become more" (M, 240274, 30 years, IDI).* One participant explained:

> *"We used to do farming and food was available for us. We used to cultivate our own vegetables, and we ate them all. Now we don't have farming so we have to bring food from outside, we have to eat outside things." (M, 240679, 25 years, IDI).*

Prices

There was overwhelming consensus amongst participants regarding food price increases with almost all participants raising this as a key change within their food environment over the past decade:

"Price has increased for all, wherever we go the prices have increased. Whatever we want to buy, if we want to buy rice, if we want to buy vegetables, if we want to buy jowar, the prices have increased a lot when comparing then and now." (M, 240274, 30 years, IDI).

"10 years back, the prices were less. Now the prices have increased for everything, for vegetables, rice, pulses, everything." (F, 030062, 27 years, Q-GIS).

Many participants perceived increasing prices within their villages to be linked with the decline in local production. One participant gave the example of local rice production, and explained how agricultural hardship and declining production has impacted upon market prices and the subsequent acquisition and consumption of rice from market-based sources:

"Then there were a lot of paddy farms and the cost was low, now there is no water, there are no paddy farms, there is no harvest, so the cost is high… so...most people do not take [from market-based vendors]." (F, 240233, 19 years, Q-GIS).

Others perceived increasing prices in villages to be due to local vendors having to source foods from urban areas as a result of declining local production, with the costs of transportation subsequently being passed on to consumers. One participant explained:

"Then the fields and farms were more, now they aren't there. All these [business] ventures have developed and hence people are not cultivating properly. The rates have increased, but we can't say anything […] they say they are not getting items here so they have to bring from the city […] now they bring from the market [in the city] to the shops [in the village]! If the rate is 5rs there, they take 1 to 2rs more here." (M, 030625, 30 years, Q-GIS).

Increasing prices was a cause for anxiety amongst some participants. One participant expressed her frustrations:

"Then the price was less but now it is very high. If we feel like buying anything now we are put off when looking at the price. We are afraid looking at the price, we are a poor

family […] to buy eatables, fruits, vegetables, the price is so high". (F, 030088, 20 years, Q-GIS).

Vendor and product properties

Increasing adulteration: Overall, resounding evidence suggests that participants perceived the adulteration of foods to have increased over the past decade with negative implications for dietary health. Participants voiced negative perceptions about the declining quality and safety of foods, and identified health risks associated with what they considered to be the adulteration of foods during production and transformation:

> *"People have changed, everything has changed… then food was good, now it is not so… We are getting adulterated goods. Rice is adulterated… Everything is adulterated! […] They are mixing rubber into the rice it seems and the rice is becoming soft! We are eating these foods… our health is not well." (F, 030625, 25 years, Q-GIS).*

> *"We used to use manure and spend time cultivating, now we are growing paddy quickly using chemicals and drugs to produce more yield, but it won't be that nutritious, it has become like ready-made rice sir, in the past it used to have some shelf life and be a little healthy, it was good for health sir. […] They are even injecting medicines into chickens. In the past one chicken used to grow in 3 or 4 months, now it's 45 days! Because of that the energy is reduced, sir. At that time, even if we ate a little we were healthy, but now we are not able to be healthy." (M, 240544, 35 years, Q-GIS).*

Accessibility

Whilst only a small number of households (n=8; 40%) in this study owned their own form of motorised transport in the form of a 'two-wheeler' motorbike, many participants described increased levels of accessibility over the past decade associated with the ever more common use of personalised motorised transport within this peri-urban community. The increased usage, if not ownership of motorbikes, was found to have changed food acquisition practices

by enabling the weekly purchase and transportation of food items in bulk from further afield. One participant explained:

> *"We bring enough for one week. We tie to the vehicle and bring. Then we used to have to tie to the bicycle, and we used to get very little, but now we are able to bring 20 kilos." (M, 030431, 35 years, Q-GIS).*

Motorbikes were considered particularly important amongst those travelling to and from urban areas for work due to the ability stop quickly for foods by the roadside as part of their daily commute:

> *"90% it has become motorbike only, Sir […] My work is in the city, if I have time in the morning I will take on the way and keep, if I have time in the evening I'll take it then." (M, 240544, 35 years, Q-GIS).*

In addition, the presence of mobile vendors, such as those selling tiffin from motorbikes was considered to have increased among a number of participants, whilst distributors from urban areas were reported to deliver non-perishable items such as snacks and sweets to vendors in the villages (Photo 7). Others referred to the importance of public transport to their daily mobility in this peri-urban setting, noting the increased levels of accessibility in recent years since the outer ring road of Hyderabad city had been built. Auto rickshaws and bus services were commonly forms of public transport associated with food acquisition from outside the local villages.

Photo 7: The delivery of non-perishable foods to local shops via motorbike in an APCAPS village.

Credit: Christopher Turner.

Convenience

Shifts in cooking fuel: Participants consistently identified increasing levels of convenience in recent years associated with the shift from traditional wood or biomass fired cooking techniques (Photo 8) to kerosene and liquid petroleum gas burning stoves and electrical appliances. Participants described increases in their quality of life associated with faster cooking times and reduced levels of stress, hard labour, and pollution:

> *"Then we were cooking on a wooden stove, and now there is gas we are using a gas stove […] then we had to bring the firewood, but now it is good […] the cooking is quick." (F, 240284, 25 years, Q-GIS).*

> *"10 or 15 years back we had to bring firewood and light the stove, now we can put the rice on the cooker and press the button and the rice is prepared […] in those days there was lot of strain to cook the curry and rice, but now it's no sweat." (M, 240391, 22 years, IDI).*

This increase in convenience was also viewed by some participants in light of increasing time constraints related to work demands:

> *"There is lot of change. In those days, we used wood and biomass with great difficulty, now it is easy […] now we have a happy life. Since LPG has come we are able to cook quickly and run for work." (M, 240635, 45 years, Q-GIS).*

In addition, participants revealed how shifts to LPG fuel had shaped their food preparation and consumption practices. Whereas in the past it was common practice to cook one larger batch of food to consume over several meals, participants stated that they were now able to prepare for each meal due to reduced cooking times and increased convenience offered by the use of LPG, *"now we are making everything in little, little, portions each day, so we are making it fast." (F, 240391, 20 years, IDI)*.

Photo 8: A traditional wood burning stove in an APCAPS village.

Credit: Christopher Turner.

Increasing time constraints: Time constraints were often linked with fitting food into the daily routine. One female participant explained how she faced time constraints related to food preparation for the other household members: *"Daily they will go to work. The cooking should be done quickly so they can take the box and go." (240253, 32 years, Q-GIS).* Increasing time

constraints were considered by some participants, particularly men, to be a driver of food and beverage consumption outside the home, linked with more urban ways of life and forms of employment. For example, one male Q-GIS participant, a lorry driver, described a picture of a tea shop which he had photographed and explained how he regularly consumes tea outside the home in the early morning before work:

> *"That is a tea shop, madam. I go there daily in the morning to drink tea and go [to work]. It is near the place where I keep my lorry, Madam. I'll stop the lorry there, drink tea, and go. I don't drink at home, I will not have time. I will go early in the morning, 4 or 5am, like that. He's the one who opens first in the village." (M, 030088, 25 years, Q-GIS).*

Another participant, a carpenter, explained how his food acquisition practices had changed over the past decade in line with his busy work schedule:

> *"We used to eat rice and roti at home and take lunch to work. Now, we eat whatever is available outside, chilli bajji, biryani, fried rice. […] it's about time, we are not able to spend time, if an urgent phone call comes we will immediately have to go. We might eat if we see a place to eat beside the road, or we might not eat at all. We cannot take food with us all the time." (M, 240417, 26 years, IDI).*

Desirability

Decreasing tastiness of foods: Many participants described how they considered the taste of foods to have decreased in recent years, primarily due to the increasing use of fertilizers and changes in cooking fuel and preparation techniques. One participant contrasted the improvements in agricultural production associated with fertilizer use with perceived reductions in taste:

> *"Without fertilizers, the vegetables which we grew were tastier, even if they grow well and look neat with the chemicals and fertilizers, however much we eat they won't taste like that." (M, 240635, 45 years, Q-GIS).*

Many participants discussed how the transition from traditional wood burning stoves (Photo 8) to gas burning stoves and induction stoves over the past decade were considered to have reduced the tastiness of foods prepared at home:

> *"In those days, we had a three-stone fire to cook and the taste was absolutely different. Now we have to cook on a gas stove or an induction stove… the taste is not at all good." (F, 030236, 30 years, IDI).*

> *"The taste was better before when we used to cook on biomass, now since the gas came people stopped using wooden fuel. We only use wooden fuel if the gas runs out but the taste of the food we eat is different. When we cook on gas the taste is not good." (F, 240391, 20 years, IDI).*

> *"On the traditional stove, it had quality, it had good taste too. Now it won't be that tasty because of the LPG." (M, 240417, 26 years, IDI).*

Intra-household dynamics

Three primary themes were identified in relation to intra-household dynamics driving food acquisition practices: (1) gendered dynamics of food acquisition; (2) drivers of children's food acquisition and consumption; and (3) perceptions of diets, nutrition and health (Table 7).

Table 7: Key themes related to intra-household dynamics.

Themes	*Sub themes (if applicable)*	*Detail*
Gendered dynamics of food acquisition	Gendered food acquisition roles	Women typically responsible for the acquisition of vegetables and groceries Men acquire ready to eat outside foods and animal source foods such as meat
	Gendered activity spaces	Men typically have larger activity spaces as part of daily life, and are typically exposed to food environments in the village, mandal headquarter, and city Women typically have smaller activity spaces as part of daily life, with many predominantly exposed to the village food environment: constraints include income generating activities in and around village, domestic work, childcare duties
Drivers of children's acquisition and consumption	Desirability	Ready to eat outside foods, snack foods and instant foods Influence of peers
	Availability and accessibility	Small local shops in and around the home and school food environments Sending children to nearby shop unsupervised
	Childcare practices	Snacks as a mechanism for pacification Convenience: work related time constraints of parents resulting in acquisition of ready to eat outside foods for children
	Parental ideals	Perception of fruits as 'foods for the children'
Perceptions and knowledge of diets, nutrition and health	Low levels of knowledge about diets, nutrition and health	Peer to peer learning about diets, nutrition and health Awareness of diet related health Anxieties related to food safety and adulteration Children's diets, nutrition and health: 'good foods'

Gendered dynamics of food acquisition

Gendered dynamics related to food acquisition and preparation were found to be complex and multidimensional. We identified distinct gender-based food acquisition roles within the majority of households, with women typically responsible for the acquisition of vegetables and groceries, whilst in contrast, men were commonly found to acquire a broader range of food items, and were in particular responsible for the acquisition of ready to eat outside foods and animal source food items such as meat. One female participant explained the gendered acquisition patterns of 'outside foods' within her household:

> *"We [referring to the women of the household] don't go much, we don't know much there, they [referring to her husband and father in law] go all the time so they know, we don't know, we don't know much." (F, 240417, 26 years, IDI).*

Gendered dynamics of food acquisition were also reinforced in relation to activity spaces by a number of participants, exemplified in the following excerpts:

"We will not make my mother go outside, they don't know, they don't go, we are there, why should they go when we can go?" (M, 240417, 26 years, IDI)

"My wife can't go alone, no, Sir […] autos will be there, busses will be there, but because it is a little far, I only will go, for anything I only will go and bring." (M, 240679, 25, IDI).

"My two sons and my husband, they go to the city everyday with work, they have to go, they don't stay in the village. If I need anything I call my son and he will bring." (F, 030445, 46 years, IDI).

Triangulated analysis of the maps, photographs and transcripts further supports the notion of gendered activity spaces in relation to food acquisition. Amongst the Q-GIS participants, eight of the eleven (73%) men took photographs of the food environment outside their village, compared to only three of the eleven women (27%). Comparing photographs of the food environment at the intra-household level, there were five instances where only the male participant photographed outside of the village, three where both the male and female participant photographed outside the village, and a further three where neither participant photographed outside the village. One female participant described how she didn't take photographs from outside her home as she didn't leave the house during the data collection period:

"I felt if I could go out and take photos it would have been good. But because I didn't go out, I didn't take [photographs]. If I go outside I will know, no?" (F, 030062, 27 years, Q-GIS).

Men generally tended to travel further afield for work as part of their daily activities, and experienced a broader range of food environments and more diverse types of food vendors as part of daily life, particularly those travelling to the city. Whilst more than half (*n*=9; 56%) of the women for which data was available were engaged in income generating activities, including unskilled manual labour (*n*=6), and semi-skilled manual labour (*n*=3), many women's activity spaces were contained within the village and nearby areas. Seven women (44%) were engaged in domestic housework duties, and some reported visiting their village just once in

2-3 months. Domestic work and childcare duties were perceived by to be primary constraints to food acquisition amongst many women, for example:

> *"I have 5 children, getting them ready for school, and me going to shop was not possible, whatever he brought I used to cook and serve that's all. Why? Because going around and bringing, chatting here for some time, there for some time, it won't be possible with children." (F, 030445, 46 years, IDI).*

> *"My husband should go. If he is not available then I will go […] I have work at home with the kids. He will bring foods from outside […] I'm not going outside too much." (F, 240274, 25 years, IDI).*

However, there was also some evidence to suggest that gender norms may be changing with regard to women's activity spaces, as one female participant explained:

> *"Before we were not able to go out. Now we are going out, going here and there, we are knowing everything. In those days, we used to be at home and we didn't know anything about outside things. Now it has changed." (F, 240391, 20 years, IDI).*

Drivers of children's food acquisition and consumption

Drivers of children's food acquisition and children's diets were a key concern amongst many participants, particularly women, and were found to be multifaceted.

Desirability: Many female Q-GIS participants photographed children eating foods, especially snacks in and around the home. Participants perceived snacks, fast foods and instant foods to be highly desirable and commonly consumed amongst children and younger generations, despite recognition of their unhealthy properties:

> *"Nobody in our house likes fast foods […] people say that food is not good, you know, Maggi noodles, oily foods, we know this so we don't eat them. When the children are there they will eat them, so we'll make them." (F, 030062, 27 years, Q-GIS).*

Children's preferences and desires were in some cases found to shape the foods consumed in the household. One father explained how he purchases ready to eat outside foods to appease his children: *"If the children say daddy the rice is not good then I will bring 2 packets of Biriyani." (M, 030088, 25 years, Q-GIS).*

The influence of peers among children and adolescents was also found to be important in shaping the desirability of foods. One mother acted out a typical scenario, playing the role of her child: *"Mother make this, make that, everyone is doing these foods, will you not do them mother?" (F, 240242, 36 years, Q-GIS).*

Availability and accessibility: Dimensions of availability and accessibility were also found to be important to children's food acquisition and consumption. Sending children to the local village shops unsupervised was found to be a common daily practice (Photo 9). One female participant explained how children were sent on daily food acquisition errands to nearby shops, incentivised by the opportunity to buy chocolates: *"We will send them daily for vegetables. Every day they go to by something in that shop. After taking vegetables they will buy chocolates with the remaining money, like 2 to 3 rupees." (F, 240284, 25 years, Q-GIS).*

Photo 9: Children buying snacks from a local shop in an APCAPS village.

Credit: Christopher Turner.

Participants also expressed their concerns about children's exposure to food vendors when travelling unsupervised to and from school, and also within the school food environment (Box 5). One participant explained, *"Anywhere at school, the shops are placed next to the school, is it not? They will eat chocolates at school." (F, 030088, 20 years, Q-GIS).* Another mother, employed as a cook at a local school, described her struggles to prevent her children from consuming unhealthy snacks and sweets at school, and referred to a photograph she had taken of a child holding a small sweet cake in the palm of his hand:

> *"Here they are eating daily, that's why I took the photo […] They only decide! [referring to the children]. Their parents will not be there, they are at home. They take money from the house and eat here [referring to the photograph], they will not know, Sir. We tell the children at home, I have to say many times they are not good, like that. They do not hear and they do not care!" (F, 240635, 38 years, Q-GIS).*

Childcare practices: We found evidence of children pestering mothers for fast foods, snacks and sweets at home. Some mothers discussed how they reluctantly used these food items as mechanisms for pacification when faced with time constraints: *"Children ask, they want this or that, chocolates, crisps, cake. They will cry, so we go and bring as there is no time." (F, 240391, 20 years, IDI).* Others revealed how convenience shaped their decision making about what to feed their children, particularly in relation to work-related time constraints and the purchase of ready to eat outside foods for children. For example, one father explained how long working hours limited time for childcare and food preparation, resulting in the purchase of tiffin from mobile vendors in the village to feed the children during the busy morning routine before school:

> *"Time, we will not get time! We will be at work by 9am. We don't have time to take care of the children. So, in the morning it will be tiffin. After giving them a shower, we give them tiffin to eat and send them [to school]. At night, it will be 8 or 9pm when we come home." (M, 240679, 25 years, Q-GIS).*

Parental ideals: Although participant's narratives around children's diets typically focused on concerns related to the daily acquisition and consumption of foods considered to be unhealthy, one contrasting narrative that consistently emerged was the characterization of

fruits as foods for children. Whilst fruits were reportedly not readily available in the villages and were seldom discussed by participants in relation to their own consumption, when probed, many participants described purchasing fruits such as bananas from mandal headquarters as they were considered to be 'good for the children'.

Box 5: Case study: The school food environment

The school food environment was a focal point in relation to children's food acquisition and consumption. This case study focuses on a father's experiences of sending his children to school with money to purchase snacks, and his concerns regarding the types of foods being consumed when travelling to and from school. The excerpt below reveals his anxieties about unsupervised acquisition and consumption of foods amongst schoolchildren:

> *"…in the morning when they go they ask me for 2 rupees to buy biscuits, like that. How can I see what kind of things they are buying and eating? I see only giving money, but what they eat we can't see, no?! I cannot go with them to school. They come home on the 5pm bus, that's why I'm asking what kind of food are you eating? Don't eat this type of food, like that we will say […] buy good ones and eat good items like biscuits…" (M, 030431, 35 years, Q-GIS).*

He went on to explain how schoolchildren are warned about food safety through the 'fear of food', and how he restricts the amount of money given to his children to limit their daily purchases and curb their acquisition and consumption of 'bad foods':

> *"When the school starts we have to warn the children about fear of food. These bad foods, that one and this one will be there …flies are there, the children will eat […] we have the responsibility, so if they ask 4 rupees, I will give 2 rupees. If I give 4 rupees, they will buy some other thing. It will not be good, I'm thinking that only." (M, 030431, 35 years, Q-GIS).*

The notion of 'good food' in this case study is primarily framed from a food safety perspective in relation to adulteration and contamination and the dietary health and wellbeing of children: *"food without adulteration, food which is good for health, even it is food in a shop, then our children will flourish well." (M, 030431, 35 years, Q-GIS).* There was little evidence of awareness about the nutritional content of foods consumed by children, and the characterization of biscuits as 'good foods' for children is a particular cause for concern.

Perceptions and knowledge of diets, nutrition and health

Knowledge of diets, nutrition and health: On the whole, most participants displayed limited knowledge about diets, nutrition, and health; although dietary related health was a prominent concern within the community. Participants described how they predominantly learned about diets, nutrition and health by word of mouth from peers and experiences in the family (Box 6). Many participants drew binary distinctions between 'good' and 'bad' foods. No participants referred to dietary guidelines as drivers of food acquisition and consumption.

Despite limited knowledge about diets and nutrition, awareness of diet related health was reflected in participant's desires to improve their diets with a view to mitigating against ill-health:

> *"About food, now blood pressure, diabetes, gastric problems, and stones are coming, why are they coming? What mistakes are we doing? Minimum 99% of what we are eating is good we are thinking. But we are getting many problems. Why are we getting these problems? […] We want to know how much we should eat." (M, 240417, 26 years, IDI).*

In relation to children's diets, nutrition and health, many participants emphasized the need for children to eat 'good foods': *"We should eat good food, we should give our children good food, like that we think." (M, 240679, 25 years, IDI).* A few participants also vocalized their critiques regarding the sale of unhealthy foods to children:

> *"Children are eating things that do not seem to be good. These are things that we eat [referring to adults], but if we eat them nothing will happen. Items for older people should not be put to children […] eating such snack foods is not good for the health of the child, and I do not like it." (F, 240635, 38 years, Q-GIS).*

Finally, we found tentative evidence from one participant to suggest the desirability of overweight amongst children, with one participant stating this to be one of several driving factors in the acquisition and consumption of snacks and sweets:

> *'Small cakes, they are not costly […] the children will ask for them because they are good. The neighbour's children will eat them and they will ask us to bring them. The vitamins will be good, children will grow fat, they will have glamour, that's why we bring.' (M, 030088, 25 years, Q-GIS).*

Box 6: Case study: Peer to peer learning about food hygiene.

