

Assessing proximity-based food accessibility as an indicator of urban food security: the case of Milan, Italy

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Article

Keywords: Urban food security, Food environment, Accessibility, Proximity, Inequalities, Milan

Posted Date: October 22nd, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-11245019/v1>

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Additional Declarations: No competing interests reported.

Abstract

Urban food security is strictly linked to the unequal capacity of urban environments to provide accessible food opportunities in everyday life. Drawing on the multidimensional concept of foodability, this article focuses on its spatial dimension and assesses proximity-based food accessibility as an enabling spatial dimension of urban food security. The study develops a GIS-based methodology to analyse the potential spatial accessibility of different types of food opportunities in Milan, Italy, and its relationship with the area-based socio-economic status (SES), by combining 15-minute pedestrian-network isochrones from residential addresses, outlet-specific accessibility indicators, bivariate mapping and spatial association analysis. Results reveal a highly differentiated geography of food accessibility, which is generally higher in central and semi-central areas, while peripheral areas show more heterogeneous conditions. Neighbourhood shops and food-service establishments are more accessible in higher-SES areas, whereas medium and large retail stores show a much weaker association with SES. The Spatial analysis confirms a significant spatial co-patterning between accessibility and SES. The research provides an indicator capable of highlighting urban food spatial-justice, and the approach offers useful tools to identify socio-spatial inequalities and to support more integrated urban food policies as to building fairer and more sustainable cities.

1. Introduction

Urban food security has become a key challenge for contemporary cities, as urban areas concentrate population, food demand and economic activities, but also social inequalities, environmental risks and different forms of vulnerability. Despite the general abundance of food in cities, access to healthy, adequate and affordable food may remain highly unequal distributed, contributing to the coexistence of different forms of malnutrition and to wider disparities in health and quality of life^[1–2]. Urban food security is therefore not simply a question of food availability, but a multi- and inter-dimensional issue^[3] shaped by the interaction between food systems, socio-economic conditions as the organisation and the governance of urban space. Consequently, international initiatives such as the Milan Urban Food Policy Pact and the New Urban Agenda have increasingly recognised food security and sustainable food systems as relevant fields of urban governance, requiring integrated and multi-sectoral approaches to make food systems more equitable, accessible and sustainable^[4–5].

At the same time, urban food environments are being reshaped by broader processes of economic and social transformation. Changes in food retail structures, the expansion of eating out and food-service activities, tourism and the growth of the service economy have modified both the distribution and the functions of food-related opportunities within cities. Foodification processes, in particular, demonstrate how food can become a driver of urban attractiveness and economic regeneration while also contributing to the reconfiguration of neighbourhood functions and social hierarchies^[6–7–8]. A high concentration of food-related activities does not, therefore, necessarily imply equal access to food, on

the contrary, may put food security at risk, depending on the socioeconomic conditions of the neighborhood^[9].

These transformations make accessibility a key dimension for understanding urban food security. The distribution of food opportunities within the urban environment impacts on the conditions under which residents can reach them and potentially make use of them, and these conditions may differ considerably from one neighbourhood to another and from one social group to another. In other words, food accessibility represents one of the enabling conditions through which urban food opportunities may become effectively available to residents, without, however, being equivalent to food security as a whole.

This study addresses this issue by examining proximity-based food accessibility in Milan, Italy. Milan is a particularly relevant case as a dense and diversified food environment coexists with marked socio-spatial differentiation and ongoing transformations in urban and food. The analysis focuses on the potential spatial accessibility of different types of food opportunities within walking distance and on their relationship with the socio-economic characteristics of urban areas, combining pedestrian-network accessibility measures, an area-based socio-economic status index, bivariate mapping and spatial association analysis.

This study contributes to the literature in three main ways. First, it contributes to debates on urban food security and socio-spatial justice by examining proximity-based food accessibility as an enabling territorial condition of urban food security and by assessing whether it is unevenly distributed across socio-economic contexts. Second, it provides a methodological contribution by developing a fine-grained, GIS-based measure of potential proximity-based accessibility to different food opportunities based on pedestrian-network isochrones. Third, it provides empirical evidence on the spatial configuration of food accessibility in Milan, identifying areas where socio-economic disadvantage overlaps with lower potential access to food opportunities and thereby providing a spatial evidence base for urban food planning and policy.

The article is structured into six sections. Following this introduction (1), Section 2 develops the conceptual framework by linking urban food security to food accessibility, proximity and socio-spatial justice. Section 3 presents the case study of Milan (Italy), the data and methods. Section 4 reports the results, focusing on the spatial distribution of food accessibility according to each food opportunity provided and its relationship with socio-economic status. Section 5 discusses the findings in relation to urban food security, foodability and spatial inequalities and justice, while Section 6 concludes by outlining the theoretical, methodological and policy implications, together with its limitations.

