Analyzing the Spatial Dynamics of Food Swamps and Food Deserts in Greater London: A Study of Socioeconomic Impact from 2011 to 2021

By

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In submitting this dissertation, I confirm that it is my own work.

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Abstract

In the late 1990s, the question of food accessibility, specifically concerning essential components of a nutritious diet, emerged as a significant concern within the discussions surrounding social exclusion and health disparities, particularly in impoverished neighbourhoods of British cities. Studies have also taken place determining the relationship between the geography of fast-food outlets and obesity rates in the United Kingdom. While solutions to enhance accessibility and availability of nutritious food have been introduced, there also has been a rise in the number of fast-food outlets serving foods that exacerbate the issues related to lifestyle diseases. The present study deals with Greater London for the years 2011 and 2021, which has taken several steps in improving walkability and public transport, while also alleviating the issue of diseases like obesity in children with measures involving strategic planning for fast-food outlet locations across the City of London. This dissertation undertakes buffer analysis using population point data, retail store and fast-food location information, and relates the presence of food deserts (FD) and food swamps (FS), calculated by dividing Greater London into a fishnet grid of 500m resolution, to the deprivation in the area. The resulting analysis found that in terms of area, the food swamps increased by nearly 5.6% and food deserts shrunk by 6.8% over the period of 10 years. Moreover, the prevalence of food swamps was higher in most deprived areas, while the trend was reversed in the case of food deserts. Spatial statistics tests showed significantly high spatial autocorrelation for both FS and FD. The study helps in understanding the food insecurity scenario in Greater London for future city planning strategies.

Acknowledgments

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<u>List of Abbreviations</u>

- **BNG –** British National Grid
- **FD –** Food Desert(s)
- **FF –** Fast-food
- **FS –** Food Swamp(s)
- **GdB –** GeoDatabase
- **GLA –** Greater London Authority
- **IDW –** Inverse Distance Weighting
- **IMD –** Indices of Multiple Deprivation
- **LSOA –** Lower Layer Super Output Areas
- **NHS –** National Health Service
- **RFEI –** Retail Food Environment Index
- **UK –** United Kingdom
- **US –** United States
- **USDA –** United States Department of Agriculture
- **WGS –** World Geodetic System

1. Introduction

Chapter 1 introduces the scope of this dissertation by reviewing the current research problem and rationale for the direction of this investigation with the associated research aim and objectives. A summary of the theoretical context and literature addressing the issues of food insecurity and deprivation measures provides a contextual overview. Further background pertaining particularly to Greater London is available in the Study Area section.

1.1 Research Problem and Rationale

As defined by the USDA, food insecurity pertains to the insufficient access to nutritious food on a consistent basis, impacting members of a household and impeding their capacity to sustain an active and healthful lifestyle. (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015) This research takes into account three distinct spatial environments: food deserts, food oases, and food swamps. The term "food desert" was coined in the 1990s to delineate areas marked by limited access to food retail outlets. Subsequently, various studies have employed diverse methodologies to elucidate and grasp the notion of a food desert. However, the USDA defines a food desert as "An area with limited access to affordable and nutritious food, particularly such an area composed of predominantly lower income neighbourhoods and communities" (USDA, 2009) A collaborative investigation conducted by the USDA and the U.S. Department of Health and Human Services offered a precise, practical definition of a food desert for commercial applications – "low-income census tracts where a significant number of people (at least 500) or share of the population (at least 33%) live greater than one mile from the nearest supermarket, supercentre, or large grocery store for an urban area or greater than 10 miles for a rural area." (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015) While the study in Norway looks at the accessibility of grocery stores with the association of car ownership, the 500m walking distance to increase accessibility is the justification of using the 500m buffer catchment area in a densely, well-connected Greater London area. (Rokseth, Heinen and Hauglin, 2021) The concept of a "food oasis" refers to places where people enjoy excellent access to healthful food options and environments conducive to healthy eating. This includes both financial and physical availability of high-quality, affordable, culturally suitable food and beverages that meet the nutritional needs of the local community. (Krizan *et al.,* 2015) Food swamps are identified as urban areas with disadvantaged populations, where an abundance of fast-food establishments and convenience stores predominantly provide unhealthy food choices. (Phillips and Rodriguez, 2020) Certain researchers have also introduced the concept of a "food mirage," where healthy options are available, but their prices make it difficult for residents to access nutritious food. For the purpose of this study, food oases can be regarded as the standard, with a focus solely on food deserts and food swamps. While there have been GIS-based studies in the UK region, there has been a scarcity of longitudinal comparisons over the years regarding food deserts and swamps in relation to deprivation indices. (Videira and Newing, 2020) (Marsden, Hutton and Brown, 2005) An application of a time-dependent K-Nearest Neighbor Classification method was employed to map grocery store accessibility in Germany. This approach factored in the time required to reach a grocery store using various modes of transportation. (Neumeier and Kokorsch, 2021) The study primarily concentrated on rural Germany and identified a reduction in food deserts throughout the study duration. It also suggested that food deserts might be better characterized as individual experiences rather than geographically distinct phenomena. The research underscores the importance of conducting qualitative studies to better comprehend the statistics in relation to consumer choices, such as transportation modes and market preferences. The dissertation may take a more targeted approach based on catchment areas and restrict the analysis to the proximity to the nearest grocery store (Robitaille and Paquette, 2020) A Kellogg's study utilizes a comparable methodology, although certain variables, such as distance, might differ, and certain categories, such as convenience stores, might be excluded, however, this is one of the most comprehensive study on the topic in the UK, considering factors like car ownership and other factors of deprivation, but it does not take into account the change in the landscape over the years. (Corfe, 2018)

1.2 Aim and Research Objectives

Taking into account the existing research void in the depiction of changes in food deserts and food swamps, this dissertation seeks to establish a connection between the deprivation index and the evolution or decline of food deserts and food swamps in London for the years 2011 and 2021.

A) Is there a change in the number of food deserts and food swamps from the year 2011 to 2021?

B) Is there a correlation between the existence of food deserts and food swamps with the Index of Multiple Deprivation score (quantiles) for the corresponding year?

C) Null Hypothesis: Food deserts from 2011 have disappeared and residents now (2021) have access to nutritional food – Either the food deserts are now food oases (normal) and/or have not been turned into food swamps.

Testing the hypothesis is essential in determining if the concerned authorities and stakeholders, i.e. the retailers have helped in improving the food security amongst the population. To combat diseases like obesity, diabetes, hypertension etc, the council has the responsibility to ensure that nutritional food is accessible to the residents of the community. (Brown *et al.,* 2022)

1.3 Thesis Overview

This thesis is structured into four distinct chapters. Chapter 1 serves as an introduction, setting the stage by addressing the research problem, elucidating the rationale for this investigation, and offering an overview of the existing literature on food security and deprivation, thus providing a clear understanding of the specific objectives of this study. Chapter 2 delves into the details of data acquisition and preparation methods, along with a description of the buffer and statistical analyses performed. The results are meticulously laid out in Chapter 3, emphasizing noteworthy trends and possible data anomalies. This chapter also synthesizes these findings with relevant literature to explore the implications of deprivation on food insecurity in Greater London. Finally, Chapter 4 offers a concise summary of the principal discoveries from this study and outlines potential avenues for future research within the context of further city planning frameworks.

2. Methodology

Chapter 2 will first present a detailed socio-demographic, road network, health and deprivation, and retail sector overview of Greater London. The chapter will then detail the pertinent data and qualitative methodologies to determine the grid cells associated with food swamps and food deserts, and the IMD score quantiles corresponding to each of them. Finally, spatial autocorrelation techniques will be used to analyse the presence of spatial patterns in the data.

2.1 Study Area

The area under investigation is Greater London, interchangeably referred to as the London region located in southeast England athwart the Thames River (51°25'01.07" N, 0°08'35.98" W). It encompasses a total of 33 local government districts, including the 32 London boroughs that make up the county of Greater London, along with the City of London. The geographical expanse of the London area spans 1,572 square kilometers or 607 square miles (ranked 25th of 48 counties), with a population of 9,002,488 inhabitants (ranked 1st of 48 counties), while The City of London encompasses a land area of 2.9 square kilometers (1.12 square miles) and is home to a population of 8,583 residents according to the Census 2021. (Wikipedia, 2023) This is a 7.7% (8,173,941) and a 16.4% (7,176) increase from the Census 2011. (Office for National Statistics, 2023) London, as the capital of the United Kingdom, stands as one of the world's most ancient and cosmopolitan cities, with a history stretching back nearly two thousand years. Serving as the largest metropolis in Britain, it holds the pivotal roles of being the nation's economic hub, a major transportation centre, and a vibrant cultural focal point. (Clout *et al.,* 2023)

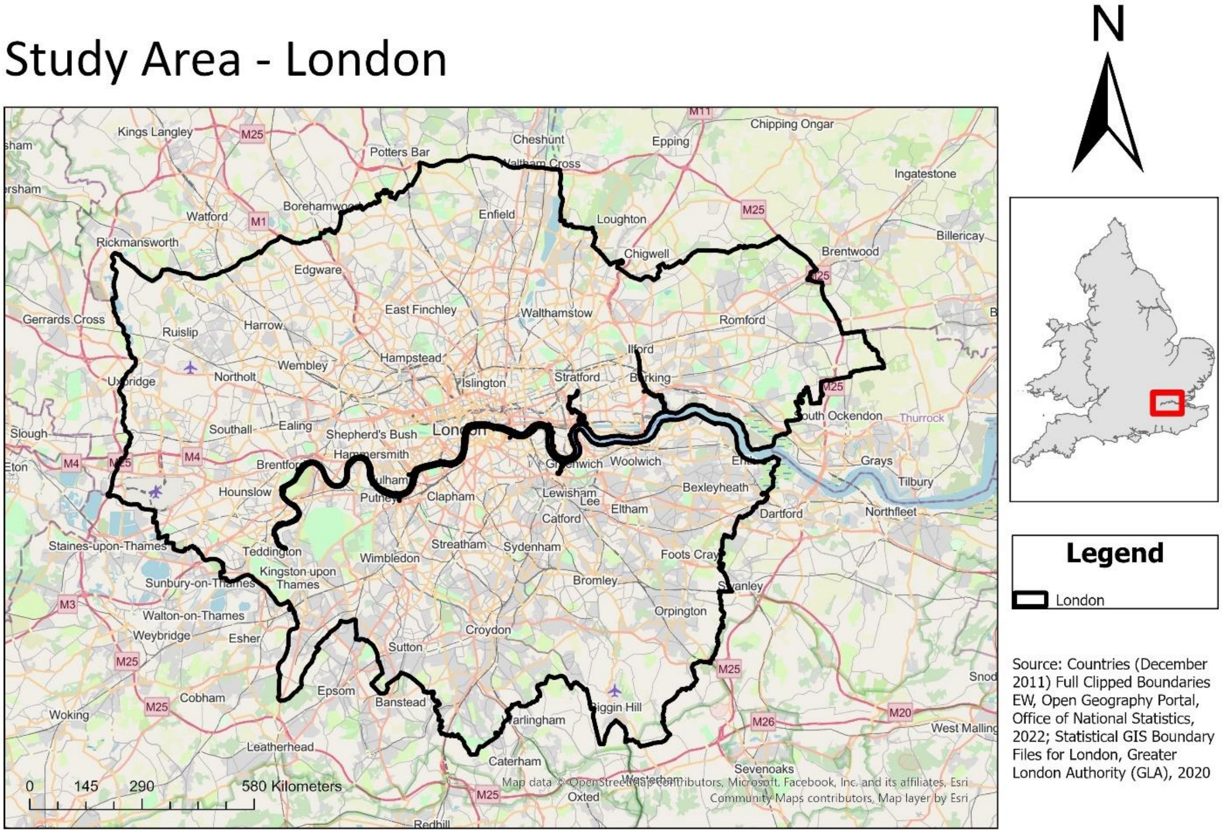


Figure 1: Study Area Map, Greater London

According to the 2021 Census data for England and Wales, London emerged as the most ethnically diverse region, with a remarkable 46.2% of its residents identifying with Asian, black, mixed, or 'other' ethnic backgrounds, and an additional 17.0% belonging to white ethnic minorities. Remarkably, London boasted the smallest percentage of individuals identifying as white British among all the regions. Furthermore, the data highlighted that a greater number of people from black, Asian, mixed, and 'other' ethnic groups chose to make London their home compared to any other region in England and Wales. These findings underscore London's status as a vibrant and culturally rich metropolis, celebrated for its unparalleled ethnic diversity. (Office for National Statistics, 2022)

London boasts a comprehensive transportation infrastructure that includes a series of ring roads, notably the M25 motorway, encircling Greater London and connecting to major motorways, facilitating efficient travel within and around the city. A network of major highways, such as the M1, M4, M3, M11, and M40, serves as vital arteries for accessing different parts of the country. (City of London Corporation, 2022) In addition to these, a well-developed system of A-roads and

B-roads connects neighbourhoods, suburbs, and the city centre. (Transport for London, 2021a) To alleviate congestion, Central London implements a Congestion Charge Zone during specific weekday hours and initiatives like Low Emission Zones and cycling lanes promote eco-friendly transportation. (Mayor of London, 2023) Furthermore, the city's road network seamlessly integrates with an extensive public transport system encompassing buses, trams, the Underground, Overground, and the Docklands Light Railway. (Transport for London, 2021b) Furthermore, funding of walking and cycling plans for the underrepresented communities and in general are being adopted currently to encourage Londoners to live a healthier lifestyle. (Transport for London, 2022) (Transport for London, 2019) The objectives outlined in the Road Modernisation Plan 2030, along with the Safe Streets for London plan by Transport for London (TfL), will be pursued by the Roads Task Force and the Mayor's Cycling Vision to improve accessibility. These initiatives encompass 17 major road schemes aimed at the creation of improved public spaces and the support of redevelopment and economic growth. Furthermore, 33 improvements to London's busiest junctions will be made, with a focus on making them safer and more appealing for vulnerable road users. To promote sustainable transportation, the plan includes the implementation of four new Cycle Superhighways and the enhancement of existing routes to ensure safer, faster, and more direct journeys into the city. Additionally, the modernization of traffic signals and the introduction of pedestrian countdowns will be carried out to facilitate greater ease in getting around the city. (Greater London Authority, 2014)