Knowledge of diets, nutrition and health was typically found to be acquired through peer to peer learning. In this case study, one participant explained how he had sought advice about food hygiene from educated people near his workplace:

> *"P: I don't have an education. I work near offices, near educated people, Sir. They will give guidance. […] In the beginning, we did not know about washing and eating, Sir. I mean vegetables should be washed as soon as they are bought, each and every item that is bought from outside should be washed, we should wash well and then they should be kept in a mesh and kept in refrigerator. All of this I came to know from those who are educated, my officers, from them only, Sir.*
>
> *I: Is it the only way that you know this, or are there any other ways that you will know?*
>
> *P: It's mostly through telling […] 'eat healthy food and carefully take good food', like that, they will give guidance to us, our Sirs" (M, 240544, AGE, Q-GIS).*

This case study demonstrates an example of peer to peer learning in this setting, and supports the need for population level nutrition education within the community to improve dietary, nutrition and health related knowledge.

Discussion

This study draws from in-depth interviews and an innovative Q-GIS approach to investigate drivers of food acquisition in peri-urban Hyderabad, as well as perceptions and experiences of change in the food environment and food acquisition practices over the past decade, and intra-household dynamics in relation to food acquisition, preparation, and consumption practices. Drivers of food acquisition this transitional peri-urban setting were diverse, multifaceted and complex, and included: 1) food prices and affordability; 2) vendor and product properties; including freshness and quality, and adulteration and contamination; and 3) a sense of community and trust. Key nodes of food acquisition included peri-urban villages, nearby mandal headquarters, and the city of Hyderabad, supporting the importance of studying food environments beyond the local residential neighbourhood (53, 57-60).

The emphasis placed on food prices and affordability as a key driver of food acquisition practices by many of the participants in our study supports evidence from multiple settings across India (19, 23, 24), including one study of women across wealth tertiles in Delhi (23). Tak et al. (61) note that whilst household expenditure on food at the national level in India has declined from over 60% in 1993-1994; the proportion of household budgets spent on food still remains high, at around approximately 50% among rural households and 40% among urban households in 2011-2012. Authors such as Pingali et al. (2) have also highlighted food price inflation over the past decade as one of the most pressing challenges for food policy in India.

The majority of households (n=14; 70%) in our study were eligible for subsidized food rations through the means tested Public Distribution System set at the Below Poverty Line, and low purchasing power may explain the importance allocated to food prices as a driver of food acquisition. Studies from HIC settings have shown that price takes precedence over proximity when making decisions about where to source foods (62, 63). Price was one of a number of key dimensions driving food acquisition from mandal headquarters rather than the local villages in our study, lending some support to these findings from HIC settings.

Perceptions of freshness and quality were also key drivers of food acquisition in our study. The preference for fresh produce from the farm gates of known local producers highlights the

prevailing strong connection to agriculture within this peri-urban setting, and supports the notion of agriculture as a key pathway to nutrition in India (33, 64), despite broader narratives of change regarding the loss of agricultural land to the built environment and shifts from agricultural labour to more urban ways of life.

Food safety in the form of adulteration and contamination was found to be a pervasive driver of food acquisition practices, with concerns at the points of production, transformation, distribution. Narratives focused on perishable produce and ready to eat outside foods from market-based sources in a similar manor to findings from other studies, both in India (19-21, 23, 30, 65), and also other LMIC settings (66-74).

Sentiments of community and trust were embedded throughout participants accounts of food acquisition, and were found to be closely connected with dimensions of affordability and the practice of favourable pricing and acquiring food on credit, as well as food safety discourse, freshness and quality, and food transfers. This theme is a novel contribution to the food environment literature, adding weight to continued calls over the past decade regarding the need to account for social interactions (58, 75), and the social and cultural dynamics between people and their food environment, food acquisition, and consumption practices (53).

In addition to the primary drivers of food acquisition noted above, we also identified a series of wider trends related to the transitioning food environment and food acquisition and consumption practices over the past decade. These trends broadly supported narratives of change related to the increasing availability of diverse foods (22, 23, 30), and increasing food prices in India (2, 61). Other trends included perceptions of increasing convenience linked with shifts in cooking fuel, although benefits were juxtaposed against narratives of the decreased tastiness of foods, which was also perceived, at least in part, to be related to increasing use of adulteration at the points of food production and transformation.

At the intra-household scale, we identified a number of key themes, including gendered dynamics of food acquisition and preparation; children's influence on food acquisition and consumption; and perceptions of diets, nutrition and health. The disproportionate burden and time constraints that women face when negotiating multiple roles as income generators,

homemakers, primary caregivers, and cooks within households supports findings from recent studies from various settings across India, where women were found to be responsible for balancing the culinary needs and expectations of household members within their available means (23, 24, 76).

Drivers of children's food acquisition and consumption highlight the inter-generational dynamics at play within households, aligning with findings from studies in India (20, 21, 23, 24, 76), and other LMICs such as Ethiopia (66) and Ghana (67, 77). In addition, consistent narratives surrounding the daily acquisition and consumption of sweets, snacks, biscuits and chocolates by children from local village shops and school settings in our study supports mounting evidence regarding the ready availability and high desirability of these generally unhealthy items amongst children and adolescents in India (17, 20-22) and other LMICs (78-85).

Narratives of dietary health were embedded within anxieties related to food safety and adulteration, as has was found by (86) in Myanmar. Whilst dietary health was a primary concern from a food safety perspective, nutrition literacy, including knowledge of what constitutes a healthy, nutritious and quality diet as well as the consequences of unhealthy diets was generally limited, consistent with previous studies from other LMICs (66, 71, 86-88).

We identify a number of tentative policy implications on the basis of our findings, whilst fully acknowledging the small scale of this qualitative study and the need for further evidence. First, evidence from our study confirms the need for food environment policies and interventions that are socio-ecological in scope in order to address the multi-scalar drivers of food acquisition and consumption, including the external and personal food environment domains and dimensions. On the basis of our findings, external food environment-based policies and interventions should seek to target improvements in the freshness and quality of fruits and vegetables at affordable prices in peri-urban villages, as well as restrict the sale of unhealthy snacks, sweets and sweet and sugary beverages, particularly to children and adolescents, from local stores and vendors in and around schools. A recent cross-sectional assessment of the external neighbourhood food environment across the 29 APCAPS sites broadly echoes these recommendations (89). At the population level, efforts targeting improvements in nutrition literacy across generations are needed in this community, in order

to: 1) improve knowledge and understanding of the importance of dietary quality for health across the lifespan, 2) emphasise the need for increased consumption of fruits and animal source foods as part of a balanced diet; and 3) highlight the need to moderate the consumption of ultra-processed, unhealthy snacks, sweets and sweet and sugary beverages - as has been identified in previous studies in India (17). Targeting children and adolescents through dietary, nutrition and health related promotion activities in Indian schools has previously been recommended by Jose et al. (90), and may provide an effective entry point to foster improvements in food acquisition and consumption behaviours in current and future generations and tackle the double burden of malnutrition.

We also identify a number of research recommendations. First, this qualitative study is among the first to apply and sensitize the novel concepts, food environment domains, and dimensions from the food environment conceptual framework by Turner et al. (12) (Figure 1) in an LMIC setting. On the whole, participants engaged critically with the food environment dimensions outlined in the conceptual framework, indicating conceptual generalizability as defined by Green and Thorogood (35), however more research is required to sensitize the conceptual framework across a range of settings in India and other LMICs, including diverse rural, peri-urban, and urban settings.

Evidence from our study suggests future conceptual and empirical food environment research may consider allocating more emphasis to food safety as a key external food environment dimension driving of food acquisition and consumption practices. Another opportunity might be to integrate the concept of social capital as a key food environment dimension in the personal food environment domain, in order to more adequately capture shared ties, norms and trust (91) related to food acquisition, as well as dynamics of reciprocity and exchange (92), and the interactions between what Coleman (93) refers to as the 'social structures between entities' (i.e. food vendors and consumers) and the 'actions of actors' (i.e. food acquisition and consumption practices). A number of pioneering food security studies have applied a social capital lens in LMICs and may provide impetus here (94, 95).

Finally, our multi method qualitative approach facilitated a comprehensive investigation into perceptions and experiences of the food environment and drivers of food acquisition at the community, intra-household, and individual levels in a peri-urban setting in Telangana, India.

Applying a temporal perspective facilitated the investigation of broader trends taking place in this transitional setting, demonstrating the utility of retrospective qualitative approaches as a means of moving beyond the reporting of contemporary practices to explore participants' narratives, memories and lived experiences of change in order to understand trajectories and turning points of dietary and nutrition related behaviours (33, 34). Further in-depth qualitative research is needed to investigate food environments and drivers of food acquisition across a range of LMIC settings, including rural, peri-urban, and urban settings to provide in-depth contextualised knowledge and understanding of drivers of food acquisition and consumption.

Strengths and limitations

The strengths of this study include: 1) the implementation, sensitization, and qualitative validation of the globally applicable food environment conceptual framework; 2) the multi-method approach, including participatory methods, facilitating an in-depth investigation into drivers of food acquisition practices from an emic perspective as part of daily life; 3) the use of a local field team with extensive knowledge and experience of the research setting; 4) the presence of the lead author for much of the primary data collection, providing first-hand knowledge and experience of the field setting and critical insights for the subsequent analysis of the qualitative data; 5) the triangulation of multiple data sources, including transcripts, maps, and photographs; 6) the use of deductive and inductive analysis techniques; 7) the use of secondary datasets, including the BE survey and corroboration with findings from FGDs on fruits and vegetables undertaken in 8 APCAPS villages; 8) the use of private in-depth interviews facilitating the investigation of gendered intra-household dynamics; 9) the use of graphic and photo-elicitation techniques to stimulate narratives about drivers of food acquisition from an emic perspective; 10) the adherence to qualitative checklists and reporting guidelines.

We identify a number of limitations. First, due to ethical considerations and the highly sensitive nature of the geocoded data it was not possible to include the Q-GIS maps and photographs. However, we have included indicative photographs from the APCAPS taken by the lead author and field team to aid the reader and give a deeper impression of the research

setting. Second, we found that men were more open to discussing their thoughts and opinions in this setting. Nine of the sixteen female participants in our study were illiterate, whilst a further three were literate but had low educational attainment which may have limited their ability to comprehend abstract concepts such as the food environment, and may have also restricted their ability to hold in-depth discussions around this concept. It is also possible that the presence of the lead author, a non-Indian male researcher may have influenced participant's responses during the qualitative data collection, however, no apparent differences were observed within the data from interviews where the lead author did or did not attend. Third, socio-demographic data was not available for four female participants as they had married into the households following the completion of the 2012-2014 APCAPS household survey. Fourth, primary data collection was conducted in only two villages. However, findings related to fruits and vegetables were corroborated and supported by focus group data from a further eight villages. In addition, whilst the finer grained particularities of our findings have direct implications within the APCAPS setting, the interrogation of my research findings in relation to the globally applicable food environment conceptual framework provides a degree of generalizability and transferability to wider food environment and public health nutrition research in LMICs. I also argue that the sites in which this research is situated can be considered to be typical of many rapidly urbanizing settings in India, as well as transitioning settings in other LMICs.

Conclusions

This qualitative study contributes to the emerging body of research investigating food environments and drivers of food acquisition in India. Participant's narratives collectively represent the emic perspectives and lived experiences of external and personal food environment domains, as well as complex and multifaceted drivers of food acquisition in peri-urban Hyderabad, Telangana. Findings broadly support previous studies from India and other LMICs regarding the importance of food prices and vendor and product properties such as freshness and quality, and adulteration and contamination. The strong emphasis on food safety in the form of adulteration and contamination concerns suggest the need to more adequately account for these aspects within conceptual and empirical food environment research going forward. In addition, evidence of a sense of community and trust addresses

an understudied dimension within the existing literature, and emphasises the role of social contracts and interactions with known people in food acquisition and consumption. Narratives of change related to shifting dimensions of availability, prices, adulteration and contamination, accessibility, convenience, and desirability were linked with broader processes and conditions related to urban development and agricultural production in this transitional peri-urban setting. At the intra-household scale, key themes such as gendered dynamics of food acquisition and preparation, drivers of children's food acquisition and consumption; and perceptions of diets, nutrition and health support findings from India and other LMICs. Findings from this study increase our knowledge and understanding of socio-ecological drivers of food acquisition and consumption in this peri-urban community in Telangana, India, and may inform the design of context-relevant socio-ecologically informed interventions to improve the food environment, diets, nutrition, and health in this setting.

Acknowledgements

We would like to thank our field team coordinator, Santhi Bhogadi, and our field team members Amaravathi Mora, Niharika Muddepaka, Prasad Undrajavarapu, Sailaja M, Sandeep Kumar Gyara, Subhash Masapeta, Dr Srivalli Addanki and Srinivas Goud Avuladas for their knowledge, expertise, and tireless work ethic throughout data collection, transcription and translation. We would also like to thank Sofia Kalamatianou for her contributions, including setting up the NVivo server, discussing the coding framework, and conducting preliminary coding.

5.5.References: Publication 4

1. High Level Panel of Experts on Food Security and Nutrition. Nutrition and food systems. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security. Rome: 2017.

2. Pingali P, Aiyar A, Abraham M, Rahman A. Diet Diversity and the Declining Importance of Staple Grains. Transforming Food Systems for a Rising India. Cham: Springer International Publishing; 2019. p. 73-91.

3. Satterthwaite D, McGranahan G, Tacoli C. Urbanization and its implications for food and farming. Philosophical Transactions of the Royal Society B-Biological Sciences. 2010;365(1554):2809-20.

4. Popkin BM. Nutrition Transition and the Global Diabetes Epidemic. Current Diabetes Reports. 2015;15(9):64.

5. Popkin BM, Adair LS, Ng SW. Global nutrition transition and the pandemic of obesity in developing countries. Nutr Rev. 2012;70(1):3-21.

6. World Health Organization – WHO. The double burden of malnutrition: Policy brief. Geneva: 2017.

7. Global Panel on Agriculture and Food Systems for Nutrition – Global Panel. Improving nutrition through enhanced food environments. Policy Brief London, UK: Global Panel on Agriculture and Food Systems for Nutrition, 2017.

8. United Nations System Standing Committee on Nutrition – UNSCN. Food environments: Where people meet the food system. 2019.

9. Food and Agriculture Organisation of the United Nations – FAO. Influencing food environments for healthy diets. Rome: 2016.

10. Swinburn B, Sacks G, Vandevijvere S, Kumanyika S, Lobstein T, Neal B, Barquera S, Friel S, Hawkes C, Kelly B, et al. INFORMAS (International Network for Food and Obesity/non-communicable diseases Research, Monitoring and Action Support): overview and key principles. Obesity Reviews. 2013;14:1-12.

11. Brug J, Kremers SP, van Lenthe F, Ball K, Crawford D. Environmental determinants of healthy eating: in need of theory and evidence. Proceedings of the Nutrition Society. 2008;67(3):307-16.

12. Turner C, Aggarwal A, Walls H, Herforth A, Drewnowski A, Coates J, Kalamatianou S, S. K. Concepts and critical perspectives for food environment research: A global framework with implications for action in low- and middle-income countries. Global Food Security. 2018;18:93-101.

13. Travert AS, Sidney Annerstedt K, Daivadanam M. Built Environment and Health Behaviors: Deconstructing the Black Box of Interactions-A Review of Reviews. Int J Environ Res Public Health. 2019;16(8).

14. Sobal J, Bisogni CA. Constructing Food Choice Decisions. Annals of Behavioral Medicine. 2009;38:S37-S46.

15. Furst T, Connors M, Bisogni CA, Sobal J, Falk LW. Food choice: A conceptual model of the process. Appetite. 1996;26(3):247-65.

16. Turner C, Kalamatianou S, Drewnowski A, Kulkarni B, Kinra S, Kadiyala S. Food Environment Research in Low- and Middle-Income Countries: A Systematic Scoping Review. Adv Nutr. 2019.

17. Gupta V, Downs SM, Ghosh-Jerath S, Lock K, Singh A. Unhealthy Fat in Street and Snack Foods in Low-Socioeconomic Settings in India: A Case Study of the Food Environments of Rural Villages and an Urban Slum. J Nutr Educ Behav. 2016;48(4):269-79 e1.

18. Patel O, Shahulhameed S, Shivashankar R, Tayyab M, Rahman A, Prabhakaran D, Tandon N, Jaacks LM. Association between full service and fast food restaurant density, dietary intake and overweight/obesity among adults in Delhi, India. Bmc Public Health. 2017;18.

19. Finzer LE, Ajay VS, Ali MK, Shivashankar R, Goenka S, Sharma P, Pillai DS, Khandelwal S, Tandon N, Reddy KS, et al. Fruit and Vegetable Purchasing Patterns and Preferences in South Delhi. Ecology of Food and Nutrition. 2013;52(1):1-20.

20. Rathi N, Riddell L, Worsley A. What influences urban Indian secondary school students' food consumption? - A qualitative study. Appetite. 2016;105:790-7.

21. Rathi N, Riddell L, Worsley A. Food environment and policies in private schools in Kolkata, India. Health Promotion International. 2017;32(2):340-50.

22. Maxfield A, Patil S, Cunningham SA. Globalization and Food Prestige among Indian Adolescents. Ecology of Food and Nutrition. 2016;55(4):341-64.

23. Bailey C, Garg V, Kapoor D, Wasser H, Prabhakaran D, Jaacks LM. Food Choice Drivers in the Context of the Nutrition Transition in Delhi, India. Journal of Nutrition Education and Behavior. 2018;50(7):675-86.

24. Daivadanam M, Wahlstrom R, Thankappan KR, Ravindran TK. Balancing expectations amidst limitations: the dynamics of food decision-making in rural Kerala. BMC Public Health. 2015;15:644.

25. Ravishankar AK. Is India shouldering a double burden of malnutrition? Journal of Health Management. 2012;14(3).

26. Shetty P. Public health: India's diabetes time bomb. Nature. 2012;485(7398):S14-6.

27. Institute for Health Metrics and Evaluation - IHME. India profile Seattle, WA: IHME, University of Washington; 2018 [cited 2019 30/08/19]. Available from: http://www.healthdata.org/India.

28. Institute for Health Metrics and Evaluation - IHME. Global Burden of Disease Database 2019 [cited 2019 30/08/19]. Available from: http://ghdx.healthdata.org/gbd-results-tool?params=gbd-api-2017-permalink/5da9be71c21eb5c160fe86ffe1938e54.

29. Kinra S, Radha Krishna KV, Kuper H, Rameshwar Sarma KV, Prabhakaran P, Gupta V, Walia GK, Bhogadi S, Kulkarni B, Kumar A, et al. Cohort profile: Andhra Pradesh Children and Parents Study (APCAPS). Int J Epidemiol. 2014;43(5):1417-24.

30. Hayter AK, Jeffery R, Sharma C, Prost A, Kinra S. Community perceptions of health and chronic disease in South Indian rural transitional communities: a qualitative study. Glob Health Action. 2015;8:25946.

31. Rao M, Prasad S, Adshead F, Tissera H. The built environment and health. Lancet. 2007;370(9593):1111-3.

32. Devine CM. A life course perspective: Understanding food choices in time, social location, and history. Journal of Nutrition Education and Behavior. 2005;37(3):121-8.

33. Gillespie S, van der Bold M. Agriculture, Food Systems, and Nutrition: Meeting the Challenge. Global Challenges. 2017;1(3).

34. Nisbett N, van den Bold M, Gillespie S, Menon P, Davis P, Roopnaraine T, Kampman H, Kohli N, Singh A, Warren A, et al. Community-level perceptions of drivers of change in nutrition: Evidence from South Asia and sub-Saharan Africa. Global Food Security-Agriculture Policy Economics and Environment. 2017;13:74-82.

35. Green J, Thorogood N. Qualitative Methods for Health Research. 3rd Edition ed: Sage Publications Ltd; 2013.

36. Chandler C, Reynolds J, Palmer J, Hutchinson E. ACT Consortium Guidance: Qualitative Methods for International Health Intervention Research. London: London School of Hygiene and Tropical Medicine, 2013.

37. Haaland A, Molyneux S, Marsh V, Mutemi W. Quality information in field research: Training manual on practical communication skills for field researchers and project personnel. Wellcome-KEMRI Research Programme and WHO/TDR: UNICEF, UNDP, World Bank, WHO, 2006.

38. Kwan MP, Ding GX. Geo-Narrative: Extending Geographic Information Systems for Narrative Analysis in Qualitative and Mixed-Method Research. Professional Geographer. 2008;60(4):443-65.

39. Kwan MP, Knigge L. Doing qualitative research using GIS: an oxymoronic endeavor? Environment and Planning A. 2006;38(11):1999-2002.

40. Milton S, Pliakas T, Hawkesworth S, Nanchahal K, Grundy C, Amuzu A, Casas JP, Lock K. A qualitative geographical information systems approach to explore how older people over 70 years interact with and define their neighbourhood environment. Health and Place. 2015;36:127-33.

41. Corbett J, Rambaldi G. 'Representing our Reality': Geographic Information Technologies, Local Knowledge and Change. In: Cope M, Elwood S, editors. Qualitative GIS: Mixed Methods in Practice and Theory: Sage Books; 2009. p. 75.

42. Coleman T. Photo elicitation as method: a participatory approach. In: Fenton N, Baxter J, editors. Practicing Qualitaitve Methods in Health Geographies. Geography of Health. 1 ed. New York, NY.: Routledge; 2016. p. 266.

