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The rural food environment and its association with diet, nutrition status, and health outcomes in low-income and middle-income countries (LMICs): a systematic review

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Abstract

Background The food environment consists of external and personal domains that shape food purchasing decisions. While research on food environments has grown rapidly within high-income countries (HICs) in response to increasing rates of overweight, obesity, and non-communicable diseases (NCDs), critical research gaps remain. The role of food environment on diet, health and nutrition has been understudied in LMICs. To date, there has not been a systematic review specifically focusing on rural LMICs. This systematic review aims to synthesize findings from studies examining the association between rural food environment domains and diet, nutrition and health in LMICs or effects of food environment interventions on these outcomes.

Methods Searches were conducted from 9 databases: Medline (PubMed), Embase (Ovid), Global Health (Ovid), PsycINFO (Ovid), EconLit (EBSCOhost), Web of Science (Social Science Citation Index), Scopus, CINAHL (EBSCOhost), and Applied Social Sciences Index and Abstracts (ProQuest) to identify studies published between 2000 and 2023 that reported associations between this/these dimensions with diets, nutrition or health outcomes. Both quantitative and qualitative studies that were published in English were included. Data extraction and quality appraisal was conducted independently by two authors, before the study findings were collated and summarized through a narrative data synthesis.

Results Nineteen eligible studies were identified from 9 databases covering 11 LMICs. The included studies employed quantitative ($n=12$), mixed method ($n=6$) and qualitative ($n=1$) designs in the neighbourhood food environment. In this review, availability dimension of the external food environment featured most prominently, followed by accessibility, affordability, desirability, and convenience dimensions of the personal food environment. Food availability was positively associated with diet ($n=10$), nutrition ($n=7$) and health ($n=1$). There was good evidence regarding associations between food accessibility, diet ($n=7$) and nutrition ($n=3$). We identified some evidence that food price and affordability ($n=8$) were considered key barriers to achieving healthy diets. Desirability ($n=4$) and convenience ($n=2$) dimensions were also associated with dietary outcomes, although we found only a few studies. Only one South African qualitative study was identified which highlighted limited availability and accessibility to local

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supermarkets and surrounding informal fruit and vegetable vendors to be a barrier to expensive, healthy foods consumption. Finally, evidence regarding health outcomes, sustainability dimension, impacts of food environment interventions on relevant outcomes and interactions between food environment dimensions was missing. Overall, seven out of nineteen studies were rated as good quality, six were rated as fair and six were rated as poor.

Conclusions Future interventions should consider improving availability and accessibility of nutritious foods to improve public health nutrition in rural LMICs. Evidence from studies assessing the workplace, home, and school food environments, food environment interventions, sustainability dimension and other key dimensions of the external food environment such as prices, vendor and product properties and marketing and regulation is needed to identify effective interventions to address malnutrition in all its forms characterized by the coexistence of undernutrition, overnutrition, undernutrition and diet-related non-communicable diseases (NCDs).

Keywords Rural food environment, Low- and middle-income countries, Diet, Nutrition, Health

Background

Globally, malnutrition in all its forms (coexistence of undernutrition, overnutrition, and diet-related non-communicable diseases (NCDs) [3–6] is the leading cause of illness and death [1, 2]. Many countries (88%) are increasingly facing multiple forms of malnutrition [1, 2]. Worldwide, one in every nine people is hungry, while one in every three people is overweight or obese [2].

This burden of malnutrition is particularly pronounced in rural areas. Forty-three percent of the world's population reside in rural LMICs [12]. Globally, stunting is 1.6 times higher, and wasting is 1.4 times higher in rural areas than urban areas [13]. At the same time, BMI has increased faster in rural settings from 1985 to 2017 [14]. The rate of increase in overweight women of reproductive age is higher in rural areas than urban areas in almost half of LMICs [15]. Further, "The State of Security and Nutrition in the World (2024)" report highlights that affordability of a nutritious diet is lower in rural areas compared to urban areas. This affordability gap is becoming increasingly critical as rural households are increasingly relying on economic food purchases [13]. Although consumption of highly processed foods is higher in urban areas, rural households are now consuming processed foods, including highly processed foods even in remote areas [13]. The rural food environment is adapting to these emerging demands. However, as rural food systems adapt, it is equally vital for consumers to shift towards sustainable healthy diets, the diet that "protects the environment while feeding a growing population with healthy, culturally appropriate, acceptable, and desirable food" [1].

Food environments are critical spaces within the food system for tackling the drivers of malnutrition [1] and offering rural consumers access to sustainable diet options. These drivers include the "physical, economic, policy and sociocultural surroundings, opportunities and conditions" that significantly influence dietary behaviour, health and nutrition [7]. Both the external domains (food availability, prices, vendor and product properties and marketing and regulation) and the personal domains (accessibility, affordability, convenience, and desirability) influence how people acquire and consume food. The expanded definition developed by Downs et al. [1], now incorporates the "sustainable properties of food and beverages", linking food environments to sustainable diets.

Individuals interact with the food environment to make decisions related to where and what foods to acquire, prepare and consume [52]. These decisions have implications on their diets, nutrition and health outcomes [52]. The growing recognition of the food environment's influence and its importance and critical role on diets and nutrition is reflected in the increasing number of publications investigating this domain [49]. This expanding body of research underscores the importance of understanding the full scope of rural food environments to design effective nutritional interventions. Key dimensions such as availability, affordability, accessibility, convenience, desirability, and sustainability must be comprehensively analyzed. While research on food environments has grown rapidly within high-income countries (HICs) in response to increasing rates of overweight, obesity, and non-communicable diseases (NCDs), it is imperative to also examine knowledge and evidence from low- and middle-income countries (LMICs), given the substantial differences in food systems and consumption patterns between HICs and LMICs. Several systematic reviews from HICs have reported associations between food environment dimensions (e.g., affordability, marketing and regulation) and dietary and health [8, 9]. These have prompted policy makers to develop interventions and policies aimed at encouraging the consumption of healthy diets to improve health outcomes [10, 11]. For instance, there are several examples of successful interventions conducted in HICs implemented by policy makers as a result of published systematic reviews, including the US Supplemental Nutrition Assistance Program (SNAP), which incentivizes the use of subsidies for the purchasing healthy foods

[54] and Hungary's broad-based junk food tax, aimed at reducing purchases of processed foods [55].

Despite the recent interests in food environment research in LMICs [16], critical research gaps remain. The role of food environment on diet, health and nutrition has been understudied in LMICs, particularly the multitude of external and personal food environment domains [1, 8, 17, 18]. At present, theoretical concepts, context specific study designs, metrics and methods remain highly inconsistent, leading to a body of literature that is increasingly heterogeneous and poorly understood. A recent scoping review on food environment research in LMICs finds limited evidence from high-quality studies examining the relationships between food environment dimensions and dietary, nutrition and health outcomes [16]. Furthermore, evidence on the associations between food environment dimensions and nutrition outcomes is unclear while findings regarding health outcomes are nearly nonexistent [16]. However, to date, a systematic review that specifically focuses on rural LMICs has not been conducted.

