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Article

The Quality Turn of Food Deserts into Food Oases in European Cities: Market Opportunities for Local Producers

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Abstract: The current conventional food system is led by large-scale agribusinesses, characterized by industrialized production and increasing distance between food production and consumption. In response, alternative food initiatives (AFIs) have typically emerged as grassroots initiatives that may not be uniformly distributed or accessible. Food deserts, areas with limited access to healthy and affordable food, are often discussed without considering food quality. Addressing this, this article aims to assess food deserts for healthy, local, and sustainable products in 11 European cities, comparing conditions before and after the implementation of innovative actions focused on shortening food chains during three years of study. The methodology involves locating alternative production and consumption spaces (APSs and ACSs) and drawing a walking distance around them, identifying densely populated areas outside these radii as food deserts. The results show that the implementation of AFIs has reduced food deserts in 9 out of 11 cities (average from 10.1% at T0 to 7.4% at Tf), opening new market opportunities for local producers and increasing consumer access to local and sustainable produce. The implementation of this study's approach can potentially transform food deserts into food oases, enhancing food security and sustainability.

Keywords: food deserts; food oasis; alternative food initiatives; food security; food accessibility; short food supply chains; sustainability; market opportunities; local producers

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1. Introduction

Globally, over 50% of the population lives in urban areas. By 2045, the world's urban population will increase by 1.5 times, to 6 billion. This trend is expected to continue, with the urban population expected to more than double its current size by 2050. At that point, nearly 7 out of 10 people will live in cities [1]. Worldwide, urban expansion faces two persistent threats: a reduction in farmland and a disconnection between urban populations and food production regions [2].

The current global food system faces significant challenges, being characterized by inefficiencies, inequities, and unsustainability. Predominantly centralized and industrialized, this system often results in extended supply chains that disconnect consumers from the origins of their food, exploit natural resources, and perpetuate food insecurity. These issues contribute to significant adverse health, social, economic, and environmental impacts, which are particularly pronounced in cities [3,4].

Socially, the industrialization and globalization of agribusiness have exacerbated inequalities in food availability and worsened socio-economic conditions for farmers, leading to negative consequences for the welfare of the rural population. Nowadays, 111.1 million people face food insecurity, with slightly rising figures in Europe [3]. Moderate or severe food insecurity affected 33.3% of adults in rural areas in 2022, compared to 28.8% in peri-urban areas and 26.0% in urban areas [3]. In addition, the current food system is associated with increasing gender inequality and a rise in malnutrition-related health diseases, the effects of which are particularly severe in cases of crisis situations, as experienced during the recent COVID-19 pandemic [5].

In response to these challenges, there is an urgent need to transform the food system into a more sustainable model that addresses economic, social, and environmental dimensions [6]. One promising approach to tackling food inequalities is through alternative food networks (AFNs) and alternative food initiatives (AFIs) that aim to shorten food supply chains and localize food production and consumption. These initiatives encompass various practices, such as farmers' markets, community-supported agriculture (CSA), urban farms, and cooperative food enterprises, which differ from conventional food systems. AFIs can be driven by consumers, producers, or both, and may range from business-oriented to socially focused practices [7]. According to the literature, AFIs are categorized based on factors like their duration, geographic scope, producer and consumer commitment, number of intermediaries, and organizational and economic models [8].

Previous research on alternative food systems (AFSs), which is a blurry term bringing alternative food initiatives and networks together, has assumed the operation of AFSs at the margins of the mainstream conventional/industrial food system to be associated with a quality turn [9]. In other words, the issue of 'quality' turn has been the main argument in the AFI literature for distinguishing alternatives from mainstream methods during the last two decades. Although opponents of the idea criticize the "alternativeness of alternative food system" [10], alternative food initiatives are characterized by sustainability, social movements, health issues, short food supply chains, biodiversity conservation, and climate mitigation. These concerns have social embeddedness as a key component, and interrelate with grassroots and social movements. According to Sato et al., (2024) [11], AFIs are socially embedded sustainable food models.

We presuppose the quality argument of AFIs as a counter movement against the industrial food system, and accept the quality conventions of food as healthy, accessible and nutritious, which are the main concerns of AFIs. Also, in contrast to market-based niches that are compatible with the mainstream food system, AFIs are grassroots innovations that support the social economy and the needs of communities [12].

AFIs promote local, fair, and high-quality food by fostering direct relationships between producers and consumers, and re-integrating food production, distribution, and consumption into local contexts through short food supply chains (SFSCs). SFSCs emphasize not only geographic proximity, but also social and relational connections, rebuilding the relationship between producers and consumers and fostering new forms of social association and market governance [13].

For a long time, there was no standard definition of SFSCs in the EU; this term was commonly used to refer to supply chains involving a minimum number of intermediaries (or even direct sales from the producer). In 2013, the EU recognized the importance of short supply chains in rural areas, and defined them in Regulation (EU) No 1305/2013 of the European Parliament and of the Council of 17 December 2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD), which entered into force with the reformed Common Agricultural Policy for 2014–2020. This regulation describes a short supply chain that includes a limited number of cooperating economic actors, provides local economic development, and is characterized by close geographical and social links between producers, processors, and consumers. This definition is further clarified by Commission Delegated Regulation (EU) No 807/2014, which stipulates that support for establishing short supply chains covers only those involving no more than one intermediary between the farmer and the consumer.

Public institutions and governance structures have begun to recognize the potential of AFIs in addressing these food system challenges. Various policy frameworks, funding programs, and infrastructural support initiatives have been implemented to develop and scale up AFIs. The European Union, for example, has supported short food supply chains through regulations that encourage local economic development and strengthen geographical and social links between producers, processors, and consumers [14]. International bodies like the United Nations FAO's City Region Food System (CRFS) project, along with other organizations like IPES-Food or MUFPP, have also advocated for food localization as a strategy for achieving sustainability and resilience in urban food systems [4,15–18].

Another similar concept is "food reconnection", an oft-quoted concept in AFI research. This concept is particularly relevant in areas known as 'urban food deserts', where connections between cities and their nearby farmlands have been replaced by industrial-scale production for export and mass consumption [2]. This process has also been called "desertification" [19].

Food deserts, characterized by limited access to healthy, affordable food, are often associated with low-income neighborhoods and socio-economic challenges. While much research has focused on access and affordability, emerging studies emphasize the importance of food quality in transforming these areas into food oases. The "quality turn" in food studies links food deserts to value-added strategies in alternative food systems (AFSs), promoting ecologically embedded rural development. Addressing food swamps, with their abundance of unhealthy options, further highlights the need for quality-focused interventions.

This paradigm shift towards the creation of SFSCs and the implementation of alternative production and consumption spaces facilitates the creation of new market opportunities for local producers. By focusing on more direct and sustainable methods of bringing farm products to consumers, these initiatives reduce environmental impacts and strengthen local economies. Local producers can benefit from greater visibility and a closer connection to their customers, leading to increased product demand and the potential for more stable and fair pricing. This approach supports a more resilient food system that values quality, sustainability, and community well-being [20].