43. Collier J. Photography in Anthropology: a report on two experiments. American Anthropologist. 1957;59:843-59.

44. Collier J. Visual Anthropology's Contributions to the Field of Anthropology. Visual Anthropology. 1987;1(1):37-46.

45. Copeland AJ, Agosto DE. Diagrams and Relational Maps: The Use of Graphic Elicitation Techniques with Interviewing for Data Collection, Analysis, and Display. International Journal of Qualitative Methods. 2012;11(5):513-33.

46. Harper D. Talking about pictures: a case for photo elicitation. Visual Studies. 2002;17(1).

47. Rose G. Visual Methodologies: An Introduction to the Interpretation of Visual Materials. 2nd Edition ed: Sage; 2007.

48. Wang C, Burris MA. Photovoice: Concept, methodology, and use for participatory needs assessment. Health Education & Behavior. 1997;24(3):369-87.

49. Wang CC. Photovoice: a participatory action research strategy applied to women's health. J Womens Health. 1999;8(2):185-92.

50. Birgante E. The use of photo-elicitation in field research: Exploring Maasai representations and use of natural resources. EchoGeo. 2010;11.

51. Gotschi E, Delve R, Freyer B. Participatory Photography as a Qualitative Approach to Obtain Insights into Farmer Groups. Field Methods. 2009;21(3):290-308.

52. Dennis SF, Gaulocher S, Carpiano RM, Brown D. Participatory photo mapping (PPM): Exploring an integrated method for health and place research with young people. Health & Place. 2009;15(2):466-73.

53. Chen X, Kwan MP. Contextual Uncertainties, Human Mobility, and Perceived Food Environment: The Uncertain Geographic Context Problem in Food Access Research. Am J Public Health. 2015;105(9):1734-7.

54. O'Brien BC, Harris IB, Beckman TJ, Reed DA, Cook DA. Standards for reporting qualitative research: a synthesis of recommendations. Acad Med. 2014;89(9):1245-51.

55. Critical Appraisal Skills Programme. Qualitative studies checklist https://casp-uk.net: 13 April; 2018. Available from: https://casp-uk.net/wp-content/uploads/2018/01/CASP-Qualitative-Checklist.pdf

56. Ministry of Electronics and Information Technology. Below Poverty Line Certificate: Government of India; 2016 [updated 13/09/19; cited 2019 20/07/19]. Available from: https://digitalindia.gov.in/content/below-poverty-line-certificate.

57. Caspi CE, Sorensen G, Subramanian SV, Kawachi I. The local food environment and diet: A systematic review. Health & Place. 2012;18(5):1172-87.

58. Cummins S. Commentary: Investigating neighbourhood effects on health - Avoiding the 'local trap'. International Journal of Epidemiology. 2007;36(2):355-7.

59. Kwan MP. The Limits of the Neighborhood Effect: Contextual Uncertainties in Geographic, Environmental Health, and Social Science Research. Annals of the American Association of Geographers. 2018;108(6):1482-90.

60. Lucan S. Concerning limitations of food-environment research: a narrative review and commentary framed around obesity and diet-related diseases in youth. Journal of the Academy of Nutrition and Dietetics. 2015;115(2):205-12.

61. Tak M, Shankar B, Kadiyala S. Dietary Transition in India: Temporal and Regional Trends, 1993 to 2012. Food and Nutrition Bulletin. 2019;40(2):254-70.

62. Drewnowski A, Aggarwal A, Hurvitz PM, Monsivais P, Moudon AV. Obesity and supermarket access: proximity or price? Am J Public Health. 2012;102(8):e74-80.

63. Aggarwal A, Cook AJ, Jiao JF, Seguin RA, Moudon AV, Hurvitz PM, Drewnowski A. Access to Supermarkets and Fruit and Vegetable Consumption. American Journal of Public Health. 2014;104(5):917-23.

64. Kadiyala S, Harris J, Headey D, Yosef S, Gillespie S. Agriculture and nutrition in India: mapping evidence to pathways. Paths of Convergence for Agriculture, Health, and Wealth. 2014;1331:43-56.

65. Umali-Deininger D, Sur M. Food safety in a globalizing world: opportunities and challenges for India. Agricultural Economics. 2007;37:135-47.

66. Berhane HY, Ekstrom EC, Jirstrom M, Berhane Y, Turner C, Alsanius BW, Trenholm J. What Influences Urban Mothers' Decisions on What to Feed Their Children Aged Under FiveThe Case of Addis Ababa, Ethiopia. Nutrients. 2018;10(9).

67. Holdsworth M. Dietary transitions in Ghanaian cities: Leveraging evidence for policy and intervention to prevent diet-related non-communicable diseases. University of Ghana,

African Population and Health Research Center, The University of Sheffield, Loughborough University, University of Liverpool, Cirad, 2019.

68. Holdsworth M, Zotor F, Pradeilles R, Griffiths P, Green M, Mensah K, Akparibo R, Barnes A, Bricas N, Laar A. Dietary transitions in Ghanaian cities: using innovative methods to map the social and physical food environments that drive consumption of unhealthy foods and beverages, to identify contextually appropriate policies and interventions: the DFC dietary transitions in Ghana study. 3rd Agriculture, Nutrition and Health (ANH) Academy Week; 25-29th June, 2019; Accra, Ghana: Agriculture, Nutrition and Health Academy; 2018.

69. Omari R, Frempong G. Food safety concerns of fast food consumers in urban Ghana. Appetite. 2016;98:49-54.

70. Pradeilles R, Laar A, Zotor F, Tandoh A, Klomegah S, Osei-Kwasi H, Bohr M, Green M, Bricas N, Holdsworth M, et al. Social and Physical Drivers of Food Choice: A participatory Photovoice Project in two Ghanaian Cities: a DFC Dietary Transitions in Ghana Study. 3rd Agriculture, Nutrition and Health (ANH) Academy Week; 24-28th June, 2018; Accra, Ghana: Agriculture, Nutrition and Health Academy; 2018.

71. Pradeilles R, Laar A, Zotor F, Tandoh A, Klomegah S, Osei-Kwasi H, Bohr M, Green M, Bricas N, Holdsworth M, et al. Social and Physical Drivers of Food Choice: A participatory Photovoice Project in two Ghanaian Cities: a DFC Dietary Transitions in Ghana Study. Sixth BSA Sociology of Food Study Group Conference: Food Systems and Society - Re-imagining Food Systems, Sustainability, Futures and the Everyday; 24-25th June 2019; Monash University, Prato, Italy: BSA Publications Ltd; 2019.

72. Wertheim-Heck SCO, Spaargaren G. Shifting configurations of shopping practices and food safety dynamics in Hanoi, Vietnam: a historical analysis. Agriculture and Human Values. 2016;33(3):655-71.

73. Wertheim-Heck SCO, Spaargaren G, Vellema S. Food safety in everyday life: Shopping for vegetables in a rural city in Vietnam. Journal of Rural Studies. 2014;35:37-48.

74. Wertheim-Heck SCO, Vellema S, Spaargaren G. Food safety and urban food markets in Vietnam: The need for flexible and customized retail modernization policies. Food Policy. 2015;54:95-106.

75. Cummins S. Neighbourhood food environment and diet:Time for improved conceptual models? Preventive Medicine. 2007;44(3):196-7.

76. Chaturvedi S, Ramji S, Arora NK, Rewal S, Dasgupta R, Deshmukh V, Grp IS. Time-constrained mother and expanding market: emerging model of under-nutrition in India. Bmc Public Health. 2016;16.

77. Holdsworth M, Pradeilles R, Zotor F, Green G, Tandoh A, Klomegah S, Osei-Kwasi H, Bricas N, Griffiths P. How unhealthy food and beverages are embedded in everyday life in Ghanaian cities. Sixth BSA Sociology of Food Study Group Conference: Food Systems and

Society - Re-imagining Food Systems, Sustainability, Futures and the Everyday; 24-25th June 2019; Monash University, Prato, Italy: BSA Publications Ltd; 2019.

78. Chacon V, Letona P, Villamor E, Barnoya J. Snack food advertising in stores around public schools in Guatemala. Critical Public Health. 2015;25(3):291-8.

79. Chan Sun M, Lalsing Y, Subratty AH. Primary school food environment in Mauritius. Nutrition and Food Science. 2009;39(3):251-9.

80. Faber M, Laurie S, Maduna M, Magudulela T, Muehlhoff E. Is the school food environment conducive to healthy eating in poorly resourced South African schools? Public Health Nutrition. 2014;17(6):1214-23.

81. Moodley G, Christofides N, Norris SA, Achia T, Hofman KJ. Obesogenic Environments: Access to and Advertising of Sugar-Sweetened Beverages in Soweto, South Africa, 2013. Preventing Chronic Disease. 2015;12.

82. Pehlke EL, Letona P, Hurley K, Gittelsohn J. Guatemalan school food environment: impact on schoolchildren's risk of both undernutrition and overweight/obesity. Health Promotion International. 2016;31(3):542-50.

83. Pehlke EL, Letona P, Ramirez-Zea M, Gittelsohn J. Healthy casetas: A potential strategy to improve the food environment in low-income schools to reduce obesity in children in Guatemala City. Ecology of Food and Nutrition. 2016;55(3):324-38.

84. Soltero EG, Ortiz Hernandez L, Jauregui E, Levesque L, Taylor JLY, Barquera S, Lee RE. Characterization of the School Neighborhood Food Environment in Three Mexican Cities. Ecology of Food and Nutrition. 2017;56(2):139-51.

85. Wojcicki JM, Elwan D. Primary school nutrition and tuck shops in Hhoho, Swaziland. The Journal of Child Nutrition and Management. 2014;38(1).

86. Downs SM, Glass S, Linn KK, Fanzo J. The interface between consumers and their food environment in Myanmar: an exploratory mixed-methods study. Public Health Nutrition. 2019;22(6):1075-88.

87. Kimoto R, Ronquillo D, Caamaño MC, Martinez G, Schubert L, Rosado JL, Garcia O, Long KZ. Food, eating and body image in the lives of low socioeconomic status rural Mexican women living in Queretaro State, Mexico. Health and Place. 2013;25:34-42.

88. Gissing SC, Pradeilles R, Osei-Kwasi HA, Cohen E, Holdsworth M. Drivers of dietary behaviours in women living in urban Africa: a systematic mapping review. Public Health Nutrition. 2017;20(12):2104-13.

89. Li Y, Mallinson P, Bhan N, Turner C, Bhogadi S, Sharma C, Aggarwal A, Kulkarni B, Kinra S. Neighborhood physical food environment and cardiovascular risk factors in India: Cross sectional evidence from APCAPS. Environment International. 2019;132.

90. Jose AP, Shridhar K, Prabhakaran D. Diet, Nutrition and Cardiovascular Disease: The Role of Social Determinants. Proceedings of the Indian National Science Academy. 2018;84(4):945-53.

91. Putnam R. The Prosperous Community. The American Prospect. 1993;4(13).

92. Adger WN. Social capital, collective action, and adaptation to climate change. Economic Geography. 2003;79(4):387-404.

93. Coleman JS. Social Capital in the Creation of Human-Capital. American Journal of Sociology. 1988;94:S95-S120.

94. Misselhorn A. Is a focus on social capital useful in considering food security interventions? Insights from KwaZulu-Natal. Development Southern Africa. 2009;26(2):189-208.

95. Lee GO, Surkan PJ, Zelner J, Olortegui MP, Yori PP, Ambikapathi R, Caulfield LE, Gilman RH, Kosek MN. Social connectedness is associated with food security among peri-urban Peruvian Amazonian communities. Ssm-Population Health. 2018;4:254-62.

5.6.Summary of Appendix 3: Publication 4

Supplemental Material for this publication is included in Appendix 3 (Chapter 8), including:

- Supplemental Material 1: Topic guides - Q-GIS approach (for IDI see Appendix 2, Supplemental Material 1).
- Supplemental Material 2: Ethical approval - Observational Ethics Committee, London School of Hygiene and Tropical Medicine (see Appendix 2, Supplemental Material 2).
- Supplemental Material 3: Ethical approval - Institutional Ethics Committee of the Indian Institute of Public Health under the banner of the Public Health Foundation India (see Appendix 2, Supplemental Material 3).
- Supplemental Material 4: CARE forms - Participant information sheets, consent forms (for IDI see Appendix 2, Supplemental Material 4).
- Supplemental Material 5: Participant flow chart Q-GIS and IDI households by village.

5.7.Contribution of publication 4 to the thesis

This publication addresses the empirical-based research gap, and addresses the fourth aim of my research, namely: to investigate the food environment and drivers of food acquisition practices in a peri-urban Indian setting, to understand perceptions and experiences of change in the food environment and food acquisition practices over the past decade, and to explore intra-household dynamics in relation to food acquisition, preparation and consumption practices. This publication constitutes the main body of empirical findings from my qualitative primary data collection investigating the food environment and drivers of food acquisition in peri-urban Hyderabad, Telangana. Findings from this publication are used to inform the revised version of the globally applicable food environment conceptual framework presented in the discussion section of the thesis.

6. Discussion

Throughout this thesis I have sought to address four key research gaps that collectively span the research process. Most broadly, my contributions to the wider literature include: critical theoretical perspectives and a globally applicable conceptual framework (Publication 1); a systematic synthesis of existing food environment literature from LMICs (Publication 2); the development, implementation, and appraisal of an emerging qualitative methodological approach (Publication 3); and empirical findings regarding the food environment and multi-scalar drivers of food acquisition and consumption from an under-researched peri-urban context in Telangana, India (Publication 4).

Reflecting critically on my positionality as a researcher, I consider my interpretivist epistemological approach to have been informed by my disciplinary background in social science, and in particular human geography. My research developed throughout the PhD in an iterative process, as is common in the social sciences. I consider this iterative process to be a key strength of my research, as it allowed me to identify and address key gaps as they emerged and thereby make novel contributions to the existing literature on food environments - particularly with regard to the recognized need to revisit theoretical perspectives and align key concepts with methods and empirical data collection. Disciplinary perspectives from human geography and my personal prior conceptions led to the implementation of socio-ecological perspectives. Human geographers are typically interested in the ways that people interact with space and place, and how power relations shape these interactions in different ways for different people. Geographical perspectives are embedded within my focus on interactions between people and their food environment across multiple spatial and temporal scales. This is reflected in the articulation of the external and personal food environment domains and dimensions within the conceptual framework, and the implementation of participatory visual methods seeking to understand perceptions and experiences of food environments garnered through daily life. In addition, the triangulation of multiple methods and data sources is also typical of geographical research, and is a technique that I utilized in the Q-GIS approach.

Reflecting on the role of my previous research background, I consider my experiences of mapping urban agriculture in sub-Saharan Africa to have informed my broadened

conceptualization of the food environment that includes both market and non-market-based sources of food. I also consider my prior experience to have influenced the approach that I took in my systematic scoping review, as my limited training in quantitative analysis and statistics posed a challenge when assessing the risk of bias among the analytical subset of articles. To address this challenge, I enlisted the expertise of colleagues with the skills required to conduct the assessment and noted their vital contributions in the acknowledgements section of the article.

As an individual, I was critically aware of my positionality as a white, non-Indian, young male researcher in peri-urban Hyderabad, and the potential for my presence during fieldwork to introduce bias or influence participant's responses. I sought to balance the need to gain first-hand knowledge and experience of the research setting with any potential risk of bias. As I identified in chapter 4, I sought to mitigate the potential risk of bias by training a team of local researchers with extensive fieldwork experience in this setting garnered through their prior research activities in the Andhra Pradesh Children and Parents Study. I drew from their intricate and tacit knowledge, expertise and understanding of both the local language and research setting throughout the entire research process in order to minimise any potential bias that I might otherwise have introduced as a young white male outsider. My primary involvement in data collection took place during the initial field team training and piloting sessions, which focused on cornerstones of high-quality qualitative research including one to one interview skills, as well as specialist techniques related to participatory research and photo- and graphic-elicitation techniques. In particular, I placed strong emphasis on the importance of voicing the emic narratives, perceptions and lived experiences of the participants through the multi-method qualitative approach. My role during field visits was to observe the interviews and supervise data collection. Despite my concerted efforts to mitigate against the potential for bias it is important to note the possibility that some degree of bias may still persist.

In the sections that follow, I continue to apply an iterative approach by elaborating on the contributions of each publication to the wider literature, before interrogating my empirical findings in relation to theoretical concepts in order to sensitise and refine the conceptual

framework and outline prospects for the continued development of food environment research in LMICs.

6.1. Contribution to the wider literature: Publication 1

Publication 1 presents critical theoretical perspectives and concepts for food environment research. This publication and the concepts presented are globally applicable, with relevance for conceptual and empirical food environment research in both HICs and LMICs. The conceptual framework offers a structured socio-ecological approach that may be used to guide food environment research across a range of diverse settings. It also provides a platform from which tailored interventions and policies can target contextually relevant food environment dimensions to facilitate pathways that lead to improved diets, nutrition and health. The global scope of the framework also creates a common theoretical and conceptual grounding that may be used to design comparative studies between HICs and LMICs.

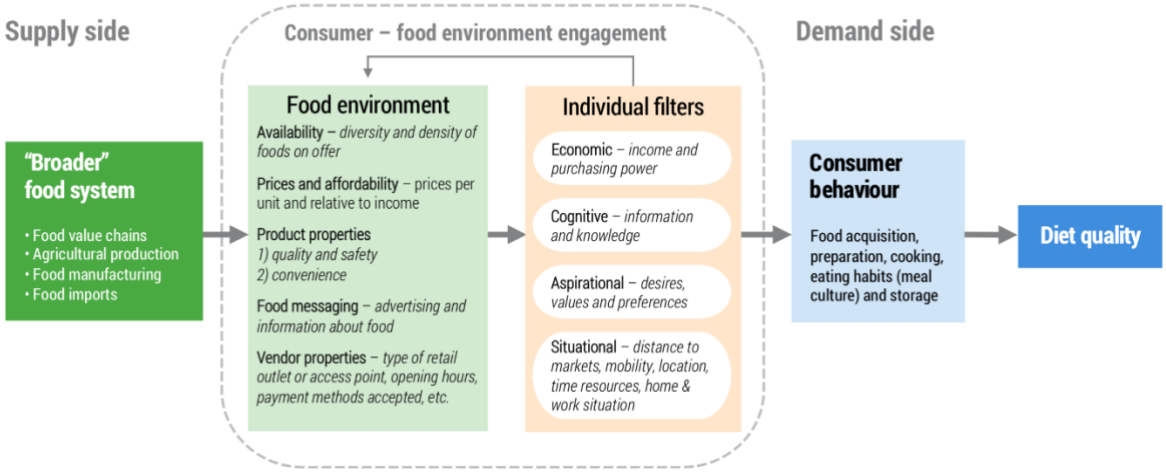
Concepts from Publication 1, including the food environment definition and conceptual framework, have gained considerable traction within the wider literature (1-8). For example, the contribution of the conceptual framework is noted in the editorial introduction of the United Nations Standing Committee on Nutrition flagship publication titled 'Food Environments: Where People Meet the Food System':

> *"More recently, Turner et al. (2018) proposed a new conceptual framework that more clearly defines the external and personal domains of food environments. The external domain includes dimensions such as availability, prices, vendor and product properties, and marketing and promotion, while the personal domain includes the dimensions highlighted by Herforth and Ahmed. All of these concepts, especially the Turner et al. framework, have been widely cited by authors throughout this publication." (3: p.3).*

More specifically, eight articles from the publication (3) utilise the conceptual perspectives related to the external and personal food environment domains (9-14), whilst others cite (15) and adapt (16) the conceptual framework. The adapted version of the conceptual framework by Marshall (17) (Figure 1) integrates concepts from the conceptual framework with contributions from the High Level Panel of Experts on Food Security and Nutrition (2017). The

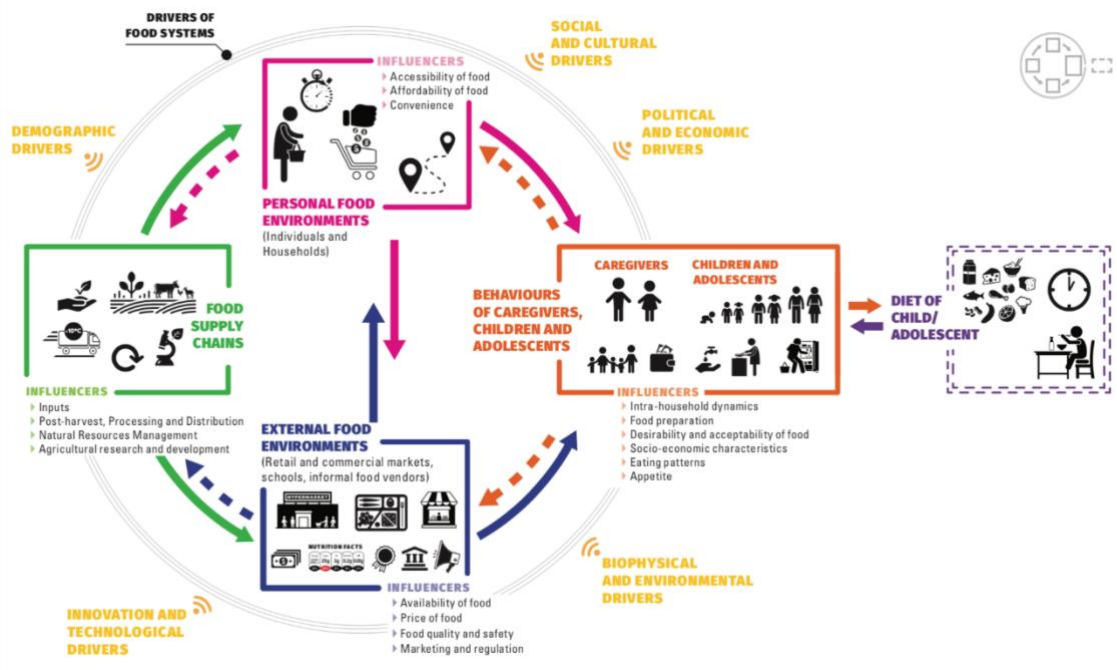
adapted framework features a supply and demand lens, as well as individual filters in place of the personal domain. In addition, at the distal end of the framework, Marshall builds on food acquisition and consumption to include broader dynamics of consumer behaviour, such as food preparation, cooking, eating habits and storage, and also focuses on diet quality as the primary outcome in place of nutrition and health outcomes.