2. Accessibility by proximity and urban food security

Urban food security is a multi- and inter-dimensional concept^[3], which also depends on the conditions under which individuals and households can reach, acquire, use and appropriate food resources in their

everyday environments. From this perspective, the urban food environment - understood as the material and immaterial context in which people encounter food and make decisions concerning its purchase and consumption^[10] - becomes a key dimension linking food security to the spatial and social organisation of cities. For instance, the distribution of food opportunities and the possibilities for reaching them shape dietary patterns, consumption and well-being^[11–12]. The characteristics of the local food environment can therefore facilitate or constrain food-related practices and contribute to reinforce inequalities in terms of health and quality of life^[13].

Food accessibility is therefore one of the mechanisms through which urban food systems intersect with urban food security and socio-spatial inequalities. Indeed, resources and opportunities are unevenly distributed across urban space and neighbourhoods provide different conditions for food access. The debate on food deserts was among the first attempts to conceptualise this relationship systematically. Since the 1990s, the term has been used particularly in Anglo-Saxon contexts, to describe areas where access to affordable, fresh and healthy food is limited^[14–15]. The relevance of the concept lies not simply in identifying areas with few food outlets, but in the frequent overlap between limited food access and concentrations of low-income households, minorities and other vulnerable populations. Food deserts therefore highlighted from the outset that food accessibility has both a spatial and a social dimension.

In European cities, however, the food-desert concept is not always easily transferable, as higher urban densities, more compact morphologies and historically more widespread neighbourhood retail often make areas of complete food-service absence less common^[16]. The issue therefore shifts from the simple presence or absence of food outlets towards the differentiated conditions under which urban populations can access them. Consequently, other concepts have spread in order to understand food accessibility. Food mirages describe situations in which adequate or healthy food is spatially available but remains economically inaccessible to lower-income populations due to high prices^[17]. Food swamps, in turn, identify environments where food outlets are abundant but the offer is dominated by energy-dense, highly processed, or otherwise unhealthy options^[18–19]. These concepts show that physical accessibility alone cannot be equated with food security.

A useful way of integrating these dimensions is provided by the concept of foodability^[20]. Rather than treating food access as a single condition, foodability conceptualises it as the outcome of 5 interrelated dimensions: i. availability of food within the food system; ii. accessibility, or the possibility of reaching food opportunities within reasonable distances; iii. affordability, resulting from the relationship between food prices and purchasing power; iv. awareness, including the knowledge and competences required to make informed food choices; and v., appropriateness of the food offer, namely its capacity to respond to nutritional, cultural, religious or other specific needs.

This multidimensional perspective is particularly relevant for urban food security as it allows to connect food security with the broader capabilities approach^[21]. Food accessibility can be understood as the possibility of reaching and participating in (food) activities and opportunities^[22], whilst Sen's capability

perspective emphasises that equality cannot be assessed only through the formal distribution of resources but must also consider people's ability to convert available resources into effective opportunities and functionings^[21]. Applied to urban accessibility, this distinction highlights the difference between the potential opportunities provided and their effective appropriation by individuals. Fol and Gallez^[23] express this distinction through the idea of accessibility as *get-at-ability*. In this sense, food accessibility can be interpreted as both a spatial condition and a component of the capacity to appropriate urban resources, therefore, food accessibility provides a way of examining the geography of urban inequality at the neighbourhood scale and of considering how the spatial organisation of food environments contributes to or constrains socio-spatial justice.

Within this multidimensional framework, the present study focuses specifically on spatial accessibility. This is not intended as an exhaustive measure of foodability or urban food security, but as one of their enabling dimensions, since its absence represents an additional constraint that individuals must overcome through other mobility, economic or organisational resources. In particular, the concept of accessibility by proximity^[24] makes it possible to connect issues of food access and food justice with those of active mobility, health and sustainability^[25]. Reaching food opportunities through active mobility can promote not only access to food, but also health, local economic vitality, and a reduction in environmental impacts^[26]. This perspective allows to integrate urban food planning and policy with proximity-based planning approaches such as the 15-minute city, which aim to organise urban services so that essential everyday opportunities can be reached within a short (15-minute) trip^[27]. Applied to food, proximity-based accessibility therefore refers to the extent to which the urban environment provides residents with the potential to reach food opportunities through active forms of mobility and without necessarily relying on additional transport resources.

From a socio-spatial justice perspective, the key question is consequently therefore areas with different socio-economic profiles are provided with comparable conditions of access. Unequal proximity may reinforce pre-existing inequalities by concentrating accessible food opportunities in already advantaged areas or by requiring populations in less well-served neighbourhoods to mobilise additional resources to reach them. Conversely, spatial proximity can act as an enabling condition that expands the set of opportunities potentially available to residents.

Proximity-based food accessibility can therefore be treated as a territorial indicator of one specific dimension of urban foodability as urban food security. By identifying how food opportunities are distributed in relation to residential locations and socio-economic conditions, it reveals the spatial structures that can facilitate or constrain food access. This provides the conceptual basis for the empirical analysis developed below, which evaluates the potential accessibility offered by Milan's urban food environment and examines whether these opportunities are distributed differently across socio-economic contexts.