The existing literature [7,21–27] studies the impact of different kinds of AFIs in urban areas, particularly those addressing citizens' access to healthy and local food. Additionally, some studies explore the effects that AFIs have on food deserts and the quality turn of food deserts into food oases [21,22,24,26,27]. However, it is highlighted that the features of AFIs may vary depending on socio-economic, cultural, and geographical factors [7,25]. There is, therefore, a need to explore and compare the effect of AFIs in terms of turning food deserts into food oases across different countries and socio-economic contexts.

The purpose of this study is to contribute towards filling this gap by comparing the situation of food deserts from AFIs across the Living Labs (LLs) of 11 European cities before and after the implementation of innovative actions focused on SFSCs, in the context of the FUSILLI Project (Fostering the Urban food System Transformation through Innovative Living Labs Implementation). Specifically, the contribution of this study is to evaluate food desert areas and areas that are accessible to AFIs, with a focus on the accessibility of healthy, local, affordable, and sustainable food products. In doing so, this study offers a novel approach to comparing the status of "food deserts" in different European cities, in correlation with size and population, in different contexts.

After the introduction chapter, the methodology employed to obtain the results presented in Section 3 will be outlined. Following this, the discussion highlights the strengths and limitations of the study and suggests opportunities for future research. Finally, the conclusions can be found in Section 5.

The Effects of AFIs on Accessibility and Food Deserts in the Literature

Food deserts are areas where people have limited access to healthy and affordable food [28–30]. This concept often evokes images of residents traveling great distances to reach the nearest fresh food market [31]. Typically, food deserts are associated with low-income households and neighborhoods, with much of the literature focusing on the physical aspects, income levels, and socio-economic structures that define these areas [32]. However, only some studies have addressed the food quality available in these regions. The "quality turn" in food studies is an emerging field that links food deserts with the value-added strategies of AFSs. This shift emphasizes an ecologically embedded approach to rural development, moving away from the modernization paradigm [31,33]. On the other hand, food swamps are areas with sufficient retail access to food, but an overabundance of unhealthy food options [34]. The relationship between food swamps and food deserts is a relatively new study area, highlighting the importance of quality-focused AFIs in addressing these issues.

Emphasizing food quality has the potential to transform food deserts into food oases. The literature suggests that AFIs, by prioritizing quality, can play a crucial role in improving accessibility and reducing food deserts and swamps. The discussion around food swamps underscores the importance of the healthiness of available food, bringing the question of quality turn to the forefront. This quality turn, introduced by AFS discussions, might convert food deserts into thriving food oases [21,22] or eliminate them [23]. For instance, Jeremy L. Sage, (2017) [24] proposes that placing farmers' markets in disadvantaged areas, rather than near existing conventional markets, could address inequalities in food access and improve the overall quality of food available to residents. Similarly, Larsen and Gilliland, (2009) [35] and Karakaya, (2023) [36,37], emphasize how the introduction of community food programs and local markets can shape and reduce food deserts, especially when these actions expand beyond existing locations.

Shi and Hodges, (2015) [38] highlight the importance of introducing new farmers' markets to improve accessibility, while also considering other factors, such as urban–rural differences, consumer characteristics (age, income, household size) and perceptions of local foods. Safta, (2024) [26] examines the contribution of alternative food networks in addressing food insecurity in Detroit, a city with a long history of food access challenges. Gori, (2023) [7] reviews studies on the impact of AFIs in urban areas, particularly focusing on enhancing access to healthy and local food. In the same line, a study by Cummins et al., (2014) [25] finds that reducing the distance to food access points, such as through the introduction of grocery stores in underserved urban areas, improves food security. However, both Gori, (2023) [7] and Cummins et al., (2014) [25] note that such interventions may have varying effects depending on the context, and may yield limited benefits if restricted to pre-existing areas without expanding into underserved regions.

Török, (2024) [39], in his review on "Understanding the relevance of farmers' markets from 1955 to 2022", concludes that while in USA, farmers' markets are mainly assessed as a policy tool for providing fresh, healthy, and nutritious food to vulnerable consumer groups living in food deserts, in Europe, research on the contribution of farmers' markets is focused on sustainability measures as part of the SFSC concept associated with dedicated EU policies (including, among others, Farm to Fork and Green Deal). These findings highlight the context-dependent nature of AFIs, and their diverse contributions to addressing food accessibility and sustainability.

However, there is a lack of studies focusing on evaluating the effects of AFIs on food accessibility and food deserts by comparing them across different countries and contexts with the same methodology, especially in Europe. This study aims to contribute towards filling this gap.

2. Materials and Methods

The selection of AFIs is based on the quality concerns of alternative food systems in 11 European cities involved in the FUSILLI Project. The methodology then focuses on identifying the LL borders in the 11 European cities and locating their APSs and ACSs within those borders, first at the beginning of the project, in 2021 (T0), and then after 3 years of implementing innovative actions to foster urban food system transformation, in 2024 (Tf).

2.1. Literature Review for Establishing Accessibility Parameters

A comprehensive literature search was conducted using the Scopus, Science Direct, and Web of Science databases, focusing on the keywords “food deserts”, AND “walking distance” AND “accessibility”. The search was filtered to include only reviews and research articles. Additionally, research areas not directly related to the topic were excluded. Duplicated results were removed. This search yielded 69 results. No restrictions were imposed on the year of article publication, as the limited number of relevant results did not warrant the need for a time-based constraint.

To refine the selection, titles were first reviewed, excluding irrelevant studies. Then, 46 abstracts were carefully read, and 11 articles were selected for complete analysis.

The literature reveals that different studies use varying methods to define and measure food deserts [40,41]. Some research focuses on the geospatial distribution of food retail establishments relative to socio-economic population groups, analyzing the number or percentage of households located within a certain distance from food markets [32]. Other studies emphasize the physical distance to food retail units, examining the lengths, distances, and domains used to calculate food deserts [42–44].

The methodology used in this article is based on the concept of walking distances. We used universal standards to define the measurements of accessibility to food, identifying a 5 min walking distance (400 m) and a 10 min walking distance (800 m) to food retail units. In the literature, the accessibility standard of walking to public spaces and services such as public transit [45], urban green space [46], and schools [47] is defined as 400 m and 800 m. Accessibility to food is no exception; the 5 min walking distance is commonly used as a standard for disadvantaged groups, such as the elderly, children, and individuals with disabilities [48,49]. In contrast, the 10 min walking distance represents the walkable distance for adults [19,40,50–57]. This approach allows for a consistent and comparable analysis of accessibility in the context of food deserts.

2.2. Mapping the Geography of Alternative Food Systems

Urbanization is not just limited to city landscapes, but is a global process that extends into various territories [58]. Modern urbanization involves ongoing social and metabolic flows that blur the lines between urban and rural spaces, making traditional categories insufficient for explaining the spatial developments of the 21st century. These planetary urbanization processes are driven by diverse resources (labor, materials, fuel, water, food) and produce various byproducts (waste, pollution, carbon) [58].

