WEIRD and non-consensual food deserts and swamps: A scoping review of operational definitions

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# Conflict of interest statement

The authors declare no conflicting interests.

# **Research highlights**

- Operational definitions of food deserts and food swamps were critically analyzed.
- A scoping review was conducted.
- Large heterogeneity in the operational definitions of food deserts and food swamps was found.
- Studies largely differed in all the elements of the operational definitions.
- Recommendations to advance food environment research are derived.

# 1 WEIRD and non-consensual food deserts and swamps: A scoping review of operational

- 2 definitions
- 3

## 4 Abstract

5 The aim of the present study was to critically analyze operational definitions of food deserts and 6 food swamps included in empirical studies published in peer-reviewed journals. A scoping review 7 was conducted following the recommendations of the Joanna Briggs Institute and PRISMA-ScR 8 guidelines. A search of the scientific literature was performed to identify empirical studies including 9 operational definitions of food deserts and/or food swamps in three databases: Scopus, PubMed, 10 and Scielo. A total of 932 scientific articles were identified in the three databases, from which 157 11 articles were included in the review. The included studies were mainly published in WEIRD 12 (Western, Educated, Industrilaized, Rich and Democractic). They presented a total of 107 13 operational definitions of food deserts and 30 operational definitions of food swamps. Large 14 heterogeneity in the operational definitions of food deserts and food swamps was found. Published studies largely differed in all the elements of the operational definitions analyzed in the 15 study. Results stress the need for standardization and the development of more objective and 16 17 multivariate continuous measures of physical food accessibility that reflect the complexity of 18 modern food environments globally. A series of recommendations to advance food environment 19 research are derived.

- 20
- 21 *Keywords:* food environment; food retail; food access; food availability.

#### 22 **1. Introduction**

23 Malnutrition in all its forms continues to be one of the most important public health problems 24 worldwide (FAO et al., 2023). The food systems, defined as "the entire range of actors and their 25 interlinked value-adding activities involved in the production, aggregation, processing, 26 distribution, consumption and disposal of food products that originate from agriculture, forestry or 27 fisheries, and parts of the broader economic, societal and natural environments in which they are 28 embedded" (FAO, 2018) have been identified as one of the key underlying causes of malnutrition 29 (Swinburn et al., 2019; Brouwer, McDermott and Ruben, 2020; Hawkes et al., 2020). In the last 30 decades, food systems have shifted towards the production of low-cost ultra-processed products 31 based on a limited number of commodities, failing to provide enough healthy, safe, affordable and 32 sustainable foods (Swinburn et al., 2019; Popkin, Corvalan and Grummer-Strawn, 2020).

33 Food environments are one of the three core elements of food systems. They can be defined 34 as the physical, economic, political, and socio-cultural context through which consumers interact 35 with the food system to obtain, prepare, consume and discard food (HLPE, 2017). Availability and 36 physical access are two of the dimensions of the food environment that influence food choice and 37 eating habits (Sawyer et al., 2021; Konapur, Gavaravarapu and Nair, 2022). Availability refers to 38 the food supply, whereas physical accessibility refers to the location of food retail outlets and ease 39 of reaching that location considering distance, travel time, and/or cost (Penchansky and Thomas, 40 1981; Caspi et al., 2012).

Two concepts have been widely used in the literature to describe food availability and physical access in specific areas: food deserts and food swamps. The concept of food deserts emerged in the mid 1990s to describe areas where residents do not have physical access to healthy foods (Beaumont *et al.*, 1995; Cummins and Macintyre, 2002). The concept of food swamps is more recent and responds to the shift of the food supply chain towards the production of ultra-processed products high in nutrients associated with non-communicable diseases. It refers to areas with "excessive" access to unhealthy foods (Cooksey-Stowers, Schwartz and

Brownell, 2017; Hager *et al.*, 2017; Garg *et al.*, 2023). Despite debate around the concepts, a large number of studies have reported that living in a food desert or food swamp is associated with an increased risk of obesity and non-communicable diseases (Cooksey-Stowers, Schwartz and Brownell, 2017; Hager *et al.*, 2017; Garg *et al.*, 2023). However, other studies have found no or small associations (Fitzpatrick, Greenhalgh-Stanley and Ver Ploeg, 2019; Key *et al.*, 2023). In addition, empirical evidence to support the causal effect of living in a food desert or a food swamp on nutrition and health outcomes is still limited (Zhen, 2021).

55 One of the potential motives underlying non-consensual results is the lack of methodological 56 standardization (Beaulac, Kristjansson and Cummins, 2009; Caspi et al., 2012; Ver Ploeg, Dutko 57 and Breneman, 2015; Gebremariam et al., 2017; Titis, Procter and Walasek, 2022). Previous 58 reviews have reported heterogeneity in the approaches used for measuring food availability and 59 physical access (Charreire et al., 2010; Ver Ploeg, Dutko and Breneman, 2015; Gebremariam et al., 2017; Titis, Procter and Walasek, 2022). However, to the authors' knowledge, no study has 60 61 performed a systematic assessment of the operational definitions of food deserts and food 62 swamps.

63 In this context, the aim of the present study was to critically analyze operational definitions 64 of food deserts and food swamps included in empirical studies published in peer-reviewed journals. Results are expected to provide insights to refine and standardize methodological 65 66 approaches for assessing physical access to food and its effects on health and wellbeing. This is 67 particularly relevant to advance food environment research in emerging countries, where studies 68 on the topic are still scarce (Turner et al., 2018, 2020; Blake et al., 2021; Karanja et al., 2022). So 69 far, most of the studies on the topic have been conducted in WEIRD (Western-Educated-70 Industrialized-Rich-Democratic) countries (Muthukrishna et al., 2020; Turner et al., 2020). 71 Therefore, the operational definitions commonly used in the literature may not be applicable in 72 non-WEIRD settings (Turner et al., 2018).

#### 74 2. Methods

75 The scoping review was conducted following the recommendations of the Joanna Briggs Institute 76 (Peters et al., 2020) and PRISMA-ScR guidelines (Tricco et al., 2018). This type of review is 77 adequate for identifying and analyzing concepts and mapping the available evidence (Munn et 78 al., 2018). The guiding question for the scoping review was: What operational definitions of food 79 deserts and food swamps have been used in the scientific literature? In the preesnt work an 80 operational definition is regarded as an explicit, unambigious and detailed explanation of the 81 conditions for identifying a food desert or a food swamp (Winne, 2023). The population of the 82 scoping review was empirical studies, published in peer-reviewed journals assessing the retail 83 food environment and/or analyzing its influence on behavioral and/or health outcomes. The 84 concepts were operational definitions of food deserts and food swamps, whereas the context was 85 both WEIRD and non-WEIRD countries.

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# 87 2.1. Search strategy

A search of the scientific literature was performed to identify scientific studies including operational
definitions of food deserts and/or food swamps in three databases: Scopus, PubMed, and Scielo.
The databases were selected to cover the scientific literature across health, behavioral and social
sciences globally with special emphasis in Latin America. The search was completed on August
2023 using the following specific terms in English: "food desert" or "food swamp".

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# 94 2.1. Inclusion criteria

95 Only empirical studies published in peer-reviewed scientific journals and written in English, 96 Spanish or Portuguese were included. Commentaries, editorials, and reviews were excluded. All 97 included studies had to present a detailed operational definition of food deserts and/or food 98 swamps. Thus, studies missing key methodological details for the identification of food deserts or 99 food swamps were excluded.

#### 100 2.2. Study selection

101 One of the authors conducted the literature search in the selected databases and imported the 102 resultant records into Mendeley. Duplicates were removed. The screening of title and abstracts 103 was performed against the inclusion and exclusion criteria by two independent researchers to 104 evaluate eligibility. Discrepancies were solved by a third researcher.

Full-text screening was performed by two independent researchers. Reasons for exclusion were documented and discrepancies were solved by a third researcher, who provided a tiebreaking vote.

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#### 109 2.2. Data extraction

110 Data extraction was performed on an Excel spreadsheet using a template developed by one of 111 the authors. The following data were extracted: authors, publication year, country where data were 112 collected, operational definition of food desert, operational definition of food swamps. The data 113 was then synthethised using inductive coding to address the research question. The following 114 elements of the definitions were analyzed: measure, food outlets regarded as healthy, food outlets 115 regarded as unhealthy, other food outlets included in the definition, unit of analysis for the 116 identification of food deserts and/or food swamps, unit of measurement of distance (m or km), 117 type of distance used to measure proximity to food outlets (e.g., Euclidean or network distances), 118 cut-off criterion or thresholds to identify food deserts and/or food swamps, other conditions.

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### 120 3. Results

The PRISMA flow chart describing the review process is shown in Figure 1. A total of 932 scientific articles were identified in the three databases, from which 201 were duplicate. After title and abstract inspection, 265 records were removed, giving as a result 466 articles to be screened in full-text. However, the authors did not have access to the full text of 41 articles. From the 425 articles assessed for eligility, 268 were excluded. The main reasons for exclusion were the lack of inclusion of an operational definition of food deserts or food swamps (n=186), and not being research articles (n=52) (Figure 1). In addition, 14 articles were excluded because they lacked methodological details in the operational definition of food deserts and/or food swamps. A total of 157 articles were included in the review.

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# 131 **3.1. Description of the included studies**

The first study including an operational definition of food deserts date from 2002. The number of studies including operational definitions of food deserts and/or food swamps has increased over time and at least one study has been published every year from 2011 (Figure 2). The last decade (2013-2023) represents 81% of the studies included in the review.

136 Most of the studies included in the review were counducted in WEIRD countries (n=146), 137 whereas only 11 (7%) were conducted in non-WEIRD countries (Figure 2). The United States of 138 America is the country where most studies were conducted (n=118, 75%), followed by Canada 139 (n=14, 9%). Other WEIRD countries where studies were counducted include Slovak Republic 140 (n=5), The Netherlands (n=2), Australia (n=1), Belgium (n=1), Germany (n=1), New Zealand (n=1) 141 and the United Kingdom (n=1). Studies in non-WEIRD countries are more recent, dating from 2016. Brazil is the non-WEIRD country with the largest number of studies (n=6), followed by 142 143 Mexico (n=2), China (n=1), Guatemala (n=1), Iran (n=1), Japan (n=1), and Korea (n=1).

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#### 145 **3.2. Operational definitions of food deserts**

Operational definitions of food deserts were included in 146 studies, published between 2002 and 2023. The great majority of the studies (n=136, 93%) were conducted in WEIRD countries (USA n=112, Canada n=13, Slovak Republic n=5, The Netherlands n=2, Australia n=1 Belgium n=1, Germany n=1, United Kingdom n=1) and only 10 (7%) were conducted in non-WEIRD countries

150 (Brazil n=4, Mexico n=2, China n=1, Iran n=1, Japan n=1, Korea n=1).

151 The included studies presented a total of 107 different operational definitions of food deserts 152 (Table 1). All the definitions included a measure of the physical availability or accessibility of food 153 outlets selling healthy foods. A wide range of stores were regarded as healthy food outlets, being 154 large retail stores, particularly supermarkets (n=68) and grocery stores (n=61), the most common. 155 Some studies described specific characteristics supermarkets and grocery stores must have to 156 be regarded as healthy food stores: being run by national or regional chains, minimum number of 157 employees (ranging from 5 or 50), being size (over 2500 square feet), annual revenue (over 2 158 million dollars), or including a fresh produce departament. A few studies identified healthy food 159 outlets by conducting field audits to evaluate the availability of specific foods or used secondary 160 databases of food availability on food stores. Two of the studies included food prices as an 161 additional criterion, identifying healthy food outelts as those who sold healthy foods at an 162 affordable price.