Figure 1: Food environment framework Marshall (17).



Another example of the uptake of the concepts from Publication 1 is the UNICEF framework on food systems for children and adolescents (2), which incorporates the external and personal food environment domains and dimensions (Figure 2). The UNICEF framework links the external and personal food environment domains with additional components, including the influence of food supply chains and behaviours of caregivers, children and adolescents, which collectively interact to shape diets of children and adolescents. The external domain here refers to market-based sources of food and the school environment, whilst the personal domain is framed at the household and individual level. This framework also includes a range of wider food system drivers, such as demographic, social and cultural, political and economic, biophysical and environmental, and innovation and technological drivers.

Figure 2: The UNICEF framework on food systems for children and adolescents (2).



A further example of the wider application of the concepts from Publication 1 is the conceptual model by Travert et al. (1), which depicts interactions between the built environment, individuals and their physical activity and dietary behaviours (Figure 3). This adaptation integrates the socio-ecologically framed external and personal domains from the food environment framework with the Capability, Opportunity, Motivation and Behaviour model developed by Michie et al. (18). This model aims to "understand key interaction mechanisms so that the relationship between behaviours and the built environment can be analysed in different contexts." (1: p.1455).

Figure 3: A conceptual model depicting the interactions between the built environment, individuals, and their behaviours (1).

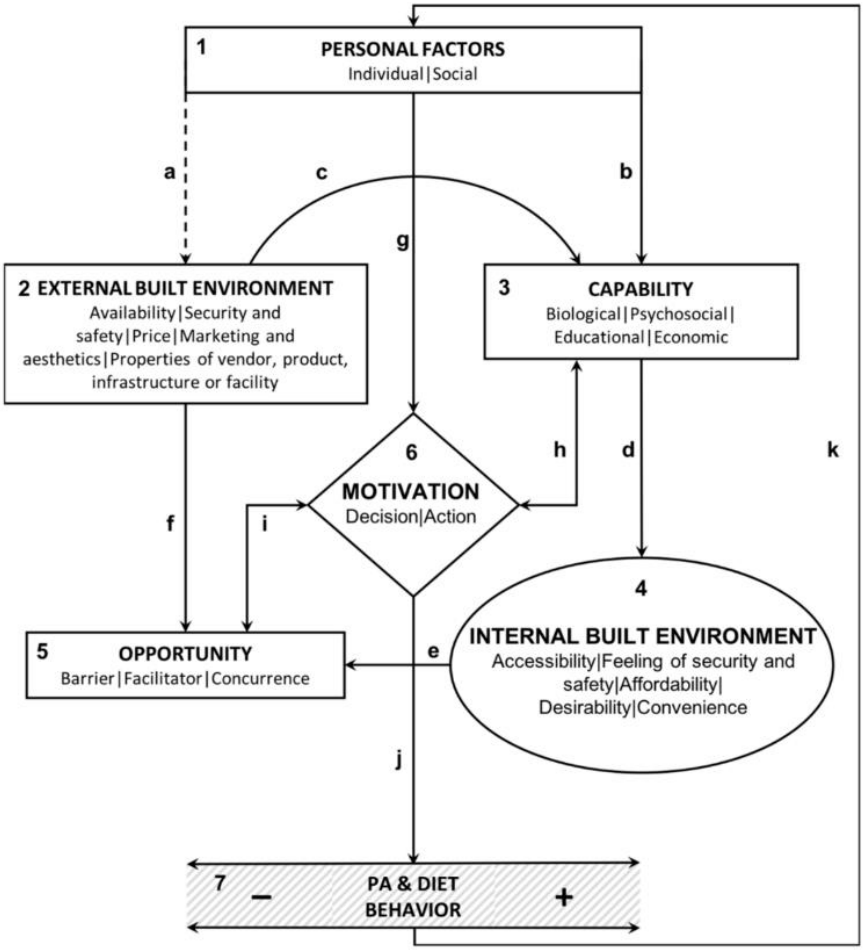


Figure 3. Conceptual model depicting the interactions between the built environment, individuals and their behaviors.

The selection of examples above outline the uptake and subsequent adaptation of the food environment conceptual framework within the wider literature, outlining the relevance, applicability and adaptability of this socio-ecological approach within the field of public health research.

6.2.Contribution to the wider literature: Publication 2

Publication 2 is the first systematic review article to focus explicitly on food environment research from LMICs, providing an important contribution to the wider literature. Systematic scoping reviews have been identified as a particularly useful approach when synthesizing

knowledge from a diverse body of literature that has yet to be reviewed (19, 20). The synthesis of seventy articles spanning 22 LMICs has wide ranging relevance to the broader literature due to the inclusive scope of the review design, featuring comprehensive search terminology and broad eligibility criteria, permitting quantitative, qualitative, and mixed methods studies at national, community, school, and household levels; as well as dietary, nutrition and health outcomes. Findings from Publication 2 complement and support evidence from review articles in HICs with regard to the paucity of evidence from high-quality analytical studies testing for associations between food environment exposures and dietary, nutrition, and health outcomes; and the subsequent need to improve theoretical concepts, study designs, methods, and metrics (21-25). Key contributions that may guide future food environment research include the identification of a limited number of food environment publications from low and low- and middle-income countries, particularly in sub-Saharan Africa, as well as the established lack of attention to undernutrition within the current literature from LMICs. In addition, this comprehensive systematic scoping review of the literature from LMICs paves the way for further targeted systematic reviews that may provide more fine-grained detailed analysis of the evidence of effectiveness of interventions at specific scales, such as national, community, school, and household food environments, and for specific dietary, nutrition, and health outcomes.

Finally, the results from this systematic scoping review were presented at the UNICEF Innocenti 'Food Systems for Children and Adolescents' meeting in November 2018, informing discussion around food environments for adolescent nutrition and guiding the formulation of the forthcoming 'State of the World's Children' report due for publication in October 2019.

6.3.Contribution to the wider literature: Publication 3

Publication 3 presents the development, implementation and appraisal of a novel Q-GIS approach within the context of the published food environment literature to date. The manuscript is intended to be submitted to a qualitative methods journal to provide in-depth knowledge and experiences garnered throughout the research process to guide future studies.

Since the initial conception of the novel Q-GIS approach in 2016 a small but emerging body of research utilising visual methods to investigate food environments and drivers of food acquisition in LMICs has been developing, as was noted in publication 3. For example, a food environment project featuring photovoice was presented by Holdsworth et al. (26) and Pradeilles et al. (27) at the Agriculture, Nutrition and Health Academy Week in Accra, Ghana in 2018, and the British Sociological Association Food Study Group Conference in 2019 (28). This project featured participants from socio-economically deprived neighbourhoods in two Ghanaian cities, Accra (*n*=64) and Ho (*n*=32). Holdsworth et al. used a socio-ecological approach to investigate factors in the social and physical food environments that drive the consumption of energy-dense nutrient-poor foods and beverages (29). Photovoice was conducted in combination with the collection of 24-hour dietary recall data (*n*=192) and GIS mapping and analysis of the availability and advertisement of foods and beverages. Preliminary findings from this study demonstrated the ability of visual methods such as photovoice to create a platform from which communities may reveal unique context relevant insights into drivers of food and beverage acquisition and consumption. Similarly, Pradeilles et al. utilised photovoice to investigate the role of social and physical environments shaping food choices in the same settings in Ghana. The majority of participants' photographs and subsequent discussion were found to relate to the neighbourhood food environment, capturing food availability, opening times, accessibility and affordability, food on display and appearance, advertising, and hygiene standards and practices of food vendors and personnel (27, 28).

Another example includes a pilot photovoice project presented by Trübswasser (30) at the Agriculture, Nutrition and Health Academy Week research conference in Hyderabad, India, 2019. This project sought to investigate perceptions of the food environment among public school adolescents 15-19 years of age (*n*=16) in Addis Ababa, Ethiopia. Photovoice was conducted in combination with 24hr dietary recall, anthropometry, and an objective survey of the food availability and advertising using adapted protocols from the International Network for Food and Obesity/non-communicable diseases Research, Monitoring and Action Support (INFORMAS) group (31), and photography of vendor shopfronts. Preliminary results found photovoice to be a particularly useful approach to obtain deeper understanding of

perceived and objective aspects of the food environment amongst adolescents in Addis Ababa.

Results from Publication 3 complement these studies and will contribute to the emerging body of research using visual methods to investigate food environments and drivers of food acquisition in LMICs. In particular, Publication 3 provides novel insights regarding the strengths and limitations of geospatially referenced visual methods that may be used to inform the future development and refinement of the participatory Q-GIS approach.

6.4.Contribution to wider literature: Publication 4

Publication 4 contributes contextualised knowledge and understanding of the food environment and drivers of food acquisition and consumption in a transitional peri-urban setting in Telangana, India. Key drivers of food acquisition practices included: 1) prices and affordability; 2) vendor and product properties – including freshness and quality, and adulteration and contamination; and, 3) as a sense of community and trust. These findings contribute to the emerging literature from LMICs highlighting the importance of both environmental and individual-level drivers of food acquisition and consumption (28, 29, 32-35). For example, evidence presented by Holdsworth (35) and Pradeilles et al. (28) from the 'Dietary transitions in Ghanaian cities' project highlights the importance of both environmental and social factors influencing dietary behaviours. Environmental drivers included food prices and food safety related to food adulteration, hygiene, and sanitation, whilst social drivers included the role of family members among women, and the importance of peer influence among men.

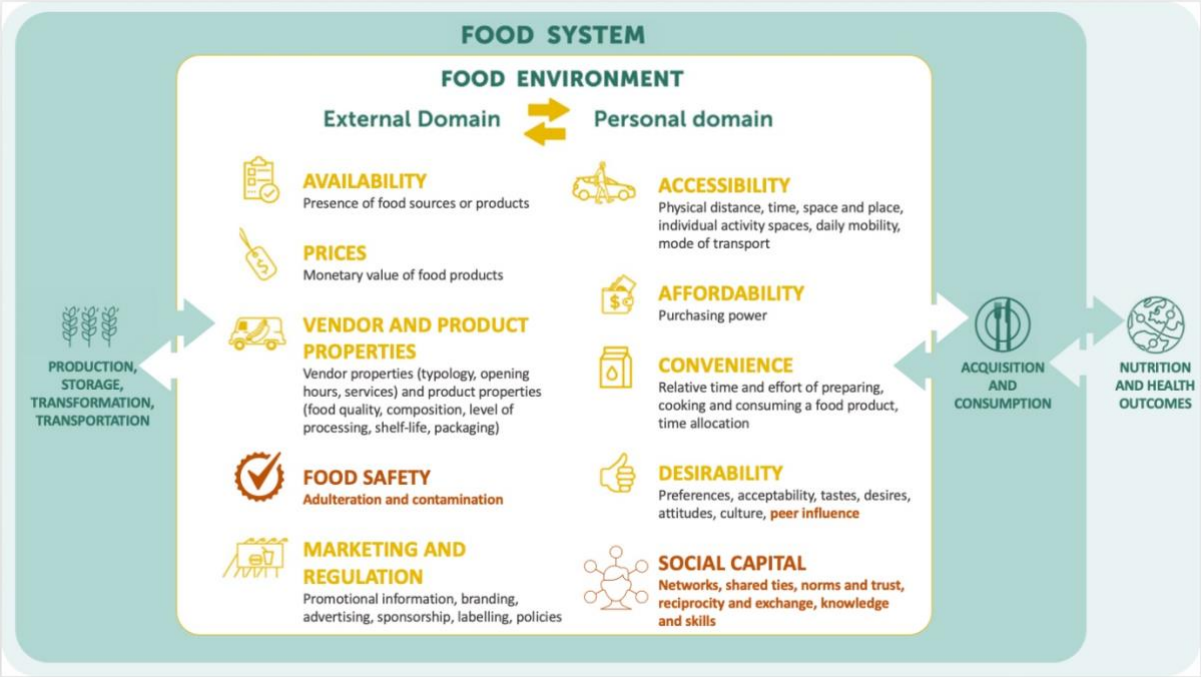
Whilst the finer grained particularities of our findings have direct implications for the APCAPS sites and similar contexts in India, the qualitative validation and sensitization of key food environment concepts and dimensions from the conceptual framework provide a degree of what Green and Thorogood (36) refer to as generalizability and transferability to wider food environment and public health nutrition research in LMICs. The parallels between the findings from Publication 4 and the wider literature from other LMIC settings lends further support regarding the wider relevance of the findings presented.

6.5. Prospects for the continued refinement of food environment research

Going forward, there is a need for theoretical and empirical food environment research to continue to address socio-ecological drivers of food acquisition and consumption. As is noted in Publication 1, calls within food environment research have recognised the need to complement external environmental influences of diets with personal level dimensions (25), whilst obesity driven research has called for the need supplement individual-level strategies with wider structural environmental interventions (37). That these respective research agendas both recommend integrated approaches that account for both individual and environmental drivers of food acquisition affirm the utility of socio-ecological theory, and support the notion of the need for a new research paradigm within food environment research that is more sensitive to environmental and individual level determinants of food acquisition and consumption. The conceptual framework presented in Publication 1 provides a point of departure here by delineating the external and personal domains and dimensions.

Findings from my systematic scoping review (Publication 2) and my primary data collection presented (Publication 4) also support the need to account for socio-ecological drivers of food acquisition and consumption. Around half of the studies included in my systematic review featured both external and personal food environment dimensions, although one-third of these focused exclusively on availability in combination with accessibility, the two most common dimensions from each respective domain. This indicates that whilst external and personal domains have been addressed, there is scope for significantly broader consideration of other personal level dimensions that may be shaping food acquisition and consumption practices in LMICs. This is also supported by findings from my primary data in Publication 4. Based on these findings, as well as feedback from several oral presentations and also consultations with leading food environment experts, I present a number of suggested revisions to the food environment conceptual framework from Publication 1 (Figure 4).

Figure 4: A revised food environment conceptual framework.



To aid the reader the new dimensions and aspects are demarcated in dark orange.

I propose the addition of two new food environment dimensions: 'food safety', under the external food environment domain; and 'social capital', under the personal food environment domain. Food safety captures aspects of adulteration and contamination. Although food safety was previously included under the 'vendor and product properties' dimension, lifting food safety as a new dimension, as recommended in Publication 4, more adequately captures the importance of food safety as a driver of food acquisition and consumption. The inclusion of 'food safety' as a separate dimension also harmonizes the framework with existing food environment definitions by the Food and Agricultural Organisation (38: p. vii), the Global Panel on Agriculture and Food Systems for Nutrition (39: p.83), the High Level Panel of Experts (40), as well as the definition of food security (41). In doing so, the conceptual framework may help bridge these research efforts that share the common goal of improving diets, nutrition, and health in LMICs, as was suggested in Publication 1. Further, the inclusion of food safety as a key food environment dimension may also serve to engage scholars from the field of food safety in a more direct way with conceptual and empirical food environment research in LMICs.

Social capital encapsulates aspects related to networks between food system actors, shared ties, social norms, and trust, as well as reciprocity and exchange and knowledge and skills. Social capital was a key driver of food acquisition in Publication 4 in the form of the theme 'sense of community and trust' related to 'known people'. This theme highlights the importance of social contracts and inter-personal relationships with known people that are currently inadequately accounted for within theoretical and empirical food environment research. Social capital has been found to be important within wider food security research from a diverse range of settings, as was outlined in Publication 4, providing an additional pathway through which food environment and food security research may align. For example, Lee et al. (42) found social networks to be important in maintaining food security within peri-urban communities in Peru. Investigating mechanisms of social capital from a food environments perspective may improve understanding of what Lin (43) refers to as the embedded resources within social networks, such as the sense of community and trust found to be shaping food acquisition and consumption amongst 'known people' in the APCAPS.

Further, social capital has also been integrated within food security research in HICs, demonstrating that this dimension is compatible with the global scope of the food environment conceptual framework (44-46). The inclusion of social capital within food environment conceptual framework also harmonises with the model by Rao et al. (47) depicting the multi-scalar determinants of health and well-being in neighbourhoods, which features social capital at the community level. Adapting new concepts such as social capital to food environment research born out of empirical knowledge and understanding gained from LMICs would represent a welcome addition to the HIC dominated literature to date.

In addition to the inclusion of the two new dimensions noted above, I have also included 'peer influence' under the personal food environment dimension 'desirability'. This is intended to capture social dynamics related to the influence of others, such as family members or friends that may shape food acquisition and consumption practices. A number of publications have highlighted the importance of families and peer influence on food acquisition and consumption in LMICs, including amongst men (29, 35), women (29, 32, 33, 35), and children and adolescents (29, 35, 48).

Further changes include the depiction of reciprocal arrows between the food environment interface and the wider food system box, as well as between 'acquisition and consumption' and 'nutrition and health outcomes', building on the supply and demand dynamics introduced by Marshall (17). This minor but important change is intended to better capture the interactive flows back and forth between the various stages, for example, between food production and the external food environment.

Future research may seek to apply an equity lens to the conceptual framework, especially given the primacy of equity within the 2030 Agenda for Sustainable Development (49). Equity is a key mediator that conditions the operation of the food environment domains and dimensions for different people in different ways, forming a series of opportunities and constraints that influence dietary, nutrition, and health outcomes. For example, food acquisition and consumption practices may vary dramatically between neighbours within a community, and even individuals within a household, due to varying levels of equity such as socio-economic status, gender dynamics, or ethnicity, despite a shared external food environment beyond the doorstep. Indeed, equity can be considered a cornerstone of the personal food environment. Exactly how horizontal and vertical forms of equity mediate the various dimensions of the food environment for different people requires further research across a range of settings. A salient approach would be to apply different equity lenses to the personal food environment domain in order to investigate how individual-level dimensions of accessibility, affordability, desirability, convenience and social capital condition socio-ecological interactions with the external food environment domain to shape food acquisition and consumption practices. I made strides to investigate intra-household gendered dynamics of food acquisition and preparation as part of my primary data collection. Publication 4 presents empirical evidence of gendered activity spaces in relation to food acquisition that may serve as a point of departure for future equity-focused food environment research in LMICs.

In summary, the opening four parts to this discussion chapter outline how my research has contributed to the wider conceptual and empirical literature on food environments in LMICs. Building on these contributions, the final section of the discussion presents the prospects for the continued development of food environment concepts. Green and Thorogood note that

a fundamental aim of qualitative analysis is to “both reflect the complexity of the phenomena studied, and present the underlying structures which ‘make sense’ of that complexity.” (36: p.206). Further, they note the virtues of qualitative research for the development of definitions, concepts, and theories. The revised conceptual framework presented above is grounded in my empirical findings and supported by the wider literature, and represents the continued iterative development of the underlying theoretical concepts that seek to make sense of the complex, dynamic and rapidly evolving food environments and drivers of food acquisition practices in LMICs. There is a need to apply these concepts across a range of settings, and it is my hope that these contributions may continue to be iteratively developed and refined going forward.

6.6.References: Discussion

1. Travert AS, Sidney Annerstedt K, Daivadanam M. Built Environment and Health Behaviors: Deconstructing the Black Box of Interactions-A Review of Reviews. Int J Environ Res Public Health. 2019;16(8).

2. United Nations Children's Fund - UNICEF. Food systems for children and adolescents: Working together to secure diets. Florence, Italy: Innocenti, 2019.

3. United Nations System Standing Committee on Nutrition – UNSCN. Food environments: Where people meet the food system. 2019.

4. Branca F, Lartey A, Oenema S, Aguayo V, Stordalen GA, Richardson R, Arvelo M, Afshin A. Transforming the food system to fight non-communicable diseases. BMJ. 2019;364:l296.