3. Study area, data and methods

Within the framework outlined above, Milan has been selected as a relevant case for investigating proximity-based food accessibility and its relationship with urban food security. The city combines a dense built environment and an extensive commercial fabric with marked socio-spatial differentiation, as its urban structure comprises a highly serviced central area, consolidated semi-central neighbourhoods and heterogeneous peripheral sectors in which population density, urban morphology and the provision of services vary considerably.

Milan's food environment has also undergone significant transformations. Central and semi-central neighbourhoods have experienced a growing concentration of restaurants, bars and other food-service activities associated with eating out, tourism, cultural investment and the expansion of the service economy^[28–29]. At the same time, the retail food landscape reflects the coexistence of multiple alternative food networks such as *Gruppi di acquisto solidale* (GAS)^[30], urban farming^[31] and food governance such as school canteens^[32].

These characteristics make Milan an exemplary case for examining whether a dense and various urban food environment provides equal spatial food accessibility across neighbourhoods with different socio-economic profiles. The study covers the administrative territory of the Municipality of Milan.

The analysis combines four main datasets: (1) socio-demographic information from the 2021 Italian Population and Housing Census, provided by the Italian National Institute of Statistics (Istat); (2) administrative data on retail and food-related establishments provided by the Municipality of Milan and Lombardy Region for 2024; (3) geocoded residential street addresses within the municipality, provided by the Municipality of Milan; and (4) spatial data on the pedestrian street network derived from OpenStreetMap.

The census section, the smallest Italian geographical unit used, was adopted as the spatial unit for the analyses. After joining the census data and excluding sections with missing information and a residential population density lower than 100 inhab./Km², the final sample comprised 4,461 census sections.

The first analytical dimension concerns proximity-based food accessibility. The datasets on food opportunities made it possible to geolocate and classify establishments according to their administrative category: neighbourhood shops; medium and large retail stores; and food-service establishments, including restaurants, bars, pubs and other premises where food or beverages are served for consumption. For neighbourhood shops and medium and large retail stores, information on food retail floor area was also available and was used as a measure of outlet size.

Food accessibility was calculated through a GIS-based pedestrian network analysis using residential street addresses as origins, in order to better grasp the actual configuration and connectivity of the street network. Using OSMnx, a Python package for downloading, modelling, analysing, and visualising urban networks from OpenStreetMap data^[33], 15-minute pedestrian isochrones were generated from

each residential address, assuming a walking speed of 4.5 km/h, corresponding to the average walking speed of a standard pedestrian^[34].

Then, food outlets located within each isochrone were counted separately by outlet category using the QGIS Count Points in Polygon algorithm^[35]. For neighbourhood shops and medium and large retail stores, outlet counts were weighted by commercial floor area, in order to account for differences in the scale of the available food opportunities. The results obtained at the individual residential-address level were then aggregated to the census-section level by calculating, for each outlet category, the mean accessibility value across all residential addresses located within each census section, using the Join attributes by location (summary) tool in QGIS.

Census-section accessibility values were then normalised to a 0–1 range using min-max scaling and, subsequently, combined to derive three main indicators of potential spatial accessibility:

- Food-store accessibility was calculated as the sum of normalised accessibility to neighbourhood shops and medium and large retail stores.
- Food-service accessibility corresponds to the normalised accessibility to restaurants, bars and other food-service related to eating out, leisure, tourism and other consumption-oriented activities.
- Overall food accessibility was calculated as the sum of the normalised accessibility values for all outlet categories, providing a synthetic measure of the intensity of food opportunities potentially reachable on foot.

For cartographic representation, the continuous values of the accessibility indicators were classified using the Jenks natural breaks method, which identifies class boundaries by minimising differences within class and maximising between classes, while the original continuous values were retained for the statistical and spatial analyses.

The second analytical dimension concerns the socio-economic profile of the areas in which these accessibility opportunities are located. An area-based socio-economic status (SES) index was constructed using the characteristics of the resident population in each census section. The index includes four main dimensions: educational attainment, represented by the incidence of residents with upper-secondary and university qualifications; labour-market position, represented by the unemployment rate; household structure, represented by the incidence of households with five or more members; and citizenship, represented by the incidence of residents with foreign citizenship. Following Krishnan's proposal^[36], principal component analysis (PCA) was used to combine these indicators into a synthetic score. The KMO value was 0.63, indicating a moderate but acceptable level of sampling adequacy, while Bartlett's test was statistically significant, supporting the suitability of the correlation matrix for factor extraction. Based on the Kaiser criterion (eigenvalue > 1), one component was retained, accounting for 41.3% of the total variance. The resulting component was oriented so that higher scores indicate higher SES.