In terms of life expectancy, London has demonstrated notable advancements. In 1990, the average life expectancy for males was 73 years, while for females, it was 79 years. By 2019, these figures had risen significantly to 81 years for men and 84 years for women. (THE INSTITUTE FOR HEALTH METRICS AND EVALUATION, 2019) The disparities in life expectancy between the most deprived and least deprived individuals in London do not seem to be widening over time, in contrast to the trend observed for England as a whole. While the nation has experienced a notable expansion in the life expectancy gap since 2011-13, in London, this gap has actually seen a modest reduction. (Mayor of London, 2019) As of 2019, ischemic heart disease, stroke, and colorectal cancer continued to hold their positions as the foremost, third, and seventh leading causes of mortality. Meanwhile, diabetes emerged as the third most impactful factor contributing to both death and disability combined. The critical drivers behind this dual burden of death and disability encompassed a range of factors, including a high body-mass index, elevated fasting plasma glucose levels, dietary risks, hypertension, elevated LDL cholesterol levels, and malnutrition. These factors collectively played a substantial role in shaping the health landscape, underscoring the need for comprehensive public health interventions and strategies to address these challenges effectively. (THE INSTITUTE FOR HEALTH METRICS AND EVALUATION, 2019) Despite London having the second-highest percentage of children in the 5-15 age group meeting the recommended daily intake of five portions of fruits and vegetables in the UK, and performing at an average level in terms of physical activity metrics, the city still faces a significantly higher risk of childhood obesity, approximately 30% higher than other regions. This heightened risk can be attributed to factors related to material deprivation, primarily indicated by child poverty rates in the region. (Greater London Authority, 2010) The Greater London Authority, in partnership with the National Health Service (NHS), is unwavering in its commitment to elevating health standards across London through a comprehensive and multifaceted approach. These initiatives encompass a holistic vision for improving the overall well-being of Londoners. Under the banner of "Healthy London," a series of programs are diligently pursued. "Healthy Children" seeks to ensure that every child in London enjoys a healthy start in life, setting the stage for lifelong well-being. Concurrently, "Healthy Minds" aspires to create an environment where all Londoners have access to world-class mental health support, promoting mental well-being and resilience. "Healthy Places" focuses on forging an environment and economy that actively foster both mental and physical health, delivering benefits to all residents of London. Additionally, "Healthy Communities" endeavors to cultivate thriving and inclusive communities across London's diverse population. Lastly, the "Healthy Living" initiative strives to make healthy choices more accessible and convenient for all Londoners, encouraging individuals to lead healthier lives. (Mayor of London, 2019) The outcomes of proceedings by the Department of Health and Social Care suggested banning allocation of new fast-food establishments at least 400 meters away from schools to restrict their promotion among children. (Department of Health and Social Care, 2021) Furthermore, these efforts reflect a significant shift in healthcare priorities, emphasizing preventive healthcare measures and a renewed focus on individual empowerment. Greater emphasis is placed on proactive measures to avert illness, encouraging individuals to take responsibility for their own health and effectively manage their health conditions through self-care. Primary care services are undergoing transformation to enhance accessibility and responsiveness, ensuring that healthcare is more readily available to all. Moreover, there is a concerted effort to integrate healthcare services seamlessly across hospital, community, and social care boundaries, improving care coordination and offering patients a smoother and more efficient healthcare experience. Collectively, these multifaceted initiatives represent a dedicated commitment to uplift the overall health and well-being of London's residents. (NHS England (London Region), 2013)

The Index of Multiple Deprivation assesses various forms of deprivation within specific small geographic areas. In previous literature the comparisons using the indices have been done on different extents, say LSOAs and Boroughs. However, because they are a relative measure, the Indices cannot be utilized to gauge the actual changes in deprivation within an area over a period of time. (Domman, 2019) Nonetheless, this study uses rankings and scores interchangeably to compare areas and the two years – 2011 and 2021. It is to be noted that the closest dataset available for the said years is for the years 2010 and 2019, which paints the scenario for the gap in the relative years. This is also because the data for the 2010 report was obtained in 2008, while the data for the 2019 report was obtained in 2015 and 2016. (Leeser, 2019) (Haringey Council, 2011) A report by Trust for London, which rebased the English Indices of Multiple Deprivation for the year 2019 for London revealed a complex landscape of economic disparities, where neighbourhoods from various deciles are juxtaposed in all boroughs to some extent. The boroughs in London with the highest levels of deprivation have notably reduced their level of deprivation when compared to other regions across the country. (Domman, 2019) (London Council Members briefing) Out of London's 4,835 Lower-layer Super Output Areas (LSOAs), only eight, which equates to a mere 0.2 percent, fall within the top 5 percent of the most deprived areas in England. Additionally, an additional 99 LSOAs, accounting for just two percent, fall into the top 10 percent of England's most deprived areas. (Leeser, 2019) On the other hand, London's boroughs play a noteworthy role in income deprivation, as they encompass eight of the 32 most income-deprived authorities when assessed by average rank. Additionally, four more boroughs are featured among the 32 most deprived regions on the Income Scale, which accounts for the number of individuals experiencing income deprivation within an area. This illustrates that while London may have fewer areas characterized by extreme income deprivation, it does exhibit a broader distribution of income deprivation across its various boroughs. (Domman, 2019) Moreover, deprivation among older adults (aged 60 and above) in London remains a stubborn challenge, showing no signs of decline. It's noteworthy that seven out of the ten English local authorities with the highest levels of income deprivation affecting older people are situated within London's boroughs. While some Londoners approach retirement with substantial assets, a considerable portion of the capital's elderly population still grapples with financial difficulties during their retirement years. (Bosetti, 2019) The relatively high levels of income deprivation hint at a potential imbalance between wage levels and the cost of living, especially in certain regions, which could disproportionately affect vulnerable groups such as children and the elderly. Overall, however, London has seen a decline in deprivation when ranked against other parts of the country and is less deprived according to the 2019 IMD records. (Leeser, 2019) (Domman, 2019) While a general trend can be seen in the maps for the two years – northeast quarters being particularly deprived as compared to southwest and central parts, highly deprived clusters may be seen at a closer extent in the centre, which is an example of Modifiable Areal Unit Problem and is beyond the scope of this study. (Trust for London, 2019) (McLennan *et al.,* 2011) (insert maps IMD)

Retail constitutes the most substantial portion of spending for residents in London. More specifically, within retail expenditure, the largest portion is allocated to food and non-alcoholic beverages. Hence, it is crucial to comprehend the retail sector, particularly the grocery retail market. In London, there are nearly 9,000 grocery stores, with the majority, about 80 percent, being independently operated. Nevertheless, in terms of actual sales, these independent stores contribute to approximately 13 percent of the total expenditure on grocery items in London. On the other hand, major multiple grocery retailers like Tesco and Asda, even though they make up just one-fifth of all stores in London, command the lion's share, accounting for 87 percent of the spending on grocery items. The London grocery market exhibits a high level of concentration in terms of sales, even more so than the broader UK market. This concentration can be attributed to the fact that large retail chains possess greater purchasing power compared to smaller, independent stores. Additionally, these larger retailers often maintain uniform pricing nationwide. (GLA Economics, 2005) Consequently, this study focuses exclusively on large retail stores when assessing metrics related to food insecurity. In the 2005 study and even today, proximity to a grocery store has remained a significant factor in consumer research and purchasing decisions. The primary rationale behind this focus is the fundamental consideration: "Can I easily reach the store?" This underscores the vital importance of a store's proximity to its potential customers, which directly influences its sales. To illustrate this, the analysis was revisited using a radius of half a mile, equivalent to an 11-minute walk based on National Travel Survey data. Remarkably, approximately 60 percent of London's population resides within this half-mile radius, ensuring convenient walking distance access to major grocery stores like Asda, Morrisons, Sainsbury's, Tesco, or Waitrose. The current study employs a 500-meter buffer, enabling a walk of less than 10 minutes to reach the grocery store. This enduring emphasis on proximity underscores its continued relevance and importance in both past and present consumer research and shopping behaviour. (GLA Economics, 2005) In a 2020 study focused on Tesco, one of the United Kingdom's foremost retailers and ranked as the world's ninth highest-grossing retailer, researchers analyzed data dating back to 2015. Their investigation aimed to discern the shopping preferences of Greater London residents across the 411 Tesco stores in the region. The study yielded a significant finding, linking the prevalence of obesity and metabolic disorders in both adults and children to diets characterized by high carbohydrate and fat intake. Conversely, it revealed a notable inverse correlation between obesity and metabolic disorders and the consumption of items with higher fibre and protein content. (Aiello *et al.,* 2020) (nature tesco grocery) This means that the fast foods that are rich in calories, abundant in saturated fat, and lacking in essential micronutrients, will only worsen the situation. (Fraser and Edwards, 2010) A report released by Public Health England introduced London's inaugural "takeaway map" for boroughs, shedding light on how the local environment poses challenges for children in avoiding the obesity crisis. The map unveiled a total of 8,622 takeaway establishments, with official data underscoring the higher prevalence of overweight and obese children residing in economically disadvantaged areas. (Lydall, 2016)

2.2 Data Acquisition and Preparation

2.2.1 Data Sources

1. Greater London boundary shapefile - Statistical GIS Boundary Files for London, London Datastore (Greater London Authority, (., 2013)
2. The United Kingdom boundary shapefile – Open Geography Portal, Office for National Statistics (Open Geography Portal, 2022)
3. Population Points for the United Kingdom (2011 and 2020) – WorldPop Hub (WorldPop, 2020)
4. The UK retail point data (2014 and 2021) – Open Data, Geolytix (GEOLYTIX, 2023)
5. Fast-food location points GeoDatabase (GdB) (2014 and 2021) – Points of Interest, Edina Digimap (Ordnance Survey, 2015) (Ordnance Survey, 2021)
6. The English Indices of Multiple Deprivation at the LSOA level (2010 and 2019) – The Government of UK (Ministry of Housing, Communities & Local Government, 2011) (Ministry of Housing, Communities & Local Government, 2019)

2.2.2 *Data Preparation*

Most of the steps are carried out in the ArcGIS Pro 3.1 Map Environment, a desktop GIS application by ESRI. The colour palette provided by the software is based on COLORBREWER2, a colour advice for cartography. Some data cleaning prior to addition in the software was carried out in MS Excel. All the calculations were carried out in ArcGIS Pro using the "Field Calculator" in the respective layer attribute tables.

Firstly, the population count raster data was downloaded from WorldPop Hub for the years 2011 and 2020, which was the closest dataset available for the years in consideration, i.e. 2011 and 2021. The data was at 100mx100m resolution in the WGS1984 projection. The resulting points when converted from raster in the BNG were at 72mx72m resolution and, were naturally displaced from their original positions, although only slightly. This however, meant that the total number of residents in Greater London from the resulting dataset was slightly different from the census data from the Office for National Statistics. According to the official census data, the population of Greater London grew in the 10 years, however, the population count from the WorldPop dataset for the year 2019 (or 2021) was less than that of the year 2011. This again is a negligible difference which may be ignored, more about the choice of dataset in the Discussion section. A bounding box was created around the Greater London shapefile, and the raster for the whole United Kingdom was masked on to it using the "Extract by Mask" tool to get the raster for the study area. The raster was converted to points using "Raster to Point" tool. "Create Fishnet" tool was used to create a 500mx500m fishnet grid including fishnet labels for the study area. The population points were joined to the fishnet points and summarized over the fishnet polygons using "Summarize" in the attribute table to get the population counts for the 500mx500m fishnet grid points and the population for the grid cells to be used later in the analysis. All the steps were carried out for both the years using appropriate data and shapefiles.

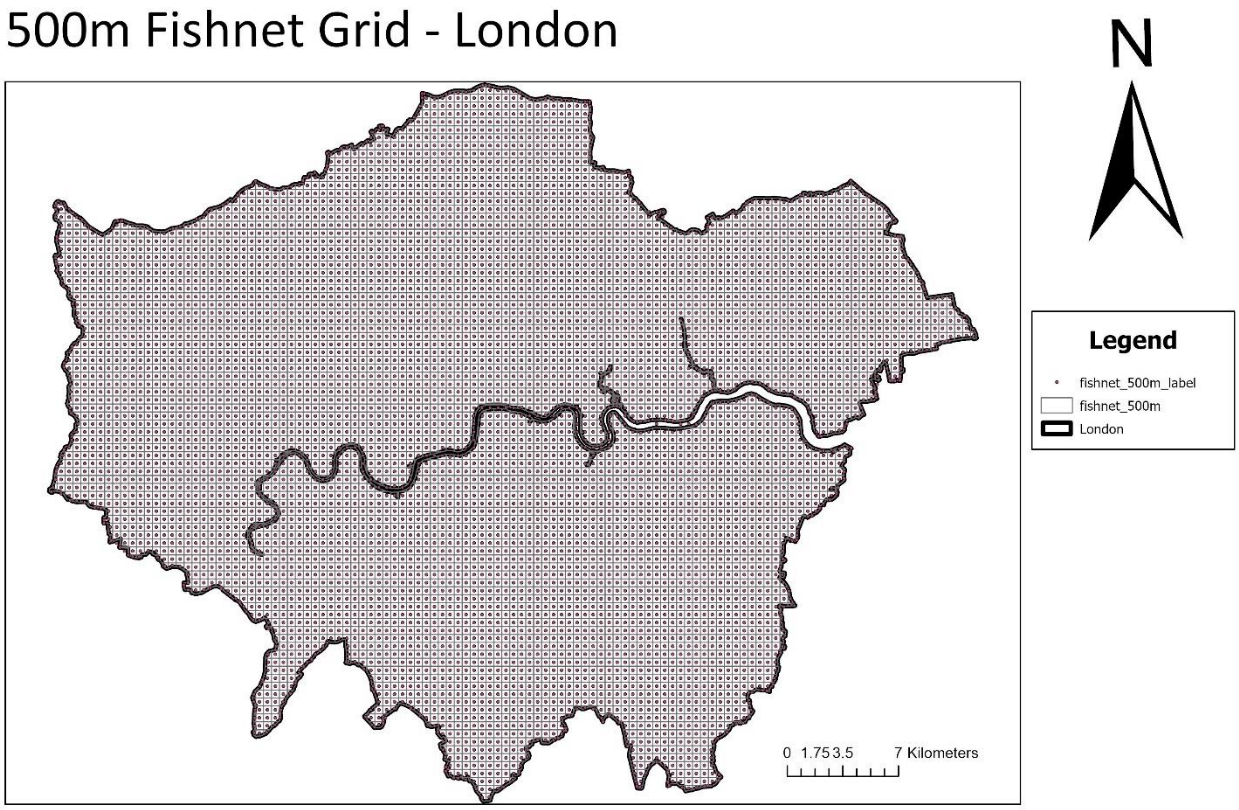


Figure 2: 500mx500m Fishnet Grid Cells and Labels – Greater London

For the food retail grocery store location data, only 8 of the top 10 supermarket chains by revenue were considered for this study, as the data for SPAR and Co-op supermarket chains was not available for the year 2014, which was the dataset available for the closest year to 2011. (YouGov, 2023) (McHugh, 2023) The data was readily available at the Open Data portal on the Geolytix data sources, which updates retail store data regularly for each quarter of the year. The original source for the data is Edina Digimaps, however the up-to-date data sources by Geolytix was preferred for this study. The XY data was projected in the map environment for the years 2014 and 2021, after filtering the 8 supermarket chain locations in MS Excel. This was then intersected with the Greater London shapefile to get the location points for further analysis. The eight supermarket chains in the study are: Tesco, Asda, Sainsbury's, Morrisons, Aldi, Lidl, M&S and Waitrose. The number of grocery retail stores in the year 2011 were 7290 and in the year 2021 were 8865.