5. Esdaile E, Thow AM, Gill T, Sacks G, Golley R, Love P, Wen LM, Rissel C. National policies to prevent obesity in early childhood: Using policy mapping to compare policy lessons for Australia with six developed countries. Obes Rev. 2019.

6. Mackay H. Food sources and access strategies in Ugandan secondary cities: An intersectional analysis. Environment and Urbanization. 2019.

7. McIsaac JD, Spencer R, Stewart M, Penney T, Brushett S, Kirk SFL. Understanding System-Level Intervention Points to Support School Food and Nutrition Policy Implementation in Nova Scotia, Canada. Int J Environ Res Public Health. 2019;16(5).

8. Walls H, Baker P, Chirwa E, Hawkins B. Food security, food safety & healthy nutrition: are they compatible? Global Food Security-Agriculture Policy Economics and Environment. 2019;21:69-71.

9. Fan S. Achieving healthy and sustainable food environments for all. Food environments: Where people meet the food system. Nutrition: United Nations System Standing Committee on Nutrition; 2019.

10. Raneri J, Padulosi S, Meldrum G, King O. Supply-side measures improving food environments: Promoting neglected and underutilized species to boost nutrition in LMICs. Food environments: Where people meet the food system. Nutrition: United Nations System Standing Committee on Nutrition; 2019.

11. Ohly H, Broadley M, Mcardle H, Shahzad B, Zia M, Joy E, Khan M, Medhi R, Zaman M, Lowe N. Exploring socio-cultural aspects of the food environment: study perspectives from Pakistan. Food environments: Where people meet the food system. Nutrition: United Nations System Standing Committee on Nutrition; 2019.

12. Peng W. Nutritional implications of Tibetan Plateau resettling and urbanization programmes. Food environments: Where people meet the food system. Nutrition: United Nations System Standing Committee on Nutrition; 2019.

13. Coonrod J, Sow L, Wilson S. Transforming food environments through community-led action. Food environments: Where people meet the food system. Nutrition: United Nations System Standing Committee on Nutrition; 2019.

14. Parent G. Using legal frameworks to build healthy and sustainable food environments. Food environments: Where people meet the food system. Nutrition: United Nations System Standing Committee on Nutrition; 2019.

15. Bajoria M, Van Zutphen K, Olson R, Lingala S, Kraemer K. Last-mile nutrition: What role for the private sector? Food environments: Where people meet the food system. Nutrition: United Nations System Standing Committee on Nutrition; 2019.

16. Lee RE, Medina AV, Mama SK, Reese-Smith JY, O'Connor DP, Brosnan M, Cubbin C, McMillan T, Estabrooks PA. Health is power: An ecological, theory-based health intervention for women of color. Contemporary Clinical Trials. 2011;32(6):916-23.

17. Marshall Q. Cash transfers and the food environment: Eight ways to improve diet quality. Food environments: Where people meet the food system. Nutrition: United Nations System Standing Committee on Nutrition; 2019.

18. Michie S, van Stralen MM, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. Implement Sci. 2011;6:42.

19. Peters MD, Godfrey CM, Khalil H, McInerney P, Parker D, Soares CB. Guidance for conducting systematic scoping reviews. Int J Evid Based Healthc. 2015;13(3):141-6.

20. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, Moher D, Peters MDJ, Horsley T, Weeks L, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. Ann Intern Med. 2018;169(7):467-73.

21. Caspi CE, Sorensen G, Subramanian SV, Kawachi I. The local food environment and diet: A systematic review. Health & Place. 2012;18(5):1172-87.

22. Engler-Stringer R, Le H, Gerrard A, Muhajarine N. The community and consumer food environment and children's diet: a systematic review. BMC Public Health. 2014;14:522.

23. Gamba RJ, Schuchter J, Rutt C, Seto EY. Measuring the food environment and its effects on obesity in the United States: a systematic review of methods and results. J Community Health. 2015;40(3):464-75.

24. Gustafson A, Hankins S, Jilcott S. Measures of the consumer food store environment: a systematic review of the evidence 2000-2011. J Community Health. 2012;37(4):897-911.

25. Penney TL, Almiron-Roig E, Shearer C, McIsaac JL, Kirk SFL. Modifying the food environment for childhood obesity prevention: challenges and opportunities. Proceedings of the Nutrition Society. 2014;73(2):226-36.

26. Holdsworth M, Zotor F, Pradeilles R, Griffiths P, Green M, Mensah K, Akparibo R, Barnes A, Bricas N, Laar A. Dietary transitions in Ghanaian cities: using innovative methods to map the social and physical food environments that drive consumption of unhealthy foods and beverages, to identify contextually appropriate policies and interventions: the DFC dietary transitions in Ghana study. 3rd Agriculture, Nutrition and Health (ANH) Academy Week; 25-29th June, 2019; Accra, Ghana: Agriculture, Nutrition and Health Academy; 2018.

27. Pradeilles R, Laar A, Zotor F, Tandoh A, Klomegah S, Osei-Kwasi H, Bohr M, Green M, Bricas N, Holdsworth M, et al. Social and Physical Drivers of Food Choice: A participatory Photovoice Project in two Ghanaian Cities: a DFC Dietary Transitions in Ghana Study. 3rd Agriculture, Nutrition and Health (ANH) Academy Week; 24-28th June, 2018; Accra, Ghana: Agriculture, Nutrition and Health Academy; 2018.

28. Pradeilles R, Laar A, Zotor F, Tandoh A, Klomegah S, Osei-Kwasi H, Bohr M, Green M, Bricas N, Holdsworth M, et al. Social and Physical Drivers of Food Choice: A participatory Photovoice Project in two Ghanaian Cities: a DFC Dietary Transitions in Ghana Study. Sixth BSA Sociology of Food Study Group Conference: Food Systems and Society - Re-imagining Food Systems, Sustainability, Futures and the Everyday; 24-25th June 2019; Monash University, Prato, Italy: BSA Publications Ltd; 2019.

29. Holdsworth M, Pradeilles R, Zotor F, Green G, Tandoh A, Klomegah S, Osei-Kwasi H, Bricas N, Griffiths P. How unhealthy food and beverages are embedded in everyday life in Ghanaian cities. Sixth BSA Sociology of Food Study Group Conference: Food Systems and Society - Re-imagining Food Systems, Sustainability, Futures and the Everyday; 24-25th June 2019; Monash University, Prato, Italy: BSA Publications Ltd; 2019.

30. Trübswasser U. How do adolescents understand their food environment? A pilot study using Photovoice in urban Ethiopia. 4th Agriculture, Nutrition and Health Academy Week 2019; 24-28th June, 2019; Hyderabad, India. https://anh-academy.org/anh2019-programme: Agriculture, Nutrition and Health Academy; 2019.

31. Swinburn B, Sacks G, Vandevijvere S, Kumanyika S, Lobstein T, Neal B, Barquera S, Friel S, Hawkes C, Kelly B, et al. INFORMAS (International Network for Food and Obesity/non-communicable diseases Research, Monitoring and Action Support): overview and key principles. Obesity Reviews. 2013;14:1-12.

32. Bailey C, Garg V, Kapoor D, Wasser H, Prabhakaran D, Jaacks LM. Food Choice Drivers in the Context of the Nutrition Transition in Delhi, India. Journal of Nutrition Education and Behavior. 2018;50(7):675-86.

33. Daivadanam M, Wahlstrom R, Thankappan KR, Ravindran TK. Balancing expectations amidst limitations: the dynamics of food decision-making in rural Kerala. BMC Public Health. 2015;15:644.

34. Gissing SC, Pradeilles R, Osei-Kwasi HA, Cohen E, Holdsworth M. Drivers of dietary behaviours in women living in urban Africa: a systematic mapping review. Public Health Nutrition. 2017;20(12):2104-13.

35. Holdsworth M. Dietary transitions in Ghanaian cities: Leveraging evidence for policy and intervention to prevent diet-related non-communicable diseases. University of Ghana, African Population and Health Research Center, The University of Sheffield, Loughborough University, University of Liverpool, Cirad, 2019.

36. Green J, Thorogood N. Qualitative Methods for Health Research. 3rd Edition ed: Sage Publications Ltd; 2013.

37. Swinburn BA, Sacks G, Hall KD, McPherson K, Finegood DT, Moodie ML, Gortmaker SL. Obesity 1 The global obesity pandemic: shaped by global drivers and local environments. Lancet. 2011;378(9793):804-14.

38. Food and Agriculture Organisation of the United Nations – FAO. Influencing food environments for healthy diets. Rome: 2016.

39. Global Panel on Agriculture and Food Systems for Nutrition – Global Panel. Food systems and diets: Facing the challenges of the 21st century. London, UK: Global Panel on Agriculture and Food Systems for Nutrition, 2016.

40. High Level Panel of Experts on Food Security and Nutrition. Nutrition and food systems. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security. Rome: 2017.

41. Food and Agriculture Organisation of the United Nations – FAO. Rome Declaration on World Food Security and World Food Summit Plan of Action. World Food Summit Rome: 1996 November 1996. Report No.

42. Lee GO, Surkan PJ, Zelner J, Olortegui MP, Yori PP, Ambikapathi R, Caulfield LE, Gilman RH, Kosek MN. Social connectedness is associated with food security among peri-urban Peruvian Amazonian communities. Ssm-Population Health. 2018;4:254-62.

43. Lin N. A Network Theory of Social Capital. In: Castiglione D, van Deth J, Guglielmo W, editors. The Handbook of Social Capital. Oxford, UK.: Oxford University Press; 2008.

44. Chriest A, Niles M. The role of community social capital for food security following an extreme weather event. Journal of Rural Studies. 2018;64:80-90.

45. Dean WR, Sharkey JR. Food insecurity, social capital and perceived personal disparity in a predominantly rural region of Texas: An individual-level analysis (vol 72, pg 1454, 2011). Social Science & Medicine. 2011;73(1):183-.

46. Johnson CM, Sharkey JR, Dean WR. Eating Behaviors and Social Capital are Associated with Fruit and Vegetable Intake Among Rural Adults. J Hunger Environ Nutr. 2010;5(3):302-15.

47. Rao M, Prasad S, Adshead F, Tissera H. The built environment and health. Lancet. 2007;370(9593):1111-3.

48. Maxfield A, Patil S, Cunningham SA. Globalization and Food Prestige among Indian Adolescents. Ecology of Food and Nutrition. 2016;55(4):341-64.

49. United Nations General Assembly – UNGA. Transforming our world: the 2030 Agenda for Sustainable Development. GA Res. 70/1. UN GAOR, 70th Session, Suppl. 49, U.N. Doc. A/RES/70/1. United Nations General Assembly, 2015.

7. Conclusion

This thesis provides a series of critical contributions to the rapidly emerging body of literature investigating food environments and drivers of food acquisition in LMICs. The four publications collectively span the research process, addressing key research gaps with implications for theoretical and empirical research, as well as public health policy.

Theoretical contributions include the food environment definition and conceptual framework, which are intended to accelerate a robust and coherent global research agenda to inform action. The emphasis placed on implications for LMICs and the call to move beyond the focus on overweight and obesity towards a new food environment research paradigm that is sensitive to malnutrition in all its forms breaks new ground within the theoretical literature.

The systematic scoping review presents the synthesis of seventy articles from 22 LMICs, revealing the rapid development of food environment research in these settings over the past decade. The prominence of upper-middle income countries and outcomes related to overweight and obesity highlights the urgent need to address low- and lower-middle income countries, and provides evidence of the critical need address malnutrition in all its forms. This publication also identifies a paucity of evidence from high quality analytical studies, consistent with the review literature from HICs, and indicates the need to improve study designs, methods and metrics to better capture external and personal food environment domains and dimensions.

The development and assessment of the feasibility and utility of the novel Q-GIS methodological approach contributes to a small but emerging number of studies using visual methods to investigate food environments and drivers of food acquisition in LMICs. The case study from peri-urban Hyderabad, Telangana, India, demonstrates how a Q-GIS approach featuring PPM and follow-up graphic and photo-elicitation interviews can be used to investigate food environments and drivers of food acquisition in an LMIC setting. The identification of key strengths and limitations and the presentation of the prospects for the continued development is intended to inform the refinement of this approach.

Empirical findings from the qualitative investigation of the food environment and food acquisition and consumption practices in two villages of peri-urban Hyderabad, India, have a series of research and policy implications. Key drivers of food acquisition included prices and affordability, vendor and product properties, and a sense of community and trust, indicating the need for interventions and policies that are socio-ecologically informed, addressing both external and personal food environment domains. Critical reflection of these findings in relation to the wider literature led to the iterative development of the theoretical concepts from my first publication. It is my hope that the revised conceptual framework, featuring the inclusion of food safety as an external dimension, and social capital as a personal food environment dimension, will constitute salient contributions to the existing framework, adding further nuance to help make sense of the complex, dynamic and rapidly evolving food environments and drivers of food acquisition practices in LMICs. Contextualised knowledge and understanding about food environments and drivers of food acquisition and consumption in LMICs will be key to the successful design and implementation of targeted public health policies to improve food environments so that people have better opportunities to consume nutritious, healthy diets.

8. Appendices

8.1.Appendix 1: Publication 2

Supplemental Material for this publication is also available online:

https://academic.oup.com/advances/advance-article/doi/10.1093/advances/nmz031/5488467

Supplemental Material 1: Search strategy - Scopus

ABS("Food Environment*" **OR** "Food desert*" **OR** "Food swamp*" **OR** "Obesogenic environment*" **OR** "Nutrition* environment*") **AND ABS**(LIC **OR** LICs **OR** "low income econom*" **OR** "low income countr*" **OR** LMIC **OR** LMICs **OR** "Lower Middle Income Countr*" **OR** "Low and Middle Income Countr*" **OR** "upper middle income econom*" **OR** "upper middle income countr*" **OR** "Developing Countr*" **OR** "Developing Econom*" **OR** "Developing World Countr*" **OR** "Global South" **OR** Afghanistan **OR** Benin **OR** {Burkina Faso} **OR** Burundi **OR** {Central African Republic} **OR** Chad **OR** Comoros **OR** {Democratic Republic of Congo} **OR** Eritrea **OR** Ethiopia **OR** Gambia **OR** Guinea **OR** "Guinea Bissau" **OR** Haiti **OR** Korea **OR** Liberia **OR** Madagascar **OR** Malawi **OR** Mali **OR** Mozambique **OR** Nepal **OR** Niger **OR** Rwanda **OR** Senegal **OR** {Sierra Leone} **OR** Somalia **OR** {South Sudan} **OR** Tanzania **OR** Togo **OR** Uganda **OR** Zimbabwe **OR** Angola **OR** Armenia **OR** Bangladesh **OR** Bhutan **OR** Bolivia **OR** {Cabo Verde} **OR** Cambodia **OR** Cameroon **OR** Congo **OR** Djibouti **OR** Egypt **OR** {Ivory Coast} **OR** {Cote d ivoire} **OR** {El Salvador} **OR** Georgia **OR** Ghana **OR** Ghana **OR** Guatemala **OR** Honduras **OR** India **OR** Indonesia **OR** Jordan **OR** Kenya **OR** Kiribati **OR** Kosovo **OR** {Kyrgyz Republic} **OR** Lao **OR** Lesotho **OR** Mauritania **OR** Micronesia **OR** Moldova **OR** Mongolia **OR** Morocco **OR** Myanmar **OR** Nicaragua **OR** Nigeria **OR** Pakistan **OR** {Papua New Guinea} **OR** Philippines **OR** {Sao Tome and Principe} **OR** {Solomon Islands} **OR** {Sri Lanka} **OR** Sudan **OR** Swaziland **OR** {Syrian Arab Republic} **OR** Syria **OR** Tajikistan **OR** "Timor Leste" **OR** Tunisia **OR** Ukraine **OR** Uzbekistan **OR** Vanuatu **OR** Vietnam **OR** {West Bank and Gaza} **OR** Yemen **OR** Zambia **OR** Albania **OR** Algeria **OR** {American Samoa} **OR** Argentina **OR** Azerbaijan **OR** Belarus **OR** Belize **OR** {Bosnia and Herzegovina} **OR** Botswana **OR** Brazil **OR** Bulgaria **OR** China **OR** Colombia **OR** {Costa Rica} **OR** Croatia **OR** Cuba **OR** Dominica **OR** {Dominican Republic} **OR** Ecuador **OR** {Equatorial Guinea} **OR** Fiji **OR** Gabon **OR** Grenada **OR** Guyana **OR** Iran **OR** Iraq **OR** Jamaica **OR** Kazakhstan **OR** Lebanon **OR** Libya **OR** Macedonia **OR** FYR **OR** FYROM **OR** Malaysia **OR** Maldives **OR** {Marshall Islands} **OR** Mauritius **OR** Mexico **OR** Montenegro **OR** Namibia **OR** Nauru **OR** Panama **OR** Paraguay **OR** Peru **OR** Romania **OR** {Russian Federation} **OR** Russia **OR** Samoa **OR** Serbia **OR** {South Africa} **OR** {St. Lucia} **OR** {St Lucia} **OR** {St. Vincent and the Grenadines} **OR** {St Vincent and the Grenadines} **OR** Suriname **OR** Thailand **OR** Tonga **OR** Turkey **OR** Turkmenistan **OR** Tuvalu **OR** Venezuela) **PUBYEAR AFT 2000**

Supplemental Table 1: Key characteristics of all included studies (*n*=70)

Article type	Article	Year	Country[1]	Income quartile[2]	Concept	Data	Sample	Methods			Food Environment Dimensions[3]								
								GIS-based	Market-based	Stakeholder-based	Availability	Prices	VPP	Marketing	Accessibility	Affordability	Convenience	Desirability
Quantitative	Anggraini et al. (78)	2016	IDN	LM	FE	P	Women, 19 to 50 Y.O. w/ BMI ≥18.5 kg/m2 (*n*=188)		✓	✓	✓								
	Azeredo et al. (83)	2016	BRA	UM	FE, School FE	S	9th grade adolescents (*n*=109,104) from 2824 public and private schools			✓	✓								
	Barrera et al. (84)	2016	MEX	UM	FE, OE	P	Schoolchildren (*n*=725) from 60 elementary schools	✓	✓		✓								
	Castro-Sánchez et al. (55)	2014	MEX	UM	FE	S	Municipalities of Monterrey Metropolitan Area (*n*=9)	✓			✓				✓				
	Cerovečki and Grünhagen (61)	2016	HRV	UM	FD	P,S	Districts of Zagreb (*n*=6)		✓		✓	✓	✓						
	Chacon et al. (62)	2015	GTM	LM	OE	P,S	Preschools (*n*=2) and primary schools (*n*=2)		✓		✓		✓	✓	✓				✓
	Chan Sun et al. (66)	2009	MUS	UM	FE, School FE	P	Head teachers from public primary schools (*n*=174)			✓	✓								
	Chor et al. (85)	2016	BRA	UM	FE	P	Civil servants, 35 to 74 Y.O. in six Brazilian states (*n*=14,749)			✓	✓								
	Costa et al. (58)	2015	BRA	UM	FE	P,S	Health Academy Program units (*n*=18) in Belo Horizonte	✓	✓		✓				✓				
	Dake et al. (86)	2016	GHA	LM	FE, Local FE	P	Adults (*n*=657) from forty households in three urban poor communities of Accra	✓	✓	✓	✓								
	Davies et al. (59)	2017	BRA	UM	FD	P,S	Shops (*n*=554)	✓	✓		✓	✓	✓		✓	✓			

Supplemental Table 1: Continued

Duran et al. (56)	2013	BRA	UM	FE	P,S	52 Census Tracts in Sao Paulo		✓		✓					
Duran et al. (28)	2015	BRA	UM	FE, Micro FE	P,S	Retail food stores (n=305), fruits and vegetable markets (n=8), and restaurants (n=472)		✓		✓	✓	✓	✓		
Duran et al. (73)	2016	BRA	UM	FE, Consumer FE, Community FE	P,S	Adults (n=1842) and retail food stores (n=298), specialized fresh produce indoor markets (n=7) and weekly street fresh produce markets (n=8)	✓	✓		✓	✓	✓			
Estima et al. (19)	2014	BRA/ USA	UM/ H	FE, Home FE	P	Adolescents from São Paulo (n=1148), and St. Paul/Minneapolis (n=1632)			✓	✓					
Faber et al. (63)	2014	ZAF	UM	FE, School FE	P	School principals (n=85), feeding coordinators (n=77), food handlers (n=84), educators (n=687), randomly selected grade 5 to 7 learners (n=2547) and a convenience sample of parents (n=731). School menu (n=75), meal served on survey day, and foods at vendors (n=74)		✓	✓	✓	✓	✓	✓		✓
Gartin (71)	2012	PRY	UM	FD	P	Households (n=68), Stores (n=17) in San Lorenzo		✓		✓	✓	✓			
Godin et al. (74)	2017	GTM	LM	FE, School FE	P	Adolescents (n=1042) from four (two public, two private) secondary schools		✓		✓			✓		
Hua et al. (31)	2014	CHI	UM	FE	P,S	Socio-economically distinct neighbourhoods (n=3) in Kunming	✓	✓		✓	✓		✓	✓	
Ivanova et al. (57)	2012	BGR	UM	NE	P	Survey: Managerial staff from hotels with restaurants (n=34) Observation: Independent restaurants (n=30)		✓	✓	✓			✓		