Context-specific empirical research is necessary for understanding how the food environment influences diet, nutrition, and health in rural LMICs. An understanding of consumer behavior with respect to different food environments and which food environment dimensions are of particular importance to dietary and nutritional outcomes across diverse rural LMIC settings and populations, is crucial. Such knowledge may support evidence-based decision-making and guide the design of future interventions. This systematic review aims to bridge this gap by synthesizing the scope, extent, and range of published literature on the impact of the rural food environment on diet, health and nutrition and related interventions on these outcomes in LMICs.

Methods

Identification of studies

This systematic review was registered prospectively on PROSPERO (CRD42023425324) and follows the PRISMA reporting guidelines [19]. We used the strategy reported by [16] to search Scopus, and we developed comparable strategies to also search Medline (PubMed), Embase (Ovid), Global Health (Ovid), PsycINFO (Ovid), EconLit (EBSCOhost), Web of Science (Social Science Citation Index), Scopus, CINAHL (EBSCOhost), and Applied Social Sciences Index and Abstracts (ProQuest).

The databases were initially searched December 15, 2023, and searches were updated on January 27, 2025. Search results were limited to documents published between January 1, 2000 and December 31, 2023. The search terms used in these databases were the following: ("Food Environment*" OR "food landscape*" OR foodscape* OR "nutrition* landscape*" OR "nutrition* desert*" OR "nutrition* swamp*" OR "Food desert*" OR "Food swamp*" OR "Obesogenic environment*" OR "Nutrition* environment*")). Search strategies for the databases are presented in supplementary Table 1.

Titles and abstracts were independently screened by two reviewers (SC and AZ) identifying articles with the potential to meet the inclusion criteria outlined below. Full texts were retrieved and again independently assessed for eligibility by the same two reviewers. Any disagreements were resolved through discussion between the two reviewers (SC and AZ) and with a third reviewer (PCV) where required.

Systematic reviews were excluded, however reference lists of relevant reviews identified in database searches were checked to identify any additional eligible primary studies. Protocols, theses, conference proceedings/abstracts, news articles, case series and case reports were also excluded. Forward and backward citation chasing was conducted on studies identified and included as full text. These citations were screened following the same process outlined for database searches. Any disagreement was resolved by consensus. Screening was conducted using EndNote 20.

Inclusion criteria

Original, peer reviewed studies including quantitative and qualitative studies were considered for inclusion if they featured one or more rural settings specific to the LMIC context[1]; analyzed at least one characteristic/domain of the food environment[2]; and reported associations between this/these characteristics/dimensions with diets, nutrition status, or health outcomes (e.g. prevalence of obesity, hypertension, diabetes or any other health outcome) or impacts of food environment interventions on these outcomes as well as the interactions between food environment domains [16].

Geographic filters were included, restricting the search to LMICs as defined by the World Bank for the fiscal year 2023 [53]. We restricted the search to studies published since the year 2000 as no potentially relevant articles were identified prior to this date [16]. Only peer-reviewed journal articles published in the English language were included. No age limits were set for databases.

[1] According to the World Bank "There is no universal standard for distinguishing rural from urban areas, and any urban–rural dichotomy is an oversimplification." For instance, in South Asia, rural areas are often defined as places that are characterized by low population density, open land, fewer buildings, agricultural landscape and located outside towns and cities.

[2] External domain: Food availability, food prices, vendor and product properties, marketing and regulation; Internal domain: Accessibility, affordability, convenience and desirability; Sustainability properties of food and beverages.

Table 1 Food environment domains and dimensions, adopted from Turner et al. [16] and Downs et al. [1]

Food environment domains and dimensions	Measurement
External domain	
Food availability	Presence of food sources or products in a given context
Food prices	The actual monetary cost of purchasing food
Vendor and product properties	The characteristics of food vendors (opening hours, type of service etc.) and food products (quality, nutritional composition, level of processing, shelf life, packaging)
Marketing and regulation	Food marketing in various types (advertising, branding, sponsorship and promotional information) and includes other types of food policy regulations (food labeling)
Personal domain	
Food accessibility	Individual's activity that influences food acquisition (physical distance to shops, time, daily mobility and mode of transport)
Affordability	Consumer's purchasing power
Convenience	Relative time and effort to prepare, cook, and consume food products
Desirability	Individual's preferences, acceptability, tastes, desires, attitudes, culture, knowledge, and skills
Sustainability properties of food and beverages	Environmental and social impact related to food and beverages

Exclusion criteria

Studies were excluded if they: 1) did not feature one or more rural LMIC setting; 2) did not describe at least one dimension of the food environment; 3) did not include relevant outcomes including health, diet and nutrition; and 4) were not original peer-reviewed published articles.

Data extraction and quality appraisal

Relevant information was extracted from each of the included studies and placed into a standardized data form. Extracted data included author (year); study setting and location; data collection; sample; respondents and sample size; study design and method; food environment dimension(s) assessed (availability, prices, vendor and product properties, marketing, accessibility, affordability, convenience, desirability or promotion and quality, sustainability properties of food and beverages); outcome measure(s) (diet, nutrition and health outcomes); and associations. Data were extracted by one reviewer (SC) and checked by a second (AZ).

Quality appraisal was conducted independently by two authors (SC, AZ), before the study findings were collated and summarized through a narrative data synthesis given the considerable heterogeneity across the different studies and reported outcome measures. The risk of bias for each study to be of "good", "fair" or "poor" quality was assessed by following the guidelines outlined in the NHLBI tool for quality assessment, MMAT-checklist and CASP checklist as appropriate. The US National Heart Lung and Blood Institute (NHLBI) checklist was used for longitudinal and cross-sectional studies [20] while Critical Appraisal Skills Programme (CASP) checklist assessed qualitative studies [21]. Mixed-method studies were evaluated using the Mixed-Methods Appraisal Tool (MMAT) checklist [22]. These ratings are used to guide the interpretation of results and conclusions. For instance, findings from poor-quality studies are not used to draw definitive conclusions but rather to highlight the need for further research to gather more robust evidence.

Conceptual framework

We apply the food environment framework developed by Turner et al. [16] for conceptualizing the LMIC food environment as indicated in Table 1. They define food environments (work, school, home, neighbourhood) as defined in Turner's [16] and Downs' [1] frameworks as the "interface at which the consumer engages with the broader food system to acquire and consume foods", influenced by two key domains (external and personal domains). This globally applicable framework identifies the external domains which consist of exogenous domains including food availability, prices, vendor and product properties and marketing and regulation and the personal domains which relate to individual-level domains such as accessibility, affordability, convenience, and desirability [16]. However, for this review we also consider the recent conceptual framework developed by [1],[3] which incorporates dimensions similar to Turner's food environment framework and provides an expanded definition of the food environment and includes "sustainability properties of food and beverages". This recent definition of the food environment states that consumers interact with the food system which includes the "sustainability of foods and beverages in wild, cultivated, and built spaces that are influenced by the socio-cultural and

[3] The importance of wild, and cultivated, food environments are highlighted in the framework. More information is available in [1].