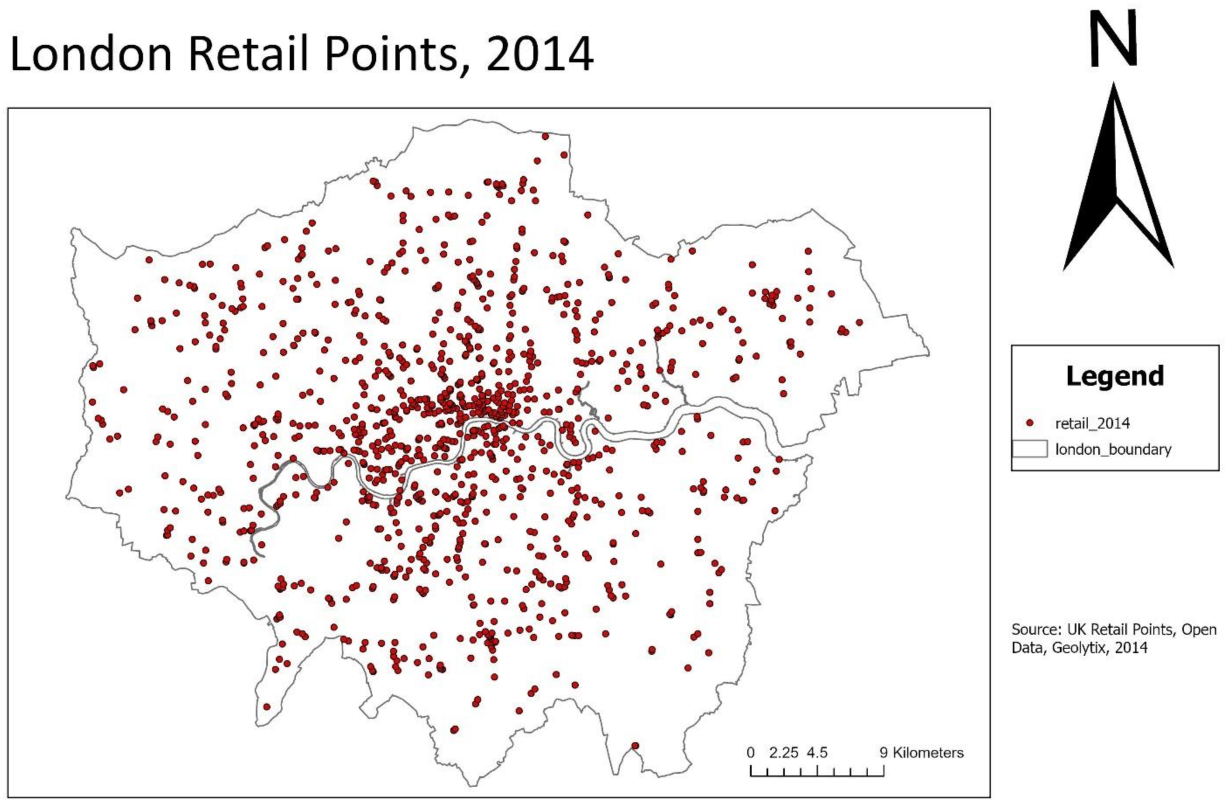


Figure 3: London Retail Points, 2011

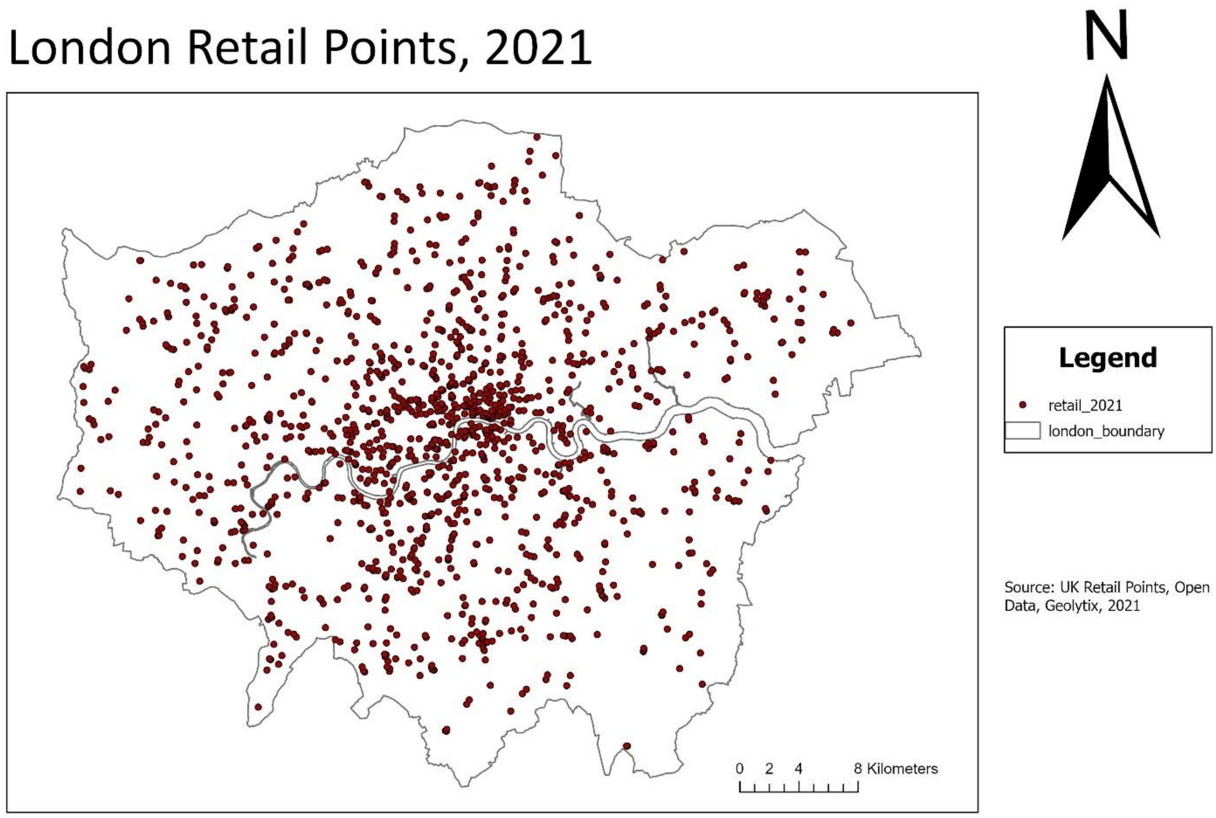


Figure 4: London Retail Points, 2021

The fast-food location dataset was available at Edina Digimaps, and the most accessible was in the form of a “Food and Accommodation” GeoDatabase. Again, the data was only available for the year 2014, which is used as a substitute for the year 2011. The GdB was downloaded for the years 2011 and 2021. The class_name field which contains the type of establishment was filtered to “Fast Food and Takeaway Outlets” and “Fish and Chips” to filter out the desired location points in MS Excel. This was added to the map environment and the XY data projected. The number of fast-food locations in the year 2011 were 8334 and in the year 2021 were 9685.

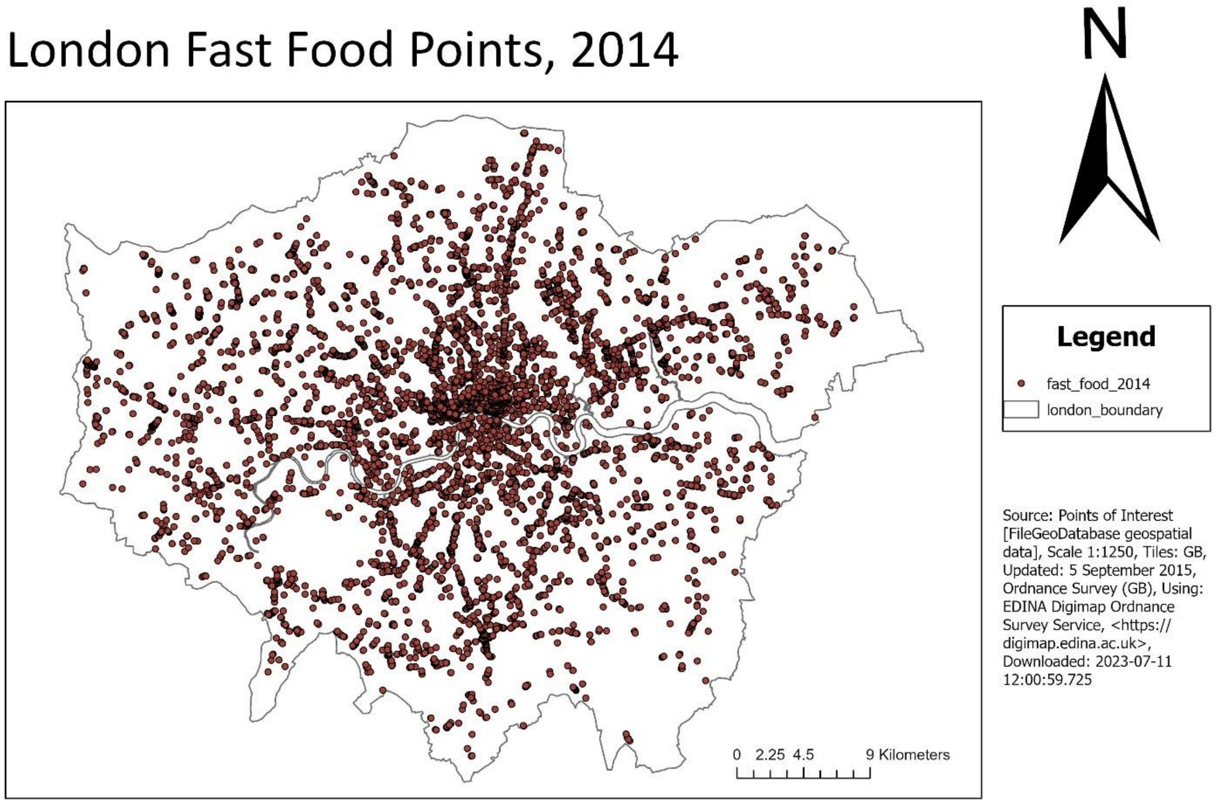


Figure 5: London Fast-food Points, 2011

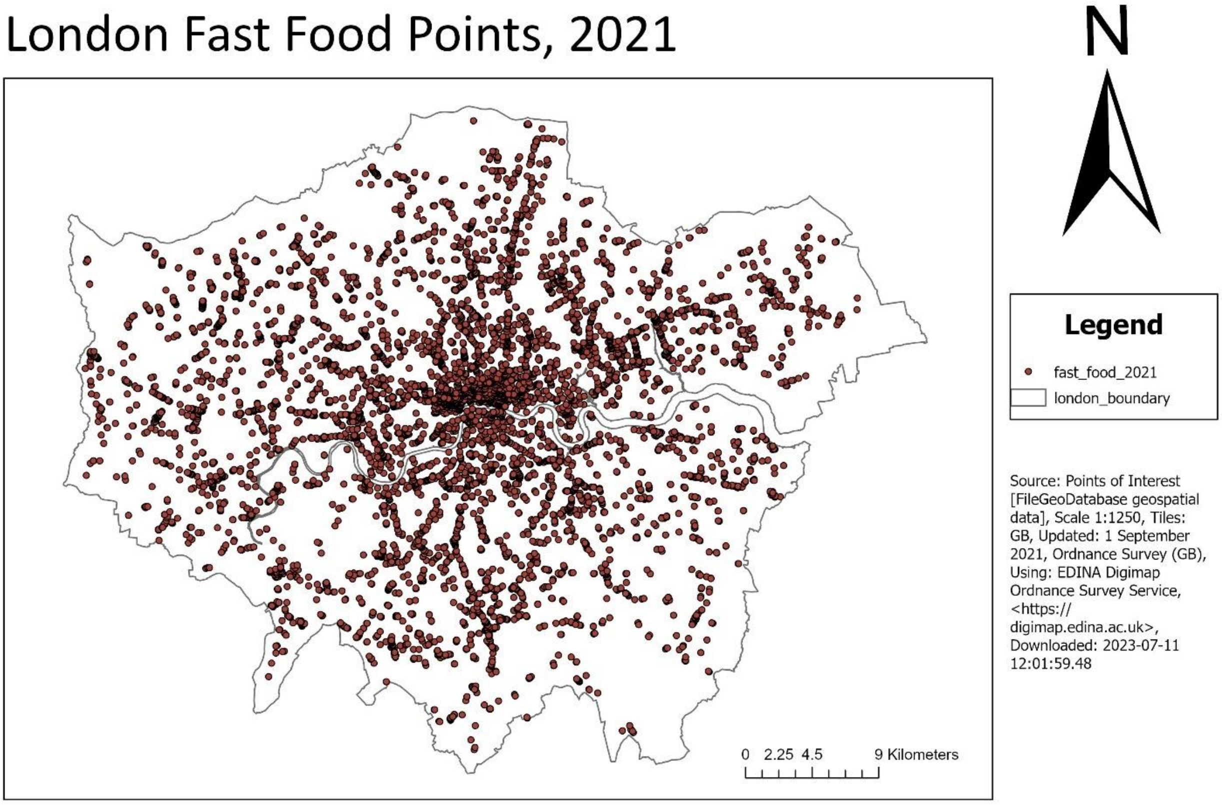


Figure 6: London Fast-food Points, 2021

The English Indices of Multiple Deprivation (IMD) data was downloaded from the Government of UK website for the years 2010 and 2019. As discussed, the report for each year that is released takes the data from previous years, there is an obvious mismatch between the years taken for this study and the dataset. The dataset is downloaded at the LSOA level, which is then to be converted to the fishnet grid extent for the analysis. The 2010 dataset had 193 null values for the IMD score, which is the criteria taken into consideration to map the deprivation in Greater London and can be interchangeably used as the IMD ranking, and thus can be compared. The values for the LSOAs with Nulls were found out using Inverse Distance Weighting, where the values of the surrounding LSOA IMD scores were used to calculate the missing data. The intermediate maps for the process are in the appendix of this dissertation. As in the case of food desert calculation below, areal weighting techniques were required to get the IMD scores for the fishnet grid polygons. The intersection of the LSOAs and the fishnet polygons was used to determine the IMD scores at the respective grid cells.