Supplemental Table 1: Continued

Jaime et al. (87)	2011	BRA	UM	OE, FE	S	Men and women (n=2,122) from 31 sub-municipalities in Sao Paulo	✓			✓			
Kanter et al. (29)	2014	GTM	LM	NE, FE	P	Large supermarket (n=1)		✓		✓	✓		
Kelly et al. (72)	2014	THA	UM	FE	S	University students (n=1,516) from the Thai Cohort Study			✓	✓			✓
Liao et al. (60)	2016	CHI	UM	FE	P,S	Neighbourhoods (n=948) from 54 central districts of 12 cities	✓	✓		✓			
Martins et al. (30)	2013	BRA	UM	FE	P	Food stores (n=44) in 3 census tracts in the city of Santos		✓		✓	✓	✓	
Mendes et al. (79)	2013	BRA	UM	FE, OE	S	Individuals (n=3,404) >18 Y.O.	✓			✓			
Moodley et al. (64)	2015	ZAF	UM	OE	P	Five areas in Soweto: Klipspruit West, Mofolo South, Dube, Meadowlands, and Orlando East.	✓	✓		✓		✓	✓
Ng et al. (70)	2015	MYS	UM	OE	P	Malaysian TV channels (n=103)		✓				✓	
Patel et al. (80)	2017	IND	LM	FE	P	Adults (n=5264) in 134 Census Enumeration Blocks in Delhi	✓			✓			
Safdie et al. (25)	2013	MEX	UM	FE, School FE	P	27 schools randomly selected and assigned to basic intervention (n=8), plus intervention (n=8) and control (n=11). Students (n=886) randomly selected for outcome evaluation		✓		✓		✓	
Schram et al. (54)	2015	PHL, VNM	LM	FE	S	Vietnam and The Philippines		✓		✓			
Soares et al. (69)	2014	BRA	UM	OE	P	Households (n=1,555) in the city of Pelotas, Southern Brazil			✓	✓			
Soltero et al. (65)	2017	MEX	UM	FE, School FE	P,S	Schools (n=32) in Guadalajara, Puerto Vallarta, Jalisco, and Mexico City		✓		✓			

Supplemental Table 1: Continued

	Steyn et al. (26)	2015	ZAF	UM	NE	P,S	Sixteen schools from two school districts, including learners in intervention schools (n=500) and control schools (n=498)				✓						
	Su et al. (27)	2017	CHI	UM	FD	P,S	Communities of Shenzhen City (n=8117)	✓							✓			
	Vedovato et al. (76)	2015	BRA	UM	FE	P	Mothers of children ≤10 Y.O. (n=538) from randomly selected households within 36 census tracts in Santos City			✓	✓		✓		✓			
	Velasquez-Melendez et al. (81)	2013	BRA	UM	OE	S	Individuals >18 Y.O. (n=3,425) in the city of Belo Horizonte	✓			✓							
	Wang and Shi (22)	2012	CHI	UM	FE	S	School-age children 6 to 18 Y.O. (n=185) from urban districts			✓	✓	✓	✓		✓	✓		
	Wijnhoven et al. (20)	2014	BGR[4]	UM/ H		P	Schools: round 1 (n=1831); round 2 (2045)			✓	✓							
	Wojcicki and Elwan (68)	2014	SWZ	LM	NE, School NE, OE	P,S	Primary schools (n=2) in Hhoho district (one private, one public)		✓		✓							
	Wu et al. (23)	2017	CHI	UM	FE, OE	S	Communities (n=216) from nine provinces			✓	✓	✓			✓			✓
	Zhang et al. (24)	2016	CHI	UM	FE	S	Children 6-17 Y.O. (n=348) from nine provinces	✓		✓					✓			
	Zhang et al. (82)	2012	CHI	UM	FE, Retail FE	S	Adults (n=9788) living in 218 communities across nine provinces			✓	✓							✓
	Zhou et al. (88)	2017	CHI	UM	FE, OE	S	Districts of Wuhan (n=189)	✓			✓							
	Zuccolotto et al. (77)	2015	BRA	UM	FE	P	Pregnant women (second trimester) (n=282) in Ribeirão Preto City			✓	✓		✓		✓	✓		
Qualitative	Fuster and Colón-Ramos (21)	2017	SLV/ USA[5]	LM/ H	FE	S	Four focus groups with adults (n=28) in El Salvador; Thirty in-depth interviews with recently migrated mothers (n=15) from Central America			✓	✓	✓	✓	✓	✓		✓	✓

Supplemental Table 1: Continued

Fuster et al. (45)	2013	SLV	LM	FE	P	Four focus groups with adults (*n*=28) and key informant interviews with community Tecnicos (*n*=6) in El Salvador	✓	✓		✓		✓	✓	✓	✓
Hardin and Kwauk (32)	2015	WSM	UM	FE	P	Public health, global health, and development workers (*n*=40)	✓	✓	✓				✓	✓	✓
Hunter-Adams (46)	2017	ZAF	UM	FE	P	Interviews with Somali, Congolese, and Zimbabwean women (*n*=23); Nine focus groups with Somali, Congolese, and Zimbabwean men and women (*n*=48)	✓	✓	✓	✓		✓	✓		✓
Hunter-Adams and Rother (47)	2016	ZAF	UM	FE	P	Interviews with Somali, Congolese, and Zimbabwean women (*n*=23); Nine focus groups with Somali, Congolese, and Zimbabwean men and women (*n*=48)	✓	✓	✓				✓	✓	✓
Kimoto et al. (33)	2014	MEX	UM	OE, FE	P	Mexican women (*n*=27) aged 23–44 years from low SES households	✓	✓		✓		✓	✓	✓	✓
Kolopaking et al. (38)	2011	IDN	LM	Home FE	P	Mothers (*n*=19), aged 25-45 years, with children from two elementary schools representing low-income, urban children in East Jakarta	✓	✓	✓	✓		✓	✓	✓	✓
Maxfield et al. (41)	2016	IND	LM	FE	P	Free listing included adolescents (*n*=29), 14 from a government school and 15 from a private school in Vijayapura city; Pile sorting included adolescents (*n*=65)	✓	✓			✓			✓	✓
Monterrosa et al. (40)	2015	MEX	UM	FE, School FE	S	597 online posts on the government website forum	✓				✓				

Supplemental Table 1: Continued

Pehlke et al. (42)	2016	GTM	LM	FE, School FE	P	School caseta vendors (n=4), school principals (n=4) and children 7–12 years of age in 1st–6th grades (n=48) from two schools on outskirts of Guatemala City	✓	✓						✓	✓
Pehlke et al. (43)	2016	GTM	LM	FE, School FE	P	School caseta vendors (n=4), school principals (n=4) and children 7–12 years of age in 1st–6th grades (n=48) from two schools on outskirts of Guatemala City.	✓		✓	✓	✓		✓	✓	✓
Phulkerd et al. (34)	2017	THA	UM	FE	P	Senior government officials (n=28)	✓				✓				
Rathi et al. (35)	2016	IND	LM	FE, School FE, Neighborhood FE	P	Students (n=15), parents (n=15), and principals (n=10) from ten secondary schools in Kolkata	✓	✓		✓	✓	✓		✓	✓
Rathi et al. (36)	2017	IND	LM	FE, School FE	P	52 Interviews, including adolescents aged 14–15 years (n=15), parents (n=15), teachers (n=12) and principals (n=10) from 10 private schools in Kolkata	✓	✓	✓	✓	✓				✓
Smit et al. (44)	2016	ZAF	UM	FE	P, S	Adult residents of Khayelitsha, Cape Town (n=30)	✓	✓	✓			✓			✓
Snowdon et al. (39)	2010	FJI, TON	UM	OE	P, S	Policy advisors from Ministries, private sector, and civil society (n=not specified) formed two multi-sectoral stakeholder groups (one per country)	✓	✓	✓	✓	✓	✓		✓	
Veeck et al. (37)	2014	CHI	UM	FE	P	Students (n=16) from upper middle high schools in Changchun, China	✓	✓	✓	✓	✓	✓		✓	✓

Supplemental Table 1: Continued

Mixed-Methods	Barr (48)	2017	DOM	UM	FE	P	Female household representatives (n=30) in La Esquina	✓		✓	✓		✓	✓	✓			
	Bridle-Fitzpatrick (49)	2015	MEX	UM	FE, FD, FS	P	Families w/ child 12-15 Y.O. (n=20) purposively recruited from three schools in low, middle, and high-SES communities of Mazatlan		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Chaudhari et al. (50)	2013	MEX	UM	FE	P	Households in Maycoba w/ one adult ≥35 Y.O. (n=71); Focus group members (n=10); Family-owned stores (n=7)		✓	✓	✓							
	Fernandes et al. (75)	2017	GHA	LM	School FE	P	Children 5-17 Y.O. (n=4258) from 1951 households located in 111 communities across 60 districts; Nine focus groups with caregivers and adolescents (n=72)			✓	✓					✓	✓	✓
	Finzer et al. (51)	2013	IND	LM	FE	P	Households (n=245) in South Delhi; Key informants (n=65)			✓		✓			✓	✓	✓	✓
	Gupta et al. (52)	2016	IND	LM	FE, Retail FE	P	Street vendors (n=44) in three low-SES settings in northern India: two villages and one urban slum	✓	✓	✓	✓		✓					
	Peyton et al. (53)	2015	ZAF	UM	FD, Urban FE	P,S	Wards (n=111) across 24 sub-councils in Cape Town municipality; Owners and employers of informal retailers (n=20)	✓		✓	✓	✓	✓		✓	✓		
	Pulz et al. (67)	2017	BRA	UM	FE, University FE	P	Snack bars (n=13) and restaurants (n=6) within the university		✓		✓	✓	✓	✓				

[1]ISO ALPHA-3 abbreviation; [2]World Bank classification - Gross National Income per capita, 2017; [3]Dimensions listed in conceptual framework (Figure 1); [4]Wijnhoven (20) also included the following HICs: CZE, GRC, HUN, IRL, LVA, LTU, MLT, NOR, PRT, SVN, SWE; [5]Fuster and Colón-Ramos (21): Only LMIC data reported; [6]Abbreviations: FD, food desert; FE, food environment; FS, food swamp; H, high-income country; LM, lower-middle-income country; NE, nutrition environment; OE, obesogenic environment; P, primary; P,S, primary and secondary; S, secondary; SES, socio-economic status; UM, upper-middle-income country; Y.O., years old.

Supplemental Table 2: Quantitative articles – measurement methods and tools

Measurement methods	Tools		Articles
Market-based	Inventories of food products		(25, 57, 59-64)
	Tools adapted from HICs - e.g. the Nutrition Environment Measurement Survey (NEMS)		(29-31, 56, 67, 71)
	Tools developed in LMICs	Obesogenic Environment Study in Sao Paulo (ESAO-SP) Observational Survey Tools	(58, 73)
		Goods and Services Index (GASI)	(65)
	Surveys of food vendor typologies (proxy measures of food availability)		(78, 84, 86)
	Menu evaluations		(68)
Stakeholder-based	Survey questionnaires	Community level availability	(23, 24, 57, 82)
		School level availability	(20, 63, 66, 78, 83)
		Household level availability	(19, 22, 69, 72)
GIS-based	Spatial analysis software tools (count, density and proximity of vendors)	Administrative areas	(24, 31, 55, 58, 60, 64, 79, 81, 87, 88)
		Radius-based buffer tool	(58, 59, 73, 80, 84, 86)
		Travel time	(27)

Supplemental Table 3: A synthesis of results from articles assessing food environment exposure and diet, nutrition, and health outcomes (*n*=23)

Study type	Article	Year	Country[1]	Income quartile[2]	Study Design	Data	Scale	Quality[3]	Sample	Exposure(s)	Outcome(s)	Significant association[4]		
												Dietary outcomes and behaviours	Nutrition outcomes	Health outcomes
Quantitative: Observational and Cohort Studies	Anggraini et al. (78)	2016	IDN	LM	CS	P	C	Poor	Women, 19 to 50 Y.O. w/ BMI ≥18.5 kg/m2 (*n*=188)	Food store choice (frequency of visits/month)	Frequency of food consumption	✓	n/a	n/a
	Azeredo et al. (83)	2016	BRA	UM	CS	S	Sc	Poor	9th grade adolescents (*n*=109,104) from 2824 public and private schools	Availability of school cafeteria and outlets at school entrance	Regular consumption of unhealthy foods	✓	n/a	n/a
	Barrera et al. (84)	2016	MEX	UM	CS	P	Sc	Poor	Schoolchildren (*n*=725) from 60 elementary schools	Count of vendors; Count of physical activity spaces	BMI/A Z-scores by sex (measured height and weight) classified as overweight and obesity	n/a	✓	n/a
	Chor et al. (85)	2016	BRA	UM	CS	P	C	Poor	Civil servants, 35 to 74 Y.O. in six Brazilian states (*n*=14,749)	Perceived neighbourhood availability of healthy foods; Perceived neighbourhood walkability	Diet quality (Proxy: FV consumption)	✓	n/a	n/a
	Dake et al. (86)	2016	GHA	LM	CS	P	C	Poor	Adults (*n*=657) from forty households in three urban poor communities of Accra	Count of vendors; Count of physical activity spaces	BMI (kg/m2) (measured height and weight)	n/a	✓	n/a
	Duran et al. (73)	2016	BRA	UM	CS	P,S	C	Good	Adults (*n*=1842) and retail food stores (*n*=298), specialized fresh produce indoor markets (*n*=7) and	Density of vendors; proximity to vendors	FV consumption (≥5 d/week); SSB consumption (≥5 d/week)	✓	n/a	n/a

Supplemental Table 3: Continued

								weekly street fresh produce markets (n=8)					
Gartin (71)	2012	PRY	UM	CS	P	C	Poor	Households (n=68), Stores (n=17) in San Lorenzo	Store ranking for each household; household income	Household BMI (kg/m2) (measured height and weight – calculated as the mean BMI of household members)	n/a	×	n/a
Godin et al. (74)	2017	GTM	LM	CS	P	Sc	Fair	Adolescents (n=1042) from four schools (two public, two private)	Food store choice (frequency of purchase); substance use, sedentary behaviour, physical activity, bullying victimization, weight goal	SSB consumption per day	×	n/a	n/a
Jaime et al. (87)	2011	BRA	UM	CS	S	C	Poor	Men and women (n=2,122) from 31 sub-municipalities in Sao Paulo	Density of vendors (per 1,000 inhabitants)	Proxy indicators for healthy and unhealthy diets incl. FV intake (≥5 days per week), soft drink consumption (≥5 days per week) BMI (kg/m2) (self-reported height and weight)	✓	×	n/a
Kelly et al. (72)	2014	THA	UM	CS	S	C	Poor	University students (n=1,516) from the Thai Cohort Study	Availability of vendors when a child, 10 years ago, at present; Accessibility to closest vendors and travel mode used	Frequency of consumption of indicator foods, including healthy foods (e.g. FV) and problem foods (e.g. snacks, fried foods, instant foods, processed meats, baked goods, soft drinks); BMI (kg/m2) (self-reported height and weight); Doctor-diagnosed diseases (e.g. hyperlipidaemia,	✓	×	×

Supplemental Table 3: Continued

										diabetes, hypertension, ischemic heart disease)			
Mendes et al. (79)	2013	BRA	UM	CS	S	C	Poor	Individuals (n=3,404) >18 Y.O.	Availability of supermarkets and hypermarkets; Health Vulnerability Index (HVI)	BMI (kg/m2) (self-reported height and weight) categorized into normal (18 kg/m2 ≤ BMI < 25 kg/m2) and overweight (BMI ≥ 25 kg/m2)	n/a	×	n/a
Patel et al. (80)	2017	IND	LM	CS	P	C	Poor	Adults (n=5264) in 134 Census Enumeration Blocks in Delhi	Count of full service and fast food restaurant vendors	Dietary intake (frequency of consumption of 15 food groups; BMI (kg/m2) (measured height and weight - incl. obesity and overweight ≥25 kg/m2; and the South Asian cut-point of BMI ≥23 kg/m2)	✓	×	n/a
Vedovato et al. (76)	2015	BRA	UM	CS	P	C	Fair	Mothers of children ≤10 Y.O. (n=538) from randomly selected households within 36 census tracts in Santos City	Count of food sources; means of transportation, household food acquisition (30 days); perceptions of FE	Degree of food processing (low and high)	✓	n/a	n/a
Velasquez-Melendez et al. (81)	2013	BRA	UM	CS	S	C	Poor	Individuals >18 Y.O. (n=3,425) in the city of Belo Horizonte	Counts of food vendors, parks, squares, physical exercise spaces; population density; neighbourhood income; homicide rate	BMI (kg/m2) (self-reported height and weight)	n/a	×	n/a
Wang and Shi (22)	2012	CHI	UM	L	S	C	Good	School-age children 6 to 18 Y.O. (n=185) from urban districts	Density of supermarkets; wet markets; fast food restaurants; and age; household income per capita; owning car; bus stop; sex; maternal education	Dietary intake: kilocalories, carbohydrates, protein, and fat (g)	✓	n/a	n/a

Supplemental Table 3: Continued

	Wijnhoven et al. (20)	2014	BGR [5]	UM/H	CS	P	Sc	Poor	Schools: round 1 (n=1831); round 2 (2045)	School Nutrition Environment Score	BMI/A Z-scores (measured height and weight); School BMI/A Z-score (calculated as the mean of the children's BMI/A Z-scores)	n/a	✓	n/a
	Zhang et al. (24)	2016	CHI	UM	L	S	C	Poor	Children 6-17 Y.O. (n=348) from nine provinces	Proximity of vendors to children's home	BMI (kg/m2) (measured height and weight)	n/a	✓	×
	Zhang et al. (82)	2012	CHI	UM	CS	S	C	Poor	Adults (n=9788) living in 218 communities across nine provinces	Count and density of food vendors; fast-food preferences; dietary knowledge	BMI (kg/m2) (measured height and weight)	n/a	×	n/a
	Zhou et al. (88)	2017	CHI	UM	CS	S	C	Poor	Districts of Wuhan (n=189)	Food environment: Count of vendors; Land use: e.g. land use composition; Socio-economic: 12 Variables e.g. % low-income household	District-level BMI (kg/m2); Obesity incidence (% of obese individuals amongst middle aged adults)	n/a	✓	n/a
	Zuccolotto et al. (77)	2015	BRA	UM	CS	P	C	Fair	Pregnant women (second trimester) (n=282) in Ribeirão Preto City	Perceptions of FE	FV intake	×	n/a	n/a
Quantitative: Experimental Studies	Safdie et al. (25)	2013	MEX	UM	RCT	P	Sc	Fair	27 schools randomly selected and assigned to: basic intervention (n=8), plus intervention (n=8) and control (n=11). Students (n=886) randomly selected for outcome evaluation.	n/a	School availability of food and beverages; Individual food intake at recess (direct observation) of highly recommended foods (e.g. fresh FV), foods recommended for consumption no more than two times a week (e.g. non-fried tacos, meat, and non-recommended foods (e.g. candies, ice cream, fried foods, pizzas, SSBs); BMI (kg/m2) (measured height and weight, age- and sex-specific	✓	✓	n/a

Supplemental Table 3: Continued

											International Obesity Task Force (IOM) cut-off points used to classify non-overweight or overweight/obese status).			
	Steyn et al. (26)	2015	ZAF	UM	RCT	P,S	Sc	Poor	Sixteen schools from two school districts, including learners in intervention schools (n=500) and control schools (n=498)	n/a	Dietary diversity score (DDS), fat intake score (FIS) and sugar intake score (SIS)	✖	n/a	n/a
Mixed-Methods	Fernandes et al. (75)	2017	GHA	LM	CS	P	Sc	Fair	Children 5-17 Y.O. (n=4258) from 1951 households located in 111 communities across 60 districts; Nine focus groups with caregivers and adolescents (n=72)	Age, sex, ethnic group, region, education level of HH head, female head HH, sibling <5 Y.O., recipient of free school meals (Y/N), commuting time to/from school (mins), HH asset score, HH size	FV purchasing patterns, FV consumption patterns	✓	n/a	n/a

[1]ISO ALPHA-3 abbreviation; [2]World Bank classification - Gross National Income per capita, 2017; [3]Assessed using the NHBLI Checklists and the Mixed Methods Appraisal Tool; [4]Significant association: ✓ = at least one significant association, ✖ = no significant associations, n/a = not applicable; [5]Wijnhoven (2014) also included the following HICs: CZE, GRC, HUN, IRL, LVA, LTU, MLT, NOR, PRT, SVN, SWE; [6]Abbreviations: C, community; CS, cross-sectional; DDS, dietary diversity score; FE, food environment; FIS, fat intake score; FV, fruits and vegetables; H, high-income country; HH, household; L, longitudinal; LM, lower-middle-income country; P, primary; P,S, primary and secondary; RCT, randomised control trial; S, secondary; Sc, school; SIS, sugar intake score; SSB, sugar-sweetened beverages; UM, upper-middle-income country; Y.O., years old.