This approach considers the entire spectrum of urbanization, where concentrated urbanization refers to the clustering of populations, services, infrastructure, and investments; differentiated urbanization describes the continuous transformation of socio-spatial organizations; and extended urbanization explains the spread of urban fabric beyond traditional boundaries.

Since food is one of the metabolic inputs within urbanization processes, we use this conceptualization to define categories of urban fabric in association with the flow of food procurement, consumption, and production spaces. The food-related spaces are categorized under six main headings: alternative production spaces, alternative procurement and processing spaces, conventional consumption spaces, alternative consumption spaces, alternative waste management spaces, and alternative governance spaces. Specifically, this study aims to explore APSs and ACSs, defined as locations where local, healthy, and sustainable food is produced, procured, purchased, sold, distributed, and/or consumed, understanding sustainable not only at the environmental level, but also considering its economic and social dimensions [59]. Table 1 classifies the main APSs and ACSs identified among the 11 cities.

Table 1. Main APS and ACS locations.

Alternative Production Spaces	Alternative Consumption Spaces
Urban farms	Farmers markets
Urban community gardens	Local food markets
Roof-top food gardens	Ecological markets/shops
Community-supported agriculture	Fair-trade markets/shops
Producer cooperatives	Food festivals and gastronomic fairs
Ecovillages	Community kitchens
Agri-parks	Consumer cooperatives
	Buyers' food clubs
	Neighborhood food communities
	Farm-side produce sales
	Van markets

Source: elaborated by authors.

The study of the cities at T0 and Tf involved four main steps: (1) identification of the LL borders; (2) identification and location of AFIs (APSs and ACSs); (3) analysis of the accessible areas to AFIs; and (4) evaluation of the food deserts within the LL borders.

2.3. Identification of Living Lab Boundaries

The cities involved in this study are San Sebastian (Spain), Nilüfer-Bursa (Turkey), Kolding (Denmark), Turin (İtaly), Kharkiv (Ukraine), Differdange (Luxembourg), Tampere (Finland), Rijeka (Croatia), Castelo Branco (Portugal), Athens (Greece), and Rome (Italy). They represent comprehensive geographical, climate, socio-economic, and cultural coverage of most of the situations and conditions in Europe.

The LL boundaries delineate areas where innovative actions are implemented and experimented. They are crucial as they represent the concentrated area of AFIs and their service range in terms of spatial accessibility.

These borders were decided upon by cities based on the locations where innovation actions were being implemented, according to the priorities and needs of the scope of action of each municipal agenda. Then, they were mapped using Google Maps, and subsequently reviewed and approved by the respective cities. Once confirmed, the finalized LL borders were meticulously drawn in ArcGIS 10.8 (https://www.esri.com.tr/tr-tr/surumler/10-8-surumler, accessed on 17 January 2025) using open-street base maps. In some cities, such as Rijeka, Rome, and Nilüfer, these boundaries align with the administrative borders of districts or of the cities themselves. However, in other cities, the LL boundaries differ from the administrative boundaries. For example, in Turin, the LL experimentation area is confined to a specific neighborhood, whereas in Castelo Branco, the LL extends beyond the city limits to encompass the entire region.

2.4. Identification and Location of AFIs (APSs and ACSs)

The identification of AFIs that were already being implemented in each LL at the start of the project was conducted through a workshop with the project managers. Data were gathered, together with further research on web-based sources, news, and social media, from cities and other alternative local and international networks in 13 languages (including English and local languages), and all of the presentations and documents that the cities and other partners in the FUSILLI Project Share Point had provided were scanned.

All the locations gathered were then inserted into Google Earth in KMZ format, and converted to shapefile format for combination with the OpenStreetMap (OSM) basemap on the ArcGIS platform. Thus, the data gathered and the points that were digitized and spatialized in shapefile format on OSM to correctly define their locations could be brought together in ArcGIS. As a basemap, we used OSM in the ArcGIS environment, which is open-source and has a general layout of 12 different city contexts. It is known that OSM has an accuracy in Europe of between 70 and 90%, and so we used scales of 1/50.000 and smaller. OSM data have positional accuracy of 1.57 m, which is suitable for generating planimetric maps with a scale of 1:5000 or smaller [60,61]. Google Earth was used for gathering spatial data representing the locations of the AFIs retrieved from city representatives. ArcGIS was used to combining the location data of each AFI and to manage the accessibility analysis. The accessibility analysis used was Radius analysis based on Euclidian distance, because of a lack of street network data for the 12 cities. In order to interpret the spatial distribution of the points and accessible areas in association with the general land use layout of the cities, we used the Corine database (2018).

After three years of implementing innovative actions, the coordinates for the new APSs and ACSs in the 11 cities were added to Google Earth, applying the same model, by combining them with the OSM database in ArcGIS.

2.5. Analysis of the Accessible Areas to AFIs at T0 and Tf

After the identification and location of the AFIs, two radii of 400 m and 800 m were drawn around each AFI, representing the accessible areas. The total accessible area was defined as the aggregated buffer areas of 400 m and 800 m radius distance. At Tf, the same dynamic was applied by drawing 400 m and 800 m radii around each new AFI to calculate the areas of accessibility after the implementation of innovative actions. For each city, the surface area of accessible areas at 400 and 800 m, and the total accessible area, were calculated at T0 and Tf.

2.5.1. Total Accessible Area vs. LL Area

To enable a meaningful comparison between the 11 cities, which have significantly different LL area sizes, a correlation in percentage terms was conducted between the total accessible area and the LL area. This was accomplished using Formula (1):

$$\%\ \text{Total accessible area vs. LL area} = \text{Total accessible area} \times 100/\text{Total LL area} \quad (1)$$

This approach allowed for the normalization of the accessible area data, ensuring that the comparison between cities of varying LL sizes was accurate and relevant.

2.5.2. Total Accessible Area vs. Population

The same pattern was followed to correlate the accessible area data with each city's population. A percentage-based correlation was conducted between the total accessible area and the population within the LL. By evaluating the availability of resources in proportion to the population, this method provides a clearer insight into how accessibility impacts communities of different sizes. This correlation was calculated using Formula (2):

$$\%\ \text{Total accessible area vs. LL population} = \text{Total accessible area} \times 100/\text{LL population} \quad (2)$$

2.6. Evaluation of the Food Deserts Within the LL Borders at T0 and Tf

The spatial analyses of food deserts were performed in ArcGIS 10.8, using a buffer tool with 400 m and 800 m distances from each AFI in each city. Populated areas outside these radii or accessible areas are classified as food deserts, while areas without concentrated populations located outside the accessible areas are not considered food deserts. At Tf, the area of food deserts was again calculated in the 11 cities after the implementation of innovative actions.

2.6.1. Food Desert Area vs. LL Area

To compare the 11 cities with varying LL area sizes, a percentage correlation was conducted between the food desert area and the total LL area. This correlation was determined using Formula (3):

$$\%\ \text{Food deserts area vs. LL area} = \text{Food deserts area} \times 100/\text{Total LL area} \quad (3)$$

This method standardizes the data by relating the food desert area to the overall LL area in each city, enabling a fair comparison. This approach provides a clearer understanding of the prevalence of food deserts in cities of different geographical sizes.