[DeprivationScoreField] * ([Shape_Area] / [SUM_Shape_Area])

Since the IMD scores range from 0 to 158 in some LSOAs, the appropriate way to proceed was to reclassify the scores into five quantiles for easier analysis. This was done using the “Reclassify Attributes” tool in the attribute table of the resulting IMD scores for the grid cells above after arranging them in ascending order. This process again, was carried out for the two years, and the resulting tables show the quantiles and the ranges.

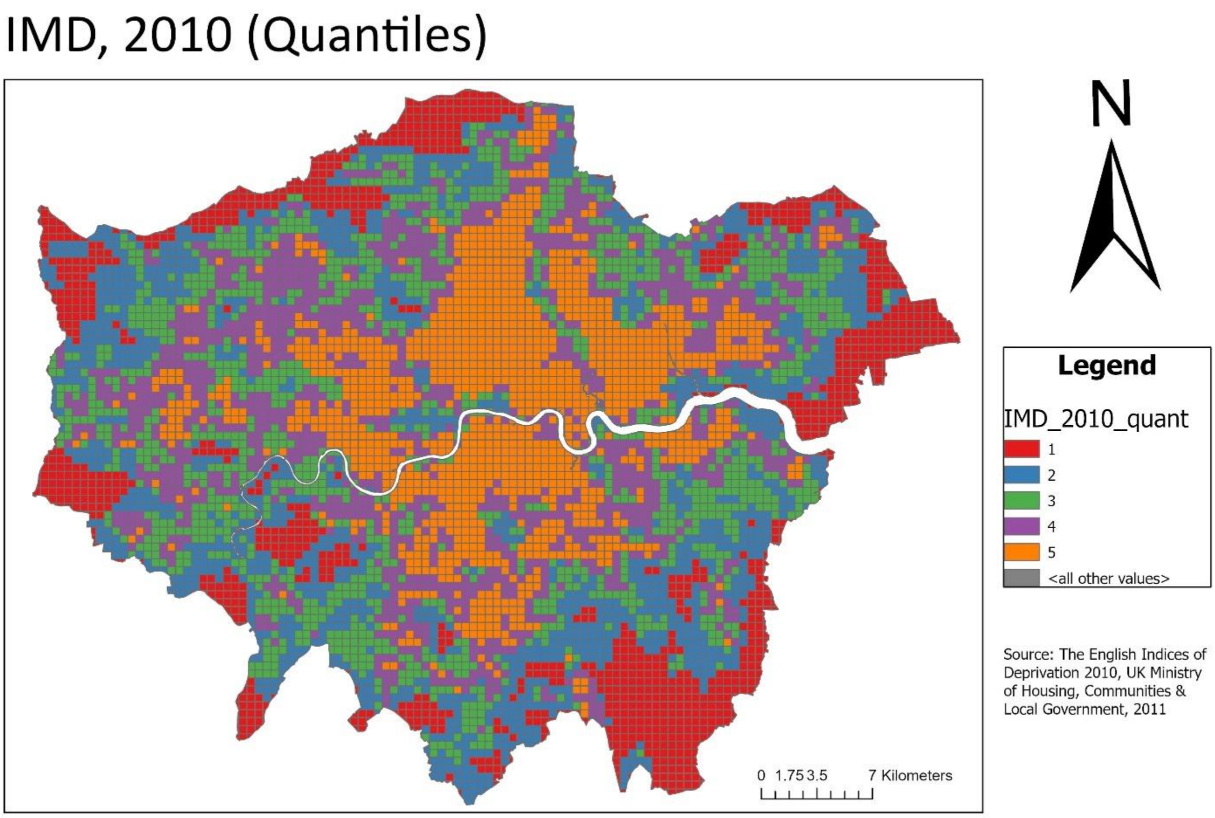


Figure 7: IMD Quantiles, London, 2010

Quantile	Range
1	0.00-1.83
2	1.83-6.49
3	6.49-14.13
4	14.13-30.21
5	30.21-157.16

Table 1: Quantile Ranges - IMD 2010

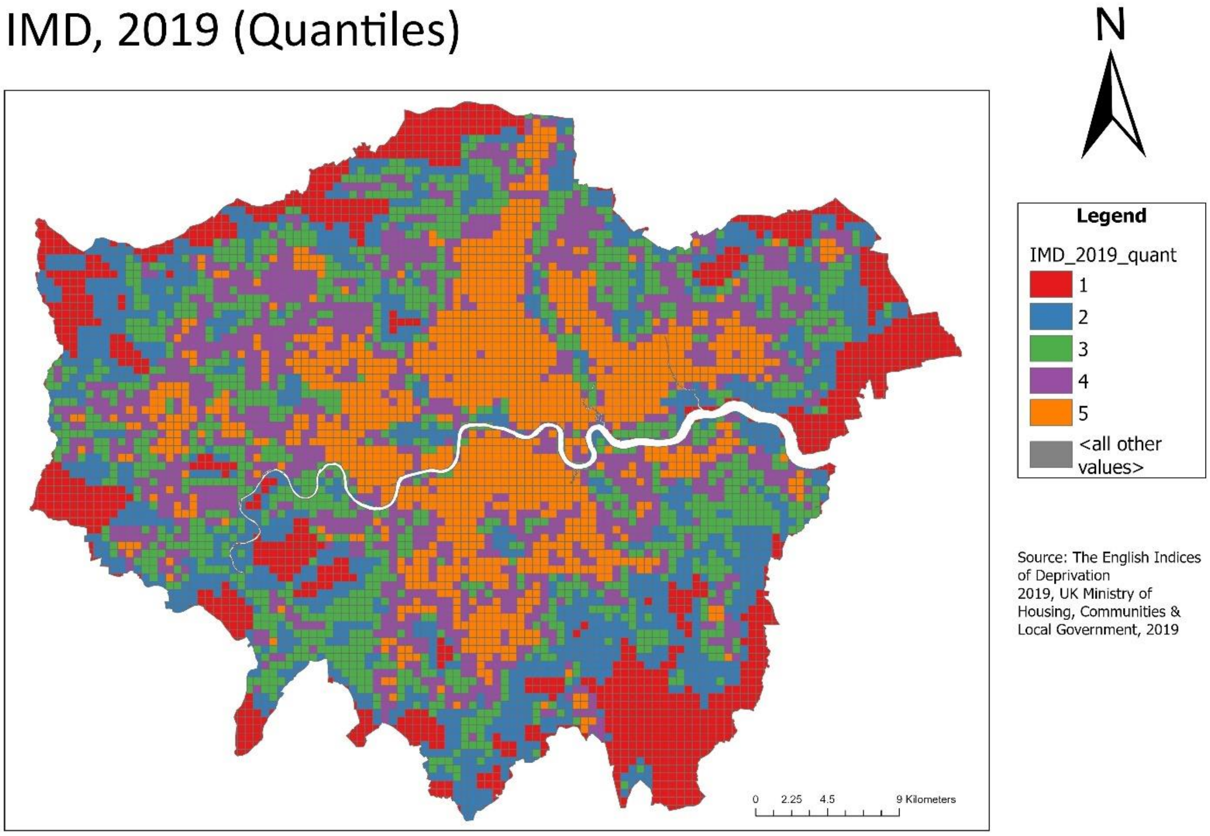


Figure 8: IMD Quantiles, London, 2019

Quantile	Range
1	0.00-1.74
2	1.74-5.86
3	5.86-12.71
4	12.71-26.32
5	26.32-134.84

Table 2: Quantile Ranges - IMD 2019

Finally, buffer catchment areas were drawn around population count points for FS calculations and retail store or grocery store point locations for FD calculations. The buffer distance was 500m, and were dissolved in FD calculation, while they were kept undissolved for FS calculation, as individual RFEI values were required for each buffer. The "Buffer Analysis" tool under the Geoprocessing tools was used for the process.

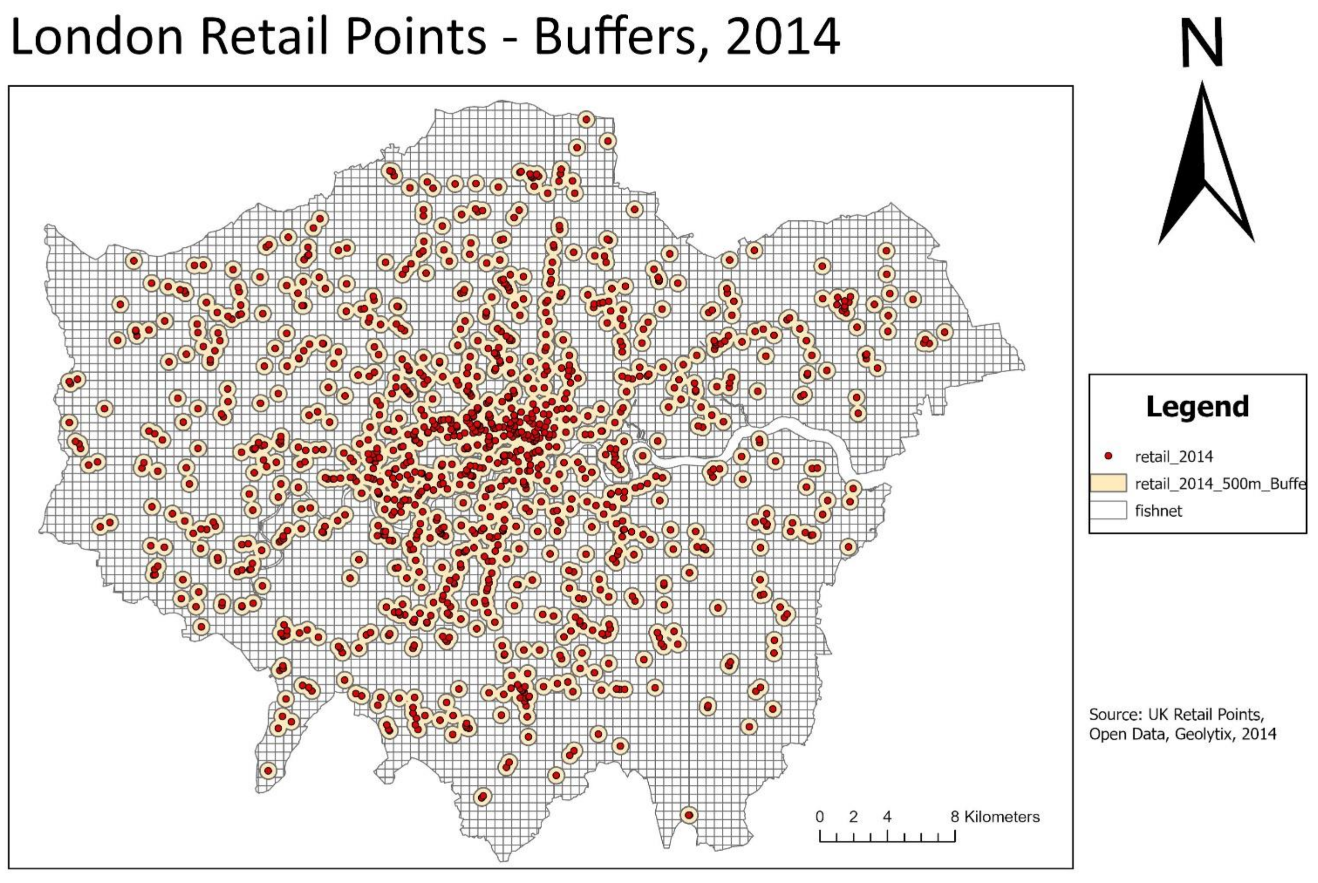


Figure 9: London Retail Point Buffers (500m), 2011

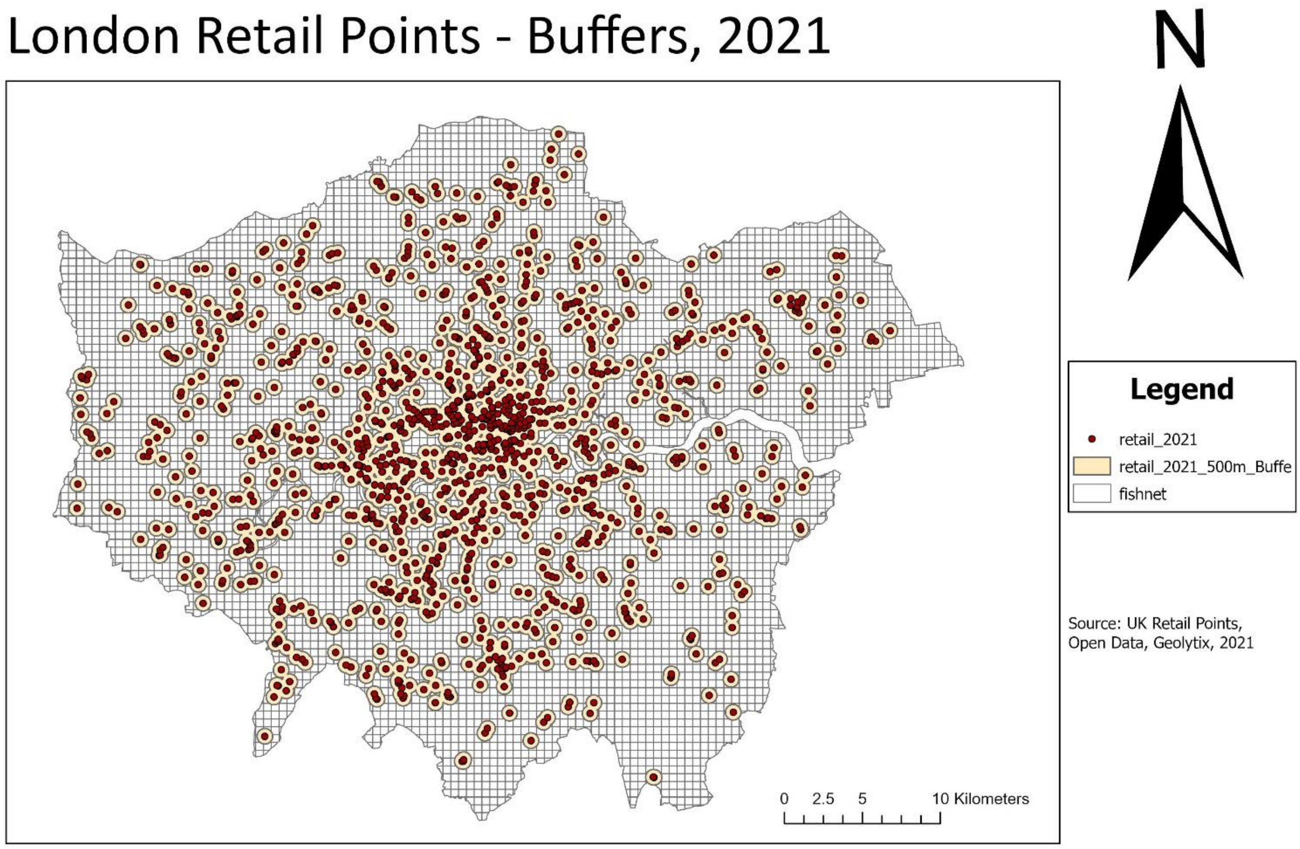


Figure 10: London Retail Point Buffers (500m), 2021

2.3 Buffer Analysis

2.3.1 Food Swamps

Once the data were assembled, the next stage involved the creation of 500 meter undissolved buffers around the locations of each retail stores. With the buffers in place, the subsequent task was to calculate the Retail Food Environment Index (RFEI) within each of these buffer zones. The next step involved intersecting the buffer zones with the retail store points and fast-food locations. This spatial operation determined which retail stores and the fast-food joints fell within each buffer zone. The RFEI is a fundamental indicator, computed as the ratio of fast-food outlets to grocery stores. The identification of areas with an overabundance of fast-food outlets compared to grocery stores was then taken place. This was carried out using the field calculator tool in the attribute table of the resulting intersected layers – the buffers, retail store points and the fast-food joints locations. These regions, characterized by higher RFEI scores (=>5), were classified as potential food swamps.