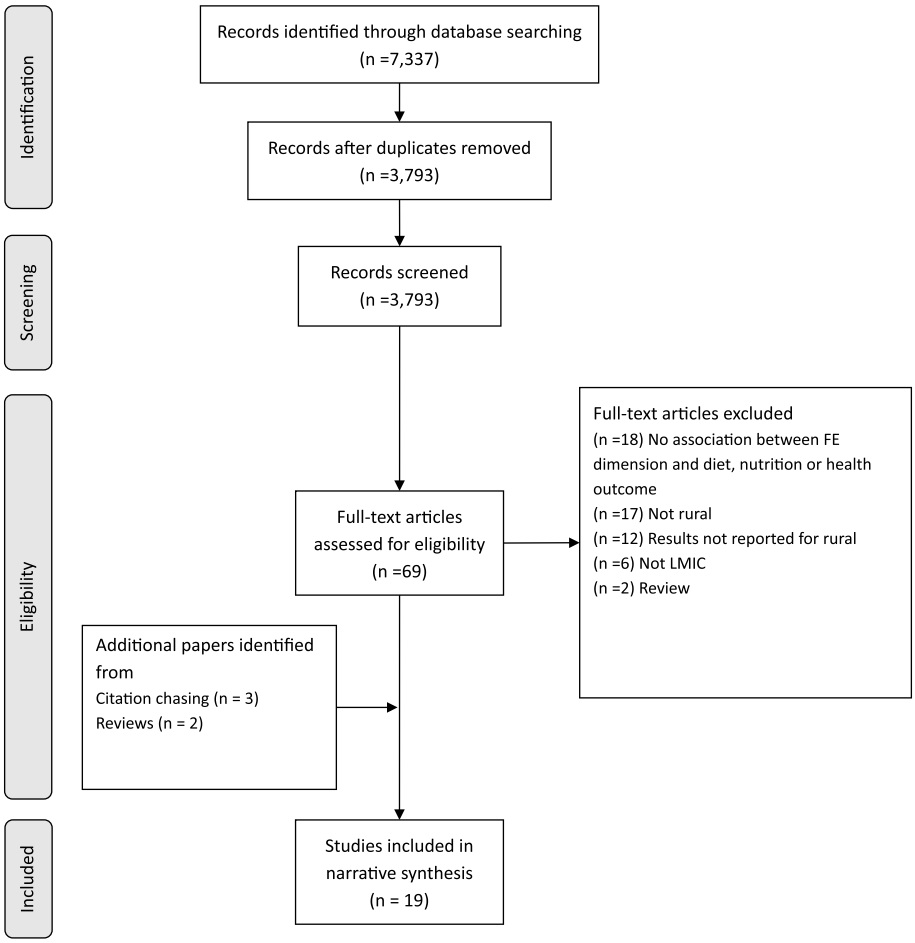

Fig. 1 PRISMA diagram [19]. Moher, D., Liberati, A., Tetzlaff, J., Altman, D., The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement . PLoS Medicine, Vol. 6(7). Available fromhttp://journals.plos.org/plosmedicine/article?id=10.1371/journal.pmed.1000097

political environment and ecosystems within which they are embedded" [1].

Results

Search results

Details of the study screening process are presented in a PRISMA flow diagram (Fig. 1). Electronic databases yielded 3,793 hits after deduplication. The searches were conducted on December 15, 2023. Following title and abstract screening, 69 studies were retrieved at full text from which 15 studies were considered eligible for inclusion in this review.

Amongst the database searches, 50 potentially relevant reviews were identified and checked for additional rural food environment studies yielding a further two studies for inclusion. Forward and backward citation chasing was performed on these 16 studies yielding three additional studies for inclusion. Thus, in total, 19 studies were included in this review.[4]

Characteristics of studies

The majority (83%) of identified studies were published between 2019 and 2023. Characteristics of studies are described in Table 2. The identified studies covered 11 LMICs. Eleven (54.5%) studies represented upper middle-income countries (China ($n=5$), Mexico ($n=2$), Jamaica, Thailand, Namibia and South Africa), six (36%) studies featured lower middle-income countries (Myanmar, Kenya, India ($n=3$) and Vietnam ($n=2$)), and one (9%) study included a low-income country (Uganda). There were no multi-country studies.

[4] This research has been conducted as part of the CGIAR Regional Integrated Initiative Transforming Agrifood Systems in South Asia, or TAFSSA and the CGIAR Research Initiative on Resilient Cities.

Table 2 Characteristics of included studies examining the association between food environment and diet, nutrition, or health outcomes

Author (Year)	Study Setting & location	Dates of data collection	Respondents & Sample size	Study design & Method	FE dimensions	Outcome measure (s)	Association with FE dimensions			Quality of study
							Diet	Nutrition	Health	
[30]	Rural; Zhejian, China	October to December 2021	Schoolchildren aged 8–16 years ($n=4970$); 47.3% female	Cross-sectional; Community-based health survey	Av	BMI (kg/m2) (measured height and weight); Frequency of unhealthy foods (snacks, sugary beverages, and deep-fried foods) (less than 1 time/week, 1 ~ 2 times/week, "3 ~ 4 times/week, 5 ~ 6 times/week, 1 time/day and ~ 2 times/day)	✓	✓	n/a	Good
[23]	Rural & urban; Wakiso, Uganda	July 2017 and January 2018	Women of reproductive age; For quantitative component ($n=73$) and for qualitative component ($n=18$)	Mixed method; Survey (24 h food recall with the context of eating events), photovoice and in-depth interviews	Av, Acc, Aff	Dietary practices	✓	n/a	n/a	Fair
[32]	Rural & urban; Jamaica, Caribbean	2007 and 2008	Adult men and women aged 18–74 years ($n=2529$). Men = 796, women = 1731	Cross-sectional; Secondary data analysis of Jamaica Health and Lifestyle Survey 2008 (JHLS II) and GIS	Av, Acc	Mean Body mass index (BMI) ((calculated as weight divided by height squared (kg/m2))	n/a	x	n/a	Good
[35]	Rural & urban; Magway, Myanmar	June and August 2017	Adult men and women consumer surveys ($n=362$); 20 market surveys Each focus group with eight women aged 21–61 years ($n=32$)	Mixed method; Focus group discussions, market surveys, food consumption surveys	Av, Acc, Aff	Food consumption patterns and preferences	✓	n/a	n/a	Fair
[36]	Rural; Nairobi (Mukuru and Kibera), Kenya	March and July 2019	Women aged 19–57 years; Five focus group discussions ($n=26$) in four villages within Mukuru (2 FGDs) and Kibera (3 FDGs)	Mixed method; GIS mapping, market survey and focus group discussions including participatory social mapping	Av, Aff, Con, Des	Food purchasing patterns	✓	n/a	n/a	Fair

Table 2 (continued)