The analytical strategy combined descriptive, correlational and spatial approaches. First, the spatial distribution of overall food accessibility and its main components was mapped in order to identify differences across the city and between food opportunities. Second, Spearman's correlation was used to assess the overall association between SES and the different food accessibility indicators. The spatial dimension of this relationship was then explored through a bivariate choropleth map, jointly representing SES and overall potential proximity-based food accessibility, in which both variables were classified into three ordered classes using the Jenks natural breaks method, generating a 3×3 matrix of socio-spatial configurations. Finally, Lee's L bivariate spatial association statistic was applied to assess whether SES and food accessibility exhibited significant spatial co-patterning, using a k-nearest-neighbours spatial structure with eight neighbours, a bisquare local weighting scheme, and 9,999 random permutations to assess statistical significance.

4. Results

4.1 Potential Spatial Food Accessibility

The results reveal a highly differentiated geography of proximity-based food accessibility across Milan. Overall accessibility is generally higher in central and semi-central areas and lower in the outer areas of the municipality, although the distribution does not follow a uniform centre–periphery gradient (Fig. 1).

Milan's potential proximity-based food accessibility is therefore characterised by a strong central concentration, an intermediate belt with generally medium or high accessibility and a fragmented peripheral geography in which well-served local poles coexist with areas characterised by limited accessibility.

This differentiation becomes clearer when outlet categories are examined separately. Food-service establishments display the most pronounced central and semi-central concentration. Neighbourhood shops also show a central concentration, but their distribution is more dispersed. Medium and large retail stores instead follow a different pattern, since they are less concentrated in the historical centre and more frequently located in semi-peripheral and peripheral areas.

4.2 Food accessibility and socio-economic status

Spearman's correlation analysis identifies positive and statistically significant relationships between SES and the accessibility indicators, although the strength of the association varies according to outlet type. Accessibility to large retail structures shows only a very weak relationship with SES ($\rho = 0.073$, $p < .001$), suggesting that their distribution is relatively independent of the socio-economic profile of census sections, whilst stronger associations are found for neighbourhood shops ($\rho = 0.364$, $p < .001$) and food-service establishments ($\rho = 0.380$, $p < .001$). These results indicate that higher-SES sections tend to provide better walking access to food opportunities, particularly to neighbourhood shops and food-service establishments.

The bivariate map in Fig. 2 provides a more detailed representation of the relationship between SES and overall food accessibility. A concentration of sections combining high SES and high overall food accessibility is located in central and semi-central areas and, conversely, several outer areas combine low SES with low accessibility. Mixed configurations are also present: on the one hand, some lower-SES sections display medium or high accessibility, in particular near local commercial concentrations and large retail stores, on the other hand, some sections combine higher SES with relatively limited food accessibility.

Although the bivariate representation is descriptive and does not establish whether the observed combinations constitute statistically significant spatial patterns, the overall Lee’s L analysis confirms a positive, but relatively weak, spatial association between SES and the three proximity-based food accessibility (Table 1).

Table 1
Global bivariate spatial association between SES and proximity-based food accessibility

Indicator	Lee’s L	Permutation p-value
Overall food accessibility	0.2508	0.0002
Food-store accessibility	0.2189	0.0002
Food-service accessibility	0.1985	0.0002

Overall food accessibility shows the highest Lee’s L value ($L = 0.2508$), followed by food-store accessibility ($L = 0.2189$) and food-service accessibility ($L = 0.1985$). All associations are statistically significant (permutation $p = 0.0002$), indicating that the observed positive spatial co-patterning does not result from random spatial arrangement. At the same time, the relatively low magnitude of the coefficients suggests that SES captures only a small part of the spatial organisation of food accessibility.

The local Lee’s L results presented in Fig. 3 identify where specific combinations of SES and accessibility form statistically significant local spatial associations. High SES-High Overall food accessibility areas form a broad concentration across central and semi-central Milan. Low SES-Low Overall food accessibility associations occur more frequently in peripheral areas, although they do not form a continuous outer ring. High-Low and Low-High associations are less extensive and more locally specific. Low SES-High Overall food accessibility sections demonstrate that socio-economic disadvantage can coexist with a relatively dense spatial offer, in particular close to local retail centres. High SES-Low Overall food accessibility sections show that socio-economic advantage does not invariably correspond to a dense food environment. Finally, a substantial proportion of census sections does not display statistically significant local associations.

Taken together, results indicate a significant but relatively weak spatial relationship between SES and proximity-based food accessibility. Nevertheless, the recurrence of High-High configurations in central

and semi-central areas and Low-Low configurations in several peripheral sectors shows that proximity-based food accessibility is embedded, albeit only partially, in the broader socio-spatial structure of the city.

5. Discussion

The findings show that the spatial dimension of urban food security is unevenly distributed across Milan. Different areas of the city provide different territorial capacities for reaching food opportunities on foot, and these capacities are mainly associated with the socio-economic geography of the resident population. These findings are consistent with the literature on food justice, which has shown that food accessibility is not simply a matter of aggregate food provision but reflects the unequal distribution of resources and opportunities across social groups and urban spaces^[37–38–39]. From this perspective, the case of Milan confirms the relevance of moving from the presence of food resources to consider the territorial conditions under which these resources become potentially accessible.