163 Food deserts were identified considering units of analysis of very different size, ranging 164 from residential addresses, to grids of different area (e.g., 100 m x 100 m), to towns (Table 1). 165 Census tracts, block groups, and areas within the city were the most common geographical units. 166 Operational definitions were grouped in 11 main types of approaches to measure the physical availability of healhty food outlets. A first group of definitions were based on the density 167 168 of healhty food outlets within a specified geographic area (Table 1). Three definitions regarded 169 areas with no healthy food outlets as food deserts but differed in the type of stores regarded as 170 indicators of the availability of healthy foods. Two definitions regarded food deserts as areas with 171 less than one healhty food outlet per square kilometer or 1,000 inhabitants. The other defitinions 172 based on density identified food deserts using relative criteria based on the distribution of the data 173 across units of analysis, considering the lower tertile, the lower guartile or areas with a density of 174 healthy food outlets below average.

175 The largest proportion of definitions (n=52) were based on the coverage of healthy food 176 outlets, i.e., the number of healthy food outlets accessible within a pre-specified travel distance 177 or time. Twenty eight definitions created buffered areas around the centroid of the units of 178 analysis, ranging in radius from 250 m to 4 km in urban setings and from 4 km to 16 km in rural 179 areas according to Euclidean or network distances. Most of the definitions referred to walking 180 distances, whereas one included public transportation and another car driving. The most 181 frequently applied criteria for identifying food deserts in these definitions was lack of a healthy 182 food outlet within the buffered area, whereas one of the definitions used a relative criterion based 183 on the lower quartile of the number of healthy food outlets within the buffered area. The other 24 184 definitions based on coverage created service areas around healthy food outlets, ranging in 185 distance between 500 m and to 22 km in urban settings and 8 km to 16 km in rural settings 186 (measured using Euclidean or network distances), or a travel time ranging between 10 and 30 187 minutes. The lack of service areas within the geographic unit of analysis was the most common 188 criterion to identify food deserts. However, one study considered 2 service areas as threshold and 189 two studies used the lower quartile of the number of service areas as cut-off criterion.

190 Proximity to the closest healthy food outlet was considered in 18 definitions (Table 1). One 191 study used the average distance to the closest healthy food outlet as a continuous variable, 192 whereas two studies regarded areas with average distances in the top quartile as food deserts. 193 These three studies used weighted distances considering population density or the number of 194 household without vehicle. Eleven definitions regarded geographic areas as food deserts if the 195 distance to the closest healthy food outlet was larger than a distance threshold ranging from 250 196 m to 3.2 km in urban settings or 16 km in rural settings. One definition used the average distance 197 to the three nearest healthy food outlets, whereas another definition based on proximity measures 198 used travel times, setting 10 and 15 min as thresholds for the identification of rural food deserts. 199 Furthermore, one definition identified food deserts based on the percentage of the address points 200 within a census block group located farther than 1 km from a healthy food outlets. Three types of 201 distances were used for the calculations: Euclidean, network or self-reported distances in a 202 survey.

203 One of the studies also considered proximity to a food desert, identified as such areas 204 located closer than 400 m to a food desert based on coverage of healthy food outlets. In adition, 205 three definitions combined proximity to a healthy food outlet with other measures such as 206 coverage and/or density (Table 1).

207 Another group of definitions were based on the proportion of the population within a 208 geograpic area with low access to healthy food outlets. Low access was measured based on a 209 distance theshold that ranged between 800 m to 32 km for urban areas and between 16 km and 210 32 km for rural areas (measured using Euclidean distances). Three definitions calculated the 211 percentage of population with low access to a healthy food outlet, whereas the majority set 212 thresholds for the identification of food deserts ranging from 30% to 50%. The most frequently 213 used threshold was at least 500 people or 33% of the population in the census tract, which 214 corresponds to the USDA definition.

The final set of definitions were proposed by three studies, which calculated food desert indexes using a series of variables related to the physical availability of healthy food outlets (Table 1). Two of the studies incorporated socioeconomic variables of the areas in the construction of the index. The identification of food deserts was based on the distribution of the data.

A major difference among the operational definitions of food deserts was whether indicators of socioeconomic vulnerability were included or not (Table 1). Fifty eight definitions only refer to physical availability, whereas the remaining 50 included requirements on additional indicators for the identification of food deserts. Requirements related to household income were the most common (n=47), whereas two studies only inlcuded requierments on vehicle ownership.

A total of 47 operational definitions included requirements on household income, poverty rate, and/or other indicators of the socioeconomic status of the units of analysis (deprivation indexes, socioeconomic status index, socioeconomic distress index, unemployment, or housing prices). Heterogenity in the cut-off criteria for the definition of food deserts was identified (Table 1). The criterion included in the USDA definition of food deserts was the most commonly used by the studies: census tracts where median household income is equal or lower than 80% of the
median income in the surrounding area or 20% of the population or more with household incomes
below poverty level.

Nineteen of the 47 definitions imposed additional socioeconomic requirements for areas identified as food deserts (Table 1). Fifteen introduced requirements on vehicle ownership, six on the percentage of the population over 65 years old, three on population density, two on proximity to a bus stop, one on neighborhood walkability, and one on educational level. One of the studies relying on calculation of a food desert index included a wide range of socioeconomic indicators.

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#### 238 **3.3. Operational definitions of food swamps**

A total of 26 studies included an operational definition of food swamps, published from 2015 onwards. Nineteen studies were counducted in WEIRD countries (USA n=12, Canada n=5, Belgium n=1, New Zealand n=1), whereas the reamining 7 were conducted in non-WEIRD Latin American countries (Brazil n=5, Guatemala n=1, and Mexico n=1).

243 A total of 30 operational definitions of food swamps were reported by the 26 studies. 244 Definitions were highly heterogeneous, as no two studies used the exact same definition (Table 245 2). Although all the studies identified food swamps based on the absolute or relative physical 246 availability or accessibility of unhealhty food outlets, the types of stores regarded as unhealthy 247 outlets widely differed. The majority of the studies considered convenience stores (n=23) and fast 248 food restaurants (n=21) as unhealthy food outlets. Fewer studies have included small 249 grocery/corner stores (n=6), candy shops (n=6), bars (n=5), as well as other types of stores such 250 as behind-glass corner stores, snack bars, pubs, canteens or supercenters (Table 2).

Food swamps were identified at the level of widely different units of analysis, from homes to municipalities, using seven main approaches to measure the availability of unhealthy food outlets: density of unhealthy food outlets, coverage of unhealthy food outlets, ratio/proportion of unhealthy food outlets, and proximity to unhealthy food outlets. 255 Five studies used definitions based on density, considering the absolute number of 256 unhealthy food outlets or the number per 10,000 inhabitants in a specific area (buffer areas around 257 homes or schools, neighborhoods, census tracts, and municipalities). Arbitrary cut-off points have 258 been used for identifying food swamps based on density. Three studies regarded areas with 4 or 259 more unhealthy food outlets as food swamps, although they have worked with areas of very 260 different size (250 m buffer areas around schools, 400 m buffer areas around homes, and 261 neighborhoods) (Table 2). The other two studies using density measures relied on relative cut-262 off points, regarding areas in the top quartile or top tertile of the distribution of the number of 263 unheahtly food outlets per 10,000 inhabitants as food swamps.

Coverage measures were used to identify food swamps in three definitions studies. The number of service areas around unhealthy food outlets in the neighbourhood were calculated considering a 1000 m network distance from the outlets. One definition used a pre-defined cut-off criterion to categorize neigborhoods as food swamps, whereas the other two studies considered the top quartile of the distribution as cut-off point for the identification of food swamps.

269 Operational definitions involving the comparison between the number of unhealthy and 270 healthy outlets within a specified area were the most frequent (Table 2). Nine studies used the 271 ratio between unhealthy and healthy food outlets within a specified area, one study relied on the 272 percentage of unhealthy and healthy food outlets, two studies identified food swamps based on 273 the proportion of unhealthy and intermediate food outlets, whereas five studies calculated the 274 proportion of healthy food outlets. Nine of the studies only calculated continuous food swamp 275 measures, whereas the others the other seven used absolute arbitrary or relative cut-off pointsto 276 identify food swamps. Finally, one study conducted in Mexico used promixity measures, defining 277 food swamps as blocks with a shorter distance to unhealthy food outlets (convenience stores) 278 than to any other type of outlet.

Two of the definitions considered both the number of service areas around unhealthy food outlets and the ratio between service areas around healthy and unhealthy food oulets. For service

areas, the thresholds were based on the top quartile, whereas for ratio they were based on themedian.

283 The inclusion of socioeconomic indicators for the identification of food swamps was not 284 common. Only four definitions introduced requirements related to socioeconomic characteristics 285 of the areas regarded as food swampls. One of the definitions required food swamps to be areas 286 of low household income and high population density, another definition only included a 287 requirement for low income and the third imposed the requirement of low household income and 288 high percentage of black and brown minorities. In addition, one of the definitions based on the 289 ratio between unhealthy and healthy food outlets adjusted the values for population density and 290 income.

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#### 292 4. Discussion

Results from the present work showed that most studies including operational definitions of food deserts or food swamps have been conducted in WEIRD countries. Therefore, the definitions may not accurately reflect the characteristics of the food environment and the food purchasing habits of citizens from non-WEIRD countries. This suggests that refinements to the operational definitions may be needed to advance food environment research globally, as highlighted by (Turner *et al.*, 2018).

299 Large heterogeneity in the operational definitions of food deserts and food swamps was 300 found. Published studies largely differed in all the elements of the operational definitions analyzed 301 in the study: type of measure, definition of healthy/unhealthy food outlets, distance or time 302 thresholds, unit of analysis, type of distance, and additional conditions related to other socio-303 economic characteristics of the areas. Heterogeneity in the definitions was found among studies 304 conducted in both WEIRD and non-WEIRD countries. Lack of standardization hinders the 305 comparability across studies and can contribute to the lack of consensus regarding the influence 306 of the food environment on health outcomes. Similar results have been reported by previous

studies analyzing measures of food availability and physical access (Charreire *et al.*, 2010; Ver
Ploeg, Dutko and Breneman, 2015; Gebremariam *et al.*, 2017; Titis, Procter and Walasek, 2022).
In the following sub-sections, key aspects of the operational definitions of food deserts and food
swamps are discussed and recommendations to advance food environment research are
provided.

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#### **Food retail outlets regarded as proxy for healthy and unhealthy foods**

314 Operational definitions of food deserts and food swamps are based on the location of food retail 315 outlets, regarded as proxy for the availability of healthy or unhealthy foods. Most studies assume 316 that large retail stores, such as supermarkets, supercenters and full-service grocery stores, are 317 sources of healthy foods. Current definitions often overlook the relevance of other types of outlets 318 selling healthy foods, such as small stores and farmers' markets, which may be particularly 319 relevant in low-income settings and non-WIERD countries (Valdez, Dean and Sharkey, 2012; 320 Battersby and Crush, 2014; Bridle-Fitzpatrick, 2015; Crush, Nickanor and Kazembe, 2019; 321 Metoyer et al., 2022; Farah et al., 2023). Although supermarkets may represent the most frequent 322 source of healthy foods in specific settings, they have also been identified as a major source of 323 unhealthy foods, both in WEIRD (Mackay et al., 2021; Mackenbach, Hobbs and Pinho, 2022; 324 Petimar et al., 2023; Vandevijvere et al., 2023) and non-WEIRD countries (Khonje, Ecker and 325 Qaim, 2020; Machín et al., 2020; Meza-Hernández, Villarreal-Zegarra and Saavedra-Garcia, 326 2020; Phulkerd et al., 2023). The rise of supermarkets in emerging regions, such as Asia and 327 Latin America, has been associated with the nutrition transition and increased consumption of 328 ultra-processed products (Popkin and Reardon, 2018; Huse et al., 2022). In this sense, a recent 329 study has reported a positive association between the increase in supermarket density in Mexican 330 cities and higher blood pressure among adults with undiagnosed hypertension (Armendariz et al., 331 2022).