2.6.2. Food Desert Area vs. Population

The same method was applied to correlate the food desert area with the population in each city. A percentage-based correlation was performed between the food desert area and the population within the LL. By assessing resource availability relative to population size, this method explains how food deserts affect communities with varying population densities. This correlation was determined using Formula (4):

$$\%\ \text{Food deserts area vs. LL population} = \text{Food deserts area} \times 100/\text{LL population} \quad (4)$$

Apart from the correlations between accessible areas or food deserts, and LL boundaries or population, other factors were examined, such as the location of cities within Europe (categorized as north, central, east, or south), and whether the cities were coastal or inland. However, no significant correlations were identified between these geographic factors and the extent of food deserts in the studied cities.

3. Results

The results include the following: (1) the identification of LL borders, (2) the percentage of accessible areas, and (3) the food desert areas. These results were compared at the beginning (T0) and end of the implementation of innovative actions for 3 years (Tf) to assess the impact of AFIs on reducing food deserts in the 11 European cities. The results are shown in Table 2, Figures 1–3.

Table 2. The results of the analysis of accessible areas and food deserts at T0 and Tf in the 11 LL cities.

LL City	Time	LL Population	Area of LL Border (km^2)	Total Accessible Area (km^2)	Food Desert Area (km^2)
San Sebastian	T0 Tf	188,743	60	8.7 26.3	8.5 1.3
Nilüfer	T0 Tf	536,365	507.1	59.3 67.5	17.6 12.6
Kolding	T0 Tf	90,000	605	22 25	43 41
Turin	T0 Tf	33,816	8	11.7 12.5	0.1 0.05
Kharkiv	T0 Tf	1,158,485	344	156 158	34.3 32
Differdange	T0 Tf	29,764	22.2	5.1 7.8	1.1 0.4
Tampere	T0 Tf	250,353	523.4	59 63	99 97
Rijeka	T0 Tf	107,964	43.4	9.9 9.9	7.1 7.1
Castelo Branco	T0 Tf	47,849	1438.2	7 9.1	15.6 12.6
Athens	T0 Tf	643,452	39	20 28.7	10 5.6
Rome	T0 Tf	2,873,000	1285	339 339	102.7 102.7

Source: own elaboration of authors, based on cities' statistics and GIS data.

3.1. Living Lab Demographic Context: Size and Population

For each city, the boundaries of their LLs, and the number and characteristics of the AFIs they would implement as part of their Urban Food Plan, were independently determined. The following different patterns of LLs could be found:

Most of the LLs (San Sebastian, Kharkiv, Tampere, Rijeka, Athens, and Rome) are considered to be within the boundaries of the city or municipality, excluding the metropolitan area. A similar pattern is observed in all these cities: a high population concentrated within a relatively small area, although there are some differences among them. The San Sebastian and Rijeka LLs are the most comparable in size and population, both coastal cities in southern Europe. However, while Kharkiv and Tampere are both large in terms of surface area, Kharkiv's population is four times that of Tampere. The Rome LL stands out as the only case with a large area and a significantly larger population.

The Castelo Branco and Kolding LLs present a contrasting case. They encompass the city and its metropolitan area, following a pattern of large surface area, but lower population density, with these locations characterized by a city center surrounded by rural areas. The Castelo Branco LL is considered to cover the entire region of Beira Baixa in Portugal, with a population density of 0.03 inhabitants/m^2. The Kolding LL is not as large as Castelo Branco, but has nearly double the population. Another key difference is their geographical location in Europe, one in the north and the other in the south.

The Mirafiori LL in Turin is unique within the cities analyzed in the present study, as it represents a single neighborhood in Turin's peri-urban, more industrial zone. Consequently, its surface area is much smaller than that of the other LL, but with a higher population density, surpassing that of Differdange, at 4.23 inhabitants/m^2.

The Differdange LL could be considered similar to the Castelo Branco and Kolding LLs, since it includes other towns in the commune in addition to the city of Differdange. However, it is much smaller in terms of surface area and population, making it more comparable to the Turin LL in these aspects.

Nilüfer is 1 of 17 districts in the province of Bursa, Turkey. It is a residential city experiencing rapid growth in both size and population. Regarding surface area, the Nilüfer LL is similar to that of Kharkiv or Tampere, but in terms of population, it has half the population of Kharkiv and double that of Tampere.

3.2. Analysis of the Accessible Areas to AFIs at T0 and Tf

Figure 1 represents the accessible areas at 400 m from each AFI location in the 11 cities, at T0, in light pink. In dark pink, the accessible areas at 800 m are depicted. The total accessible areas are the sum of the light pink and dark pink areas. The blue circles represent food deserts at T0. The total accessible areas for each LL are quantified in Table 2.