RFEI= (fast food) / (supermarket and grocery stores)

Food swamps are characterized by an RFEI exceeding 5.0, indicating an elevated risk of lifestyle diseases such as diabetes and obesity. In this study, we define food swamps as areas with an average index of at least 5.0. (Robitaille and Paquette, 2020) In other words, these are areas where, on average, there are five times as many fast-food establishments as there are supermarkets or grocery stores selling healthy food.
The process was carried out for both the years, i.e., the respective shapefiles were used to create buffers and calculate the appropriate RFEI for the years 2011 and 2021.

2.3.2 Food Deserts

Firstly, relevant data layers were prepared, including a grid layer representing 500m by 500m grid cells covering the study area, population points, and retail store points marking the locations of food retail establishments. Additionally, a dissolved buffer layer was created around the retail store locations. The calculation of population coverage by dissolved buffers came next, a vital step in assessing the influence of retail stores on the surrounding population. To achieve this, the "Intersect" tool was employed, determining the percentage of overlap between the dissolved buffers and the grid cells. Another critical step involved the calculation of the percentage of overlap between the dissolved buffers, representing retail store catchment areas, and the individual grid cells. This calculation was pivotal in understanding the extent to which each grid cell was influenced by the presence of nearby retail stores. To accomplish this, a new field was introduced into the attribute table to store the calculated percentage of overlap. The Field Calculator was then applied to determine this percentage for each grid cell within the dataset. The population within each grid cell was already aggregated as explained in the data preparation. Subsequently, population contributions within the dissolved buffers were calculated. This step involved the creation of a new field within the attribute table of the dissolved buffer layer. The field was populated using the Field Calculator, which performed a calculation based on the percentage of overlap between the buffer and the associated grid cell, relative to the total population.

Buffer Overlap (Areal Contribution) = (Shape_Area / [Total_Grid_Cell_Area]) * 100
Population Contribution = [BufferPopulationField] * ([BufferOverlapPercentageField] / 100)

Finally, the 33% population criteria were applied to each grid cell. The analysis included creating a summary table, achieved through the "Summary Statistics" tool, where the dissolved buffer data was grouped by the associated grid cell. This summary table was then joined with the grid layer, allowing for the calculation of the percentage of population coverage for each grid cell. Grid cells with less than 33% of the total population living outside the buffer zone threshold were categorized as potential food deserts, contributing to the identification and mapping of areas with limited access to food retail establishments.
Again, all the steps were repeated for both the years with the respective dataset involved.

2.3.3 *Indices of Multiple Deprivation*

The IMD data for both the years as prepared above, was spatially joined with the food desert and food swamp grid cells obtained above. This results in four different shapefiles, which are essential in carrying out spatial autocorrelation techniques to determine the relation between deprivation data and the presence of both food swamps and food deserts in the respective grid cells. Moreover, it results in determining the distribution and number of grid cells in each IMD quantile.

2.3.4 *Spatial Autocorrelation*

While the interpretation of the results of the Global Moran's I and the Local Moran's I is discussed in the Results section, this is a brief overview of the process involved and the input values used to evaluate spatial statistics for the analysis.

Four layers – FD2011, FD2021, FS2011 and FS2021 were used to evaluate if the food deserts and food swamps showed clustering patterns. The input field value to determine clustering was the percentage of population falling under the buffer catchment areas for FD. The maximum value was 33%, and so the clustering patterns was to be observed for the FD. For FS, the Mean RFEI was chosen as the input field. The minimum value of RFEI was 5, so the clustering pattern was to be observed for FS.

For the Global Moran's I, a report was generated for each layer to determine the overall clustering scenario for the data. For Local Moran's I, the maps for each layer were generated in order to determine the local clustering patterns, if any. Furthermore, scatter plots were generated to evaluate the association between the Local Moran's I and the input field value or the average values in the neighbouring areas.

3. Results

The following chapter presents the results formulated from the implementation of a GIS *Closest Facility* network analysis approach. The primary focus of the chapter is centred around quantifying the change in exposure from changing to walking and cycling from motorised transportation to evaluate the viability of active transportation in reducing NO_2 air pollution exposure. To spatially correlate exposures with modal change, individual analyses will be drawn out outlining the main network type being travelled along. The focus is then turned to addressing changes made in NO_2 exposure during two frequently made journeys in Leicester.

3.1 Buffer Analysis

3.1.1 Food Swamps

The following maps show the grid cells that are considered to be food swamps under the criteria that the RFEI is greater than or equal to 5.

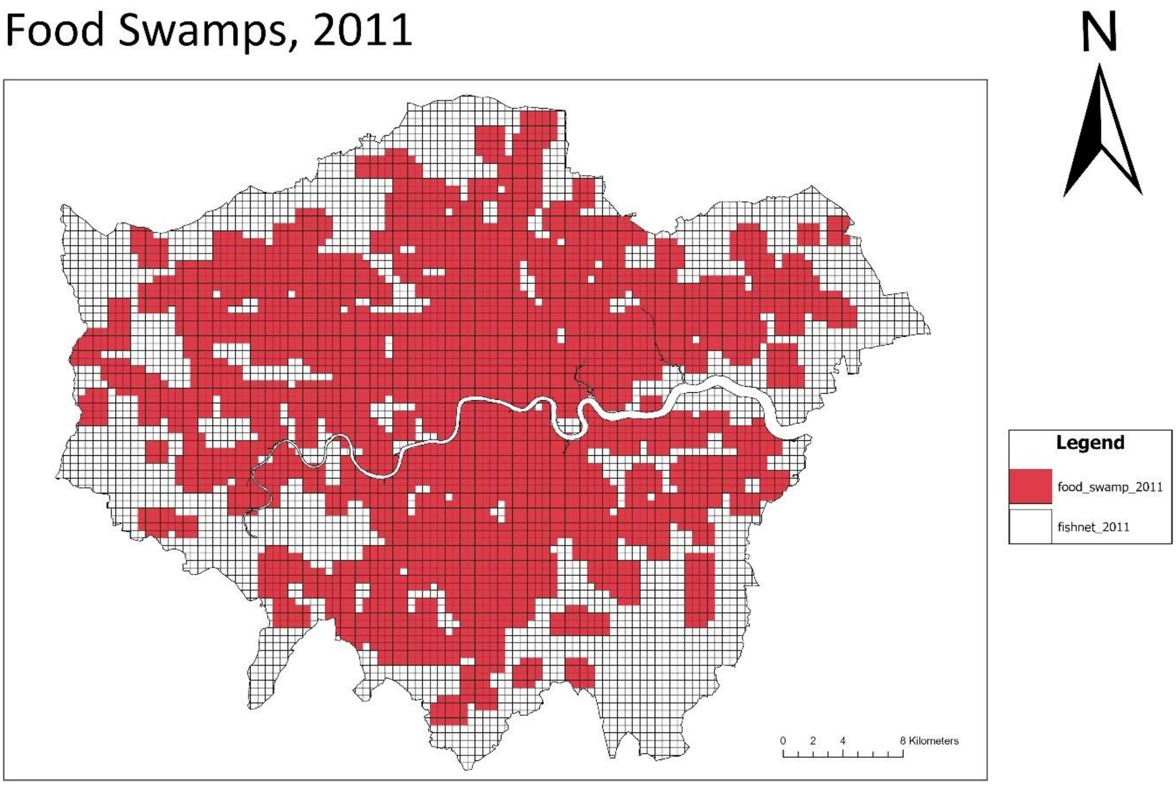


Figure 11: Food Swamps, London, 2011

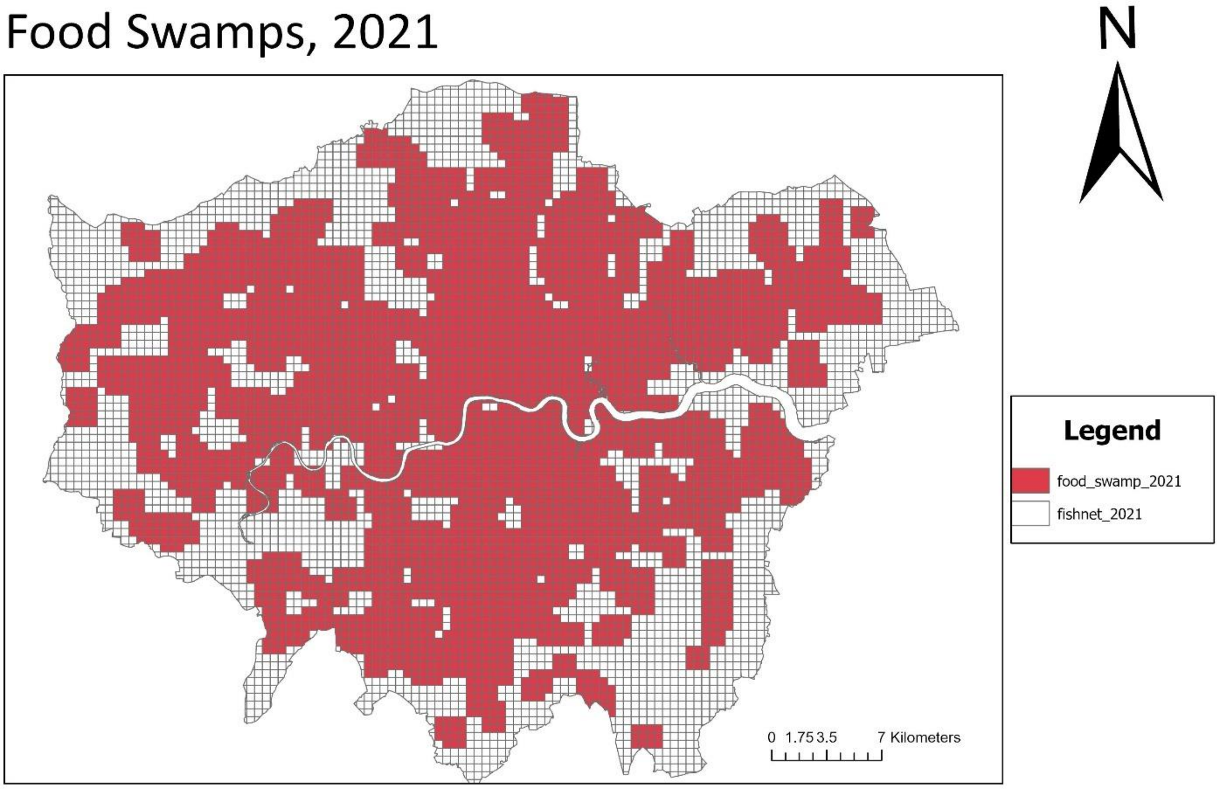


Figure 12: Food Swamps, London, 2021

The following table shows the grid cells that are considered to be food swamps under the criteria that the RFEI is greater than or equal to 5.

	2011	**2021**
Number of Grid Cells	3887	4105

Table 3: Number of Grid Cells in Greater London falling under the criteria of Food Swamps

Out of the total 6671 grid cells, the number of grid cells considered to be food swamps in Greater London in 2011 are 3887, and in 2021 are 4105. These amount to 58.26% in the year 2011 and 61.53% in the year 2021.

Since the calculation of food swamps was based on the ratio of fast-food joints to the grocery stores in a single buffer, and the resulting intersection between the buffers did not take into account the area covered by the intersecting buffers. Therefore, the number of resident population falling inside food swamps is greater than the actual number. Even a minute amount of area intersecting the buffer, which qualifies as a food swamp, with the respective grid cell, the whole grid cell is considered to be a food swamp. Therefore, the population falling under food swamps is as follows:

	2011	2021
Population in food swamps	7,154,091/8,408,760	7,315,122/8,407,433

Table 4: Population in Greater London falling under the criteria of Food Swamps

This amounts to 85.07% of the total population falling in food swamps in the year 2011 and 87.00% of the total population falling in food swamps in the year 2021. Again, these figures are inflated due to the method adopted in determining the food swamps.