Convenience stores and fast-food restaurants have been regarded as stores mostly selling unhealthy foods. Most of the definitions consider both outlets selling packaged foods and prepared foods, whereas others only consider one of the two types of outlets. Convenience stores are not the only type of food outlet where unhealthy packaged foods can be purchased, as discussed above. Regarding fast food restaurants, studies have shown that the nutritional quality of the available foods is not necessarily worse than those offered in full-service restaurants (Auchincloss *et al.*, 2014; Robinson *et al.*, 2018; Liu *et al.*, 2020).

The complexity of modern food environments may require moving away from the identification of specific types of food outlets as proxy of the availability of healthy and unhealthy foods. Alternative approaches may consider the influence of different types of food outlets on dietary and health outcomes (Recchia et al., 2022) or the consideration of outlets selling specific food groups (Bao et al., 2020). Although this approach may be the most reliable, it requires store audits, which may not be feasible for studying food environments at the level of large areas.

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#### 346 *Measures of access to healthy and unhealthy food outlets*

347 The operational definitions of food deserts and food swamps of the studies included in the literature review have used measures of both availability (e.g., density) and access (e.g., 348 349 coverage) to food outlets selling healthy and unhealthy foods. For food deserts, access measures 350 based on the distance to the closest healthy retail outlet are the most frequent. These measures 351 are most appropriate to analyze the difficulties experienced by citizens to access to adequate and 352 healthy food. However, it is worth highlighting that no single measure is expected to fully describe 353 the accessibility of food outlets, as previously highlighted by (Apparicio, Cloutier and Shearmur, 354 2007) and (Charreire et al., 2010). Qualitative research may contribute to understand how citizens 355 conceptualize physical access to food and make their decisions on where to buy (Mcentee, 2009), 356 which can inform the selection of food access measures.

Food swamps are a relative new concept, and no operational definition has been used more than once in the scientific articles included in the scoping review. Areas with excessive access to unhealthy foods have been identified based on both absolute, i.e., access to unhealthy food outlets, and relative measures, i.e., relative access to healthy and unhealthy food outlets. These two measures capture different characteristics of the food environment. Research is still needed to identify which better predicts behavioral and health outcomes.

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#### 364 Size of the unit of analysis

365 Another key difference among the operational definitions of food deserts and food swamps was 366 related to the size of the unit of analysis, which ranged from individual households to towns. The 367 consideration of large units of analysis may underestimate the difficulties faced by individual 368 households within the area (Widener, 2018). In addition, restricting the analysis of food access to 369 specific areas may underestimate physical access to food outlets due to boundary effects (Chen. 370 2017). Despite methodological challenges, food access measures should attempt to consider 371 individual households as units of analysis or at least consider the percentage of households within 372 an area, as corrently done by the USDA definition. This approach has already been used by 373 several authors (e.g., Lebel et al., 2016; Davies, Frausin and Parry, 2017; Mishra, Sharma and 374 Pani, 2023).

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# 376 Thresholds for defining proximity to a food retail outlet

The operational definitions of food deserts and food swamps have used a wide range of thresholds for defining proximity to food retail outlets. Some of the studies have relied on purely relative thresholds selected based on the distribution of the data. However, this approach does not ensure that citizens living in the identified areas actually have inadequate access to healthy foods or excessive access to unhealthy food, as previously highlighted by (Ver Ploeg, Dutko and Breneman, 2015). 383 On the other hand, absolute thresholds to define proximity are largely inconsistent. Some 384 studies have used arbitrary thresholds, whereas others refer to behavioral data to identify central 385 measures of distance or time travelled by consumers when making their food purchases. Studies 386 exploring citizens' perception and food purchase patterns can largely contribute to the definition 387 of objective and context-appropriate criteria to define proximity to retail outlets. In addition, 388 research on how different thresholds influence conclusions regarding the influence of physical 389 access on dietary and health outcomes may contribute to advance food environment research. 390 For example, (lizaka et al., 2020) reported that participants living less than 300 m from the nearest 391 supermarket were more likely to eat fruits almost every today compared to those living 500 m or 392 more.

393 Different thresholds have been considered for different transportation modes. Although 394 most studies only consider walking distances, others have considered travelling distances for 395 cars, or public transport. Measures based on travel time from individual households to food outlets 396 for different modes of transportation may improve the ecological validity of food access measures. 397 Similarly, walking time measures would benefit from the consideration of walkability and 398 criminality indexes, particularly in low-income settings (Kim and Park, 2020; Lee and Contreras, 399 2021; Tobin et al., 2022). In addition, understanding inhabitants' behaviors regarding the means 400 of transportation most frequently used to purchase food items could contribute to the development 401 of context-based indicators and thresholds of proximity.

402

# 403 Inadequate physical access to food limited to socioeconomic vulnerable areas

A major difference across operational definitions of food deserts, and to a lower extent, across definitions of food swamps, is related to the inclusion of indicators of socioeconomic vulnerability. Approximately half of the operational definitions of food deserts and four definitions of food swamps were restricted to socioeconomic vulnerable areas. This approach may underestimate the impact of physical access to food in the dietary patterns of other population groups, including 409 low-income populations living in medium-income areas (Ver Ploeg et al., 2012). Behavioral 410 economics suggests that making healthy foods the default choice may promote healthier food 411 choices given the habitual and intuitive nature of food purchase decisions (Ensaff, 2021). 412 Therefore, citizens not having physical access to healthy food may require additional interest, 413 motivation, and resources to eat healthily, regardless of their income. Vulnerable populations may 414 have fewer resources to overcome the barriers imposed by physical access to food compared to 415 non-vulnerable populations and therefore may be disproportionately affected. Therefore, 416 analyzing the moderating effect of socioeconomic vulnerability on the influence of physical access 417 on dietary and health outcomes seems a promising way forward. In this sense, (Jiao et al., 2012) 418 evaluated physical access to food independently from socio-economic indicators and 419 subsequently presented results for vulnerable populations living in food deserts.

420 On the other hand, considering analyses of residential segregation, i.e., "the degree to 421 which two or more groups live separately from one another" (Massey and Denton, 1988), and its 422 associations with social, economic and health disparities (Williams, 2001; Massey, 2011; Cortés, 423 2021), may contribute to understand the distinctive characteristics of areas with low access and 424 availability of healthy food retail outlets. Studies on food environments from United States have found that urban neighborhoods with higher proportions of lower socioeconomic status and higher 425 426 representation of specific ethnic groups (e.g., with afro or black ancestry), tend to present fewer 427 availability of healthy food outlets (e.g., supermarkets), and more availability of unhealthy food 428 outlets (e.g. grocery stores) (Bower et al., 2014; Havewala, 2021). However, these studies have 429 used proxy measures of residential segregation, based on socio-demographic composition of 430 geographic areas. A promising approach is adopted by (Havewala, 2021), who analyzed the 431 relational pathways between residential segregation and food retail outlets. Using measures of 432 different dimensions of spatial segregation (i.e., evenness, exposure, clustering, centralization, and concentration). The study showed that segregated groups by ethic/race origin and income 433

- 434 present lower availability of and larger distances to healthy food outlets compared to less healthy
- 435 food outlets.

# 437 **5. Conclusions.**

438 Results from the present scoping review showed that the operational definitions of food deserts 439 and food swamps included in empirical articles published in scientific peer-reviewed journals are 440 largely non-consensual and mainly applicable to WEIRD countries. A series of recommendations 441 to advance food environment research were derived. Results support previous calls for moving 442 beyond simplistic definitions of food deserts and food swamps (Mcentee, 2009; Widener, 2018; 443 De Master and Daniels, 2019). Instead, more objective and multivariate continuous measures of 444 physical food accessibility are needed to reflect the complexity of modern food environments 445 globally. This approach is aligned with the recommendation to avoid dichotomization of predictor 446 variables across disciplines, including spatio-temporal statistics (Irwin and McClelland, 2003; 447 Kyomuhangi et al., 2021).

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# **Table 1.** Operational definitions of the food deserts included in the studies.

| Type of<br>measure                    | Measure  | Healthy food outlets  | Distance or time to<br>healthy food outlet  | Conditions related to<br>household income                   | Other conditions  | Unit of analysis | Type of<br>distance    | Country | Reference  |
|---------------------------------------|--|---|---|---|---|------------------|------------------------|---------|--|
| Density of<br>healthy<br>food outlets | No healthy food<br>outlet within the<br>unit of analysis                                     | Supermarkets, large grocery<br>stores, warehouse clubs, fruit<br>and vegetable markets        | Within the unit of<br>analysis and 800 m<br>buffer around the<br>boundary   | -   | -   | Census tract     | Euclidean<br>distances | USA     | (Ma <i>et al.</i> ,<br>2013; Liese <i>et al.</i> , 2014; Sohi<br><i>et al.</i> , 2014; Sohi<br><i>et al.</i> , 2014;<br>Santorelli and<br>Okeke, 2017; A.<br>M. Testa, 2019;<br>A. Testa, 2019;<br>Testa and<br>Jackson, 2019;<br>Fortin-Miller <i>et al.</i> , 2021; Testa<br><i>et al.</i> , 2021) |
|                                       |  | Grocery store   | Within the unit of<br>analysis  | -   | -   | Town             | -                      | USA     | (Campbell <i>et</i><br><i>al.</i> , 2020)  |
|                                       |  | Supermarkets  | Census tract and a<br>buffer zone of 800m<br>from the tract<br>boundary   | -   | -   | Census tract     | Euclidean<br>distance  | USA     | (Amin,<br>Badruddoza<br>and McCluskey,<br>2021)  |
|                                       | Less than one<br>healthy food<br>outlet per square<br>kilometer                              | Grocery stores  | -   | Highest quintile of<br>households under the<br>poverty line | -   | Census tract     | -                      | USA     | (Semple and Giguere, 2018)   |
|                                       | Number of<br>healthy food<br>outlets lower than<br>the average of<br>rural counties<br>(3.8) | Supermarkets, retail grocery stores   | Within the unit of<br>analysis  | -   | -   | County           | -                      | USA     | (Morton <i>et al.</i> ,<br>2005)   |
|                                       | Number of<br>healthy food<br>outlets within the<br>unit of analysis in<br>the lower quartile | Supermarkets (offering a full<br>range of grocery items and at<br>least ten employees)        | 1000 m from the<br>population weighted<br>average distance of<br>all the postal codes<br>within the<br>neighborhood<br>boundaries | Percentage of low<br>income households<br>above city median | Residents aged 65<br>years and older<br>above city median<br>Households<br>without automobile<br>above the city<br>median | Neighborhood     | Network<br>distance    | Canada  | (Smoyer-Tomic,<br>Spence and<br>Amrhein, 2006)   |
|                                       |  | Supermarkets and larger<br>grocery stores, fruit and<br>vegetable markets, warehouse<br>clubs | Within the unit of<br>analysis  | -   | -   | ZIP codes        | Network<br>distance    | USA     | (Potluri <i>et al</i> .,<br>2020)  |
|                                       |  | Seafood shops, fruits and vegetables establishments   | Within the unit of analysis   | _   | -   | Neighborhoods    |                        | Brazil  | (Andretti <i>et al.</i> ,<br>2023)   |
|                                       | Number of<br>healthy food  | Fish and seafood shop, fruits<br>and vegetables shops,  | Within the unit of analysis   | -   | -   | Municipalities   |                        | Brazil  | (Victor <i>et al.</i> ,<br>2023)   |