Supplemental Table 4: Quality assessment – National Heart, Lung and Blood Institute (NHLBI) checklists

NHLBI Checklist: Cross Sectional and Cohort Studies (17)[1]

Article	Score	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14
Anggraini et al. (78)	Poor	Y	Y	Y	Y	Y	N	Y	N	N	N	Y	N/R	Y	N
Azeredo et al. (83)	Poor	Y	Y	Y	Y	N	N	N/A	N	N	N	Y	N/R	N/R	N
Barrera et al. (84)	Poor	Y	C/D	Y	N	N	N	N/A	Y	Y	N	Y	N/R	Y	N
Chor et al. (85)	Poor	Y	Y	Y	N	N	N/A	N/A	Y	Y	N/A	N	N/A	N/A	N
Dake et al. (86)	Poor	Y	N	C/D	N	N	N/A	N/A	C/D	Y	N/A	Y	N/R	N/A	Y
Duran et al. (73)	Good	Y	Y	Y	Y	N/R	N/A	N/A	Y	Y	N/A	Y	N/A	N/A	Y
Gartin (71)	Poor	Y	Y	Y	Y	Y	N/A	N/A	Y	N	N/R	N	N/A	N/A	N
Godin et al. (74)	Fair	Y	Y	Y	Y	N	N/A	N/A	Y	Y	N/R	Y	N/R	N/A	N
Jaime et al. (87)	Poor	Y	Y	Y	N/R	N/R	N/A	N/A	Y	Y	N/A	N	N/A	Y	N
Kelly et al. (72)	Poor	Y	Y	Y	N/R	N/A	N/A	N/A	N	N	N/A	Y	N/A	Y	N
Mendes et al. (79)	Poor	Y	Y	Y	Y	N	C/D	C/D	N	N	N	Y	N/A	N/A	C/D
Patel et al. (80)	Poor	Y	Y	Y	Y	N	N	N/A	Y	Y	N	Y	N/R	N/A	Y
Vedovato et al. (76)	Fair	Y	Y	Y	Y	Y	N/A	N/A	Y	N	N	Y	N/A	N/A	N
Velasquez-Melendez et al. (81)	Poor	Y	Y	Y	Y	N	C/D	C/D	Y	Y	N	Y	N/A	N/A	Y
Wang and Shi (22)	Good	Y	Y	N	Y	N	Y	Y	Y	Y	Y	Y	N/A	N	Y
Wijnhoven et al. (20)	Poor	Y	Y	Y	Y	Y	N/A	N/A	Y	Y	N/A	Y	N/A	C/D	N
Zhang et al. (24)	Poor	Y	Y	Y	Y	N	N	N	Y	Y	N	Y	N/A	Y	Y
Zhang et al. (82)	Poor	Y	Y	Y	Y	N	Y	N/A	Y	Y	N/A	Y	N/A	Y	N
Zhou et al. (88)	Poor	Y	Y	N/R	N/R	N	N	N	Y	C/D	N/R	C/D	N/A	N/A	Y
Zuccolotto et al. (77)	Fair	Y	Y	Y	Y	Y	N/A	N/A	Y	Y	N/A	Y	N/A	N/A	Y

NHLBI Checklist: Controlled intervention studies (17)[2]

Article	Score	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14
Safdie et al. (25)	Fair	Y	C/D	N/R	N	N/R	Y	Y	Y	Y	N/R	Y	Y	C/D	Y
Steyn et al. (26)	Poor	Y	C/D	C/D	N/R	N/R	N/R	Y	Y	N/R	N/R	Y	N	N/A	Y

Supplemental Table 4: Continued

[1]NHBLI Checklist: observational and cohort studies (1. Was the research question or objective in this paper clearly stated? 2. Was the study population clearly specified and defined? 3. Was the participation rate of eligible persons at least 50%? 4. Were all the subjects selected or recruited from the same or similar populations (including the same time period)? Were inclusion and exclusion criteria for being in the study pre-specified and applied uniformly to all participants? 5. Was a sample size justification, power description, or variance and effect estimates provided? 6. For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured? 7. Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed? 8. For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (e.g., categories of exposure, or exposure measured as continuous variable)? 9. Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants? 10. Was the exposure(s) assessed more than once over time? 11. Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants? 12. Were the outcome assessors blinded to the exposure status of participants? 13. Was loss to follow-up after baseline 20% or less? 14. Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?); [2]NHBLI Checklist: controlled intervention studies (1. Was the study described as randomized, a randomized trial, a randomized clinical trial, or an RCT? 2. Was the method of randomization adequate (i.e., use of randomly generated assignment)? 3. Was the treatment allocation concealed (so that assignments could not be predicted)? 4. Were study participants and providers blinded to treatment group assignment? 5. Were the people assessing the outcomes blinded to the participants' group assignments? 6. Were the groups similar at baseline on important characteristics that could affect outcomes (e.g., demographics, risk factors, co-morbid conditions)? 7. Was the overall drop-out rate from the study at endpoint 20% or lower of the number allocated to treatment? 8. Was the differential drop-out rate (between treatment groups) at endpoint 15 percentage points or lower? 9. Was there high adherence to the intervention protocols for each treatment group? 10. Were other interventions avoided or similar in the groups (e.g., similar background treatments)? 11. Were outcomes assessed using valid and reliable measures, implemented consistently across all study participants? 12. Did the authors report that the sample size was sufficiently large to be able to detect a difference in the main outcome between groups with at least 80% power? 13. Were outcomes reported or subgroups analysed pre-specified (i.e., identified before analyses were conducted)? 14. Were all randomized participants analysed in the group to which they were originally assigned, i.e., did they use an intention-to-treat analysis?); [3]Abbreviations: C/D, cannot determine; N, no; N/A, not applicable; N/R, not reported; Y, yes.

Supplemental Table 5: Quality assessment – Mixed Methods Appraisal Tool (MMAT)

Mixed-methods appraisal Tool (18)[1]

Article		Q 5.1	Q 5.2	Q 5.3	Q 1.1	Q 1.2	Q 1.3	Q 1.4	Q 3.1	Q 3.2	Q 3.3	Q 3.4	Q 4.1	Q 4.2	Q 4.3	Q 4.4
Fernandes et al. (75)	Fair	Y	Y	Y	Y	Y	Y	N	Y	Y	N/A	C/D	N/A	N/A	N/A	N/A

[1]Overall: (5.1. Is the mixed methods research design relevant to address the qualitative and quantitative research questions (or objectives), or the qualitative and quantitative aspects of the mixed methods question (or objective)? 5.2. Is the integration of qualitative and quantitative data (or results*) relevant to address the research question (objective)? 5.3. Is appropriate consideration given to the limitations associated with this integration, e.g., the divergence of qualitative and quantitative data (or results*) in a triangulation design?); Qualitative component: 1.1. Are the sources of qualitative data (archives, documents, informants, observations) relevant to address the research question (objective)? 1.2. Is the process for analysing qualitative data relevant to address the research question (objective)? 1.3. Is appropriate consideration given to how findings relate to the context, e.g., the setting, in which the data were collected? 1.4. Is appropriate consideration given to how findings relate to researchers' influence, e.g., through their interactions with participants? 4. Quantitative; descriptive: 4.1. Is the sampling strategy relevant to address the quantitative research question (quantitative aspect of the mixed methods question)? 4.2. Is the sample representative of the population understudy? 4.3. Are measurements appropriate (clear origin, or validity known, or standard instrument)? 4.4. Is there an acceptable response rate (60% or above)?; [2]Abbreviations: C/D, cannot determine; N, no; N/A, not applicable; Y, yes.

8.2.Appendix 2: Publication 3

Supplemental Material 1: Topic guide – In depth interviews

Topic Guide: One to One In-Depth Interviews

Introduction of concept

This research is about your 'food environment', including all sources of food such as market, own production (if any) and gifts from friends or family. We also hope to learn about your personal food acquisition practices and what you think is important in shaping the foods that you eat.

Ice breaker

"We would like you to tell us about how food fits into your daily life and activities"

- Can you tell me about the events of the past seven days? What has been happening?

(Probe: Work; spare time activities)

Personal Food Environment interactions

- Can you tell me about how getting food fits into your daily routines and activities?

  Where did you get food from this week? Can you give examples?

  Can you describe some other regular food sources?

(Probe: who; what; when; where; why; how many times; how get there?)

- Can you talk me through a normal day, thinking about where you get your food?

  Are there any sources of food that stand out as being particularly important or to you?

(Probe: what reason; in what way important?)

- Are there any sources of food that we have not talked about? *Probes:*
  - *Market sources (Street foods, Snacks, Drinks, Supermarkets, Wholesale)*

- *Own production (Home garden, Rural area)*
- *Gifts from friends/family (Festivals)*

- What factors do you think are important in shaping where you get your food from?
  Probes:
  - *Availability/accessibility (distance, travel time, activities, transport)*
  - *Price/affordability (monetary value of products)*
  - *Vendor and product properties (opening hours, services, quality, safety)*
  - *Convenience (time and effort of preparing, cooking, eating)*
  - *Marketing and regulation (advertising, branding, labelling)*
  - *Desirability (preference, taste, desire, culture, skills, knowledge)*

Perceptions of the local food environment

- How has your local food environment has changed over the past 10 years?

  How do you feel about the changes?

- In what way has it changed? Can you give some examples? *Probes:*
  - *Availability/accessibility (distance, travel time, activities, transport)*
  - *Price/affordability (monetary value of products)*
  - *Vendor and product properties (opening hours, services, quality, safety)*
  - *Convenience (time and effort of preparing, cooking, eating)*
  - *Marketing and regulation (advertising, branding, labelling)*
  - *Desirability (preference, taste, desire, culture, skills, knowledge)*

- Do you think you have changed the way you get foods over this time?

  Can you give some examples? Why do you think you have changed? *Probes:*

  - *Market sources (Street foods, Snacks, Drinks, Supermarkets, Wholesale)*
  - *Own production (Home garden, Rural area)*
  - *Gifts from friends/family (Festivals)*

How do you feel about your local food environment today?

What things do you value?

What, if anything, would you like to see change?

Intra-household dynamics

- Who is usually the household food provider?

- Who makes decisions about what to eat in the household?

(Probes: why?)

- Who physically goes out to get the food for the household?

  (Probes: who; what; when; where; why; how often; how do they get there?)

- Who usually prepares and cooks?

  (Probes: who; what; when; where; why; how often?)

Supplemental Material 2: - : Ethical approval - Observational ethics committee, London School of Hygiene and Tropical Medicine

London School of Hygiene & Tropical Medicine
Keppel Street, London WC1E 7HT
United Kingdom
Switchboard: +44 (0)20 7636 8636
www.lshtm.ac.uk

LONDON SCHOOL of HYGIENE &TROPICAL MEDICINE

Observational / Interventions Research Ethics Committee

Mr Christopher Turner
LSHTM

19 April 2017

Dear Christopher,

Study Title: A Qualitative Investigation of Consumer-Food Environment Interactions in the APCAPS, India; Comparing Standard In-depth Interviews with a Novel Qualitative Geographical Information Systems Approach

LSHTM ethics ref: 12257

Thank you for your application for the above research, which has now been considered by the Observational Committee.

Confirmation of ethical opinion

On behalf of the Committee, I am pleased to confirm a favourable ethical opinion for the above research on the basis described in the application form, protocol and supporting documentation, subject to the conditions specified below.

Conditions of the favourable opinion

Approval is dependent on local ethical approval having been received, where relevant.

Approved documents

The final list of documents reviewed and approved by the Committee is as follows:

Document Type	File Name	Date	Version
Investigator CV	Christopher Turner CV Jan 2017	31/01/2017	1
Investigator CV	Suneetha Kadiyala CV Jan 2017	31/01/2017	1
Investigator CV	Sanjay Kinra CV	31/01/2017	1
Investigator CV	Sarah Milton CV Jan 2017	31/01/2017	1
Information Sheet	Participant information sheet	31/01/2017	1
Information Sheet	Consent form	31/01/2017	1
Advertisements	Recruitment Procedure	31/01/2017	1
Local Approval	apr29_2014_finalapproval_HMSC_APCAPS	31/01/2017	1
Local Approval	IEC APCAPS approval-2015Jul	31/01/2017	1
Local Approval	APCAPS_NIN Ethics Approval_May 2016	31/01/2017	1
Local Approval	Kinra_6471_approval_29072013	31/01/2017	1
Protocol / Proposal	Research Protocol_A Qualitative Geographical Information Systems Approach to Mapping Geo-narratives of Consumer-Food Environment Interactions in APCAPS, India	31/01/2017	1
Protocol / Proposal	Graphic Elicitation Interviews Topic Guide	31/01/2017	1

Information Sheet	Participant information sheet 05:04:17	05/04/2017 2
Covering Letter	Clarification Request_Cover letter_LSHTM	05/04/2017 1

After ethical review

The Chief Investigator (CI) or delegate is responsible for informing the ethics committee of any subsequent changes to the application. These must be submitted to the Committee for review using an Amendment form. Amendments must not be initiated before receipt of written favourable opinion from the committee.

The CI or delegate is also required to notify the ethics committee of any protocol violations and/or Suspected Unexpected Serious Adverse Reactions (SUSARs) which occur during the project by submitting a Serious Adverse Event form.

At the end of the study, the CI or delegate must notify the committee using an End of Study form.

All aforementioned forms are available on the ethics online applications website and can only be submitted to the committee via the website at: http://leo.lshtm.ac.uk

Additional information is available at: www.lshtm.ac.uk/ethics

Yours sincerely,

[redacted]

Professor John DH Porter
Chair

ethics@lshtm.ac.uk
http://www.lshtm.ac.uk/ethics/

Improving health worldwide

Supplemental Material 3: Ethical approval - Institutional Ethics Committee of the Indian Institute of Public Health under the banner of the Public Health Foundation India

Institutional Ethics Committee

Indian Institute of Public Health-Hyderabad /
Public Health Foundation of India
ANV Arcade, Plot No.1, Amar Cooperative Society, Kavuri Hills, Madhapur, Hyderabad - 500081, A.P., INDIA

Communication of Decision of the IEC[1]
Form II

TRC-IEC No Application No:	**IIPHH/TRCIEC/092/2017**	**Date:**	**21-04-2017**	
Project Title:	**A Qualitative Investigation of Consumer- Food Environment Interactions in the APCAPS, India; Comparing In- depth Interviews with a Novel in the Geographical Information Systems Approach**			
Principal Investigator:	Christopher Turner			
Review	**Full Review**	☒	**Expedited Review**	☐
Date of review:	**20th April 2017**			
Date of previous review:	*(in case of re-submitted applications)*			
Decision of the IEC:	**Approval**	☒	**Resubmission**	☐
	Conditional Approval	**Study can begin** ☐	**Study cannot begin**	☐
Requirements to be fulfilled in case of conditional approval:				
Suggested alterations in case of resubmission:				
In case of approval, *recommended for a period of :*	**Approval is valid for a period of one year from the date of issue**			
Comments:				

Please note: Beginning of the research based on this approval implies acceptance of the following conditions:

1. *PI will inform the Secretariat of the start date of the study.*
2. *The PI will inform the IEC in case of any adverse events.*
3. *The PI will inform the TRC (Technical Review Committee) and IEC in case of any change of study procedure (including- changes in the informed consent form, recruitment procedure, potential research participant information), site and investigator.*
4. *The PI will inform the TRC - IEC Secretariat on termination of the study and submit a final report within 3 months of completion of the study.*
5. *Members of the IEC have the right to monitor the study with prior intimation.*
6. *Progress report to be submitted to the TRC-IEC Secretariat every 6 months from the date of start of study.*
7. *This permission is only for the period mentioned above.*

[redacted]

Name and signature of Member Secretary
Dr. Nanada Kishore K

Chairperson, IEC, IIPH
Dr. T.P. DAs

[1] Adapted from the ICMR form: available at
http://www.icmr.nic.in/bioethics/Communication%20of%20Decision%20of%20the%20IEC.doc

Page **1** of **1** FORM II PHFI IEC/Ver3/09

Participant information sheet: In-depth interviews

Principle investigator: MPhil Christopher Turner (London School of Hygiene and Tropical Medicine and the Leverhulme Centre for Integrative Research on Agriculture, Nutrition and Health)

Project name: A Qualitative Investigation of Consumer-Food Environment Interactions in the APCAPS, India

Participant information sheet for (Print)_____

Introduction

We are researchers working for the National Institute for Nutrition, Hyderabad, and the London School of Hygiene and Tropical Medicine, London. We are researching the food environment of your community as part of APCAPS, including information about when, where, why and how people such as yourself acquire food.

This information sheet provides details about the study and invites you to take part in this research. You do not have to make your decision today about whether or not you will participate. Before you make your decision, you may talk to anyone that you feel comfortable with about what taking part in this research entails.

This information sheet may contain words that you do not understand. Please ask me to stop as we go through the information and I will take time to explain. If you have any further questions at a later stage, you may ask me or another member of the research team.

Type and purpose of the research

The food environment is thought to be important in shaping diets and health by making food vendors and products available, accessible, affordable, desirable and convenient to people as they go about their everyday lives. We want to find out more about your behaviours and experiences related to the food environment in your community. Our aim is to learn more about your food environment and how you interact with it to acquire food, so that we might be able to identify ways to sustain or improve it and thereby positively impact diets and health in your community. In particular, we are interested in how acquiring food fits into your day to day life and activities. We are also interested in finding out about how men and women experience and interact with the food environment in your community. We are also interested in finding out the best way to capture people's interactions with their food environment.

Participant selection

You are being invited to participate in this research as we are interested in learning more about the food environment of the APCAPS. We feel that your knowledge, experiences and behaviours can contribute to our understanding of consumer-food environment interactions and food acquisition in your community. You were selected at random from all the residents in your village community. Your village was chosen as we think it will help us understand more about how people interact with the food environment in the wider APCAPS sites.

Voluntary participation

Your participation in this research is entirely voluntary. It is your choice whether to participate or not. You may change your mind and stop participating at any point during the project, and any data collected will be destroyed.

Procedures

We are asking you to help us learn more about how people such as yourself interact with the food environment in your community. We are therefore inviting you to take part in this research project. If you accept, you will be asked to participate in a one to one in-depth interview about your experiences of the food environment in your community, including how you interact with food sources to acquire food.

We would like to know about the things that you think are important in your food environment, including things that influence where, when, with whom, why and how you get the foods that you eat.

During the interview you will be asked questions about your interactions with the food environment in your community. We will ask you to discuss the things that you think are important in your food environment, including things that influence where, when, with whom, why and how you get the foods that you eat. We would like to know about the types of food vendors that you usually visit, and the types of foods that you acquire. We will also ask you to tell us about how your food environment interactions fit in with your daily movements and activities. We are interested in learning about the factors that are important to you.

The interview will be conducted in Telugu and led by researchers from the National Institute for Nutrition. None of the questions are intended to ask about embarrassing topics or sensitive information, and you are free to not answer or withdraw at any point should you feel uncomfortable. Here is an example of the kind of questions you may be asked, “Can you tell me about this picture?”.

The interview will take place in your home, or in a private space that you are comfortable with, and no one else but the researchers will be present during this discussion. An audio recording of the interview will be taken. The audio files will be kept safe and stored at the National Institute for Nutrition. The information recorded is confidential, and no one else except the research team will have access to the files. We may use quotes from the discussions when presenting findings from our research but these will be strictly anonymous. The files will be destroyed after 10 years.

Duration

Part one will last for three days. The follow-up interviews for part two will take place after a few weeks. You will be contacted by the research team to arrange a convenient date and time when you will be available. The interview is expected to last around one hour.

Risks/discomfort

You will be required to wear and/or carry the small GPS device and camera. However, this is not expected to cause discomfort or put you at risk. It is possible that other people, including strangers, may ask questions about the devices or wish to know about the study. You will be provided with information and instructions about how to respond if such as situation is to arise.

During the one to one interview, it is possible that you may feel uncomfortable talking about some of the topics. This is not our intention, and you do not have to answer any question if you feel uncomfortable at any time. We would like to remind you that you can withdraw from the study at any time.

Benefits

There will be no direct benefit to you, however we hope that you may find it interesting to see the maps and photographs of your daily movements your food environment. We also hope that the research may help you reflect on your own practices. Your participation will help us to understand more about how to improve or sustain health in your community.

Confidentiality

Your personal information, maps and photographs will remain strictly confidential. The information that we collect from this research project will be anonymised, kept private and safely stored on password protected computers at the National Institute for Nutrition in Hyderabad, India. Researchers will only be able to access the data for the specific purposes of analysis.

Sharing the results

Nothing that you tell us today will be attributable to you. Your responses may be shared with others or quoted in publications, but only in anonymized form. Results and findings will be published so that other interested people may learn from the research.

Right to refuse or withdraw

You do not have to answer any question or take part in the discussion if you feel uncomfortable at any time. You are free to withdraw from the study at any point should you feel uncomfortable, with no consequence to your status within the on-going APCAPS research.