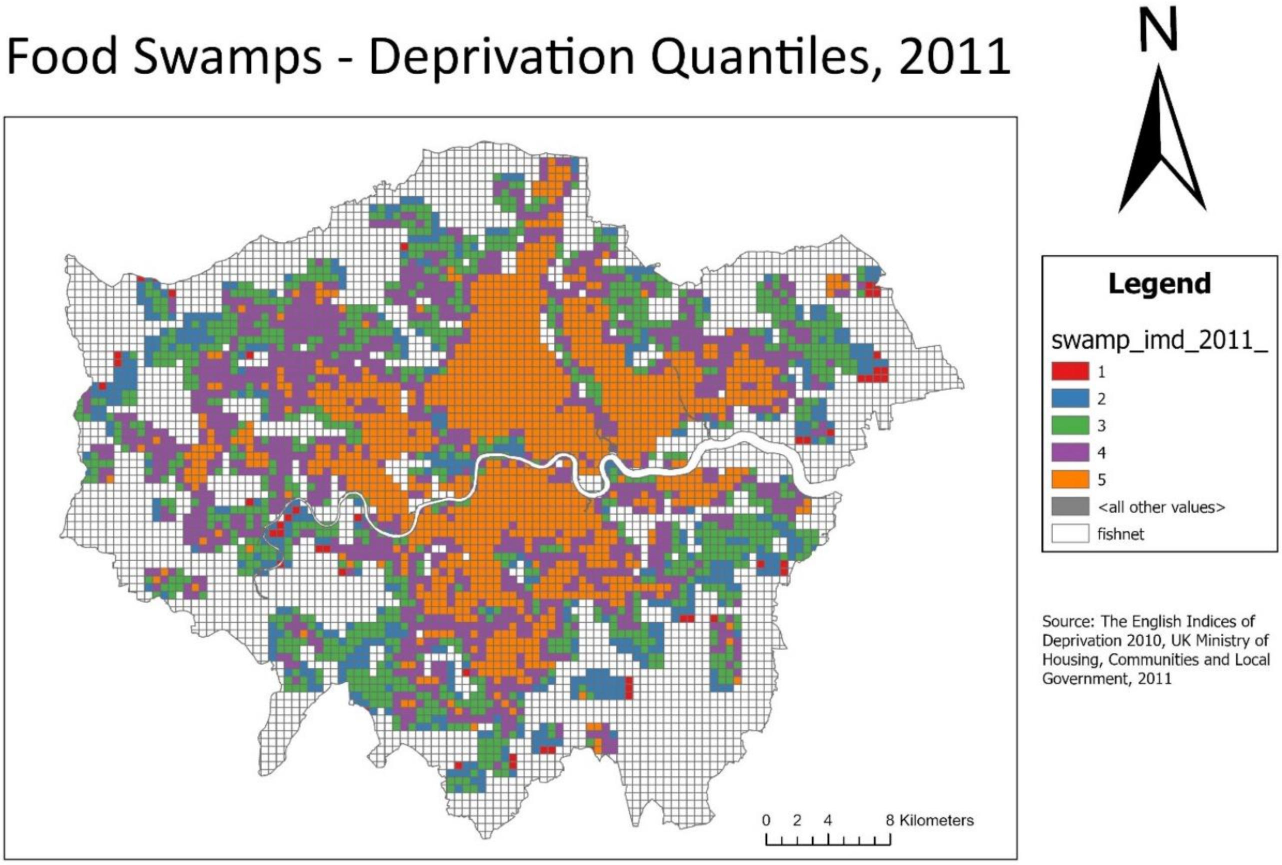


Figure 13: Food Swamps and Deprivation Quantiles, London, 2011

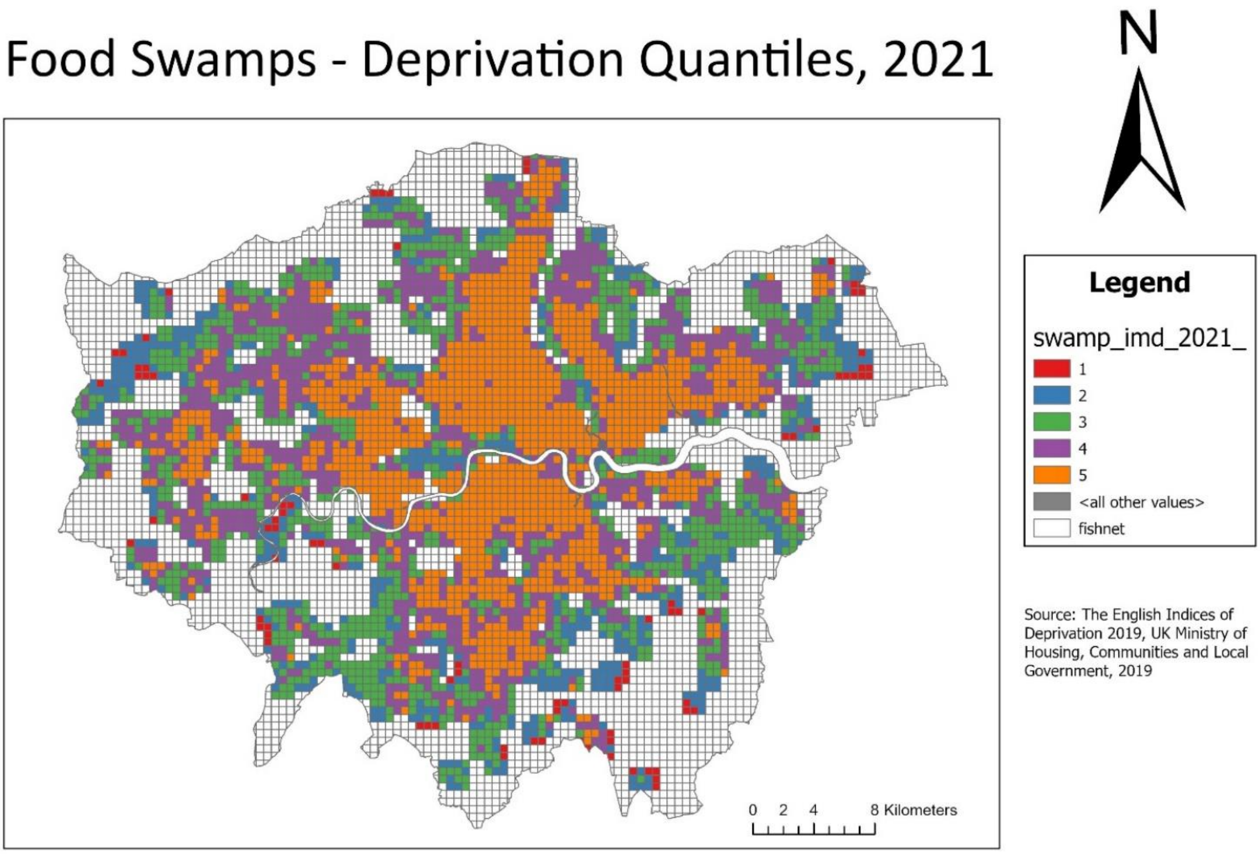


Figure 14: Food Swamps and Deprivation Quantiles, London, 2021

The following table shows the number of grid cells falling in the food swamps category and the quantile distribution for the IMD score for the respective grid cells in Greater London.

Quantile	2011	2021
1	54	94
2	474	551
3	939	1006
4	1143	1156
5	1277	1298

Table 5: Grid cells in Greater London falling under the criteria of Food Swamps and respective IMD quantile distribution

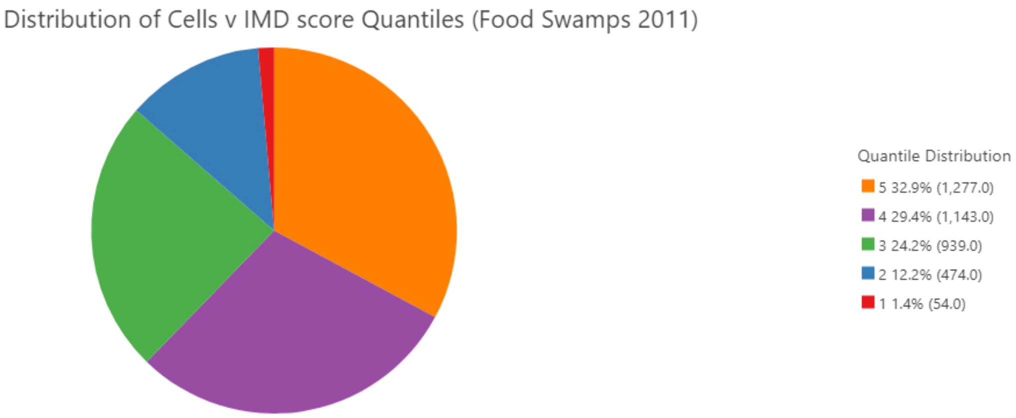


Figure 15: Distribution of Cells and IMD Quantiles for Food Swamps, London, 2011

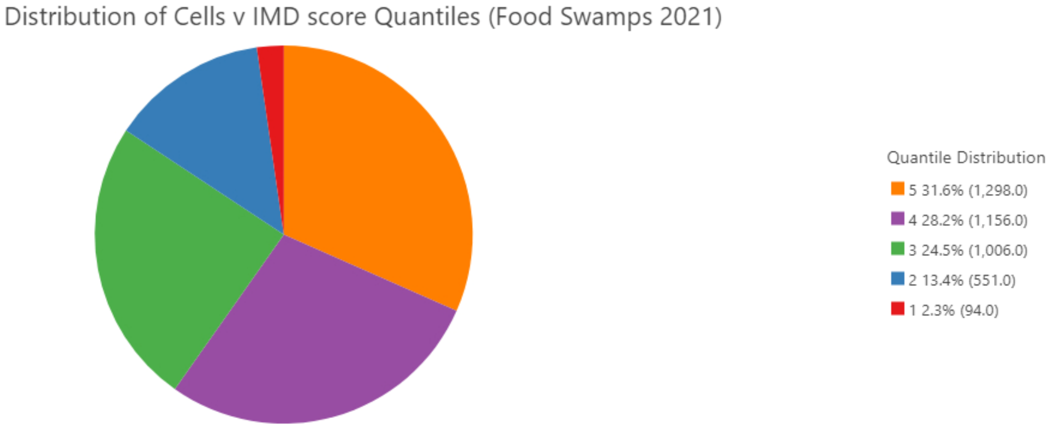


Figure 16: Distribution of Cells and IMD Quantiles for Food Swamps, London, 2021

3.1.2 Food Deserts

The following maps show the grid cells in Greater London that are considered to be food deserts under the criteria that less than 33% of the total population in the grid cell lies in the buffer zone.

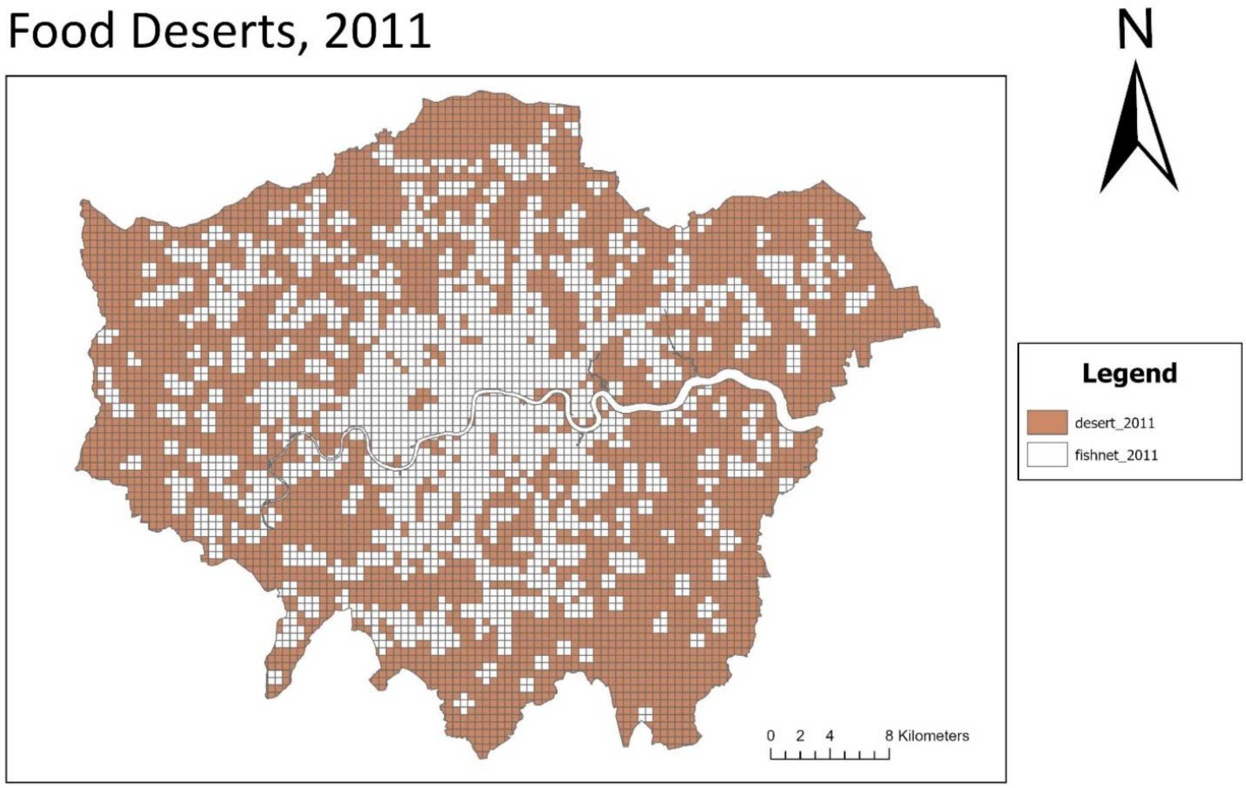


Figure 17: Food Deserts, London, 2011

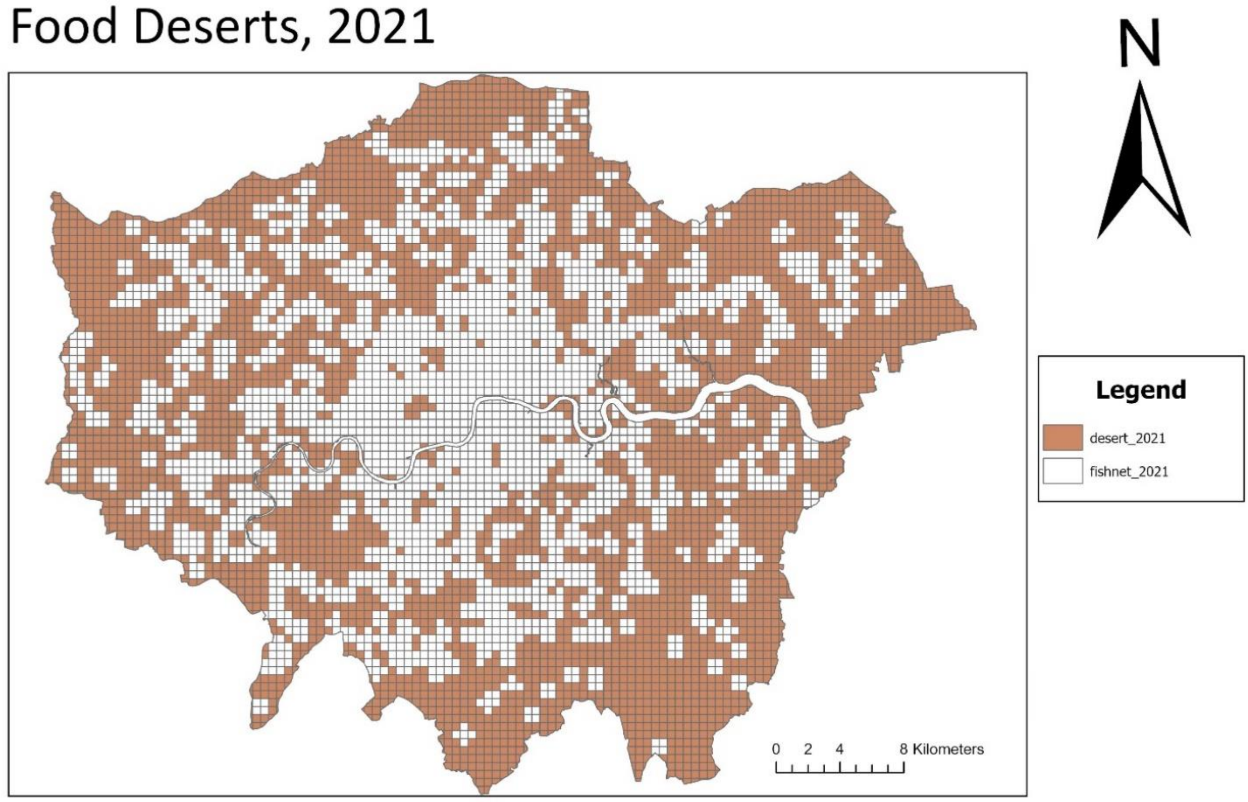


Figure 18: Food Deserts, London, 2021

The following table shows the number of grid cells in Greater London that are considered to be food deserts according to the analysis for the two years.