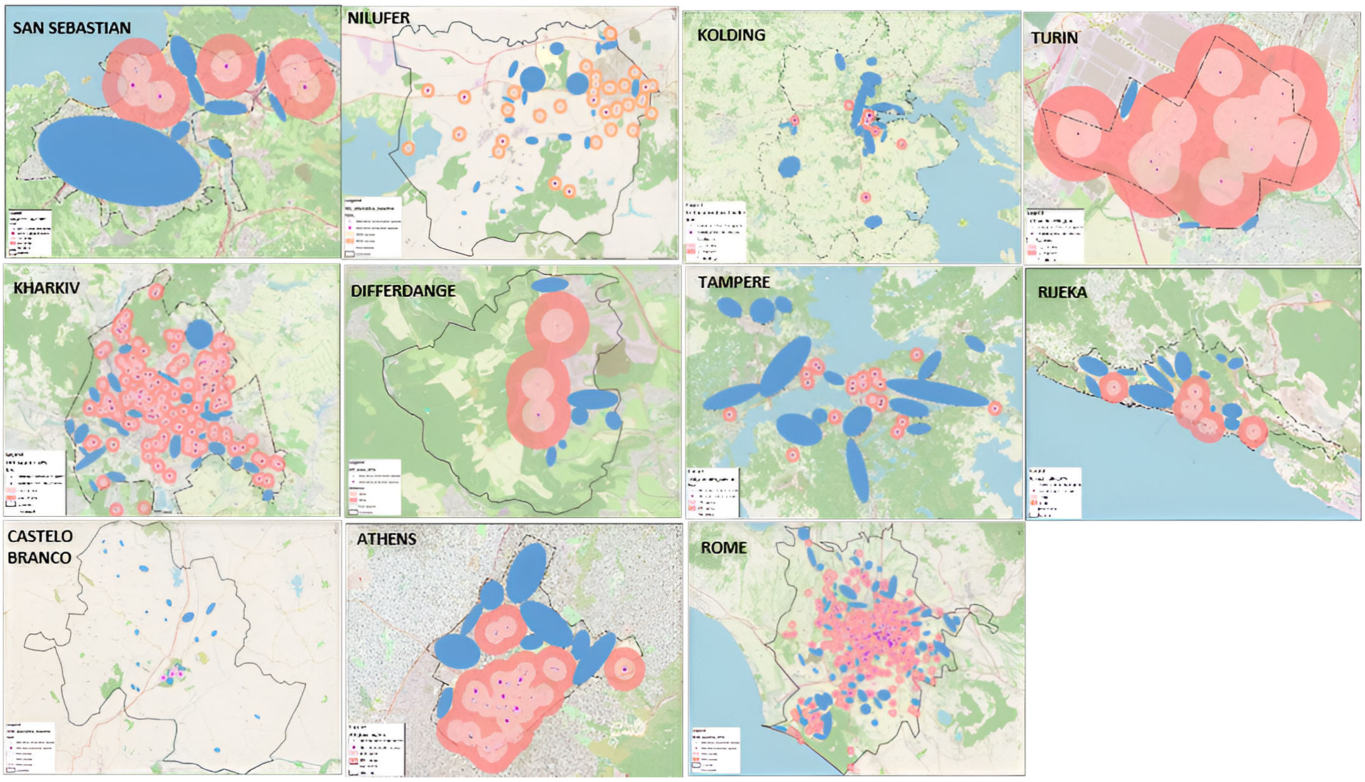

Figure 1. Representation of accessible areas and food deserts at T0 in the 11 LLs.

Figure 2 represents, in light purple, the accessible areas at 400 m from each AFI location in the 11 cities, at Tf. In green, the accessible areas at 800 m are depicted. The total accessible areas are the sum of the light purple and green areas. The blue circles represent the food deserts at Tf. The total accessible areas are quantified in Table 2.

Rome and Kharkiv are the LLs with the largest accessible areas, due to the high number of AFIs, while Differdange and Castelo Branco are the ones with the smallest accessible areas (Table 2).

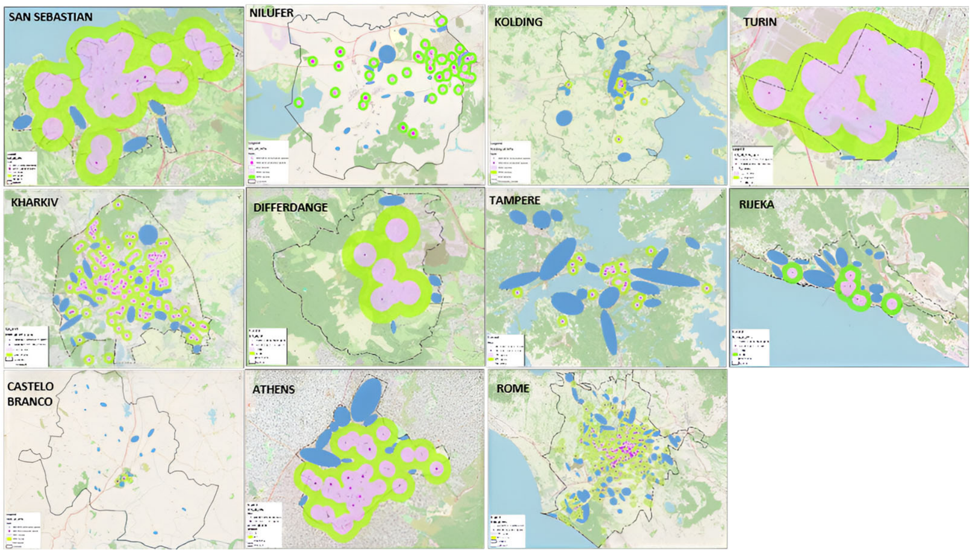

Figure 2. Representation of food deserts at Tf in the 11 LLs.

3.2.1. Total Accessible Area vs. LL Area

On average, across the 11 LLs, the percentage of the total accessible area relative to the area of the LL increased from 32.4% at T0 to 39.5% at Tf (Table 3).

At T0, if we correlate the total accessible area with the LL border area, the Turin and Athens LLs have better access to local, healthy, and sustainable food, while Kolding and Castelo Branco have poorer accessibility (Table 3).

After the implementation of innovative actions (Tf), the biggest improvement was seen in the San Sebastian and Athens LLs, which increased their accessibility to local, healthy, and sustainable food at a higher rate than the other cities, while the Rome LL maintained the same accessible area compared to T0 (Table 3).

Table 3. Total accessible area vs. LL area and vs. population at T0 and Tf.

City LL	Time	Total Accessible Area (km^2)	Total Accessible Area vs. LL Border Area (%)	Total Accessible Area vs. Population (m^2/inhab.)
San Sebastian	T0	8.7	14.5	46.1
	Tf	26.3	43.8	139.3
Nilüfer	T0	59.3	11.7	110.6
	Tf	67.5	13.3	125.8
Kolding	T0	22	3.6	244.4
	Tf	25	4.1	277.8
Turin	T0	11.7	146.3	346.0
	Tf	12.5	156.3	369.6
Kharkiv	T0	156	45.3	134.7
	Tf	158	45.9	136.4
Differdange	T0	5.1	23.0	171.3
	Tf	7.8	35.1	262.1
Tampere	T0	59	11.3	235.7
	Tf	63	12.0	251.6
Rijeka	T0	9.9	22.8	91.7
	Tf	9.9	22.8	91.7
Castelo Branco	T0	7	0.5	146.3
	Tf	9.1	0.6	190.2

Table 3. *Cont.*

City LL	Time	Total Accessible Area (km^2)	Total Accessible Area vs. LL Border Area (%)	Total Accessible Area vs. Population (m^2/inhab.)
Athens	T0 Tf	20 28.7	51.3 73.6	31.1 44.6
Rome	T0 Tf	339 339	26.4 26.4	118.0 118.0
Average	T0 Tf		32.4 39.5	152.3 182.5

Source: own elaboration, based on cities' statistics and GIS data.

3.2.2. Total Accessible Area vs. Population

On average across the 11 LLs, the percentage of the total accessible area relative to the LL population increased from 152.3 m^2/inhab. at T0 to 182.5 m^2/inhab. at Tf (Table 3).

If we correlate the total accessible area in each city with the LL population instead of the LL area, Turin continues to be the LL with the highest accessible area per inhabitant, followed by larger LLs with lower populations, such as those of Kolding or Tampere. Smaller LLs with high populations, such as those of Rijeka, San Sebastian, and Athens, had lower accessible areas per inhabitant at T0 (Table 3).

The situation at Tf is quite similar, but San Sebastian saw improved accessible area per inhabitant, while Rome remained the same (Table 3).

3.3. Evaluation of the Food Deserts Within the LL Borders at T0 and Tf

Figure 3 represents the food desert areas in each LL in blue circles, comparing the areas at T0 and Tf.