Author (Year)	Study Setting & location	Dates of data collection	Respondents & Sample size	Study design & Method	FE dimensions	Outcome measure (s)	Association with FE dimensions			Quality of study
							Diet	Nutrition	Health	
[24]	Rural; China	2004, 2006, 2009 and 2011	Men (n = 11,835, mean age = 46–51 years), women (n = 12,561, mean age = 46–51 years)	Longitudinal; China Health and Nutrition Survey (CHNS)	Av	BMI (kg/m2) (measured height and weight)	n/a	✓	n/a	Good
[25]	Rural; Pune, Maharashtra, India	2013 and 2018	Adolescents aged 18 years; (n = 418) (n = 223 boys, n = 195 girls)	Longitudinal; Pune Maternal Nutrition Study (PMNS), National Family Health Survey questionnaire	Av, Acc	BMI (kg/m2) (measured height and weight), daily consumption of foods	✓	✓	n/a	Poor
[37]	Rural; Jharkhand, India	June 2019 and January 2020	Adult men and women of Mundas, an indigenous tribal community, health workers and community leaders; Focus group discussions (n = 9 FGDs) with villagers and key informant interviews (n = 6) with health and nutrition workers and community leaders	Mixed method Survey; FGDs and key informant interviews	Des	Indigenous Food consumption	✓	n/a	n/a	Poor
Heim et al. 2021 [38]	Rural; Namibia	2016–2018	Adult men and women aged between 18–85 years of Khwe San community people; Unstructured interviews with key informants (n = 36) for cultural food domain analysis; 24-h dietary recall surveys (n = 200)	Mixed method; Participant observation, cultural domain analysis, key informant interviews, dietary surveys and ranking exercises	Av, Aff, Con, Des	Dietary diversity scores (DDS)	✓	n/a	n/a	Poor

Table 2 (continued)

Author (Year)	Study Setting & location	Dates of data collection	Respondents & Sample size	Study design & Method	FE dimensions	Outcome measure (s)	Association with FE dimensions			Quality of study
							Diet	Nutrition	Health	
Huang et al. 2019 [26]	Rural, China	1997–2011	Adult healthy men and women adults aged 20–59 years ($n=6775$) (50% male, 50% female),	Longitudinal; China Health and Nutrition Survey data	Acc	Dietary pattern (24-h individual dietary intake)	✓	n/a	n/a	Good
[33]	Rural; Telengana, India	2010–2012	Children born during the time of the Hyderabad Nutrition Trial from 1987 to 1990 ($n=5764$), male = 3329, female = 2435	Cross sectional; Andhra Pradesh children and parents study (APCAPS) and GIS	Av, Acc	11 cardiovascular risk factors, including adiposity measures, glucose-insulin, blood pressure, and lipid profile	n/a	n/a		Fair
Nguyen et al. 2021 [39]	Rural, peri-urban & urban; Vietnam	2021	Primary food shoppers; Quantitative data ($N=750$, 250 each from food rural, urban and peri-urban); Qualitative data ($N=56$, 20 rural, 20 peri-urban and 16 urban)	Mixed method; Household survey, Neighborhood transect walk (GIS), FGDs and in-depth interviews	Av, Acc, Aff, Des	Consumption of processed foods and Anthropometric measures of the children under 5	✓	✓	n/a	Fair
[27]	Rural & urban; Mexico	2002, 2005, 2012	School children aged 5–11 years and adolescents aged 12–19 years ($n=7507$)	Longitudinal; Mexican Family Life Survey; and density of food stores from the Economic censuses of 1999, 2004 and 2009	Av, Aff	Food consumption habits	✓	n/a	n/a	Fair
[34]	Rural & urban; Mae Fah Luang district & Phan district, Thailand	February to early-May 2017	Hill tribe women aged 19–50 years ($n=128$); healthy, not-pregnant and not lactating and no dietary restrictions	Cross-sectional; 24 h dietary recall survey, market survey	Av, Aff	Food consumption habits	✓	n/a	n/a	Poor
[40]	Rural & urban; Eastern Cape Province, South Africa	2021	Adult men and women aged 30–75 years, with type-2 diabetes; urban: $n=10$, rural: $n=10$	Qualitative; Photo Elicitation and FGD	Acc, Av, Aff	Perception of food, places of daily food acquisition and frequency of acquisitions	n/a	n/a	n/a	Good

Table 2 (continued)

Author (Year)	Study Setting & location	Dates of data collection	Respondents & Sample size	Study design & Method	FE dimensions	Outcome measure (s)	Association with FE dimensions			Quality of study
							Diet	Nutrition	Health	
Vuong et al. (2023) [59]	Urban, peri-urban & rural; Cau Giay, Dong Anh & Moc Chau districts, Vietnam	2018	Adult men ($n=297$) and women ($n=298$) aged 18–66 years; urban: $n=$ =217; 109 women & 108 men, peri-urban: $n=158$; 79 women & 79 men, rural: $n=220$; 110 women & 110 men	Cross-sectional; Household survey (24-h dietary survey), mapping of FE through a transect walk along with GPS coordinates	Av, Acc	Diet Quality Index –Vietnam (DQI-V); BMI (kg/m^2)	✓	✓	n/a	Good
Wang et al. 2017 [28]	Rural & urban; China	2004, 2006, 2009, and 2011	Adult men and women aged 18 years and above (mean age = 50) ($n=24,542$), rural = 16,115, urban = 8427	Longitudinal; China Health and Nutrition Survey (CHNS)	Acc	Dietary diversity score (DDS)	✓	n/a	n/a	Poor
[29]	Rural & urban; China	2000, 2004, 2006 and 2009	Adult men and women (in 2000 $n=6285$; in 2004 $n=6536$; in 2006 $n=6481$)	Longitudinal; China Health and Nutrition Survey (CHNS)	Av	Changes in respondents' BMI (kg/m2) (measured height and weight), waist-to-height ratio (WHtR) (cm), waist-to-hip ratio (WHpR) (cm)	n/a	✓	n/a	Good
[31]	Rural; Santa Cruz, Queretaro, Mexico	2021	Children aged 8–10 years ($n=218$) from the elementary school in the community	Cross-sectional; Survey and GIS	Av, Acc	Obesity (measured as body fat%, abdominal fat% and BMI z-score)	n/a	✓	n/a	Poor

All studies focused on the neighbourhood food environment except for [23] which examined both home and neighbourhood settings. ;

Significant association: ✓ = at least one significant association, x = no significant associations, n/a = not applicable

Abbreviations: Av Availability, *Acc* Accessibility, *Aff* Affordability, Con Convenience, *Des* Desirability

The identified studies represented the food environment in the neighbourhood setting ($n=19$) with one study covering both the home and neighbourhood environment [23]. Twelve studies used quantitative study designs either to map the rural food environment or report the association between food environment and diet, nutrition or health outcomes. Over 60% had a longitudinal study design ($n=6$) [24–29] of which four were from China, or cross-sectional design ($n=6$) [30–34, 23, 35–39]. Only one study had a qualitative research design [40].

Study populations covered adults, children and adolescents. Twelve studies included both men and women. Three studies included only female participants while another two studies focused only on children, with one study including both children and adolescents. Nine studies focused solely on rural environments, with the remaining ten studies comparing both urban and rural communities. Associations were shown between food environment and diet ($n=13$), nutrition ($n=8$) and health ($n=1$), in which three studies investigated both diet and nutrition outcomes.