|  | outlets in the lower tertile   | butchers, supermarkets,<br>grocery stores   |  |   |   |  |                        |           |  |
|--|--|---|--|---|---|--|------------------------|-----------|--|
|  | Number of<br>healthy food<br>outlets<br>(continuous<br>measure)                            | Supermarkets, larger grocery stores, produce stores   | Within the census<br>tract and a buffer<br>zone of half a mile<br>from the tract<br>boundary | -   | -   | Census tract   | Euclidean<br>distance  | US        | (Cerceo <i>et al.</i> ,<br>2023)   |
|  | No healthy food<br>outlet per 1,000<br>residents within<br>the unit of<br>analysis         | Club stores, supercenters,<br>grocery stores (excluding<br>"superettes")                      | Within the unit of analysis  | -   | -   | ZIP codes  | -                      | USA       | (Allcott <i>et al.</i> ,<br>2020)  |
|  | Number of<br>healthy food<br>outlets per<br>10,000<br>inhabitants in the<br>lower quartile | Public establishments for food<br>security, fresh product store,<br>butcher shop, fish market | Within the unit of<br>analysis   | -   | -   | Census tract   | -                      | Brazil    | (Honório <i>et al.</i> ,<br>2021)  |
|  | Number of<br>healthy outlets<br>per 10,000<br>inhabitants<br>(continuous<br>measure)       | Open-air organic/<br>agroecological food markets,<br>supermarkets                             | Within the unit of<br>analysis   | -   | -   | Regional<br>administration<br>(subdivision of<br>municipalities<br>according to<br>geographical<br>position and<br>history of<br>occupation) | -                      | Brazil    | (Grilo, Menezes<br>and Duran,<br>2022)   |
| Coverage<br>of healthy<br>food outlets | No healthy food<br>outlets within a<br>distance<br>threshold                               | Supermarkets, greengrocers,<br>butchers   | 2.5 km   | -   | Located in<br>collection districts<br>with a percentage<br>of households<br>without car over<br>15.8% (top<br>quartile for the<br>region) | Residential<br>dwellings   | Euclidean<br>distances | Australia | (O'Dwyer and<br>Coveney, 2006)   |
|  |  | Supermarkets  | 1000 m by foot or<br>10-minute bus ride<br>without transfers<br>combined with 500<br>m walk  | -   | -   | Blocks   | Network<br>distances   | Canada    | (Larsen and<br>Gilliland, 2008)  |
|  |  | Supermarkets  | 800 m  | -   | -   | ZIP-code   | Euclidean<br>distances | USA       | (Walker, Butler,<br><i>et al.</i> , 2011;<br>Walker, Fryer,<br><i>et al.</i> , 2011) |
|  |  | Supermarkets  | 1600 m   | Located in census tracts<br>where >40% of the<br>population live in<br>households with income<br><200% poverty<br>threshold |   | Homes  | Euclidean<br>distances | USA       | (Hamrick and<br>Hopkins, 2012)   |

| Superstores, wholesalers, warehouses, grocery stores   | 400 m (urban) 2.4<br>km (rural)                   | -  | -   | Migrant and<br>seasonal<br>farmworkers<br>labor camps   | Euclidean<br>distances | USA    | (Grauel and<br>Chambers,<br>2014)          |
|--|---|--|---|---|------------------------|--------|--|
| Supermarkets, community gardens, farmers' markets  | 1000 m from the centroid                          | Lower quintile of median income  | Lower quintile of<br>car access<br>Higher quintile of | Neighborhood  | Network<br>distance    | Canada | (Wang, Qiu and<br>Swallow, 2014)           |
| Supermarkets, supercenters   | 4 km  | -  | population density<br>-                               | Dissemination<br>areas (smallest<br>geographic<br>areas for which<br>census data are<br>disseminated) | Network<br>distances   | Canada | (Luan, Law and<br>Quick, 2015)             |
| Large retail food stores   | 3.2 km from the<br>centroid                       | -  | -   | Block groups  | Network<br>distance    | USA    | (Jaskiewicz,<br>Block and<br>Chavez, 2016) |
| Supermarket  | 1600 m (16 km for<br>rural)                       | Located in low-income<br>block groups (median<br>household income<br><u>&lt;</u> US\$28,273 or > 20%<br>of the population below<br>the poverty line) | -   | Private<br>residences   | Euclidean<br>distances | USA    | (Thomsen <i>et</i><br><i>al.</i> , 2016)   |
| Affordable stores selling fresh,<br>diverse and high-quality food<br>products among the four<br>groups of the Canadian food<br>guide (4 fruits and vegetables,<br>10 meat and alternatives, 6<br>grain products, 5 milk and<br>alternatives) (resulting from a<br>field audit) | 16 km (rural)                                     | Within communities in<br>the 5th quintile of<br>deprivation index  |   | Households  | Network<br>distances   | Canada | (Lebel <i>et al.</i> ,<br>2016)            |
| Stores selling all types of<br>staple foods (manioc flour,<br>beans, bread) and at least five<br>different types of fruit or<br>vegetable, and at least three<br>sources of animal protein<br>(tinned beef, meat on the<br>bone, chicken, or eggs).                            | 250 m (equivalent to<br>a 5-minute walk)          | -  | -   | Households  | Network<br>distances   | Brazil | (Davies,<br>Frausin and<br>Parry, 2017)    |
| National chain grocery store<br>(large full-service grocery<br>stores)   | 500 m from the<br>dissemination block<br>centroid | Lowest income quintile   | -   | Dissemination<br>blocks   | Geodesic<br>distances  | Canada | (Slater <i>et al.</i> ,<br>2017)           |
| National chain grocery store<br>(large full-service grocery<br>stores), full-service grocery<br>stores (large, local grocery<br>stores offering a good<br>selection of self-serve fruits   | 500 m from the<br>dissemination block<br>centroid | Lowest income quintile   | -   | Dissemination<br>blocks   | Geodesic<br>distances  | Canada | (Slater <i>et al.</i> ,<br>2017)           |

| and vegetables), fresh meat<br>and dairy products at |                        |                          |   |               |               |          |                          |
|--|------------------------|--------------------------|---|---------------|---------------|----------|--------------------------|
| reasonable prices, as                                |                        |                          |   |               |               |          |                          |
| assessed by local health                             |                        |                          |   |               |               |          |                          |
| dietitians involved in the study)                    |                        |                          |   |               |               |          |                          |
| Supermarkets   | 1000 m                 | -                        | - | Blocks        | Euclidean,    | Slovak   | (Bilková <i>et al.</i> , |
|  |                        |                          |   |               | and Network   | Republic | 2017)                    |
|  |                        |                          |   |               | distances     |          |                          |
| Chain supermarkets, large                            | 1600 m                 | Poverty rate higher than | - |               | Block, census | USA      | (Bao and Tong,           |
| grocery stores                                       |                        | 20%                      |   |               | blocks,       |          | 2017)                    |
|  |                        |                          |   |               | census tracts |          |                          |
| Supermarkets   | 1.2 km                 | -                        | - | Homes         | Euclidean     | USA      | (Schwartz et al.,        |
|  |                        |                          |   |               | distances     |          | 2018)                    |
| Small scale fixed food retailers                     | 1000 m (for markets    | -                        | - | 100 m x 100 m | Euclidean     | Mexico   | (González-               |
| (butcher shop, poultry shop,                         | and supermarkets)      |                          |   | grid          | distances     |          | Alejo, Frejomil          |
| fish shop, greengrocer, dried                        | 500 m for stores       |                          |   |               |               |          | and Rosales-             |
| chilies and seeds), public                           | selling animal         |                          |   |               |               |          | Tapia, 2019)             |
| market, Tianguis and wheels                          | proteins or fruits and |                          |   |               |               |          |                          |
| market, supermarket                                  | vegetables             |                          |   |               |               |          |                          |
|  | 4.0 km /0 km in model  |                          |   |               | Oulfarmenterl | 110.4    | (0                       |
| Grocery store, farmer's                              | 1.6 Km (8 Km in rural  | -                        | - | Homes         | Settreported  | USA      |                          |
| market, full service/sit-down                        | areas)                 |                          |   |               | distance      |          |                          |
| restaurant   | 500                    |                          |   | 100           | E Balance     | 14 and a | 2020)                    |
| Department stores,                                   | 500 m                  | -                        | - | 100 m × 100 m | Euclidean     | Korea    |                          |
| supercenters, large                                  |                        |                          |   | gria          | distances     |          | 2020)                    |
| supermarkets,  |                        |                          |   |               |               |          |                          |
| marketplace/shopping mails,                          |                        |                          |   |               |               |          |                          |
| special stores for organic                           |                        |                          |   |               |               |          |                          |
| formere' merkete                                     |                        |                          |   |               |               |          |                          |
| Department stores                                    | 500 m                  |                          |   | 100 m x 100 m | Fuelideen     | Karaa    | (Kim at al               |
| Department stores,                                   | 500 m                  | -                        | - | 100 m × 100 m | Euclidean     | Korea    | $(NIII \ et \ al.,$      |
| supercenters, large                                  |                        |                          |   | gna           | distances     |          | 2020)                    |
| supermarkets,  |                        |                          |   |               |               |          |                          |
| marketplace/snopping mails,                          |                        |                          |   |               |               |          |                          |
| foodo, diocount oboino                               |                        |                          |   |               |               |          |                          |
| formere' markete email                               |                        |                          |   |               |               |          |                          |
| arooory stores                                       |                        |                          |   |               |               |          |                          |
| grodely stores,                                      |                        |                          |   |               |               |          |                          |
| arcade/shopping centers, local                       |                        |                          |   |               |               |          |                          |
| Department stores                                    | 500 m                  |                          |   | 100 m x 100 m | Fuelidoon     | Koroa    | (Kim et al               |
| supercenters large                                   | 500 111                | -                        | - | arid          | distances     | Norea    | 2020)                    |
| supermarkets   |                        |                          |   | gnu           | uistances     |          | 2020)                    |
| marketnlace/shonning malls                           |                        |                          |   |               |               |          |                          |
| special stores for organic                           |                        |                          |   |               |               |          |                          |
| foods discount chains                                |                        |                          |   |               |               |          |                          |
| farmers' markets small                               |                        |                          |   |               |               |          |                          |
| drocery stores                                       |                        |                          |   |               |               |          |                          |
| arcade/shopping centers local                        |                        |                          |   |               |               |          |                          |
|  |                        |                          |   |               |               |          |                          |