	2011	2021
Number of Grid Cells	4294	4001

Table 6: Number of Grid Cells in Greater London falling under the criteria of Food Deserts

Out of the total 6671 grid cells, the number of grid cells considered to be food deserts in Greater London in 2011 are 4294, and in 2021 are 4001. These amount to 64.37% in the year 2011 and 59.98% in the year 2021.

Since the calculation of food deserts takes into account the areal weighting interpolation of the contribution of the population inside the grid cell and buffer intersect, the number of residents inside the catchment area is closer to the actual number as opposed to the case in food swamps calculations, although, since the population points are evenly spread across the fishnet for the analysis, they are not exactly the ground reality. Nonetheless, the population inside the food deserts depict a much more realistic picture when compared to food swamps.

	2011	2021
Population in food deserts	232,360/8,408,760	226,819/8,407,433

Table 7: Population in Greater London falling under the criteria of Food Deserts

This amounts to 2.76% of the total population falling in food deserts in the year 2011 and 2.70% of the total population falling in food deserts in the year 2021. Again, although the number of residents is way lower in food deserts than in food swamps, this is a more accurate measure of the ground reality.

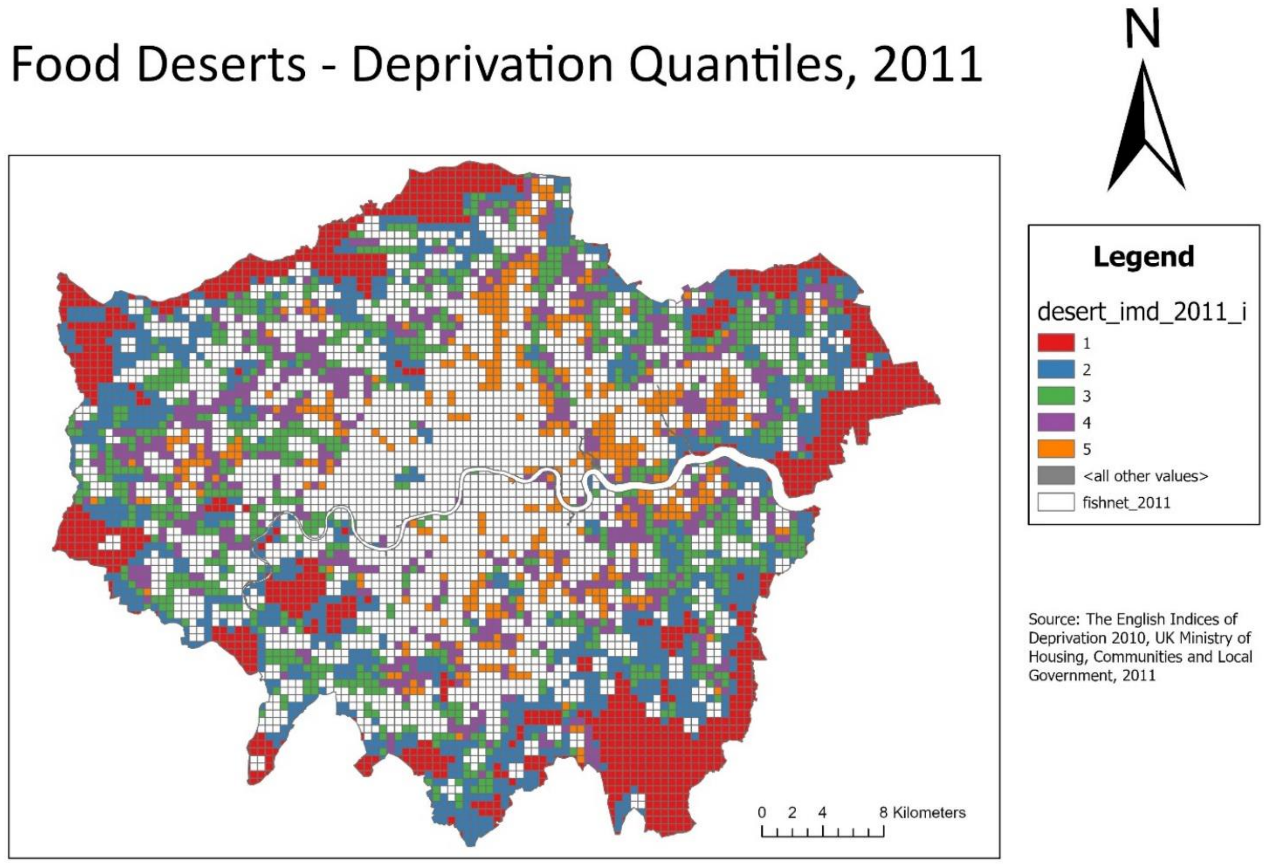


Figure 19: Food Deserts and Deprivation Quantiles, London, 2011

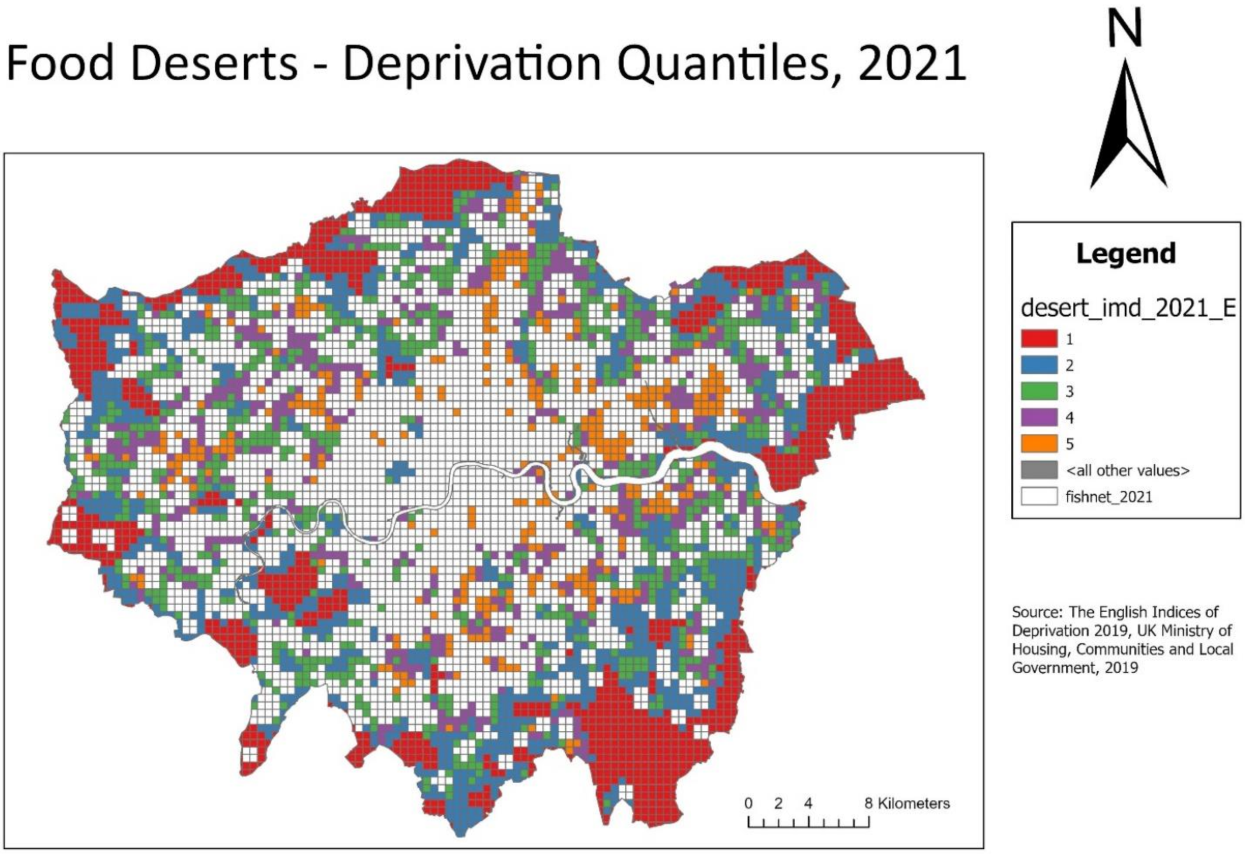


Figure 20: Food Deserts and Deprivation Quantiles, London, 2021

The following table shows the number of grid cells falling in the food deserts category and the quantile distribution for the IMD score for the respective grid cells in Greater London.

Quantile	2011	2021
1	1299	1280
2	1063	996
3	836	770
4	677	584
5	419	371

Table 8: Grid cells in Greater London falling under the criteria of Food Deserts and respective IMD quantile distribution

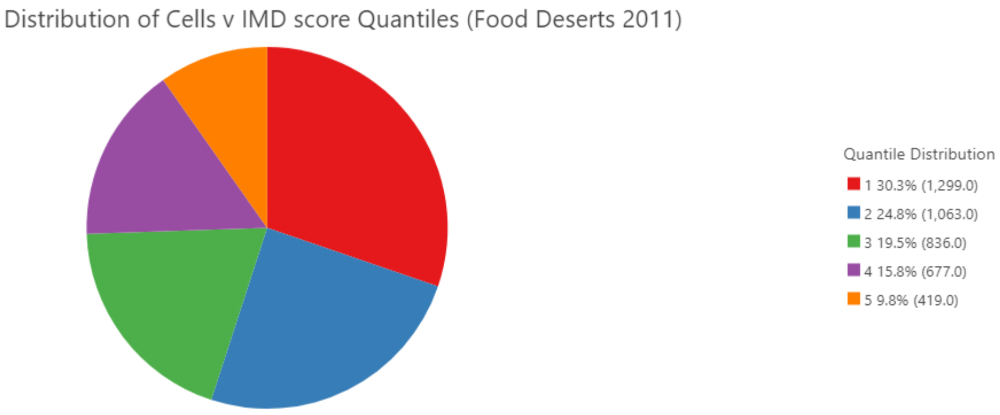


Figure 21: Distribution of Cells and IMD Quantiles for Food Deserts, London, 2011

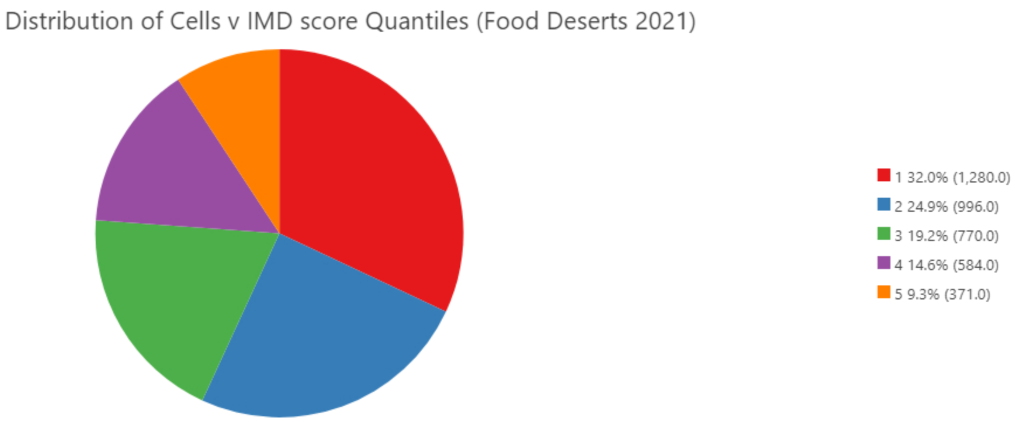


Figure 22: Distribution of Cells and IMD Quantiles for Food Deserts, London, 2021

3.1.3 Food Deserts and Food Swamps

The food desert layer, the food swamp layer and the fishnet grid containing the population data were intersected to map the cells that fall under both the categories, i.e. food swamps and food deserts. This again, does not consider the area under buffer, and only takes into account if the buffer is intersected with the grid cell or not, as was the case with food swamp calculations. Therefore, this again is a very rough estimate of the number of grid cells and the population residing in both food swamps and food deserts.

The following maps show the grid cells which fall under all three categories, i.e. food swamps, food deserts, and the cells which fall under both. The cells marked in black are under the category of both food swamps and food deserts.