In this review, two key food environment domains (external and personal) as envisaged by [16] were found. Most studies featured multiple food environment domains ($n=12$), including three mixed method studies which assessed four dimensions. The personal food environment domain was most prominent, including dimensions of accessibility ($n=11$), affordability ($n=7$), desirability ($n=4$) and convenience ($n=2$). Six studies focused on one dimension in isolation. In contrast, for the external food environment domain, *availability* was the only dimension studied but it appeared in almost 90% (17/19) of the studies included. Twelve of the eighteen included studies focused on both the external and personal food environment domains. Of these, five studies tackled availability and accessibility, the two most prominent dimensions from each respective domain.

Amongst the identified studies, various dietary and nutrition outcomes were considered. Of the nineteen studies, thirteen investigated dietary outcomes in terms of food purchasing and consumption patterns and preferences [35, 36], food intake frequency, food consumption habits, dietary diversity and dietary practices. Several data methods were used to derive these outcomes, including surveys, photo elicitation, focus group discussions (FGDs), in-depth interviews, and key informant interviews. Two studies (11%) examined dietary outcomes measured as dietary diversity scores using 24-h dietary recall survey while one qualitative study (5%) collected data on participants' perceptions of food, places of daily food acquisition and frequency of acquisitions through FGDs.

Over 40% (8/18) of the studies included nutrition outcomes. BMI, a biomarker to assess nutritional status, was obtained with height and weight measurements of the participants and considered the primary outcome in over 30% (6/18) of the studies. Only one study included obesity as the primary outcome measure. In two studies, outcomes related to undernutrition, including stunted, underweight, and wasted were considered. Finally, one study used cardiovascular risk factors including adiposity measures, glucose-insulin, blood pressure, and lipid profile as the health outcome measure.

Quality assurance

We assessed quantitative studies for bias based on the 14 criteria in the NHLBI tool for quality assessment. None of the cohort studies ($n=6$) and cross-sectional studies ($n=6$) fully met the quality criteria. About more than half (63.6%) of the studies were of good and fair quality, showing low risk of bias. Seven studies were rated as high-quality [24, 26, 29, 30, 32

Six mixed method studies were assessed using the MMAT-checklist. None of the studies fully met the quality criteria. Most studies were of good quality (80–90% of the criteria met). Of all included studies, two were of low quality [37, 38] and four were regarded as fair quality [23, 35, 36, 39]. For the qualitative components, all studies met the criteria except for the poor-quality studies. Neither of the four fair mixed-methods studies was viewed as high quality because it was unclear whether the risk of nonresponses bias was low.

Only one qualitative study was assessed using the CASP checklist [40] which was of good quality. It provided a clear statement of aims, qualitative methodology and research design and met criteria for all domains of quality.

On the whole, seven out of nineteen studies were rated as good quality, six were rated as fair and six were rated as poor.

Further details of our quality appraisal are included in the online supplemental Table 2.

External domain

Availability dimension

The most investigated dimension within the external domain of the neighbourhood food environment was availability. The association between availability and outcome of interest was reported in sixteen studies, including three studies which assessed availability in isolation [24, 29, 30] and one study covering both home and neighbourhood settings [23]. The majority of these studies were mixed method ($n=6$) [23, 35, 36, 38, 39], followed by cross-sectional ($n=6$) [30–34$n=4$) [24, 25, 27, 29] and qualitative ($n=1$) [40]. Most of these studies examined

the presence, density, or number of different types of food retail outlets and checklist of commonly consumed food items with their relevant outcomes. As per the quality assurance detailed in the online supplemental Table 2, the quality of evidence from these studies was high, with 6 studies rated good [24, 29, 30, 32, 40, 23, 27, 33, 35, 36, 39] and 4 rated poor [31, 25, 38, 34].

Longitudinal evidence from the China Health and Nutrition Survey (CHNS), rated as good quality, found significant positive relationships between density of neighbourhood and fast-food restaurants and BMI [24, 29]. For men ($n=11$, 835), an increase of one indoor restaurant in the neighbourhood was associated with a 0.01 kg/m2 rise in BMI, while for women ($n=12{,}561$), an increase of one indoor restaurant in the neighbourhood was associated with a 0.005 kg/m2 rise in BMI [24] from the 2004, 2006, 2009 and 2011 CHNS rounds. The number of western fast-food restaurants was associated with 0.34 future increase in waist-to-height ratio and 0.29 future increase waist-to-hip ratio among rural women analyzed across three rounds: 2000 ($n=6{,}285$), 2004 ($n=6{,}536$) and 2006 ($n=6{,}481$) [29]. A cross-sectional study of good quality from Vietnam showed a negative association between food outlet density and the odds of underweight among women (odds ratio = 0.62; 95% CI = 0.37–0.96) ($n=595$; 298 women and 297 men) [59]. Another cross-sectional evidence from China reported associations between number of different food retail outlets and nutrition and dietary outcomes [30]. The study found a direct positive correlation between number of fast-food restaurants, Chinese-style restaurants, fruit and vegetable stores, supermarkets/convenience stores, and milk tea shops /bakeries/dessert shops within 500 m and children's BMI ($n=4{,}970$). Further, the number of different food retail outlets had a positive impact on unhealthy food consumption, which was positively linked to children's BMI [30]. In contrast, one cross-sectional study using the Jamaica Health and Lifestyle Survey 2008 ($n=2{,}529$) (men, women) did not find an association between the density of fast-food outlets and higher levels of BMI [32].

Of the four mixed method studies of fair quality, subjective food environment measurement such as perception of food availability was found to have variable associations across populations. Two studies [23, 36] suggested that availability dimensions were important for dietary practices. Only one fair quality study examining both home and neighbourhood settings [23]. For instance, using photovoice,[5] type(s) of food available within the household and neighbourhood food outlets was perceived to have a positive influence on consumption of lower environmental impact fruit and vegetables, roots, and tubers where household availability seemed more pertinent amongst rural Ugandan women who largely produced their own food ($n=9$) [23]. Seasonality also influenced their dietary practices. Another study implemented in rural Nairobi, Kenya used a combination of objective and subjective food environment assessments (vendor mapping, collection of food prices, food quality assessments) and five FGDs with women ($n=26$) [36]. Fruits and/or vegetables were commonly sold by vendors ($n=1{,}163$), followed by packaged and dried foods and ready-to-eat meals. FGDs indicated that women usually consumed foods that were available and observed changes in food availability over time [36]. However, in another fair quality study in Myanmar, FGD women participants ($n=32$) from four study settings reported limited availability of healthy foods was a barrier to consuming them [35]. Further, market surveys (men, women) ($n=20$) showed that fresh, minimally processed and highly processed foods were available at all markets while food consumption surveys ($n=362$) indicated a preference for fruits, vegetables and red meat compared to highly processed snack foods/ beverages [35]. Similarly, a South African qualitative study of good quality using photography highlighted that limited availability of fruits and vegetables in local spaza shops made it difficult for participants (men, women) ($n=9$) to eat healthy since these shops only sold unhealthy foods [40].