|   | grocery stores, convenience<br>stores   |  |   |   |  |                           |         |   |
|---|---|--|---|---|--|---------------------------|---------|---|
|   | Supermarkets  | 1600 m (urban)<br>16 km (rural)                            | >20% of the population below poverty  | -   | Census blocks  | Network<br>distance       | USA     | (Chenarides <i>et</i><br><i>al.</i> , 2021)   |
|   | Supermarkets  | 400 m  | Neighborhood median<br>household income <u>&lt;</u><br>185% Federal poverty<br>line | >40% of the<br>households in the<br>neighborhood<br>have no vehicle   | Family childcare<br>homes  | Euclidean<br>distances    | USA     | (Francis <i>et al.</i> ,<br>2022)             |
|   |   |  |   | Average Healthy<br>Food Availability<br>Index for<br>supermarkets and<br>corners stores in<br>the neighborhood<br>is $\leq 9.5$ (out of 27)   |  |                           |         |   |
|   | Supermarkets  | 1 km   | Median household<br>income in the lowest two<br>deciles                             | Bus stop: no bus<br>stop within 500 m<br>walking distance<br>where people can<br>take the bus to the<br>supermarket<br>Senior citizens:<br>number of people<br>older than 65 in<br>the lowest two<br>deciles<br>Walkability: in the | Residential<br>areas (1000 m<br>walking distance<br>buffer around the<br>geometric center<br>of gravity of all<br>residential<br>addresses within<br>a census tract) | Walking/road<br>distances | Belgium | (Smets, Cant<br>and<br>Vandevijvere,<br>2022) |
|   | Supermarkets  | 1 km   | Low socio-economic status   | -   | Block  | Network<br>distances      | Mexico  | (Reyes-Puente<br>et al., 2022)                |
|   | Supermarkets, grocery stores,<br>farmers' market, community<br>kitchens, food pantries        | 800 m  | -   | -   | Residential addresses  | Euclidean<br>distances    | USA     | (Figueroa <i>et al.</i> , 2023)               |
|   | Supermarkets  | 1600 m   | -   | -   | Census tract   | Euclidean<br>distances    | USA     | (Coyle, Keehan<br>and Schwartz,<br>2023)      |
| Number of<br>healthy food<br>outlets within the<br>distance<br>threshold in the<br>lower quartile | Supermarkets and larger<br>grocery stores, fruit and<br>vegetable markets, warehouse<br>clubs | Driving distance of 1<br>km around the unit<br>of analysis | -   | -   | Dialysis units   | Network<br>distance       | USA     | (Potluri <i>et al.</i> ,<br>2020)             |
| Lack of service<br>areas around   | Multiple/co-op stores   | 500 m  | High Carstairs indices of<br>multiple deprivation                                   | -   | Areas within the<br>city   | Euclidean<br>distances    | UK      | (Clarke, Eyre<br>and Guy, 2002)               |
| healthy food<br>outlets   | Supermarkets, superstores, large grocery stores   | 16 km (rural)  | -   | -   | Census block   | Euclidean<br>distance     | USA     | (Hubley, 2011)                                |

| Supermar<br>national o   | kets (stores run by<br>r regional chains   | 1600 m                                 | -   | -                          | Areas within the<br>city      | Network<br>distance  | USA                | (Jiao <i>et al.</i> ,<br>2012)         |
|--|--|--|---|----------------------------|-------------------------------|--|--------------------|--|
| selling a b<br>foods)  | road selection of  |  |   |                            |                               |  |                    |  |
| Supermar<br>convenien<br>markets, i<br>food marts  | ket chain stores,<br>ice stores, ethnic<br>ndependently owned<br>s   | 800 m                                  | -   | -                          | Areas within the city         | Euclidean<br>distances   | USA                | (Johns, Dixon<br>and McHan,<br>2013)   |
| Supercent<br>supermark<br>stores with<br>employee  | ters,<br>kets/convenience<br>n more than 5<br>s  | 800 m                                  | -   | -                          | Areas within the city         | Network<br>distance  | USA                | (Chen and<br>Clark, 2013)              |
| Supermar<br>stores (>5<br>farmers' m   | kets, large grocery<br>0 employees),<br>narket   | 1000 m (urban)<br>16 km (rural tracts) | -   | -                          | Areas within the state        | Euclidean<br>distances<br>(urban)<br>Network<br>distances<br>(rural) | USA                | (Sage,<br>McCracken and<br>Sage, 2013) |
| Grocery st<br>health foo   | ores. markets, and<br>d stores   | 2000 m                                 | -   | -                          | Areas within the<br>city      | Network<br>distance  | Canada             | (Newbold <i>et al.</i> ,<br>2013)      |
| Discount s<br>stores, sp<br>(e.g., store<br>and seafo<br>vegetable   | supermarkets, ethnic<br>ecialty food stores<br>es selling meat, fish<br>od, fruit and<br>markets)  | 1000 m                                 | Disadvantaged areas<br>based on socioeconomic<br>and demographic factors<br>(e.g., population,<br>employment, income,<br>vulnerable groups) | -                          | Areas within the neighborhood | Euclidean  | Canada             | (Behjat, Koc<br>and Ostry,<br>2013)    |
| Supermar<br>gardens, f   | kets, community<br>ärmers' markets   | 1000 m from the<br>centroid            | Low income  | High population<br>density | Neighborhoods                 | Network  | Canada             | (Wang, Qiu and<br>Swallow, 2014)       |
|  |  |  |   | Low car access             |                               |  |                    |  |
| Major groo   | cery stores  | 800 m                                  | Poverty rate higher than 20%  | -                          | Areas within the<br>city      | Euclidean<br>distances   | USA                | (LeClair and<br>Aksan, 2014)           |
| Large and<br>selling goo<br>of stores w<br>according<br>Veterinary<br>Administra<br>Republic),<br>of stores s<br>of the ave<br>foods in th<br>basket), a<br>foods (sto<br>of the food<br>higher tha<br>excluded) | small grocery stores<br>od quality (exclusion<br>with deficiencies<br>to the State<br>and Food<br>ation of the Slovak<br>diverse (exclusion<br>selling less than 10%<br>rage proportion of<br>he basic food<br>nd non-expensive<br>res where the price<br>d basket was 10%<br>n average were | 1000 m (car driven<br>distance)        | -   | -                          | Areas within the city         | Network<br>distance  | Slovak<br>Republic | (Križan <i>et al.</i> ,<br>2015)       |
| Green reta<br>fruits and   | allers (stores that sell<br>vegetables)  | 800 m                                  | -   | -                          | Areas within the<br>city      | Network<br>distance  | USA                | (Chen and<br>Clark, 2016)              |

|   | Retailers authorized in the  | 800 m for residents  | Household income <                               | -  | Census blocks                    | Network                       | USA                | (McDermot,   |
|---|--|--|--|--|----------------------------------|-------------------------------|--------------------|--|
|   | Special Supplemental Nutrition<br>Program for Women, Infant<br>and Children (WIC)                                    | in nouseholds<br>without vehicle and<br>5-minute drive for<br>residents living in<br>households with<br>vehicle (urban<br>areas)<br>or 800 m for<br>residents in<br>households without<br>vehicle and 10-<br>minute drive for<br>residents living in<br>households with<br>vehicle (rural areas) | poverty threshold                                |  |                                  | distance                      |                    | igoe and<br>Stahre, 2017)                                |
|   | Supermarkets, chain stores,<br>traditional bazars, fruit and<br>vegetable markets                                    | 800 m and 1600 m<br>by foot<br>or 800 m to public<br>transport   | -  | -  | Neighborhood                     | Street<br>network<br>analysis | Iran               | (Mohammadian<br>Mosammam <i>et</i><br><i>al.</i> , 2017) |
|   | Produce stands, farmers<br>markets   | 500 m  | -  | -  | Residential<br>buildings         | Network<br>distances          | Japan              | (Ikejima, 2019)  |
| Less than 2<br>service areas<br>around healthy<br>food outlets      | Supermarkets, local grocery stores   | 1000 m   | Bottom quartile of<br>median household<br>income | Top quartile of population density   | Neighborhood                     | Network<br>distance           | Canada             | (Yang, Wang<br>and Qiu, 2020)                            |
| Service areas<br>around healthy                                     | Supermarkets, grocery stores   | 1000 m   | -  | -  | Neighborhood                     | Network<br>distance           | Canada             | (Yang, Qiu and<br>Tu, 2022)                              |
| food outlets in the lower quantile                                  | Supermarkets, supercenters, large grocery stores   | 800 m (urban)<br>16 km (rural)   | -  | -  | Homes                            | Euclidean<br>distances        | USA                | (Mishra,<br>Sharma and<br>Pani, 2023)                    |
| Lack of service<br>areas around<br>healthy food<br>outlets based on | Supermarkets (stores run by<br>national or regional chains<br>selling a broad selection of<br>foods)                 | 10 min by walking,<br>bicycling, driving or<br>public transport  | -  | -  | Areas within the county          | Network<br>distance           | USA                | (Jiao <i>et al.,</i><br>2012)                            |
| travel time   | Supermarkets and other<br>grocery and convenience<br>stores, supercenters,   | 10 min drive (rural)<br>Access to bus<br>service within 5<br>miles of the city<br>center (rural)   | -  | -  | Areas within the State           | Network<br>distance           | USA                | (Mulangu and<br>Clark, 2012)                             |
|   | Large grocery stores   | 10 and 15 min (rural)  | -  | -  | Areas within the<br>municipality | Network<br>distance           | Slovak<br>Republic | (Bilková and<br>Križan, 2015)                            |
|   | Full-service supermarket,<br>grocery store, fruit store and<br>market, vegetable store and<br>market, seafood market | 30 min (walking)<br>20 min (public<br>transit)<br>15 min (bicycle)<br>10 min (private car)   | Percentage of<br>unemployed people<br>>4.1%      | Percentage of<br>people with<br>degree lower than<br>middle school<br>>65.6% | Community                        | Road network<br>distance      | China              | (Su <i>et al.</i> , 2017)                                |
|   | Grocery stores, supermarkets,<br>hypermarkets  | 15 min walking   | -  | -  | Basic settlement<br>units        | Network<br>distances          | Slovak<br>Republic | (Trembošová<br>and Jakab,<br>2021)                       |

|   |   | Supermarkets, discounters   | 15 min travel time<br>(foot, bicycle or car)<br>and ≥33% of the<br>population has travel<br>times ≥ 15 min<br>(rural)<br>Potentially perceived<br>food deserts: <15<br>min and >33% of the<br>population<br>experience (rural) | -  | -  | 250 m × 250 m<br>grids  | Street<br>network<br>distances | Germany   | (Neumeier and<br>Kokorsch,<br>2021)            |
|---|---|---|--|--|--|---|--------------------------------|-----------|--|
| Proximity to<br>the closest<br>healthy<br>food outlet | Average distance<br>to closest healthy<br>food outlet<br>(continuous<br>measure)  | Full-service grocery store  | Average distance<br>weighted by number<br>of households<br>without vehicle   | -  | -  | Block groups  | Network<br>distance            | USA       | (Widener,<br>Metcalf and<br>Bar-Yam, 2012)     |
|   | Distance to the<br>closest healthy<br>food outlet in the<br>top quartile          | Supermarkets (offering a full<br>range of grocery items and at<br>least ten employees)  | Population weighted<br>average distance of<br>all the postal codes<br>within the<br>neighborhood<br>boundaries   | Percentage of low-<br>income households<br>above city median | Residents aged 65<br>years and older<br>above city median<br>Households<br>without automobile<br>above city median   | Neighborhood  | Network<br>distance            | Canada    | (Smoyer-Tomic,<br>Spence and<br>Amrhein, 2006) |
|   |   | Supermarket   | Average distance<br>weighted by<br>population density  | Poverty rate in the higher quartile                          | Percentage of<br>population over 65<br>years old in the<br>higher quartile or<br>percentage of<br>households<br>lacking automobile<br>access in the<br>higher quartile | Census tracts<br>(distance<br>calculated at the<br>level of blocks) | Euclidean<br>distances         | USA       | (Leete, Bania<br>and Sparks-<br>Ibanga, 2012)  |
|   | Distance to the<br>closest healthy<br>food outlet larger<br>than the<br>threshold | Supermarkets, greengrocers,<br>butchers   | 2.5 km   | -  | Located in<br>collection districts<br>with a percentage<br>of households<br>without car over<br>15.8% (top<br>quartile for the<br>region)                              | Residential<br>dwellings  | Euclidean<br>distances         | Australia | (O'Dwyer and<br>Coveney, 2006)                 |
|   |   | Supermarkets and other<br>grocery stores (except<br>convenience stores) larger<br>than 2500 square feet   | 16 km (rural)  | -  | -  | Census tract  | Network<br>distances           | US        | (McEntee and<br>Agyeman,<br>2010)              |
|   |   | Affordable stores selling fresh,<br>diverse and high-quality food<br>products among the four<br>groups of the Canadian food<br>guide (4 fruits and vegetables,<br>10 meat and alternatives, 6 | 16 km (rural)  | Within communities in the 5th quintile of deprivation index  | -  | Households  | Network<br>distances           | Canada    | (Lebel <i>et al.</i> ,<br>2016)                |