This result supports the interpretation of proximity-based food accessibility as an enabling component of foodability and urban food security. The presence of reachable outlets does not establish that residents are food secure, but it represents an important territorial condition through which food opportunities may potentially be accessed and appropriated.

Bivariate mapping and Lee's L provides complementary evidence. On the one hand, the bivariate map describes the full range of territorial relationships between SES and accessibility, including intermediate and mismatched configurations; on the other hand, Lee's L identifies where these combinations form statistically significant spatial patterns. The two approaches demonstrate that the relationship between socio-economic conditions and food accessibility is significant and not reducible to a uniform centre-periphery gradient. In this regard, this finding also nuances the conventional food-desert perspective. Indeed, the Milan case suggests that a binary identification of areas as having or lacking food opportunities may be less appropriate for understanding the more complex geographies of food access, which consist of a mosaic of locally advantaged, disadvantaged and mismatched configurations.

Furthermore, the comparison of accessibility indicators demonstrates that food outlets cannot be treated as functionally equivalent. The different categories follow distinct spatial patterns and have different implications for urban food security.

Food stores are more directly connected to routine food provisioning. Their positive spatial association with SES indicates that the potential to purchase food locally is generally more favourable in socio-economically advantaged contexts. Medium and large retail stores show a much weaker association with SES and follow more infrastructure-dependent locational patterns. Large stores may partly compensate for a limited neighbourhood-retail fabric in some peripheral areas. However, their presence does not necessarily provide fine-grained proximity. They tend to be concentrated in fewer locations, serve larger catchment areas and may be more dependent on access via motorised transport.

Food-service establishments represent a different dimension of the food environment. Their central concentration reflects the role of food in eating out, tourism, leisure and the urban service economy. Although their accessibility is positively associated with SES, a high density of restaurants and bars cannot automatically be interpreted as stronger urban food security.

Food-service density may increase the diversity and visibility of the food environment, while remaining economically selective or poorly suited to routine food provisioning. Processes of foodification may also replace ordinary neighbourhood services with consumption-oriented establishments targeting visitors or higher-income groups^[40–41]. Spatial abundance can therefore coexist with limited affordability or with a supply that fails to meet residents' day-to-day needs.

In this regard, although the SES index does not directly measure food affordability, it nevertheless indicates whether potential food accessibility is systematically more or less favourable in areas with different socio-economic profiles.

Low SES-High Food Access configurations are particularly important for distinguishing physical accessibility from effective access. These areas contain a comparatively dense food environment, but this does not demonstrate that the available establishments and products are economically affordable. They may therefore resemble a food-mirage condition, where food opportunities are physically present but cannot be fully appropriated due to prices, needs or other barriers.

Low SES-Low Food Access configurations indicate a more direct territorial disadvantage. In these areas, socio-economic vulnerability overlaps with fewer opportunities within walking distance. Residents may also have fewer resources through which to compensate for the lack of proximity by travelling farther, using private transport or relying on delivery services.

The findings support greater integration between urban food policy, commercial planning and neighbourhood planning. Policies should not focus exclusively on the aggregate number of food-related establishments but should consider their type, location, pedestrian accessibility and relationship with local socio-economic conditions.

Proximity-based food accessibility should therefore be understood as a diagnostic indicator rather than as a comprehensive measure of urban food security. Its contribution lies in identifying how the urban environment enables or constrains the potential appropriation of food opportunities, and in highlighting where food, commercial and spatial planning policies could contribute to more equitable conditions of urban food security.

6. Conclusions

This study examined proximity-based food accessibility as an enabling spatial dimension of urban food security, using Milan as an empirical case. The findings show that food opportunities are unevenly distributed across the city and that their spatial accessibility varies according to both outlet type and the

socio-economic characteristics of urban areas. Central and semi-central areas generally provide higher levels of accessibility, while the peripheral city is more heterogeneous, combining relatively well-served local poles with areas characterised by lower accessibility. The results therefore point to a differentiated urban geography rather than to a simple centre–periphery divide.

The relationship with socio-economic status further demonstrates that food accessibility is embedded in the broader socio-spatial structure of the city. Bivariate mapping and Lee’s L analysis also identify significant spatial configurations in which higher SES and higher accessibility tend to cluster in central and semi-central areas, while Low SES-Low Food Access configurations occur more frequently in peripheral sectors. At the same time, the presence of mixed and non-significant configurations confirms that socio-economic disadvantage does not automatically translate into poor food accessibility, nor does spatial abundance necessarily ensure effective food access.

These findings contribute to the debate on urban food security and socio-spatial justice by showing that proximity-based food accessibility can be interpreted as one enabling territorial component of foodability. Spatial proximity does not constitute food security in itself, but it affects the set of opportunities potentially available to residents and the additional resources required to reach food.

From a methodological perspective, the study proposes a fine-grained approach that makes it possible to move beyond the simple presence or number of food outlets and to examine how different components of the food environment become potentially accessible from residential locations. It can therefore provide a diagnostic basis for identifying areas where food, commercial and neighbourhood policies may contribute to more equitable conditions of urban foodability.