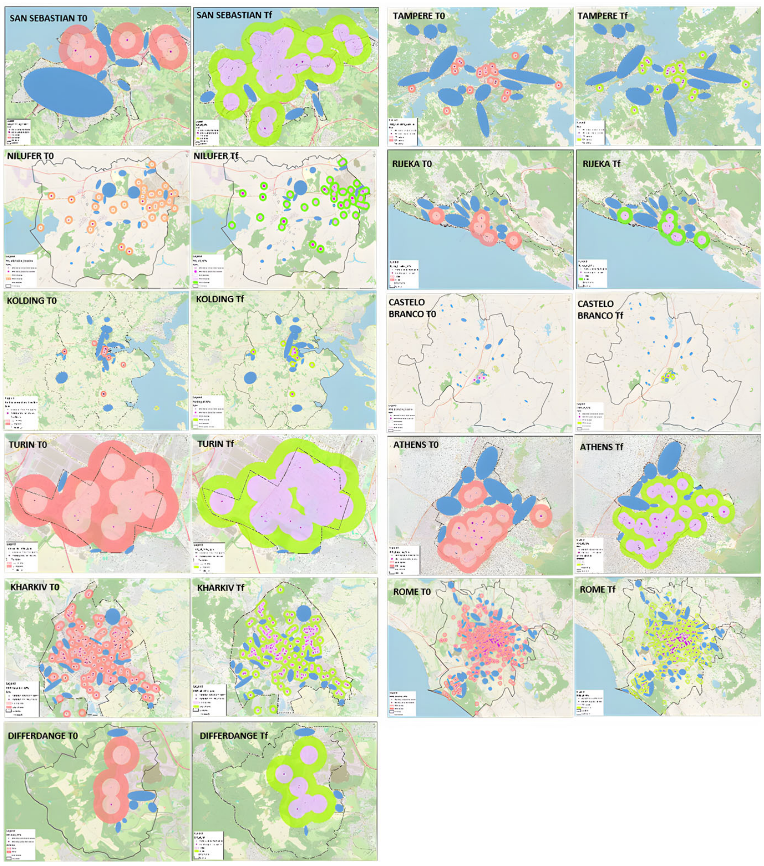

Figure 3. Comparison of representation of food deserts at T0 and Tf in the 11 LL cities.

Almost all cities (9 out of 11) reduced their food desert areas after the implementation of AFIs. Despite these improvements, at both T0 and Tf, Rome and Tampere exhibit the largest food desert areas among the LLs, whereas Turin and Differdange show the smallest areas (Table 2).

3.3.1. Food Desert Area vs. LL Area

As shown in Table 4, when comparing the food deserts within each LL border by calculating the percentage of food desert areas relative to the total LL border area, it was found that, on average, the food desert area in the 11 cities constituted 10.1% of the LL border area at T0. Following the implementation of APSs and ACSs, this percentage decreased to 7.4%. Therefore, the implementation of these types of actions had a positive impact on reducing food deserts in the cities under study.

Table 4. Food desert area vs. LL area and vs. population at T0 and Tf.

City LL	Time	Food Desert Area (km^2)	Food Desert Area vs. LL Border Area (%)	Food Desert Area vs. Population (m^2/inhab.)
San Sebastian	T0 Tf	8.5 1.3	14.2 2.1	45.0 6.9
Nilüfer	T0 Tf	17.6 12.6	3.5 2.5	32.8 23.5
Kolding	T0 Tf	43 41	7.1 6.8	477.8 455.6
Turin	T0 Tf	0.1 0.05	1.3 0.6	3.0 1.5
Kharkiv	T0 Tf	34.3 32	10 9.3	29.6 27.6
Differdange	T0 Tf	1.1 0.4	5.0 1.8	37.0 13.4
Tampere	T0 Tf	99 97	18.9 18.5	395.4 387.5
Rijeka	T0 Tf	7.1 7.1	16.4 16.4	65.8 65.8
Castelo Branco	T0 Tf	15.6 12.6	1.1 0.9	326.0 263.3
Athens	T0 Tf	10 5.6	25.6 14.4	15.5 8.7
Rome	T0 Tf	102.7 102.7	8 8	35.7 35.7
Average	T0 Tf		10.1 7.4	133.1 117.2

Source: own elaboration, based on cities' statistics and GIS data.

At T0, Castelo Branco and Turin had the lowest percentage of food deserts relative to the LL area, while Tampere and Athens were the LLs with the highest percentages. At Tf, San Sebastian and Athens had reduced their food deserts more significantly than the rest of the cities, and improved their ranking relative to T0.

All the LLs reduced their percentage of food deserts, except for Rome and Rijeka, which maintained their percentage. Despite implementing many actions focused on increasing awareness of local, healthy, and sustainable production and consumption, the locations of these actions remained the same. A similar situation occurred in other cities, such as Kolding, Tampere, Differdange, and Castelo Branco, where the number of APSs and ACSs did not significantly increase, although the intensity of actions in these spaces did. This modest effect can be attributed to the concentration of actions within existing facilities and zones, rather than their expansion into new areas.

Conversely, in San Sebastian, Nilüfer, Rijeka, and Athens, the percentage of food deserts was substantially reduced, due to an increase in the number of APSs and ACSs created during the implementation of the innovative actions. In Kharkiv, the security situation, due to the ongoing war, limited the implementation of actions.

3.3.2. Food Desert Area vs. Population

As shown in Table 4, the correlation between food desert areas and population across each LL revealed that the average food desert area per inhabitant in the 11 cities was 133.1 m^2 per inhabitant at T0. After implementing APSs and ACSs within the study period, this figure decreased to 117.2 m^2 per inhabitant at Tf.

Generally, the food desert area per inhabitant tends to be larger in sparsely populated, large LLs, and smaller in densely populated, small LLs. At T0, Castelo Branco, Tampere, and Kolding had the highest food desert areas per inhabitant, while Turin, Athens, and Kharkiv had the lowest.

By Tf, nearly all the cities reduced their food desert area per inhabitant, except Rijeka and Rome, due to the reasons discussed in Section 3.3.1. Besides this, the situation remained largely similar to the T0, except that San Sebastian achieved a more significant reduction in food desert area per inhabitant than the other cities.

4. Discussion

The LLs explored during the present study showed very different patterns, which increases the difficulty of comparing different cities across Europe. No studies have been conducted to compare different cities' LLs in terms of size and population. This comparison aims to reveal the disparities in the characteristics and peculiarities of each LL.