| grain products, 5 milk and<br>alternatives) (resulting from a<br>field audit)  |   |  |  |  |   |        |   |
|--|---|--|--|--|---|--------|---|
| Large retail food stores   | 3.2 km  | -  | -  | Block groups   | Network<br>distance                             | USA    | (Jaskiewicz,<br>Block and<br>Chavez, 2016)  |
| Stores selling all types of<br>staple foods (manioc flour,<br>beans, bread) and at least five<br>different types of fruit or<br>vegetable, and at least three<br>sources of animal protein<br>(tinned beef, meat on the<br>bone, chicken, or eggs).  | 250 m (equivalent to<br>a 5-minute walk)          | -  | -  | Households   | Network<br>distances                            | Brazil | (Davies,<br>Frausin and<br>Parry, 2017)   |
| National chain grocery store<br>(large full-service grocery<br>stores)   | 500 m from the<br>dissemination block<br>centroid | Lowest income quintile   | -  | Dissemination<br>blocks  | Geodesic<br>distances                           | Canada | (Slater <i>et al.</i> ,<br>2017)  |
| National chain grocery store<br>(large full-service grocery<br>stores), full-service grocery<br>stores (large, local grocery<br>stores offering a good<br>selection of self-serve fruits<br>and vegetables), fresh meat<br>and dairy products at<br>reasonable prices, as<br>assessed by local health<br>dietitians involved in the study) | 500 m from the<br>dissemination block<br>centroid | Lowest income quintile   | -  | Dissemination<br>blocks  | Geodesic<br>distances                           | Canada | (Slater <i>et al.</i> ,<br>2017)  |
| Supermarkets   | 0.4 km  | Median household<br>income is ≤185% of the<br>Federal Poverty<br>threshold | >30%<br>of households<br>have no vehicle<br>available<br>Quality and<br>quantity of foods<br>available: Healthy<br>Food Availability<br>Index score<br>between 0 and 8.7 | Census block<br>group  | Walking<br>distance<br>measure                  | US     | (Hager <i>et al.</i> ,<br>2017;<br>Misiaszek,<br>Buzogany and<br>Freishtat, 2018) |
| Supermarket, grocery stores  | 1600 m  | >20% of the population<br>under the poverty line                           | -  | Census tract   | Population<br>weighted<br>Euclidean<br>distance | USA    | (Bao <i>et al.</i> ,<br>2020)   |
| Supermarkets, grocery stores, fruit and vegetable stores   | 1000 m (urban)<br>16000 (rural)                   | 5th quintile of deprivation index  | -  | Residential units,<br>aggregated in<br>dissemination<br>areas (smallest<br>geographic<br>areas for which | Road network<br>distances                       | Canada | (Robitaille and<br>Paquette, 2020)  |

|   |  |   |   |  |   | census data are disseminated) |                        |                        |  |
|---|--|---|---|--|---|-------------------------------|------------------------|------------------------|--|
|   |  | Full-service grocery store<br>(selling fresh meat and poultry,<br>produce and fruit, dry and<br>packaged foods, dairy, and<br>frozen foods) | 800 m   | >20% of the population<br>under the poverty line   | Weighted average<br>of distance from<br>the census block<br>to the food outlet<br>and population of<br>the census block | Census tracts                 | Euclidean<br>distances | USA                    | (Bao <i>et al.</i> ,<br>2020)            |
|   | Average distance<br>to the three<br>nearest healthy<br>outlets larger<br>than the<br>threshold   | Grocery stores, fruit and<br>vegetable sources  | 16 km (rural)   | -  | -   | Individual<br>address points  | Network<br>distances   | Canada                 | (Sadler,<br>Gilliland and<br>Arku, 2011) |
|   | Self-reported<br>distance to<br>healthy food<br>outlet larger than<br>the threshold  | Supermarkets  | 800 m (urban)<br>16 km (rural)  | -  | -   | Homes                         | Self-reported          | USA                    | (James <i>et al.</i> ,<br>2022)          |
|   | 99% or more of<br>the address<br>points far from<br>healthy food<br>outlets  | Full-service grocery store  | 1000 m  | Socioeconomic distress<br>index (calculated based<br>on low educational<br>attainment, incidence of<br>low income, lone<br>parenthood, and<br>unemployment) in the<br>higher two quintiles | -   | Census block<br>groups        | Network<br>distances   | US                     | (Sadler,<br>Gilliland and<br>Arku, 2013) |
|   | Travel time to<br>closest healthy<br>food outlet larger<br>than the<br>threshold   | Large grocery stores  | 10 and 15 min (rural)<br>from the centroid of<br>the unit of analysis | -  | -   | Municipality                  | Network<br>distance    | Slovak<br>Republic     | (Bilková and<br>Križan, 2015)            |
| Proximity to<br>a food<br>desert          | Distance to a<br>food desert<br>closer than the<br>threshold   | -   | 400 m   | -  | -   | Family child care homes       | Euclidean<br>distances | USA                    | (Francis <i>et al</i> .,<br>2022)        |
| Coverage<br>and<br>proximity              | Distance to the<br>closest healthy<br>food outlet in the<br>higher quartile<br>and number of<br>healthy food<br>outlets in the<br>lower quartile | Supermarkets (grocery chains,<br>warehouse club stores,<br>supercenters), farmers'<br>markets   | 1 km from the<br>community centroid                                   | Median household<br>income in the lower<br>quintile  | -   | Communities                   | Network<br>distances   | Canada                 | (Lu and Qiu,<br>2015)                    |
| Coverage,<br>density,<br>and<br>proximity | High proximity,<br>high density of<br>supermarkets,<br>and mean<br>distance to three   | Supermarkets  | 1000 m  | Housing prices below<br>the median   | Percentage of<br>native Dutch<br>people below the<br>median   | 100x100 m grid                | Network<br>distances   | The<br>Netherlan<br>ds | (Helbich <i>et al.</i> ,<br>2017)        |

|                                    | outlets of<br>different chains   |  |  |   |   |                        |                        |                        |  |
|------------------------------------|--|--|--|---|---|------------------------|------------------------|------------------------|--|
|                                    | Clustering of<br>units of analysis<br>based on<br>average distance<br>to supermarket,<br>number of<br>supermarkets in<br>the buffer area,<br>and average<br>distance to the<br>three nearest<br>from different<br>chains | Supermarket chains   | 1000 m from the centroid   | Housing prices  | Percentage of<br>native Dutch<br>people | 100x100 m grids        | Network<br>distance    | The<br>Netherlan<br>ds | (Helbich and<br>Hagenauer,<br>2017)  |
| Proportion<br>of the<br>population | Proportion of the<br>population living<br>far from a healthy   | Supermarket  | 1600 m (urban)<br>16 km (rural)  | -   | -                                       | Euclidean<br>distances | Neighborhood           | USA                    | (Liese <i>et al.</i> ,<br>2018; Choi <i>et</i><br><i>al.</i> , 2021)   |
| with low access to                 | outlet (continuous measure)  | Supermarket, supercenter, or<br>large grocery store  | 800 m (urban)<br>16 km (rural)   | -   | -                                       | Euclidean<br>distances | Census tract           | USA                    | (Wood <i>et al.</i> ,<br>2023)   |
| healthy<br>food outlets            |  | Supermarkets, grocery stores   | 1600 m<br>(16 km in rural area)  | Median household<br>income <u>&lt;</u> 200% of the<br>federal poverty threshold   | -                                       |                        | County                 | USA                    | (Bevel <i>et al.</i> ,<br>2023)  |
|                                    | More than 33% of<br>the population<br>living far from a<br>healthy food<br>outlet  | Grocery store (including a fresh produce department)   | 1600 from the<br>centroid of the block<br>for urban (16 km for<br>rural) | Median household<br>income < 80% of the<br>statewide income or<br>>20% of the population<br>with incomes below<br>poverty level | -                                       | Block groups           | Euclidean<br>distance  | USA                    | (Alviola <i>et al</i> .,<br>2013)  |
|                                    |  | Supermarkets   | 1600 from the<br>centroid of the block<br>for urban (16 km for<br>rural) | Median household<br>income < 80% of the<br>statewide median<br>income or >20% of the<br>population below<br>poverty level or    | -                                       | School districts       | Euclidean<br>distances | USA                    | (Alviola, Nayga<br>and Thomsen,<br>2013)   |
|                                    | At least 500<br>people or 33% of<br>the population<br>lives far from a<br>healthy food<br>outlet   | Supermarkets, supercenters,<br>large grocery stores (annual<br>revenue over USD 2 million<br>and containing all the major<br>food departments) | 1.6 km (urban)<br>16 km (rural)  | -   | -                                       | Census tract           | Euclidean<br>distances | USA                    | (Hipp and<br>Chalise, 2015;<br>Suarez et al.,<br>2015; Pike et<br>al., 2017; Wu,<br>Saitone and<br>Sexton, 2017;<br>Gailey and<br>Bruckner, 2019;<br>Hamidi, 2020;<br>Fong et al.,<br>2021; Delk et<br>al., 2022;<br>McCullough et<br>al., 2022; |

|                                 |   |   |              |                        |     | Livings <i>et al.</i> ,<br>2023)  |
|---------------------------------|---|---|--------------|------------------------|-----|---|
| 800 m (urban)<br>16 km (rural)  | -   | - | Census tract | Euclidean<br>distances | USA | (Delk <i>et al.,</i><br>2022; Livings <i>et</i><br><i>al.</i> , 2023)   |
| 1.6 km (urban)<br>16 km (rural) | Median household<br>income ≤ 80% of the<br>median income in the<br>surrounding area or<br>≥20% of the population<br>with incomes below<br>poverty level |   | Census tract | Euclidean<br>distances | USA | al., 2023)<br>(Andrews,<br>Bhatta and<br>Ploeg, 2013;<br>Frndak, 2014;<br>Hardin-Fanning<br>and Gokun,<br>2014; Liese et<br>al., 2014, 2018;<br>Sohi et al.,<br>2014; Block and<br>Subramanian,<br>2015; Shannon<br>et al., 2015;<br>Daepp, 2015;<br>Fitzpatrick,<br>Greenhalgh-<br>Stanley and Ver<br>Ploeg, 2016,<br>2019;<br>Bohannon and<br>Henry, 2016;<br>Strome et al.,<br>2016; Chen,<br>Jaenicke and<br>Volpe, 2016;<br>Strome et al.,<br>2016; Chen,<br>Jaenicke and<br>Volpe, 2016;<br>Santorelli and<br>Okeke, 2017;<br>Dakkak W,<br>2017; Gray et<br>al., 2018; Ma et<br>al., 2018; Fossi<br>et al., 2019;<br>Gbenro, Brace<br>and Matthews,<br>2019; Kelli et<br>al., 2019;<br>Barboza-<br>Salerno, 2020;<br>Cadman |
|                                 |   |   |              |                        |     | Thomson and   |