Evidence from Vietnam, using a combination of subjective and objective food environment measurements such as household survey ($n=250$), neighborhood transect walk (GIS) ($n=10$), FGDs and in-depth interviews ($n=20$) found an association between density of food outlets in the neighborhood and ultra-processed foods consumption [39]. Rural consumers (men, women) consumed more ultra-processed foods such as instant noodles (80%), soft drinks (47%), chips and similar snacks (50%) and sweets (chocolates, candies etc.) (34%) as they were available in traditional convenience stores according to the household survey. They purchased food mostly from informal street markets (41.6%) and traditional convenience stores (39.9%). In-depth interviews with respondents revealed that they preferred shopping at convenience stores and informal open markets over formal open markets as a wide range of food items were available.

A longitudinal study using the Mexican Family Life Survey 2002–2012 ($n=7{,}507$) identified that children from rural areas with the highest density of small food retail stores and density of fruit/vegetable stores had lower BMI ($\beta = -0.84$ kg/m2; 95% CI, −1.61, −0.07) [27].

Only [33] examined the association between availability and health outcome. A cross-sectional study based

[5] Photovoice is a qualitative research method which analyzes photographs taken and selected by respondents.

in Telangana, India, examined associations between vendor density per km^2 within 400 m and 1600 m buffers of households and with 11 cardiovascular risk factors, including adiposity measures, glucose-insulin, blood pressure, and lipid profile ($n=5,764$) [33]. Results showed that higher density of fruit/ vegetable vendors within 400 m of participant households was associated with reduced cardiovascular risk factors. However, higher density of highly processed/take-away food vendors within 400 m of participant households was associated with adverse cardiovascular risk factors.

Four studies examining the availability dimension were rated poor. One cross-sectional study found a positive relationship between density of convenience stores and children's BMI (β =0.03; 95% CI, 0.01–0.06) in rural Mexico ($n=218$) [31]. Another cross-sectional study from Thailand compared dietary nutrient intakes of Hill tribe and urban women and identified that Hill tribe women consumed significantly less iron, vitamin C, animal protein and calcium than the urban group despite having similar food availability ($n=65$) [34]. A longitudinal study from Pune, India reported positive associations between the number and type of food shops per 1,000 population and BMI and daily consumption of foods amongst adolescents ($n=418$) (25[37]. Another mixed method study from Namibia using key informant interviews ($n=36$) and 24-h dietary recall surveys ($n=200$) (adults) reported a lack of availability of several food groups such as eggs, dairy, meat, nuts and seeds resulted in low dietary diversity [38].

Overall, findings from the identified studies support the notion that neighbourhood food availability is significantly associated with diet and nutrition outcomes whilst evidence associated with health outcomes and on home environment setting is limited.

Personal domain

Accessibility dimension

The second most examined dimension within the personal domain of the neighbourhood food environment was accessibility, which was included in ten studies: three longitudinal [25, 26, 28], four cross-sectional [31–33, 23, 35, 39] and one qualitative [40]. Two studies investigated accessibility in isolation [26, 28]. The quality of evidence from these studies was mixed, with 4 rated good [26, 32, 40, 23, 33, 35] and 3 rated poor [25, 28, 31].

One cross-sectional study of good quality using the Jamaica Health and Lifestyle Survey, a nationally representative population-based survey found an association between accessibility and nutrition outcome [32]. Consumers located 10 km nearer to the supermarkets were associated with a 1.7 kg/m2 higher mean BMI (95% CI 0.03 to 0.32) in the middle-class income group ($n=2,529$) [32]. Another cross-sectional study of good quality from Vietnam reported that distance to the.

nearest outlet was associated with higher Diet Quality Index –Vietnam (DQI-V) ($\beta=2.0$; 95% CI = 0.2–3.8; $p=0.036$) and its Moderation component ($\beta=2.6$; 95% CI = 1.2–4.0; p = 0.001) ($n=595$; 298 women and 297 men) [59]. A longitudinal study using CHNS data showed that accessibility was positively associated with dietary outcome [26]. Households living 1 km closer to the market could increase the overall dietary quality by 8% [26].

Three mixed method studies of fair quality found an association between accessibility and relevant outcome, two with a dietary outcome [23, 35], and one with both dietary and nutrition outcome [39]. For example, women participants in Uganda across four dietary typologies using photovoice and in-depth interviews expressed that food accessibility to neighbourhood food outlets influenced their dietary consumption of nutritious foods ($n=9$) [23]. In Myanmar, focus group participants from four study settings cited that physical proximity was not a barrier to accessing either highly processed and fried foods or fresh foods ($n=32$) [35]. No quantitative analyses were undertaken in these studies. Further, in Vietnam, rural households in closest proximity to traditional food outlets (convenience stores, informal street markets, formal open markets) had higher consumption of ultra-processed foods ($n=250$) while qualitative data revealed that limited market access and household's dependence on own production may contribute to child undernutrition (measured as stunted, underweight, and wasted) ($n=20$) [39].

Only one study examined the association between accessibility and health outcome. Cross-sectional evidence from Telangana, India did not find an association between the distance from the household to the nearest vendor and cardiovascular risk factors ($n=5,764$) [33]. Lastly, a South African qualitative study of adults (male or female) aged 30–75 years old diagnosed with Type 2 Diabetes Mellitus reported that long distances to local supermarkets and surrounding informal fruit and vegetable vendors was a barrier to healthy foods consumption [40].

Across the poor-quality studies, a longitudinal study from Pune, India found that higher food accessibility was significantly associated with BMI increase amongst adolescents ($n=418$) [25]. Accessibility to specific food groups was measured by the number of shops selling food items per 1,000 population. Higher access to cereals and pulses was associated with reduced consumption of these food groups ($\beta=-0.13$; $p<0.05$) while higher access to bakery, dry snacks, sweets, and fast foods was associated

with increased consumption (β = 0.14; $p > 0.05$). No association was observed for other food groups such as dairy, nonvegetarian foods, and fruits and vegetables. BMI was reported to have a positive association with food access (β = 0.18; $p < 0.05$). Another longitudinal study using the CHNS reported a positive association between an increase in the number of nearby food facilities and dietary diversity ($n = 16{,}115$) (β = 0.08) [28]. One cross-sectional study from Mexico showed proximity to nearest convenience stores (meters) was associated with higher BMI in school-aged children (β = 0.002; 95% CI, −0.004 to −0.001) ($n = 218$) [31].

In summary, these identified studies provide good evidence that neighbourhood food accessibility is associated with dietary and nutrition outcomes.

Affordability dimension

Affordability was examined in eight studies including five mixed methods [23, 35, 36, 39], one cross-sectional [34], one longitudinal [27] and one qualitative [40]. All found an association with dietary outcomes within the neighborhood food environment setting. One study was rated good [40], five studies were rated fair [23, 27, 35, 36, 39] and two rated poor [34, 38].