The study also has limitations because, firstly, it measures potential spatial accessibility rather than effective access to actual shopping destinations, food purchasing practices or dietary behaviours. Second, affordability is only indirectly contextualised through the area-based SES index, and food prices, household income and purchasing power are not directly measured. Third, the available data do not capture the nutritional quality, cultural appropriateness or diversity of the food offered, nor other components of the urban food system such as food aid services and online grocery shopping.

Future research could integrate spatial accessibility with information on food prices, household resources and the nutritional characteristics of local food environments, while combining GIS-based measures with surveys and qualitative interviews. Such integration would make it possible to investigate more directly how territorial opportunities are converted into actual food practices across different socio-economic groups. Within these boundaries, proximity-based food accessibility provides a useful spatial lens through which to identify inequalities in the opportunities offered by the urban environment and to support more integrated urban food and planning policies.

Declarations

Funding:

This work is part of the project funded under the National Recovery and Resilience Plan (NRRP), Mission 4 Component 2 Investment 1.3 - Call for proposals No. 341 of 15 March 2022 of Italian Ministry of University and Research funded by the European Union – NextGenerationEU; Award Number: Project code PE000000003, Concession Decree No. 1550 of 11 October 2022 adopted by the Italian Ministry of University and Research, CUP D93C22000890001, Project title “ON Foods - Research and innovation network on food and nutrition Sustainability, Safety and Security – Working ON Foods”.

Author Contribution

Conceptualisation, L.D. and M.C.; methodology, L.D. and M.C.; data analysis, L.D.; data interpretation, L.D. AND M.C.; writing, review and editing, L.D. and M.C.; visualisation, L.D.; all authors reviewed the manuscript.

Acknowledgement

The authors acknowledge Best4Food, the Interdepartmental and Multidisciplinary Center for Food Science and Technology at the University of Milano-Bicocca, for fostering the interdisciplinary environment in which this research was developed.

Data Availability

The original data presented in the study are openly available at: <https://www.istat.it/it/archivio/104317> accessed on 30 September 2026; <https://dati.comune.milano.it/dataset/ds49-economia-esercizi-vicinato-sede-fissa> accessed on 30 September 2026; <https://dati.comune.milano.it/dataset/ds589-grandi-strutture-di-vendita-nel-comune-di-milano> accessed on 30 September 2026; <https://www.dati.lombardia.it/d/2si5-tumt> accessed on 30 September 2026; <https://dati.comune.milano.it/dataset/ds58-economia-pubblici-esercizi-in-piano> accessed on 30 September 2026