|                                 |   |   |   |              |                        |     | Landry, 2020;<br>McKey, Kim<br>and Seo, 2020;<br>Sinclair, 2020;<br>Tipton et al.,<br>2020; Tong et<br>al., 2020;<br>Woodruff et al.,<br>2020; Lee and<br>Caine-Bish,<br>2021; Madzia et<br>al., 2021;<br>Moughames et<br>al., 2021; Smith<br>et al., 2021;<br>Corbera-<br>Hincapie et al.,<br>2021;<br>Gebrehiwot et<br>al., 2022;<br>Livings et al.,<br>2023; Lloyd et<br>al., 2023;<br>Phillips et al.,<br>2023; Sisk et<br>al., 2023; Tanoh<br>and Hashemi-<br>Beni, 2023) |
|---------------------------------|---|---|---|--------------|------------------------|-----|--|
| 800<br>16<br>(ca<br>lev<br>gric | 0 m (urban)<br>km (rural)<br>Ilculated at the<br>el of 500 x 500 m<br>ds) | Median household<br>income ≤ 80% of the<br>median income in the<br>surrounding area or<br>≥20% of the population<br>with incomes below<br>poverty level | - | Census tract | Euclidean<br>distances | USA | (Bohannon and<br>Henry, 2016;<br>Santorelli and<br>Okeke, 2017;<br>Brace, Moore<br>and Matthews,<br>2020; Isokpehi<br><i>et al.</i> , 2020;<br>Jettner and<br>Secret, 2020;<br>Banner <i>et al.</i> ,<br>2021; Crimarco<br><i>et al.</i> , 2022;<br>Livings <i>et al.</i> ,<br>2023; Tanoh<br>and Hashemi-<br>Beni, 2023)  |
| 1.6<br>32<br>(ca<br>leve        | 6 km (urban)<br>km (rural)<br>alculated at the<br>rel of 500 x 500 m      | Median household<br>income ≤ 80% of the<br>median income in the<br>surrounding area or  | - | Census tract | Euclidean<br>distances | USA | (Santorelli and<br>Okeke, 2017;<br>Brace, Moore<br>and Matthews,   |

|  |  |  | with incomes below   |  |   |                        |     | <i>et al.</i> , 2020;   |
|--|--|--|--|--|---|------------------------|-----|---|
|  |  |  | poverty level  |  |   |                        |     | Tanoh and<br>Hashemi-Beni,<br>2023)   |
|  |  | 800 m (urban when<br>the condition for car<br>applies)<br>or<br>32 km (regardless of<br>vehicle access)                    | Median household<br>income $\leq 80\%$ of the<br>median income in the<br>surrounding area or<br>$\geq 20\%$ of the population<br>with incomes below<br>poverty level | ≥ 100 households<br>without vehicle  | Census tract  | Euclidean<br>distances | USA | (Robinson <i>et</i><br><i>al.</i> , 2016;<br>Santorelli and<br>Okeke, 2017;<br>Isokpehi <i>et al.</i> ,<br>2020; Livings <i>et</i><br><i>al.</i> , 2023; Tanoh<br>and Hashemi-<br>Beni, 2023) |
|  | Supermarkets, large grocery<br>stores, warehouse clubs, fruit<br>and vegetable markets | 1600 m (urban)<br>16 km (rural)  | Median household<br>income $\leq 80\%$ of the<br>median income in the<br>surrounding area or<br>$\geq 20\%$ of the population<br>with incomes below<br>poverty level | -  | Census tract  | Euclidean<br>distances | USA | (Ma <i>et al.</i> ,<br>2013)  |
|  | Supermarket, supercenter or<br>large grocery store                                     | 1.6 km (urban)<br>16 km (rural)  | ≥20% poverty rate<br>or<br>median household<br>income ≤80% median<br>income  | ≥ 100 households<br>have no access to<br>a vehicle   | Census tract  | Euclidean<br>distances | US  | (Wilde, Llobrera<br>and VerPloeg,<br>2014)  |
|  | Supermarket, grocery store   | 1.6 km (urban)<br>16 km (rural)  | ≤200% of the Federal<br>Poverty threshold  |  | County  | Euclidean<br>distances | US  | (Cooksey-<br>Stowers,<br>Schwartz and<br>Brownell, 2017)  |
| More than 30% of<br>the population<br>lives far from a<br>healthy food<br>outlet             | Supermarket  | 1.6 km   | Household income<br><usd 30,000="" per="" year<br="">High poverty rate<br/>(criterion not specified)</usd>   | Car ownership:<br>without car access   | Census tract  | Euclidean<br>distances | USA | (Almalki <i>et al</i> .,<br>2021)   |
| More than 50% of<br>the population<br>does not have<br>access to a<br>healthy food<br>outlet | Supermarket  | 1 km   | Poverty rate in the higher quartile  | Percentage of<br>population over 65<br>years old in the<br>higher quartile or<br>percentage of<br>households<br>lacking automobile<br>access in the<br>higher quartile | Census tracts<br>(distance<br>calculated at the<br>level of blocks) | Euclidean<br>distances | USA | (Leete, Bania<br>and Sparks-<br>Ibanga, 2012)   |
|  | Grocery stores (>50<br>employees)  | 16 km (from the<br>population weighted<br>centroid) or 24 km<br>(for zip codes that<br>fall along a interstate<br>highway) | -  | -  | School districts<br>(distance<br>calculated over<br>zip-codes)      | Euclidean<br>distances | USA | (Schafft,<br>Jensen and<br>Clare Hinrichs,<br>2009)   |

| Food<br>desert<br>index | Number of<br>healthy food<br>outlets (1-3) +<br>proportion of<br>healthy bodegas<br>of all bodegas (1-<br>3) + proportion of<br>fast food<br>restaurants from<br>all restaurants (1-<br>3)  | Supermarkets, healthy<br>bodegas (selling 7 or more<br>healthy products - apples,<br>oranges, bananas, skim and<br>low-fat milk, water, tomatoes,<br>carrots, leafy greens, 100%<br>juice- according to an in-store<br>survey) | 400 m   | -  | -  | Block groups  | Euclidean<br>distances                           | USA | (Gordon <i>et al.</i> ,<br>2011)              |
|-------------------------|---|--|---------|--|--|---|--|-----|---|
|                         | Clustering of<br>areas based on<br>proximity to<br>closest healthy<br>food outlet,<br>number of food<br>outlets within a<br>distance<br>threshold,<br>average distance<br>to three closest<br>supermarket and<br>social deprivation | Supermarket  | 1000 km | Poverty rate   | Percentage of<br>population over 65<br>years old<br>Households<br>lacking automobile<br>access   | Census tracts<br>(distance<br>calculated at the<br>level of blocks) | Population<br>weighted<br>Euclidean<br>distances | USA | (Leete, Bania<br>and Sparks-<br>Ibanga, 2012) |
|                         | Index calculated<br>based on<br>distance to the<br>grocery store and<br>other variables<br>above 1 standard<br>deviation above<br>the mean  | Full-service grocery stores  |         | Per capita income<br>Median household<br>income<br>Median income whites<br>Median income blacks<br>Percentage of adults<br>under poverty level<br>Percentage children<br>under poverty line<br>Percentage of workforce<br>unemployed | Distance to<br>nearest bus stop<br>Elite-impoverished<br>composite<br>Comfortable-<br>distressed<br>Population mean<br>Population density<br>Percentage white<br>Percentage black<br>Percentage<br>Hispanic<br>Median age<br>Percentage<br>married<br>Percentage<br>households<br>occupied by<br>renters<br>Percentage<br>households with<br>no car<br>Average cars per<br>household<br>Percentage<br>divorced | Census block  | Euclidean<br>distances                           | USA | (Larson <i>et al.</i> ,<br>2013)              |

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Percentage single Average commute time Median housing value Percentage of housing is trailers Percentage high school dropouts Percentage of adults who are college graduates Population change from 2000-2009 Percentage uninsured Percentage obese Percentage hypertensive Percentage high cholesterol Percentage diabetes

# 1087 Table 2. Operational definitions of the food swamps included in the studies.

| 100,   |   |  |  |                       |                  |                                   |                        |                       |   |         |   |
|--|---|--|--|-----------------------|------------------|-----------------------------------|------------------------|-----------------------|---|---------|---|
| Type of<br>definition                                | Measure   | Unhealthy food<br>outlets  | Healthy food<br>outlets  | Other food<br>outlets | Unit of analysis | Distance                          | Type of<br>distance    | Cut-off criteria      | Other conditions  | Country | Reference   |
| Density of<br>unhealthy food<br>outlets              | Number of<br>unhealthy food<br>outlets in a<br>specific area                          | Convenience stores,<br>behind-glass corner<br>store, small<br>grocery/corner store     | -  |                       | Homes            | 400 m                             | Euclidean<br>distances | <u>≥</u> 4            |   | USA     | (Hager <i>et al.</i> ,<br>2017)                             |
|  |   | Snack bars, small<br>grocery stores,<br>candy shops                                    | -  |                       | Schools          | 250 m                             | Euclidean<br>distances | <u>≥</u> 4            |   | Brazil  | (Peres <i>et al.</i> ,<br>2021)                             |
|  |   | Convenience<br>stores, snack bars,<br>grocery stores,<br>candy stores                  | -  | -                     | Neighborhoods    | Within<br>the unit of<br>analysis | -                      | <u>&gt;</u> 4         |   | Brazil  | (Andretti <i>et al.</i> ,<br>2023)                          |
|  | Number of<br>unhealthy food<br>outlets per 10,000                                     | Pubs, snack bars,<br>candy shops   | -  |                       | Census tracts    | Within<br>the unit of<br>analysis | -                      | >Top quartile         |   | Brazil  | (Honório <i>et al.</i> ,<br>2021)                           |
|  | inhabitants   | Convenience stores,<br>snack bars, candy<br>shops, bars,<br>canteens                   | -  |                       | Municipality     | Within<br>the unit of<br>analysis | -                      | >Top tertile          | -   | Brazil  | (Victor <i>et al.</i> ,<br>2023)                            |
| Coverage of<br>unhealthy food<br>outlets             | Number of<br>service areas<br>around unhealthy<br>food outlets in a<br>specified area | Convenience stores,<br>fast food restaurants   | -  |                       | Neighborhoods    | 1000 m                            | Network<br>distance    | <u>≥</u> 20           | Bottom quartile<br>of median<br>household<br>income<br>Top quartile of<br>population<br>density | Canada  | (Yang, Wang<br>and Qiu, 2020)                               |
|  |   | Convenience stores,<br>fast food restaurants   | -  | -                     | Neighborhoods    | 1000 m                            | Network<br>distance    | >23 (top<br>quartile) |   | Canada  | (Yang, Qiu<br>and Tu, 2022)                                 |
|  |   | Convenience stores,<br>fast food restaurants   | -  | -                     | Neighborhoods    | 1000 m                            | Network<br>distance    | > top quartile        |   | Canada  | (Tu, Qiu and<br>Yang, 2022)                                 |
| Ratio of<br>unhealthy and<br>healthy food<br>outlets | Number of<br>unhealthy food<br>outlets/Number of<br>healthy food<br>outlets           | Fast food/limited<br>service<br>establishments,<br>convenience stores                  | Supermarkets, grocery stores   |                       | County           | Within<br>the unit of<br>analysis | -                      | -                     | -   | USA     | (Cooksey-<br>Stowers,<br>Schwartz and<br>Brownell,<br>2017) |
|  |   | Fast food/limited<br>service<br>establishments,<br>convenience stores,<br>supercenters | Supermarkets,<br>grocery stores,<br>specialty stores<br>(e.g., produce<br>markets, delis),<br>and permanent<br>farmers'<br>markets |                       | County           | Within<br>the unit of<br>analysis | -                      | -                     | -   | USA     | (Cooksey-<br>Stowers,<br>Schwartz and<br>Brownell,<br>2017) |