Ethical approval

This research has been approved by the Ethics Review Committees of the Public Health Foundation India (PHFI) and the National Institute of Nutrition (NIN), Hyderabad, India. These are committees whose task it is to make sure that research participants are protected from harm.

This proposal has further been approved by the Ethics Review Committees of the London School of Hygiene and Tropical Medicine, London, United Kingdom, which is supporting and partly funding this study.

Who to contact

If you require any further information or need to clarify some issue, you can contact any of our study team members at National Institute of Nutrition, Hyderabad

Tel: National Institute of Nutrition: Dr Bharati Kulkarni XXX–XXXXXXXX

Tel: Project Coordinator: Ms. Santhi Bhogadi: XXX–XXXXXXXX

Consent form: In depth interviews

Certificate of consent

- I have been invited to participate in research about my use of the food environment, including questions related to who, what, when, where why and how I get food.
- I agree to being interviewed about my interactions with the food environment in my community, and the types of things that influence where, when, with whom, why and how I get the foods that I eat.
- I have been informed about the research process including the nature, objective and known likely inconveniences related to this study
- My information is strictly confidential and I will have full anonymity in any publication or presentation of the data
- I am aware that anonymised data may be published electronically
- I understand that I may not gain anything by participating in the study, although it may be beneficial to my community in the long term
- I have been given a hard copy of the information sheet and consent form
- I am free to participate or not to participate in this study
- I understand that I can withdraw from the study at any point without giving any reasons, and that withdrawing from the study will not affect me in any way
- I voluntarily consent to participate in this study
- I hereby give my permission for the use of anonymised quotations in publications
- By signing this document, I have not given up my legal rights

I hereby confirm that I have read the foregoing information, or it has been read to me in my own language. I have had the opportunity to ask any questions about the research, and all questions have been answered to my satisfaction.

Name of participant (Print) _____

Signature of participant_____

Date (DD/MM/YEAR)_____

Thumbprint of participant

Statement by witness

I have witnessed the accurate reading of the consent form to the potential participant, and the individual has had the opportunity to ask questions. I confirm that the individual has given consent freely.

Name of witness (Print)_____

Signature of witness_____

Date (DD/MM/YEAR)_____

Thumbprint of witness

Statement by the researcher/person taking consent

- I have accurately read out the information sheet to the potential participant, and to the best of my ability made sure that the participant understands what has been said, including,
- The purpose and procedure of the study
- That she/he is free to participate or not participate
- That she/he may withdraw from the study at any time
- How the data will be collected, stored, protected, and used
- How the results will be shared and published.
- I confirm that the participant was given an opportunity to ask questions about the study. and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.
- A copy of this informed consent form has been provided to the participant.

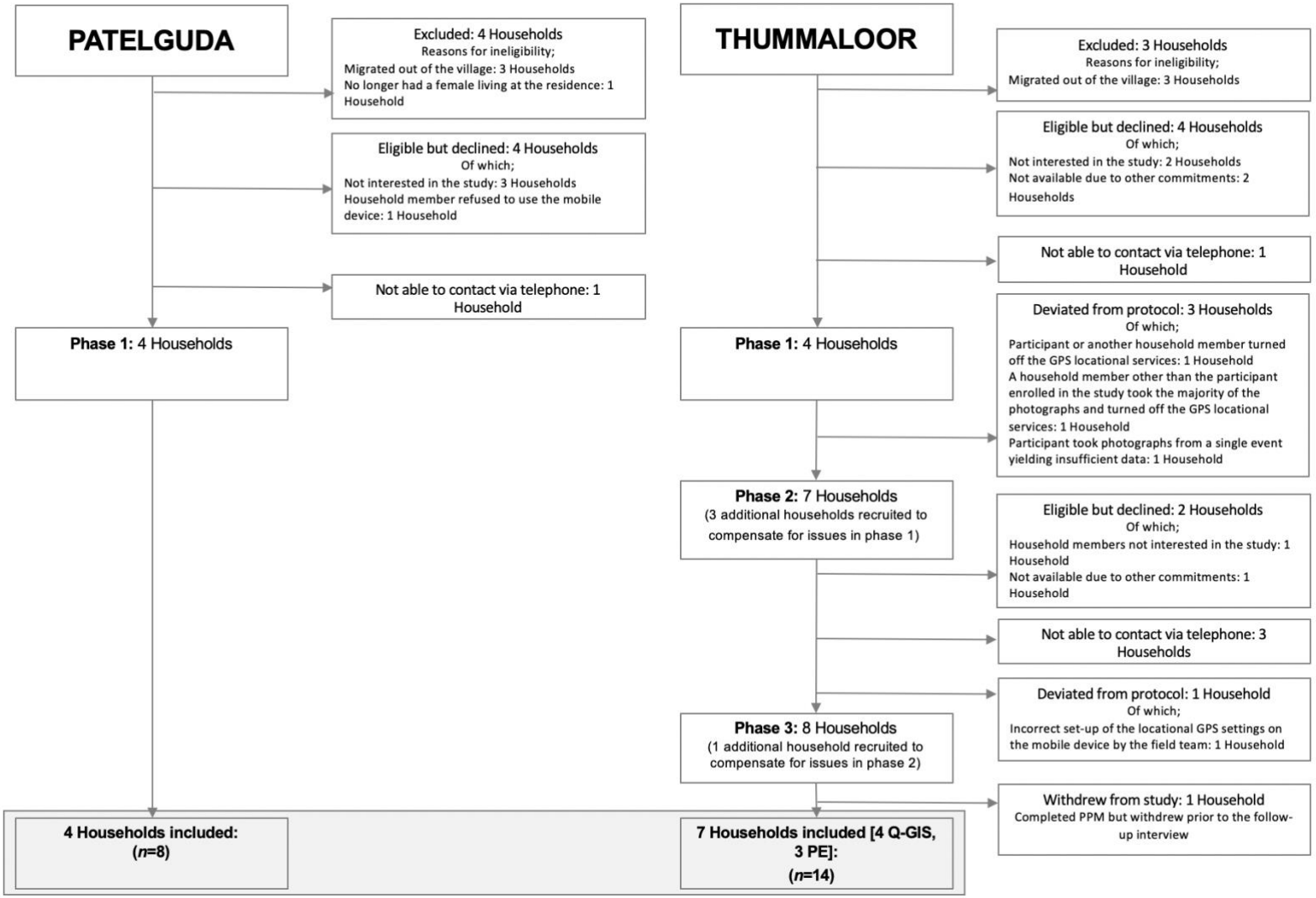
Details of researcher/person taking the consent

Name (print) _____

Signature _____

Date (DD/MM/YEAR)_____

Supplemental Material 5: Flow chart - Recruitment of Q-GIS households by village.



8.3.Appendix 3: Publication 4

Supplemental Material 1: Topic guides – Q-GIS approach (for IDI see Appendix 2 supplementary material 1).

Topic Guide: Q-GIS Graphic- and photo-elicitation interviews

This research is about your 'food environment', including all sources of food such as market, own production (if any) and gifts from friends or family. We also hope to learn about your personal food acquisition practices and what you think is important in shaping the foods that you eat.

Ice breaker

1. Introduce the map and the photographs. Explain that the map shows their photographs
2. Explain that we will annotate the maps during the interview, adding thoughts and comments
3. Start by pointing out the participant's home.

"We would like you to show and tell us, with the help of the map and the photographs, how food fits into your daily life and activities"

Personal Food Environment interactions

- Can you talk me through some of the photographs?

  Please tell me about a photograph that you like the best, or that you feel is important

  What made you decide to take the photograph, what does it represent?

  What is happening in the photo, what do you see, how does it relate to food and your daily life?

(Probe: who; what; when; where; why; how often; how did you get there?)

- Can you tell me about how getting food fits into your daily routines and activities?

  Where did you get food from this week? Can you give examples and describe some regular food sources?

  Are there any sources of food that stand out as being particularly important to you?

(Probe: who; what; when; where; why; how often; how did you get there?)

- Are there any sources of food that have been missed from the map/photographs or that we have not talked about? *Probes:*
  - *Market sources (Street food vendors, Snacks, Drinks, Supermarkets, Wholesale)*
  - *Own production (Home garden, Rural area)*
  - *Gifts from friends/family (Festivals)*

- What factors do you think are important in shaping where you get your food from? *Probes:*
  - *Availability/accessibility (distance, travel time, activities, transport)*
  - *Price/affordability (monetary value of products)*
  - *Vendor and product properties (opening hours, services, quality, safety)*
  - *Convenience (time and effort of preparing, cooking, eating)*
  - *Marketing and regulation (advertising, branding, labelling)*
  - *Desirability (preference, taste, desire, culture, skills, knowledge)*

Perceptions of the local food environment

- How has your local food environment has changed over the past 10 years?

  How do you feel about the changes?

  In what way has it changed? Can you give some examples? ***Probes:***
  - *Availability/accessibility (distance, travel time, activities, transport)*
  - *Price/affordability (monetary value of products)*
  - *Vendor and product properties (opening hours, services, quality, safety)*
  - *Convenience (time and effort of preparing, cooking, eating)*
  - *Marketing and regulation (advertising, branding, labelling)*
  - *Desirability (preference, taste, desire, culture, skills, knowledge)*

- Do you think you have changed the way you get foods over this time?

  Can you give some examples? Why do you think you have changed? *Probes:*

  - *Market sources (Street food vendors, Snacks, Drinks, Supermarkets, Wholesale)*
  - *Own production (Home garden, Rural area)*
  - *Gifts from friends/family (Festivals)*

- How do you feel about your local food environment today?

  What things do you value?

  What, if anything, would you like to see change?

Intra-household dynamics

- Who is usually the household food provider?
- Who makes decisions about what to eat in the household?

  (Probes: why?)

- Who physically goes out to get the food for the household?

  (Probes: who; what; when; where; why; how often; how did you get there?)

- Who is usually doing the food preparation and cooking?

  (Probes: who; what; when; where; why; how often?)

Q-GIS approach: acceptability & feasibility – PPM and interviews

- What was your experience of using the mobile device?

  Were you familiar with using a smartphone prior to the study?

  How did you find using the camera application?

  Were there any problems with the device?

- Were there any times when you felt uncomfortable using the device or taking photos?

  If so, can you give an example (Where; when; why?)

- Were there any times when you altered your activities because of participating in the study?

  If so, can you give an example (Where; when; why?)

- Were there any occasions when people asked why you were taking photographs?

  If so, how did they react when you told them about the study?

- Do you feel the map and photographs reflect your daily routines and interactions with food?

  If not, what is missing?

- How do you feel about discussing the map and photographs in this interview setting?

(Probe: Reason/why?)

- Have you learnt anything or had the chance to reflect on your food acquisition practices?

- Would you recommend other people to take part in a study such as this?

Supplemental Material 2: Ethical approval - Observational ethics committee, London School of Hygiene and Tropical Medicine (see appendix 2 supplemental material 2)

Supplemental Material 3: Ethical approval - Institutional Ethics Committee of the Indian Institute of Public Health under the banner of the Public Health Foundation India (see appendix 2 supplemental material 3)

Supplemental Material 4: CARE forms - Participant information sheets, consent forms (for IDI see appendix 2 supplemental material 4)

Participant information sheet: QGIS Graphic Elicitation Interviews

Principle investigator: MPhil Christopher Turner (London School of Hygiene and Tropical Medicine and the Leverhulme Centre for Integrated Research on Agriculture, Nutrition and Health)

Project name: A Qualitative Investigation of Consumer-Food Environment Interactions in the APCAPS, India

Participant information sheet for (Print)_____

Introduction

We are researchers working for the National Institute for Nutrition, Hyderabad, and the London School of Hygiene and Tropical Medicine, London. We are researching the food environment of your community as part of APCAPS, including information about when, where, why and how people such as yourself acquire food.

This information sheet provides details about the study and invites you to take part in this research. You do not have to make a decision today about whether or not you will participate. Before you make your decision you may talk to anyone that you feel comfortable with about what taking part in this research entails.

This information sheet may contain words that you do not understand. Please ask me to stop as we go through the information and I will take time to explain. If you have any further questions at a later stage, you may ask me or another member of the research team.

Type and purpose of the research

The food environment is thought to be important in shaping diets and health by making food vendors and products available, accessible, affordable, desirable and convenient to people as they go about their everyday lives. We want to find out more about your behaviours and experiences related to the food environment in your community. Our aim is to learn more about your food environment and how you interact with it, so that we might be able to identify ways to sustain or improve it and thereby positively impact diets and health in your community. In particular, we are interested in how acquiring food fits into your day to day life and activities. We are also interested in finding out about how men and women experience

and interact with the food environment in your community. We are also interested in finding out the best way to capture people's interactions with their food environment.

Participant selection

You are being invited to participate in this research as we are interested in learning more about the food environment of the APCAPS. We feel that your knowledge, experiences and behaviours can contribute to our understanding of consumer-food environment interactions and food acquisition in your community. You were selected at random from all the residents in your village community. Your village was chosen as we think it will help us understand more about how people interact with the food environment in the wider APCAPS sites.

Voluntary participation

Your participation in this research is entirely voluntary. It is your choice whether to participate or not. You may change your mind and stop participating at any point during the project, and any data collected will be destroyed.

Procedures

We are asking you to help us learn more about how people such as yourself interact with the food environment in your community. We are therefore inviting you to take part in this research project. If you accept, you will be asked to participate in the two main activities.

For the first activity we would like you to use a mobile phone device to take photographs of your food environment as you interact with it over a three-day period. We would like you to take pictures of the things that you think are important in shaping your daily food acquisition practices, including things that influence where, when, with whom, why and how you get the foods that you eat. For example, photographs could feature your regular sources of foods. This might be food stores, your own production, or gifts from others. Photographs could also feature foods that you usually eat. They could also include other factors such as the mode of transport that you use to travel to sources of food. Photographs could even include other factors that you feel are important to your diet.

We want to find out more about your behaviours and experiences related to the food environment in your community. Our aim is to learn more about your food environment and how you interact with it, and in this regard there is no right or wrong photograph. It is intended that the images you take are meaningful to you in relation to your food.

Before we start the study, you will receive training and guidance about how to operate the mobile phone device and the camera application. This will include how to turn off the device

and delete any photographs that you are not happy with or feel uncomfortable with sharing for any reason.

At the end of the three days we will collect the camera and you will be given the opportunity to view the photographs you have taken. You will be given the opportunity to delete any photographs that you are not comfortable with. You will be able to request to view the photographs at any time.

For the second activity, you will be required to participate in a follow-up interview where we will show you maps and the photographs that you have taken of your food environment interactions. During the interview you will be asked questions about your interactions with the food environment in your community. We will ask you to discuss, with the aid of the maps and pictures, the types of food vendors that you usually visit, and the types of foods that you acquire. We will also ask you to tell us about how your food environment interactions fit in with your daily movements and activities, including those shown in the maps and photographs and more generally. We are interested in learning about the factors that are important to you. You will also be asked about your experiences of using the camera during the study.

The interview will be conducted in Telugu and led by researchers from the National Institute for Nutrition. None of the questions are intended to ask about embarrassing topics or sensitive information, and you are free to not answer or withdraw at any point should you feel uncomfortable. Here is an example of the kind of questions you may be asked, “Can you tell me about this picture?”.

The interview will take place in your home, or in a private space that you are comfortable with, and no one else but the researchers will be present during this discussion. An audio recording of the interview will be taken. The audio files will be kept safe and stored at the National Institute for Nutrition. The information recorded is confidential, and no one else except the research team will have access to the files. We may use quotes from the discussions when presenting findings from our research but these will be strictly anonymous. The files will be destroyed after 10 years.

Duration

Part one will last for three days. The follow-up interviews for part two will take place after a few weeks. You will be contacted by the research team to arrange a convenient date and time when you will be available. The interview is expected to last around one hour.

Risks/discomfort

You will be required to wear and/or carry the small GPS device and camera. However, this is not expected to cause discomfort or put you at risk. It is possible that other people, including strangers, may ask questions about the devices or wish to know about the study. You will be provided with information and instructions about how to respond if such as situation is to arise.

During the one to one interview, it is possible that you may feel uncomfortable talking about some of the topics. This is not our intention, and you do not have to answer any question if you feel uncomfortable at any time. We would like to remind you that you can withdraw from the study at any time.

Benefits

There will be no direct benefit to you, however we hope that you may find it interesting to see the maps and photographs of your daily movements your food environment. We also hope that the research may help you reflect on your own practices. Your participation will help us to understand more about how to improve or sustain health in your community.

Confidentiality

Your personal information, maps and photographs will remain strictly confidential. The information that we collect from this research project will be anonymised, kept private and safely stored on password protected computers at the National Institute for Nutrition in Hyderabad, India. Researchers will only be able to access the data for the specific purposes of analysis.

Sharing the results

Nothing that you tell us today will be attributable to you. Your responses may be shared with others or quoted in publications, but only in anonymized form. Results and findings will be published so that other interested people may learn from the research.

Right to refuse or withdraw

You do not have to answer any question or take part in the discussion if you feel uncomfortable at any time. You are free to withdraw from the study at any point should you feel uncomfortable, with no consequence to your status within the on-going APCAPS research.

Ethical approval

This research has been approved by the Ethics Review Committees of the Public Health Foundation India (PHFI) and the National Institute of Nutrition (NIN), Hyderabad, India. These are committees whose task it is to make sure that research participants are protected from harm.

This proposal has further been approved by the Ethics Review Committees of the London School of Hygiene and Tropical Medicine, London, United Kingdom, which is supporting and partly funding this study.

Who to contact

If you require any further information or need to clarify some issue, you can contact any of our study team members at National Institute of Nutrition, Hyderabad

Tel: National Institute of Nutrition: Dr Bharati Kulkarni XXX–XXXXXXXX

Project Coordinator: Ms. Santhi Bhogadi: XXX–XXXXXXXX

Consent form: Q-GIS approach

Certificate of consent

- I have been invited to participate in research about my use of the food environment, including questions related to who, what, when, where why and how I get food.
- I agree to taking first person point of view photographs of my food environment with a GPS enabled camera for the duration of the study period
- I agree for maps showing the location of my photographs to be made
- I agree to being interviewed about my interactions with the food environment in relation to my movements and photographs shown in the maps
- I agree to being interviewed about my experiences of using the equipment, including the photographic camera
- I have been informed about the research process including the nature, objective and known likely inconveniences related to this study
- I am aware that the people and environment that I photograph during the study may be recognisable in the maps and photographs produced
- I am aware that I can turn off the camera at any time during the data collection
- I am aware that I will be given an opportunity to view the images upon completion of the data collection, and may further view the images at any time
- I am aware that I can withdraw consent, in which case the image will be deleted permanently from the database
- I have been made aware that full recovery of the image may not be possible once it has been made available for publication
- My information is strictly confidential and I will have full anonymity in any publication or presentation of the data
- I am aware that anonymised data may be published electronically
- I understand that I may not gain anything by participating in the study, although it may be beneficial to my community in the long term
- I have been given a hard copy of the information sheet and consent form
- I am free to participate or not to participate in this study
- I understand that I can withdraw from the study at any point without giving any reasons, and that withdrawing from the study will not affect me in any way
- I voluntarily consent to participate in this study
- I hereby give my permission for the recording of my location within the photographs I take for the duration of the study
- By signing this document, I have not given up my legal rights

Signature of consent

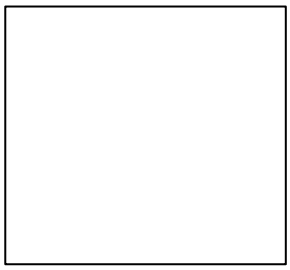
I hereby confirm that I have read the foregoing information, or it has been read to me in my own language. I have had the opportunity to ask any questions about the research, and all questions have been answered to my satisfaction.

Name of participant (Print) _____

Signature of participant_____

Date (DD/MM/YEAR)_____

Thumbprint of participant



Statement by witness

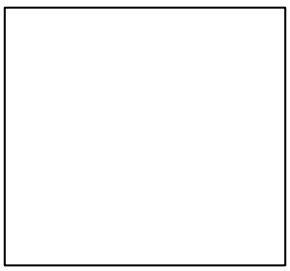
I have witnessed the accurate reading of the consent form to the potential participant, and the individual has had the opportunity to ask questions. I confirm that the individual has given consent freely.

Name of witness (Print)_____

Signature of witness_____

Date (DD/MM/YEAR)_____

Thumbprint of witness



Statement by the researcher/person taking consent

- I have accurately read out the information sheet to the potential participant, and to the best of my ability made sure that the participant understands what has been said, including,
- The purpose and procedure of the study
- That she/he is free to participate or not participate
- That she/he may withdraw from the study at any time
- How the data will be collected, stored, protected, and used
- How the results will be shared and published.
- I confirm that the participant was given an opportunity to ask questions about the study. and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.
- A copy of this informed consent form has been provided to the participant.

Details of researcher/person taking the consent

Name (print) _____

Signature _____

Date (DD/MM/YEAR)_____

Supplemental Material 5: Participant flow chart - Q-GIS and IDI households by village