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Figures

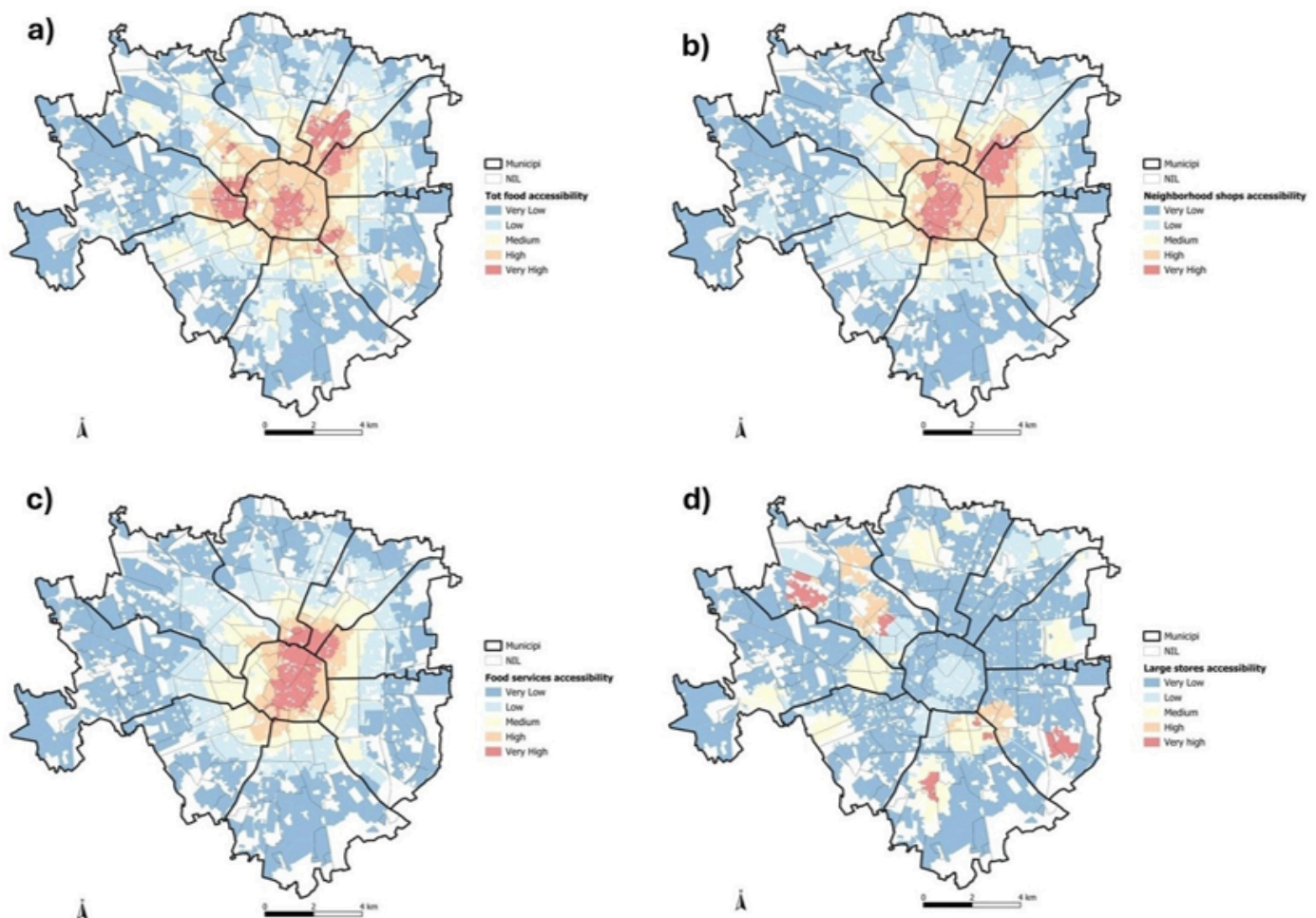


Figure 1

The distribution of proximity-based: a) Overall food accessibility; b) Neighbourhood shops' accessibility; c) Food-service accessibility; d) Large retail stores. Source: authors' elaboration on data from the Municipality of Milan (2024), OSM (2025).