| Fast food/limited<br>service<br>establishments,<br>convenience stores   | Supermarkets,<br>grocery stores,<br>specialty stores<br>(e.g, produce<br>markets, delis),<br>and permanent<br>farmers'<br>markets,<br>supercenters | County  | Within<br>the unit of<br>analysis   | -                      | -  | -   | USA            | (Cooksey-<br>Stowers,<br>Schwartz and<br>Brownell,<br>2017) |
|---|--|---|---|------------------------|--|---|----------------|---|
| Fast food/take-away<br>outlets, convenience<br>stores (bakery,<br>confectionary, dairy<br>shops, service<br>stations) | Supermarkets,<br>fruit and<br>vegetable<br>stores  | Census area<br>units  | Within<br>the unit of<br>analysis   | -                      | <u>&gt;</u> 0.9                              |   | New<br>Zealand | (Sushil <i>et al.</i> ,<br>2017)                            |
| Fast food<br>restaurants  | Grocers  | Zip-code  | Within<br>the unit of<br>analysis   | -                      |  | Adjusted for<br>population<br>density and<br>average<br>disposable<br>income and<br>standardized<br>(values range<br>between 0 and<br>10) | USA            | (Phillips and<br>Rodriguez,<br>2019)                        |
| Fast food outlets,<br>convenience stores  | Supermarkets,<br>grocery stores,<br>fruit and<br>vegetable shops   | Residential<br>units,<br>aggregated at<br>the level of<br>dissemination<br>areas (smallest<br>geographic<br>areas for which<br>census data are<br>disseminated) | 1000 m<br>reticular<br>zone in<br>urban<br>areas<br>and<br>16000 in<br>rural<br>areas | Network<br>distances   | >4   |   | Canada         | (Robitaille and<br>Paquette,<br>2020)                       |
| Fast food<br>restaurants, corner<br>stores  | Supermarkets,<br>farmers'<br>markets   | Schools   | 150 m   | Euclidean<br>distances | ≥3.89 (mean<br>across counties<br>in the US) |   | Guatemal<br>a  | (Chew, Moran<br>and Barnoya,<br>2020)                       |
| Convenience stores,<br>dollar stores, and<br>restaurants  | Supermarkets,<br>grocery stores,<br>meat markets,<br>farmers'<br>markets,<br>community<br>gardens, farm<br>road stands,<br>food parties            | Census tracks   | Within<br>the unit of<br>analysis   | -                      | >1   |   | USA            | (Almalki <i>et al.</i> ,<br>2021)                           |
| Fast food<br>restaurants  | Open-air<br>organic/<br>agroecological   | Regional<br>administration<br>(subdivision of   | Within<br>the unit of<br>analysis   | -                      | > median of the<br>municipality<br>(0.332)   | Average<br>income of the<br>head of   | Brazil         | (Grilo,<br>Menezes and<br>Duran, 2022)                      |

|   |  |  | food markets,<br>supermarkets  |   | municipalities<br>according to<br>geographical<br>position and<br>history of<br>occupation) |   |                        |   | household <<br>the median of<br>the municipality<br>(R\$2,275) or<br>percentage of<br>black and<br>brown<br>minorities > the<br>median of the<br>municipality<br>(26.9%) |        |   |
|---|--|--|--|---|---|---|------------------------|---|--|--------|---|
|   |  | Fast food<br>restaurants,<br>convenience stores  | Grocery stores,<br>farmers'<br>markets   |   | County  | Within<br>the unit of<br>analysis       | -                      | -   |  | USA    | (Bevel <i>et al.</i> ,<br>2023)             |
|   |  | Takeout,<br>convenience stores   | Supermarkets   |   | Census tract  | 1600 m<br>from the<br>tract<br>centroid | Euclidean<br>distances | >4  |  | USA    | (Coyle,<br>Keehan and<br>Schwartz,<br>2023) |
| Coverage of<br>unhealthy food<br>outlets and<br>ratio of<br>healthy/<br>unhealthy<br>outlets<br>service a<br>around u<br>food outl<br>healthy/<br>and ratio<br>outlets<br>service a<br>around u<br>specified<br>around u<br>food outl<br>healthy/<br>outlets<br>service a<br>around u<br>food outl<br>healthy<br>outlets<br>service a<br>around u<br>food outl<br>healthy<br>food outl<br>healthy<br>food outl<br>healthy<br>food outl<br>healthy<br>food outl<br>healthy<br>food outl<br>healthy<br>food outl<br>healthy<br>food outl<br>healthy<br>food outlets | Number of<br>service areas<br>around unhealthy<br>food outlets in a<br>specified area<br>and ratio between<br>service areas<br>around healthy<br>and unhealthy<br>food outlets | Convenience stores, fast food restaurants  | Supermarkets, grocery stores   | -   | Neighborhoods   | 1000 m                                  | Network<br>distance    | Service areas ><br>top quartile<br>Ratio < median |  | Canada | (Tu, Qiu and<br>Yang, 2022)                 |
|   |  | Convenience stores,<br>fast food restaurants   | Supermarkets,<br>grocery stores  | -   | Neighborhoods   | 1000 m                                  | Network<br>distance    | Service areas ><br>top quartile<br>Ratio < median | Low income<br>rate above the<br>city median  | Canada | (Tu, Qiu and<br>Yang, 2022)                 |
| Percentage of<br>unhealthy food<br>outlets  | 100x(Number of<br>unhealthy food<br>outlets)/(Number<br>of heathy food<br>outlets+Number<br>of unhealthy food<br>outlets)  | Fast food<br>restaurants,<br>convenience stores  | Grocery stores,<br>full-service<br>restaurants   |   | County  | Within<br>the unit of<br>analysis       | -                      | -   | -  | USA    | (Phillips and<br>Rodriguez,<br>2020)        |
| Proportion of<br>unhealthy and<br>intermediate<br>food outlets  | (Number of<br>unhealthy outlets<br>per square mile +<br>Number of<br>intermediate<br>outlets per square<br>mile)/Number of<br>all outlets per<br>square mile                   | Carry-out<br>restaurants, fast<br>food chain<br>restaurants,<br>convenience stores,<br>small grocers/corner<br>stores, unhealthy<br>specialty stores<br>(e.g., candy stores,<br>ice cream<br>parlors), dollar<br>stores, pharmacy<br>chain stores, gas<br>station chains | Healthy<br>specialty stores<br>(e.g., fruit and<br>vegetable<br>markets, fish<br>and seafood<br>market),<br>superstores<br>(e.g., wholesale<br>clubs),<br>supermarkets | Intermediate<br>outlets: full-<br>service<br>restaurants<br>and mixed-<br>specialty<br>stores (e.g.,<br>gourmet<br>food stores,<br>juice shops) | Community<br>statistical areas  | Within<br>the unit of<br>analysis       | -                      | -   |  | USA    | (Mui <i>et al.</i> ,<br>2017)               |

|  |   | carry-out<br>restaurants, fast<br>food chain<br>restaurants,<br>convenience stores,<br>small grocers/corner<br>stores, general<br>merchandise stores,<br>unhealthy specialty<br>stores, dollar stores,<br>pharmacy chain<br>stores, gas station<br>chains | healthy<br>specialty stores,<br>superstores,<br>supermarkets   | Intermediate<br>outlets: full-<br>service<br>restaurants<br>and mixed-<br>specialty<br>stores | Community<br>statistical areas  | Within<br>the unit of<br>analysis   | -                             | -                                    |   | USA     | (Mui,<br>Gittelsohn and<br>Jones-Smith,<br>2017)   |
|--|---|---|--|---|---|---|-------------------------------|--------------------------------------|---|---------|--|
| Proportion of<br>healthy food<br>outlets | 100xNumber of<br>healthy food<br>outlets/(Number<br>of heathy food<br>outlets+Number<br>of unhealthy food<br>outlets) | Fast food<br>restaurants,<br>convenience stores   | Supermarkets,<br>supercenters  |   | Dissemination<br>areas (smallest<br>geographic<br>areas for which<br>census data are<br>disseminated)   | 4 km<br>from the<br>centroid<br>of the<br>dissemin<br>ation<br>area   | Road<br>network<br>distances  | >0 and < 10                          | - | Canada  | (Luan, Law<br>and Quick,<br>2015)                  |
|  |   | Fast food<br>restaurants, small<br>grocery stores,<br>convenience stores  | Supermarket<br>and other<br>grocery stores<br>(except<br>convenience<br>stores),<br>warehouse<br>stores, fruit and<br>vegetable<br>markets |   | Census tract  | Within<br>the tract<br>and a<br>buffer<br>zone of<br>half a<br>mile from<br>the tract<br>boundary           | Euclidean<br>distances        | >0 and <u>&lt; 9</u> .09<br>(median) |   | USA     | (Amin,<br>Badruddoza<br>and<br>McCluskey,<br>2021) |
|  |   | Fast food<br>restaurants, small<br>grocery stores,<br>convenience stores  | Supermarkets,<br>larger grocery<br>stores, produce<br>stores   |   | Census tract  | Within<br>the<br>census<br>tract and<br>a buffer<br>zone of<br>half a<br>mile from<br>the tract<br>boundary | Euclidean<br>distances        | <u>&gt;</u> 1 and <u>&lt;</u> 4      |   | USA     | (Cerceo <i>et al.</i> ,<br>2023)                   |
|  | Number of<br>healthy food<br>outlets/(Number<br>of healthy food<br>outlets + Number<br>of unhealthy food<br>outlets)  | Fast food,<br>grillroom/shaorma,<br>delivery,<br>café/restaurant,<br>pancakes, butcher,<br>flans, chocolate,<br>tobacco, drugstore,<br>candy store,<br>warehouse, ice-<br>cream parlor, gas   | Greengrocer,<br>fish, on farm<br>store, nuts,<br>biostore  |   | Residential<br>areas (1000 m<br>walking distance<br>buffer around<br>the geometric<br>center<br>of gravity of all<br>residential<br>addresses within<br>a census tract) | Within<br>the unit of<br>analysis   | Walking/ro<br>ad<br>distances | -                                    |   | Belgium | (Smets, Cant<br>and<br>Vandevijvere,<br>2022)      |

|   |  | station, night shop,<br>disco, sex/party<br>clubs, theme park,<br>amusement hall,<br>party center, casino,<br>billiard/pool, indoor<br>playground, bowling,<br>zoo, video store,<br>cinema, theater, go<br>cart,<br>amusement/other,<br>ice skating track,<br>climbing hall, laser<br>game, ski track,<br>swimming pool,<br>sauna |  |   |        |                                       |                               |                                       |   |        |   |
|---|--|---|--|---|--------|---------------------------------------|-------------------------------|---------------------------------------|---|--------|---|
|   | Self-reported<br>number of healthy<br>food outlets<br>participants<br>nearby /Self-<br>reported number<br>of healthy and<br>unhealthy food<br>outlets nearby | Supercenter/club<br>stores,<br>convenience/corner<br>stores, fast-<br>food/limited service<br>establishments, gas<br>stations with foods  | Grocery store,<br>farmer's market,<br>full service/sit-<br>down restaurant |   | Homes  | 1.6 km (8<br>km in<br>rural<br>areas) | Self-<br>reported<br>distance | >0 and <u>&lt; 0</u> .368<br>(median) |   | USA    | (Cooksey<br>Stowers <i>et al.,</i><br>2020) |
| Proximity to<br>unhealthy food<br>outlets<br>compared to<br>healthy food<br>outlets | Shorter radial<br>distance to<br>unhealthy food<br>outlets/ Shorter<br>radial distance to<br>any other type of<br>food outlet                                | Convenience stores  | Supermarkets   | Grocery<br>store, corner<br>shop,<br>general<br>store.<br>fresh fruit<br>and<br>vegetable<br>store; red-<br>meat store,<br>poultry store;<br>fish and<br>seafood<br>store;<br>Seeds,<br>spices, and<br>food grains<br>store | Blocks | -                                     | Network<br>distance           | >1                                    | - | Mexico | (Reyes-<br>Puente <i>et al.</i> ,<br>2022)  |

Figure 1. PRISMA flow diagram for the selection of articles to be included in the scoping review.





Figure 2. Number of articles included in the scoping review per year and type of country.

Note: WEIRD stands for Western Educated Industrialized Rich and Democratic