Within the four mixed method studies of fair quality [23, 35, 36, 38, 39], affordability and limited purchasing power were cited as major barriers to consuming nutritious foods. Using photovoice, rural Ugandan women highlighted high food prices as determining their dietary practices ($n = 9$). However, only qualitative findings were presented [23]. In Myanmar, specifically lower income focus group participants indicated affordability was a constraint to consuming meat and fish, but vegetables were considered cheap especially when sold by traditional vendors [35]. Further, the consumer ($n = 362$) and market surveys ($n = 20$) reported the prices of selected foods (fruits, vegetables, red meat, processed snacks and drinks) and consumption patterns [35]. Meanwhile in rural Nairobi, Kenya, using subjective food environment measurements, focus group participants revealed that they were able to consume nutrient-rich foods such as meat and fish by purchasing lower quality meat and fish as they were sold at cheaper prices ($n = 26$) [36]. Women participants expressed the existence of trade-off between quality and price, especially for nutrient dense foods. Particularly, fruits, vegetables and animal sourced food were considered unaffordable. In this study, prices of 37 commonly consumed foods were also captured. Descriptive statistics indicated prices of nutrient rich foods (eggs, fish, fruits and some vegetables) were more expensive compared to staples and ready-to-eat foods [36]. Qualitative evidence from a mixed methods study in Vietnam showed that low price levels of processed foods potentially explained higher processed foods consumption among number of participants ($n = 20$) [39]. Moreover, financial constraints were barriers to purchasing more expensive products such as meat. Finally, according to a qualitative study in South Africa, participants perceived healthy foods to be very expensive which made them purchase cheaper packaged foods (energy-dense, processed foods, with more added sugar, salt and fat) ($n = 9$) [40].

Two studies of poor quality were mixed method [38] and cross-sectional [34]. The cross-sectional study from Thailand found a significant and positive relationship between household income and nutrient intakes ($n = 65$) (iron, animal protein, vitamin C and calcium) [34] while the Namibian mixed method study indicated that high cost of food prices influenced households' food purchases, but no other analyses were presented ($n = 36$) [38]. Participants preferred maize meal which was provided for free by the government [38].

Overall, since only one of the studies is rated good, evidence is inconclusive at present and therefore, high-quality studies are needed in this dimension.

Desirability dimension

Four mixed method studies examined the desirability dimension within their neighbourhood food environment setting, all of which found an association between desirability and dietary practices [36–39]. The quality of evidence from these studies was low, with 2 studies rated fair [36, 39] and 2 rated poor [37, 38].

In rural Nairobi, using subjective food environment measurements, FGD participants (women) reported high overall desirability of fruits and vegetables, measured using the Produce Desirability (ProDes) tool. However, the participants expressed several concerns regarding the quality of edible oil and meat. These concerns did not impact their fruits and vegetable consumption ($n = 26$) [36]. No other quantitative analyses were presented in this study. Meanwhile, a study in Vietnam that also used subjective and objective food environment measurements found that households preferred to purchase their food items from informal street markets (41.6%) and traditional convenience stores (39.9%) ($n = 250$) [39] examined using household survey data while FGDs and in-depth interviews did not provide any additional insights regarding their preferences and desires ($n = 20$) [39].

The Namibian study found that cultural norm played a key role in households' desire to consume wild game meat ($n = 36$) [38]. Another study from Jharkhand, India using FGDs, showed that factors such as desirable taste, satiety, traditional practice of food preservation and their cultural importance encouraged indigenous food

consumption using FGDs ($n=9$) [37]. No quantitative analyses on desirability dimension were presented in either of the studies [37, 38].

In summary, the lack of higher evidence on the desirability dimension indicates the need for high-quality studies.

Convenience dimension

The relationship between the convenience dimension and dietary outcomes was examined in two studies at the neighbourhood level, both of which used mixed methods [36, 38]. The quality of evidence from this dimension was weak, with one study rated fair [36] and one rated poor [38].

In rural Nairobi, Kenya, using subjective food environment measurements in the form of semi-structured focus group guide which included questions associated with food purchasing and consumption for themselves and their households, women expressed the lack of time to prepare foods as a reason for purchasing food from street vendors ($n=26$) [36] while another study reported that modern food sources were convenient for an Indigenous Community in Namibia captured through key informant interviews ($n=36$) [38]. Neither of these studies presented clear associations via quantitative analyses [36, 38].

Overall, evidence on the convenience dimension is sparse.

Discussion

The 19 studies identified in this systematic review from 11 countries provide evidence on the association between rural food environment dimensions and dietary, nutrition and health outcomes in LMICs. These studies applied various study designs and assessment tools to examine rural food environment dimensions and outcomes. Studies mostly featured quantitative designs ($n=12$), followed by mixed-method approaches ($n=6$) and then qualitative designs ($n=1$). Most studies investigated dietary outcomes and food consumption ($n=11$), while only seven studies examined nutrition outcomes, and one study focused on health outcomes.

Personal domain was the primary focus concerning the association between rural food environment dimensions and diet, nutrition, and health outcomes. Availability and accessibility were the two most prominently studied dimensions. Food availability was positively associated with diet ($n=10$), nutrition ($n=7$) and health ($n=1$). Conversely, there was one cross-sectional study using the Jamaica Health and Lifestyle Survey 2008 which did not find an association between the density of fast-food outlets and higher levels of BMI nor urban–rural differences [32]. There was also good evidence regarding associations between food accessibility, diet ($n=7$) and nutrition ($n=3$). Their prominence in the literature may highlight the significance of the food environment discourse happening in HICs, which often focuses on examining dimensions associated with food availability and accessibility [16]. It is well established that the expansion of modern retail food outlets and increased access to ultra-processed foods especially in LMICs is contributing to a nutrition transition which is characterized by an increase in overnutrition and diet-related NCDs [59]. Supporting this notion, in our review we found strong evidence on linking diet and nutrition outcomes with increased availability of processed foods and accessibility to food outlets and markets in rural LIMCs. Indeed, rural households are net food buyers who are increasingly involved in purchasing foods from markets more so than is commonly understood. For example, data from Eastern and Southern Africa confirms that rural households buy 44% of the foods they consume [56] while in Bangladesh, Indonesia, Nepal and Vietnam, rural households purchase 73% [57]. Furthermore, a recent analysis of rural households in 11 countries in sub-Saharan Africa shows that food purchases represent 56% of the foods consumed [58]. Even households residing 1 to 2 h from a small city or town (56%), and those away for more than 2 h from a city or town (52%) are purchasing processed foods and food away from home [58]. While these results may call for further recognition regarding the importance of food environment dimensions in rural LMICs, such as availability and accessibility, they do not essentially discount the impact of affordability, convenience and desirability dimensions on relevant outcomes.

Regarding other dimensions, in our review, food price and affordability ($n=8$) were consistently cited as key barriers to achieving healthy diets. Desirability ($n=4$) and convenience ($n=2$) dimensions were also associated with dietary outcomes, although we found only a few studies. However, evidence on these dimensions is inconclusive at present due to lack of high-quality studies. This calls for an increased recognition of the need to examine these dimensions of the personal food environment domain, particularly in rural LMICs experiencing the nutrition transition, given that they have the potential to influence dietary behaviours.