In this study, a general trend was observed whereby larger LLs exhibit higher levels of food accessibility due to the greater availability of AFIs. In contrast, smaller LLs typically have more limited accessible areas. When examining the correlation between the total accessible area and the LL's geographical extent, smaller LLs with more concentrated urban populations and higher densities of AFIs show greater access to local, healthy, and sustainable food sources. Considering this, evidence suggests that reducing the distance between food production and consumption through local food systems can enhance small-scale producers' market opportunities [13]. For instance, a study by Born and Purcell, (2006) [62] explores how local food systems can strengthen local economies by creating direct connections between producers and consumers, fostering economic resilience and sustainability. On the other hand, Gugerell, (2021) [13] confirmed that spatial or geographical proximity is not the most crucial variable in promoting the trustworthiness and attractiveness of AFNs (in this case, CSA), but other aspects, such as social-cognitive and institutional proximity, should be considered in order to increase market opportunities for urban farmers. On average, across the 11 Living Labs (LLs), the proportion of the area with accessibility to local, healthy, and sustainable food increased from 32.4% at the initial time (T0) to 39.5% after the implementation of innovative actions (Tf). Initially, cities such as Turin and Athens demonstrated better accessibility to food sources, while Kolding and Castelo Branco faced significant challenges. After implementing interventions to improve local food systems, San Sebastian and Athens showed the most significant improvements, markedly increasing accessibility to these food sources. Conversely, Rome did not experience any measurable improvement in its accessible area between T0 and Tf. This outcome aligns with existing research that emphasizes the role of local food systems in enhancing food accessibility. A study by Cummins et al., (2014) [25] supports the notion that urban interventions designed to reduce the distance to food access points can improve food security in some areas. This study explores the impact of opening a new grocery store in an underserved urban area, finding that while such interventions can improve food access and awareness, they may not always lead to significant changes in dietary habits or health outcomes, thus showing that the effectiveness of such interventions may vary by context. This supports the idea that urban interventions can improve food security in some areas, but may have different effects. Furthermore, the positive impact seen in San Sebastian and Athens aligns with research by Walker et al., 2010 [63], which shows that cities have developed public/private partnerships, and agreements between governments, private sector organizations, and local producers, in order to build and maintain infrastructure and necessary community facilities that increase access to local food within neighborhoods that other food retailers overlook. In contrast, in the case of Rome, the lack of improvement in addressing food deserts could be attributed to entrenched structural barriers, such as policy limitations or urban design, that obstruct the development of alternative food networks. This is consistent with the findings of Morgan and Sonnino, (2010) [64], who observed similar challenges in cities like London and New York. Another plausible explanation could be that Rome, which is already well developed in terms of AFIs, has reached saturation point, whereby the impact of further developments begins to diminish [65].

According to Varner 2006 [66] and Malagon-Zaldua 2018 [67], the economic dimension of food markets is also determined by the size of the town in which the market is located, the distance from it to other food stores, the level of crossover with other local marketing spaces, and the level of income of nearby residents. Factors such as the consumers' educational level or the market's longevity also seem to have a significant influence. Interestingly, when correlating total accessible areas with population, the data reveal that larger LLs with lower population densities tend to provide better accessibility per inhabitant. Conversely, smaller LLs with higher population densities—such as Athens—display the lowest accessible area per inhabitant, reflecting the challenges in densely populated areas. The USDA report (2010) [68,69] uses population density data to assess food access across the United States. This report highlights that areas with higher population density, particularly in urban environments, often have poorer access to affordable and nutritious food due to logistical and spatial constraints. Studies such as that by Bloem and Pee, (2017) [70] suggest that the larger a city is, the easier it will be for it to grow economically and reduce poverty. However, agglomeration economies have now been acknowledged to involve a constant tension between the benefits of grouping together and the drawbacks of facing congestion issues. This highlights the potential strength of strategically investing in medium-sized cities, as they are more likely to generate equitable growth, including for their surrounding hinterlands, thus strengthening local food systems and creating better enabling environments for improved urban nutrition through better sanitation infrastructures and increasing access to nutritious foods. According to our study, the improvement in San Sebastian suggests that well-planned urban interventions can have a substantial impact, even in more densely populated areas. San Sebastian's success shows that even in smaller, high-population LLs, targeted actions can improve food accessibility.

In terms of food deserts, almost all the LLs studied (9 out of 11) experienced a reduction in food desert area following the implementation of AFIs, suggesting that these initiatives positively impact the mitigation of food deserts in urban environments. This finding suggests that while targeted action can effectively reduce food deserts, the results can vary significantly depending on the city's pre-existing infrastructure and demographic characteristics.

Safta, (2024) [26], in his article "A Desert Mirage: The Myth of Detroit's Food Desert", discusses how alternative food networks contribute to a more nuanced understanding of food accessibility in Detroit. He argues that when both AFIs and the traditional food system are considered, not all parts of the city can be classified as food deserts. For this reason, after the implementation of APSs and ACSs, the percentage of food desert areas dropped to 7.4%. This suggests that such interventions have a positive impact in terms of reducing food deserts in the studied cities. All the LLs managed to reduce their food deserts, except for Rome and Rijeka, where the percentages remained unchanged. Despite numerous actions promoting local, healthy, and sustainable production and consumption, these interventions were concentrated in pre-existing locations, limiting their overall impact on food desert reduction. This pattern was also observed in other cities, including Kolding, Tampere, Differdange, and Castelo Branco, where the number of APSs and ACSs did not significantly increase, despite a rise in the intensity of activities within existing spaces. This limited impact could be due to a focus on existing facilities and locations rather than expansion into new areas.

This trend of positive food desert reduction through localized interventions is consistent with findings in the broader literature. Several studies, like those of Larsen and Gilliland, (2009) [35] and Karakaya, (2023) [36,37], highlight how the introduction of community food programs and local markets can shape and reduce food deserts, especially when these actions expand beyond existing locations. However, as Cummins et al., (2014) [25] note, urban interventions may have limited effects when restricted to pre-existing areas and not expanding to new, underserved regions. The mixed outcomes in Rome and Rijeka also mirror other urban studies [71], which find that concentrated but localized actions may fail to address broader accessibility issues without a city-wide expansion of services and infrastructure.

The correlation between food desert areas and population across the LLs revealed a general decrease in food desert areas per inhabitant following the introduction of APSs and ACSs, further supporting the positive role of AFIs in reducing food deserts [26]. Typically, food desert areas per inhabitant tend to be larger in sparsely populated, large LLs, and smaller in densely populated, smaller LLs [68,69]. This finding is in alignment with a study by D'Acosta, (2015) [72], who states that some of the factors contributing to the some areas continuing to suffer from food insecurity in Ohio are poverty, lack of car access, and low population density.

In summary, while the accessible area generally increases with the size of the LL due to the greater presence of AFIs, this positive relationship is moderated when accounting for population density. Cities with smaller, densely populated LLs tend to have a higher percentage of accessible areas relative to their total area, as the concentration of AFIs is more likely. In contrast, larger, sparsely populated regions often have more food deserts per inhabitant, highlighting the complex dynamics between population density, LL size, and food accessibility.

In addition to the considerations previously discussed, several methodological limitations of this study warrant further explanation. The 11 cities span a wide range of geographic, climatic, socio-economic, and cultural contexts, reflecting the diversity of conditions across Europe. This broad diversity introduces significant variation among the cities, complicating comparative analysis and making certain conclusions less robust due to the heterogeneity of the sample. This suggests that the results of this study may be generalizable to similar contexts within Europe, but may not accurately reflect realities in socio-economic and cultural settings outside of Europe. For instance, Zazo-Moratalla et al., (2025) [73], in her study on Chile, highlights that the Chilean model intermittently and regularly provides a healthy food environment within food deserts, acting as a midpoint between Global South and North models. Similarly, Bonuedi et al., (2022) [74] examines the role of access to local food markets in Sierra Leone, and finds that households with better market access consume more diverse diets and experience greater food security across both lean and non-lean seasons, compared to those in remote areas.