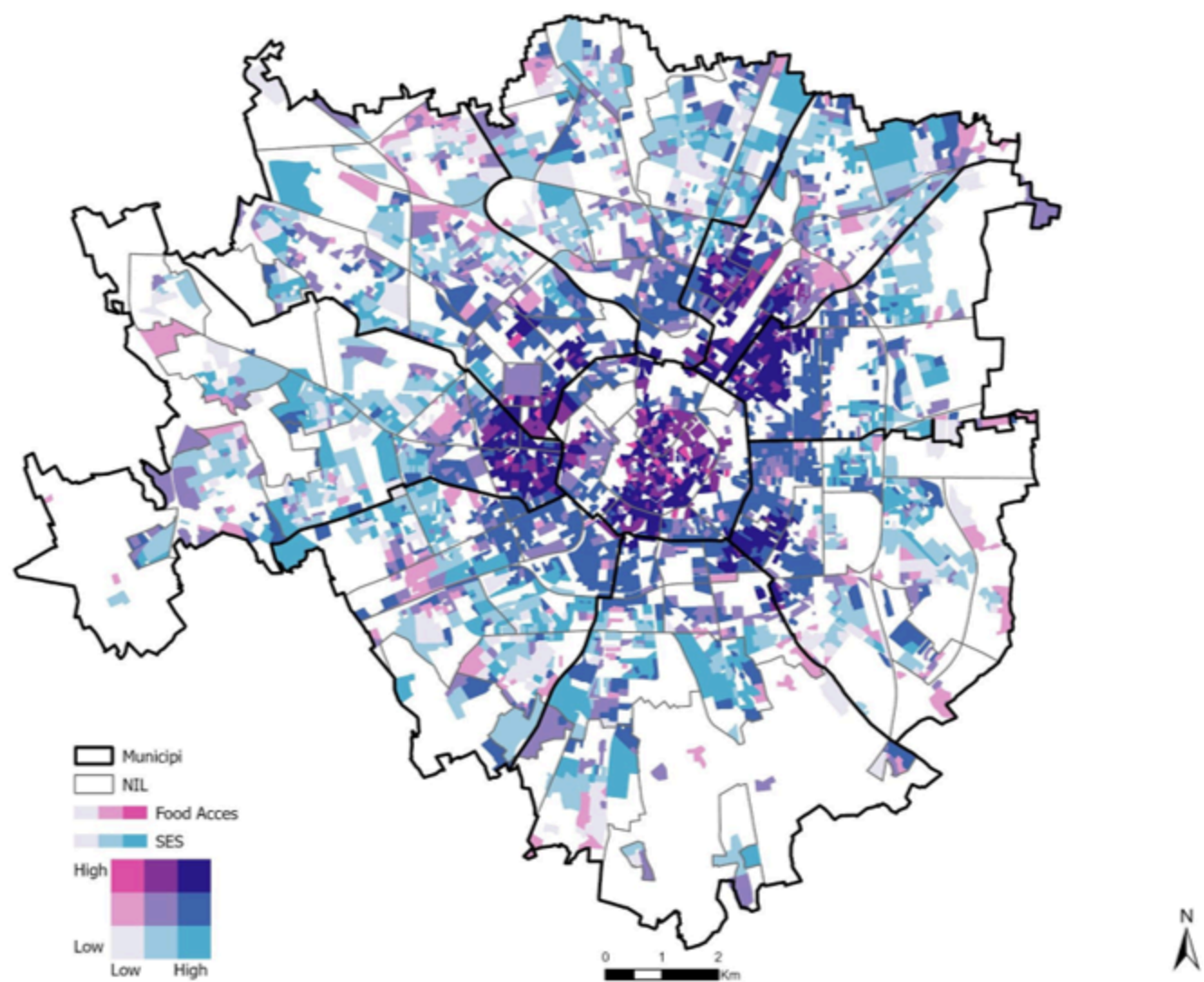


Figure 2

Bivariate distribution of socio-economic status and overall food accessibility in Milan. Source: authors' elaboration on data from ISTAT (2021), Municipality of Milan (2024), OSM (2025)

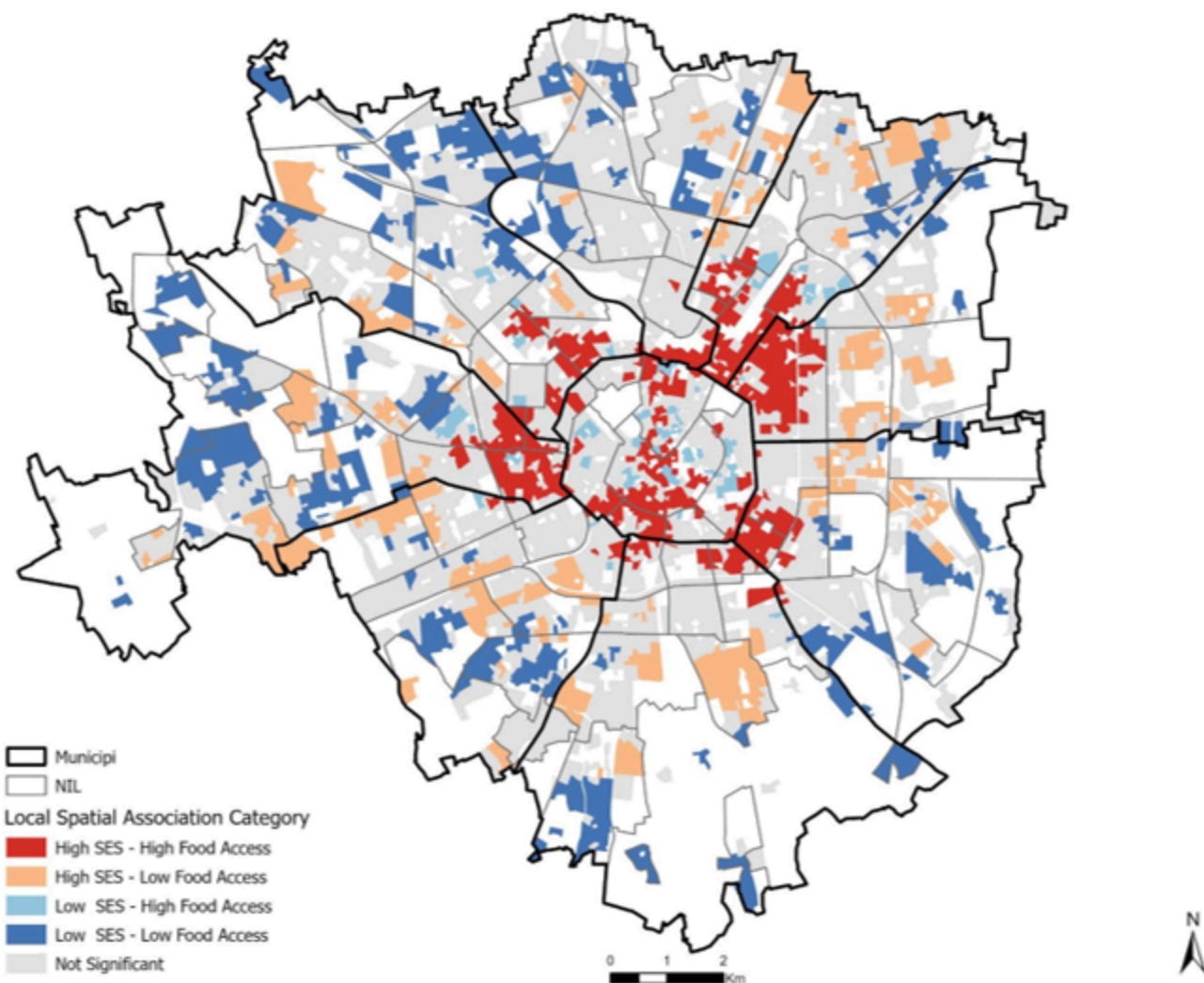


Figure 3

Local bivariate spatial associations between socio-economic status and food accessibility in Milan.
Source: authors' elaboration on data from ISTAT (2021), Municipality of Milan (2024), OSM (2025).