Findings of this review are similar to a recent systematic scoping review focused on Southeast Asia where the identified studies featured the personal domain and dimensions (accessibility, affordability, convenience and desirability). The majority of studies reported on outcomes related to food acquisition and consumption patterns with a lack of evidence on health outcomes [50].

Consistent with our review, there was no emphasis towards workplace food environments and natural food environments. Overall, food price and affordability were identified as key barriers to accessing nutritious diets [50]. However, the review focused on both urban and rural settings and included high-income Southeast Asian countries such as Singapore and Brunei [50]. Dietary behaviours in Southeast Asia were mainly influenced by social, cultural, and economic factors rather than physical (e.g. geographical) characteristics of food environments. The differences in scope, objectives and inclusion/exclusion criteria (identifying urban studies in Southeast Asia) between the two reviews may explain these differences.

Our study differs from another systematic scoping review focused on LMICs where the primary focus was on the external food environment domain and dimensions of availability, vendor and product properties, prices, and marketing and regulation, similar to findings from HICs [16]. Studies primarily represented upper-middle-income countries with no studies on low-income countries. Furthermore, the focus of outcomes related to overweight and obesity highlights the growing awareness of the nutrition transition happening in LMICs, the increased number of upper middle income countries investigated at present and the adaptation of food environment research from HICS where these outcomes have been consistently prioritized [16]. Findings on the associations between food environment dimensions and nutrition outcomes were inconsistent [16]. Food availability was associated with dietary outcomes at both the neighbourhood and school settings across various LMICs. Consistent with our review, the authors found a lack of evidence associated with health outcomes [16]. Overall, the review underscores the importance of prioritizing food environment research in low-income and lower-middle-income countries and should aim to represent the full spectrum of dietary, nutrition and health outcomes [16]. The opposing results across the two reviews may arise because of the differences in year of publication and scope, inclusion of studies on urban LMICs and lack of evidence on low-income and lower-middle-income countries.

Interestingly, another recent systematic review focused solely on urban food environments in LMICs [51]. Consistent with our review, the authors found that availability and accessibility were the two most frequently assessed food environment dimensions. Availability in the neighbourhood food environment was associated with diets, health or nutrition outcomes while accessibility in the neighbourhood food environment was associated with diet with contradictory evidence of an association with health outcomes. There was limited evidence on urban workplace and home food environments. However, there were major differences with our review. For example, there was evidence on other external dimensions such as prices, vendor and product properties, marketing and regulation which showed sparse and mixed associations. The majority of studies focused on health and dietary outcomes with limited studies showing an association with nutritional outcomes. The review featured studies on availability in the school food environment associated with relevant outcomes with most interventional studies also situated in schools.

We identified several gaps in this systematic review that warrant further investigation. Firstly, the lack of standardized food environment measures and indicators identified in this review is featured in other reviews of food environment literature [8, 16, 25, 41–45]. Developing standardized measures and indicators is necessary to capture the aspects of food environment that truly reflect food choice and inform strategies for improving rural food environments across LMICs [16, 46–48]. Secondly, the absence of attention to the workplace, home and school food environment and intervention studies is a significant omission within the literature. Future empirical research that comprehensively assesses various types of food environments across different rural settings would inform the development of interventions and policies aimed at encouraging the consumption of healthy diets. Thirdly, although the availability dimension of the external food environment is most prominent in this review, there is a critical need to expand the scope of research to understand other dimensions of the external food environment such as prices, vendor and product properties, exposure and marketing and regulation, all of which are absent in this review. Fourthly, the paucity of evidence from low-income and lower-middle-income countries is a limitation. Much of this literature has focused on upper middle-income countries as indicated by this review. It is therefore critical for food environment research to focus on low-income and lower-middle-income countries, particularly in rural settings, as there is limited understanding of how or which aspects of food environments may be impacting these populations [16]. Fifthly, although studies have combined both the external and personal food environment domains, no interactions or patterns between the two domains have been reported. Food environment research should be prioritized to enhance the integration between the external and personal food environment dimensions in LMICs. Sixthly, there were no studies examining the sustainability dimension, which is a critical dimension to study further in rural food environments. Additional research is required to improve our understanding on the influence of the sustainability dimension by facilitating data collection on consumer travel to food vendors,

the presence of food delivery services, policies related to sustainability, vendor food waste, vendor plastic use, vendor utility usage, vendor recycling and waste management practices, and food packaging [58]. Lastly, the importance of wild and cultivated food environments on diet, nutrition and health outcomes as highlighted by the Downs framework [16] is largely missing in the LMICs context and remains a key research gap in the food environment literature. Although it is well documented that a wild food environment is more relevant for rural or indigenous settings, the importance of this concept has only been largely conceptualized. As Downs et al. [1] argue, there needs to be a better integration of sustainability into the food environment research space. Addressing food sustainability is integral towards finding solutions that would improve dietary patterns and support both human and planetary health.

Strengths and limitations

This systematic review synthesizes evidence exclusively on the association between the rural food environment and diet, health, and nutrition outcomes in LMICs. No limitation was set for types of study design which enriched the review's results. In addition, this systematic review considers an expanded framework of the food environment which includes the sustainability dimension. It identified studies with longitudinal designs which may provide stronger evidence to support future policy decisions. Lastly, our synthesis of mixed methods studies is also a strength which provides a more comprehensive, holistic and nuanced understanding of food environments by capturing both objective data and subjective experiences. However, the restriction of studies published in the English language which may have excluded key studies written in other languages. Furthermore, by restricting our search to only peer-reviewed journal articles, it is possible that we may have missed potentially relevant grey-literature publications specifically in local languages.

Conclusions

This systematic review synthesized the nature, extent, and range of published literature surrounding the role of how the rural food environment influences diet, health, and nutrition outcomes in LMICs. The nineteen identified studies predominantly represent upper middle-income countries. The external domain featured the availability dimension while the personal domain focused on the accessibility dimension. The outcomes associated with these two domains were diet and nutrition. Our findings suggest that interventions focusing on improving availability of, and accessibility to nutritious foods, and reducing availability of unhealthy foods, can have a beneficial impact on healthy food intake and nutrition status. There is an absence of studies assessing the workplace, home, and school food environments, sustainability dimension, food environment interventions and other key dimensions of the external food environment such as prices, vendor and product properties and marketing and regulation. We recommend future research studies to address these evidence gaps. This will inform and guide the development and implementation of future effective interventions to improve rural food environments in LMICs.

Abbreviations

CASP	Critical Appraisal Skills Programme
NHLBI	National Heart Lung and Blood Institute
MMAT	Mixed-Methods Appraisal Tool

Supplementary Information

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Supplementary Material 1.

Supplementary Material 2.

Supplementary Material 3.

Supplementary Material 4.

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Authors' contributions

SC was the primary author of the manuscript with contribution also from AZ, AML, NM and PV. SC and AZ conducted screening, data extraction and quality appraisal. All authors reviewed the manuscript.

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Data availability

All included studies containing data have been cited in the manuscript. All data generated or analyzed during this study are included in this published article including its supplementary information files.

Declarations

Ethics approval and consent to participate

As systematic review methodology aims to synthesize information available from previous publications, ethical approval was not required.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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