Another limitation is that not all AFIs in the cities analyzed may have been accounted for. Some initiatives may need to be formally registered in the food sector or gain more visibility online or on social media. Alternative food initiatives are not branches of social movements defined by strict rules, with a single globally clear and visible network structure, or established for a single purpose. Rather, they are independent initiatives that exhibit diversity and flexibility according to local and societal needs; they can be organized locally, nationally, or regionally, or they can connect to global networks. For example, the Slow Food movement describes an alternative food network, as does the URGENCI (CSA) movement. Even the peasant markets of the Movimentos Dos Santos movement can be described as alternative food initiatives when considered independently. In addition to such initiatives tied to such types of organizations, there are also completely independent initiatives that are not part of any network structure. Therefore, it is nearly impossible to gather information on each type of alternative food initiative in a geographic region or across multiple regions from a single source. Although there are exceptions in certain cities or regions where such data are collected, due to this fragmented structure, information on the AFIs was compiled by the authors from diverse sources and presented to city representatives at different times to be checked. After additions, deletions, and corrections by the city representatives, the database reached its final form. It is acknowledged that the AFIs included in this study are only the ones for which information could be obtained. Undoubtedly, this situation is among the limitations of the research.

Furthermore, while APSs and ACSs were grouped together under the term AFIs, their spatial distribution across the 11 cities may differ. ACSs, such as farmers' markets, consumer cooperatives, and organic markets, tend to be concentrated in densely built urban areas. In contrast, APSs, such as community gardens or allotment gardens, may also be found in urban zones, but organic farms and ecovillages are typically located in peripheral or peri-urban areas. This suggests that the proportion of ACSs and APSs may vary depending on the characteristics of each LL, particularly regarding the consideration of peri-urban and regional areas. Additionally, the four-year duration of the FUSILLI funding project allowed for the assessment of only the immediate impacts of alternative food initiatives following their implementation, leaving the long-term effects unexplored.

The study's approach also considered only walkable distances as the criterion for access to AFIs, whereas other studies have included additional means of transportation, such as buses or bikes [40,41,75–78]. Moreover, emerging forms of provisioning, such as online sales or delivery services that bring local, healthy food to workplaces or sports centers, have yet to be considered. Therefore, measuring distance alone is not the only way of determining limitations to accessing healthy food. While this study focused on physical food outlets, recent research has shown that digital food environments are expanding through cell phones, social media, and food delivery platforms, which can increase food access by extending the coverage of available outlets [79,80]. Future research should include the digital food environment when identifying food deserts and food swamps [40]. Online access to food has been found to be as practical as store access regarding health outcomes, and a clear urban–rural divide persists in both store and online grocery access [75]. Some studies have observed that while urban centers may resist e-shopping, vulnerable areas on the periphery of cities and rural regions could benefit from mobile grocery stores, which gained prominence during the COVID-19 pandemic [81].

From a social perspective, Gugerell, (2021) [13] argues that reducing spatial distances to urban farmers' markets may not be the most critical factor in fostering trust and attractiveness toward AFIs. Instead, social-cognitive and institutional proximity are more crucial. In this context, consumer preferences and willingness to pay for healthier, locally sourced products are key factors that influence the success of AFIs, the opportunities for local farmers, and the reduction of food deserts. This raises the question of which comes first: consumer demand or producer supply? Increasing consumer education may hold the key to boosting demand for healthy food.

Moreover, the availability of healthy and local food is only one concern; the excessive exposure to unhealthy, processed foods is also problematic. As Bridle-Fitzpatrick, (2015) [82] points out, "food swamps", characterized by an overabundance of unhealthy food options, may be an even more significant concern than food deserts in some areas. Recent research in the Netherlands suggests that obesity prevalence is more closely related to the accessibility of unhealthy food options than fresh food availability [83]. This highlights another limitation of the current study, as unhealthy options were not considered as competing alternatives for consumption. Further research should explore this dynamic in greater detail.

On the economic front, Kato and McKinney, (2015) [21] found, in a semi-experimental study in a low-income food desert neighborhood in New Orleans, that economic constraints have a greater influence on where residents purchase food than spatial or temporal limitations. Additionally, their study identified localized social barriers, such as fragmented social networks, as structural challenges to engaging residents in alternative markets. These findings underscore the importance of adopting a multi-dimensional and dynamic approach to understanding food access, considering economic, social, and spatial factors.

5. Conclusions

The implementation of AFIs showed positive impacts on increasing accessible areas and reducing food deserts across the studied LLs. AFIs, such as the establishment of APSs and ACSs, effectively expanded food access, particularly in cities where these spaces were strategically implemented. The analysis shows that as accessible areas within LLs increased, the total food desert areas decreased, demonstrating the crucial role that AFIs play in enhancing local food accessibility. At the end of the study, the results showed that food deserts were reduced in 9 out of 11 cities, and on average, the food desert area in the 11 participating cities decreased from 10.1% to 7.4% of the LL border area after the implementation of AFIs.

However, the success of these AFIs depends heavily on their geographic expansion. The accessibility of local, healthy, and sustainable food generally increases with the size of LL regions, but this relationship is moderated by population density. Food desert areas, when correlated with the size of LLs, tend to be larger in sparsely populated, large LLs, and smaller in densely populated, smaller LLs. Despite the variation in size and population density, a reduction in food desert areas was observed across most LLs, except for a few cases, like Rome and Rijeka. This points to the potential challenges faced by highly dense or spatially constrained regions, where existing infrastructure and urban design limit the ability to reduce food desert areas entirely.

The study's findings highlight significant implications for transforming food deserts into food oases in European cities, underscoring both challenges and opportunities. The successful implementation of AFIs, such as APSs and ACSs, demonstrates their potential to expand accessible food areas and reduce food deserts, particularly in strategically planned urban environments. This transformation offers a critical market opportunity for local producers to address underserved populations by introducing sustainable, nutritious, and locally produced foods. By doing so, they not only enhance food security, but also drive economic growth within local food systems.

In densely populated LLs, while AFIs have shown effectiveness, future interventions should focus on optimizing space utilization and improving distribution networks. Further research is needed to identify the most effective ways of scaling up these interventions in cities with limited space but high population demand. LLs with larger land areas and more dispersed populations should consider holistic approaches that integrate food system planning with transportation and infrastructure development. Policymakers and urban planners should encourage local food producers to enter food desert areas. Local producers can contribute to food security while growing their businesses by creating market opportunities in these underserved regions. Creating more efficient food supply chains, increasing local food production, and improving transport access to alternative food sources can reduce the extent of food deserts in such regions. The findings also suggest that factors such as socio-economic context, municipal support, and governance strategies play crucial roles in shaping food deserts. As these aspects were not fully explored in this study, they present important areas for future research, which could yield insights that further enhances food accessibility and informs more effective urban planning and policy interventions.

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