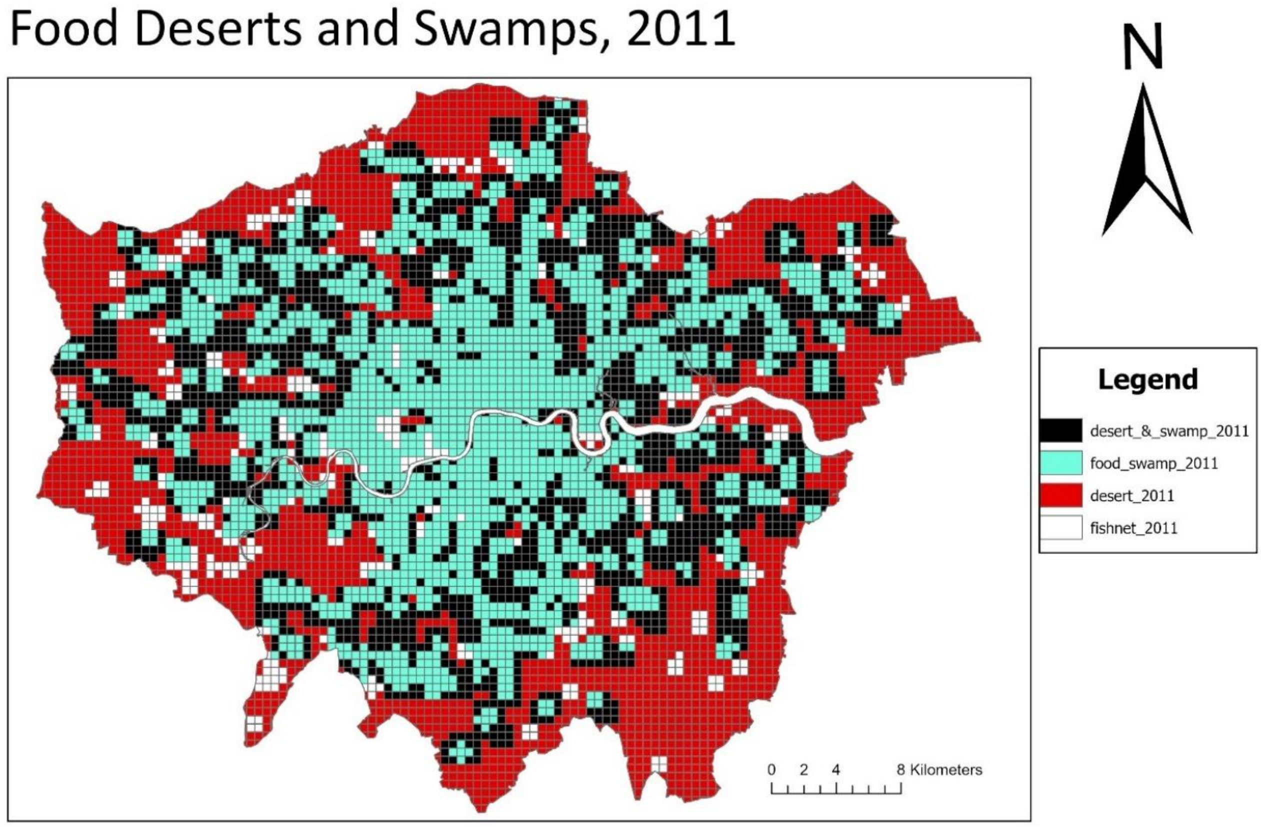


Figure 23: Food Deserts and Swamps, London, 2011

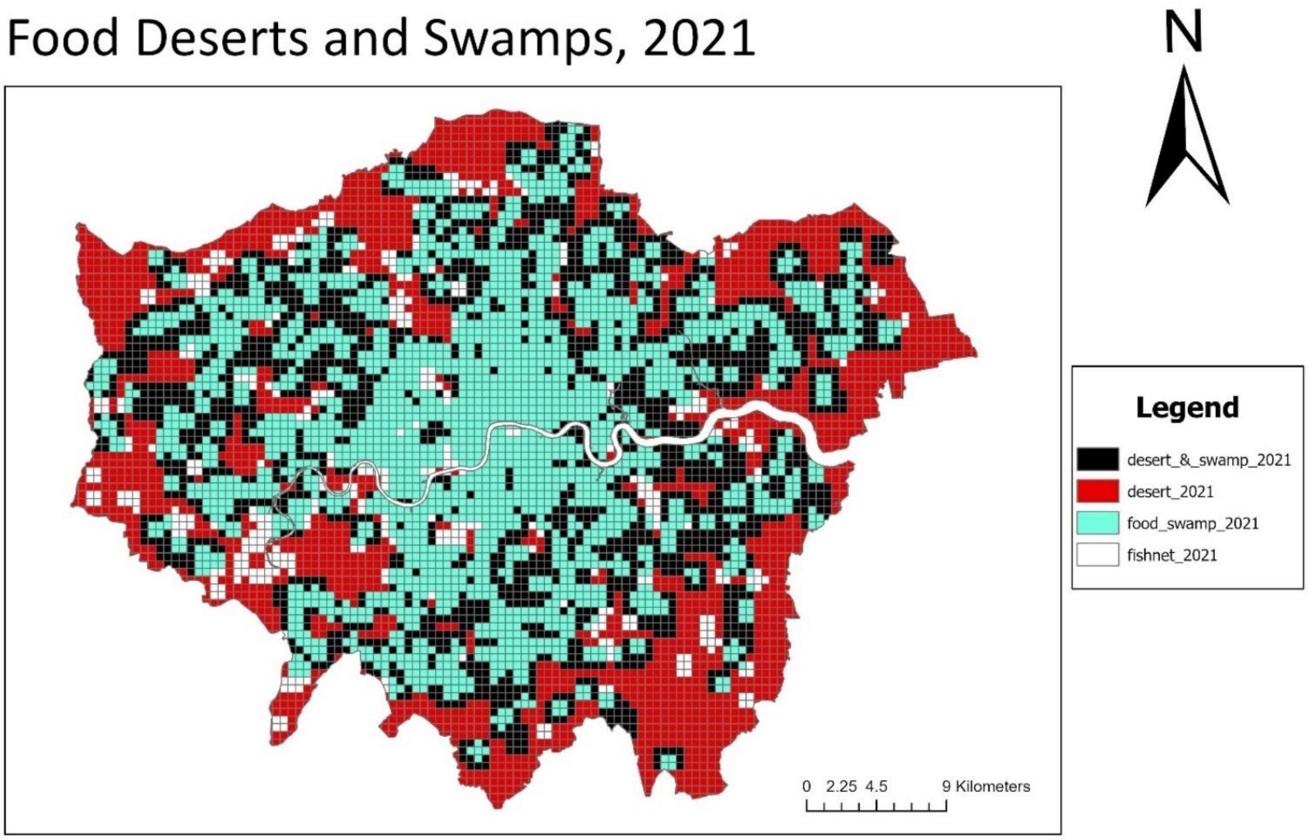


Figure 24: Food Deserts and Swamps, London, 2021

Year	Population	Number of Grid Cells
2011	2,584,809	1,857
2021	2,366,137	1,813

Table 9: Population and number of grid cells falling under both Food Swamps and Food Deserts for 2011 and 2021

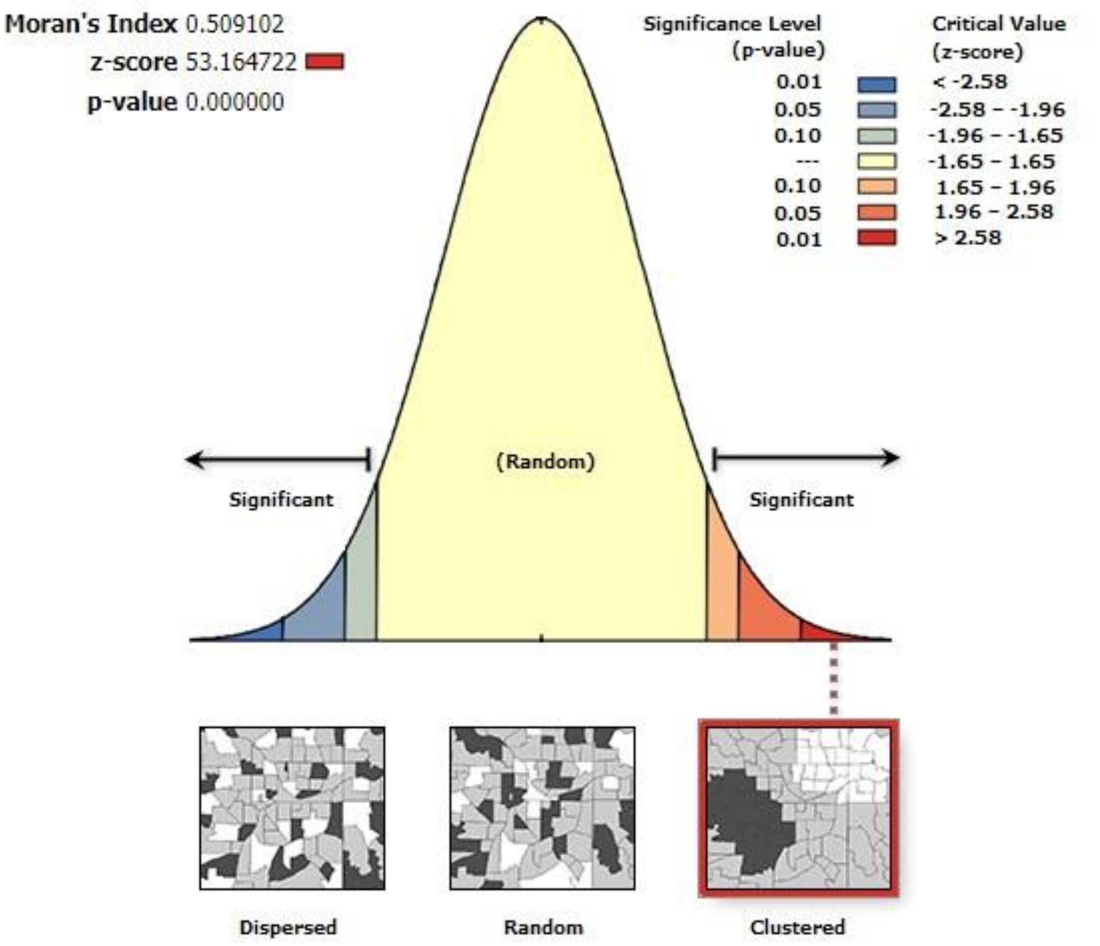
This amounts to 27.83% of the total grid cells in 2011 and 27.17% of the total grid cells in 2021. This results in 30.73% of the total population living in areas which are both food swamps and food deserts in 2011 and, 28.14% of the total population in 2021. This is considered a vital statistic as it shows the placement of fast-food joints in areas where the population is deprived of nutritious food, and thus would lead to more health problems as compared to areas which are just food swamps. This can be a possibility since the food swamps appear to be more central, while the food desert are generally in the outskirts of Greater London. Therefore, a ring forms around the centre which overlaps both the grid cells, and thus puts the population residing there in the vicinity of more calorie and fat rich foods.

3.2 Spatial Autocorrelation

For further spatial analysis, spatial autocorrelation tests were ran in ArcGIS Pro on the food swamp and food desert layers. Global Moran's I was conducted to get a general picture of the spatial patterns in the data, and Local Moran's I (Anselin Local Moran's I) was carried out to determine the location of clusters in the data, if any. Both are available in ArcGIS Pro 3.1 under Geoprocessing Tools > Spatial Statistics > Cluster and Outlier Analysis, with their respective names. The input field or criteria for clustering for both the years in food swamps layers was the RFEI value, while for the food deserts layers was the percentage values of the population being under the buffer catchment area.

3.2.1 Food Deserts

Spatial Autocorrelation Report



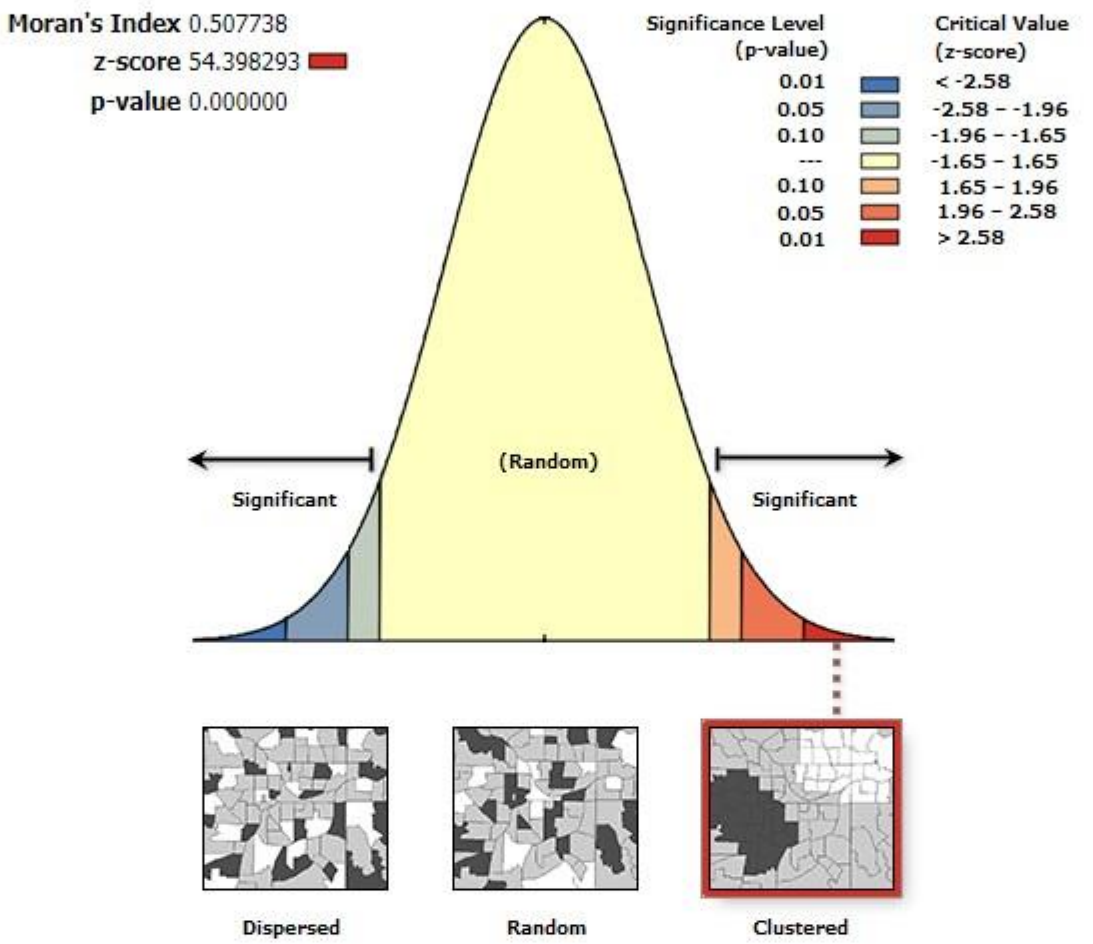
Given the z-score of 53.164722, there is a less than 1% likelihood that this clustered pattern could be the result of random chance.

Global Moran's I Summary

Moran's Index	0.509102
Expected Index	-0.000214
Variance	0.000092
z-score	53.164722
p-value	0.000000

Figure 25: Global Moran's I Report, Food Deserts, London, 2011

Spatial Autocorrelation Report



Given the z-score of 54.398293, there is a less than 1% likelihood that this clustered pattern could be the result of random chance.

Global Moran's I Summary

Moran's Index	0.507738
Expected Index	-0.000210
Variance	0.000087
z-score	54.398293
p-value	0.000000

Figure 26: Global Moran’s I Report, Food Deserts, London, 2021

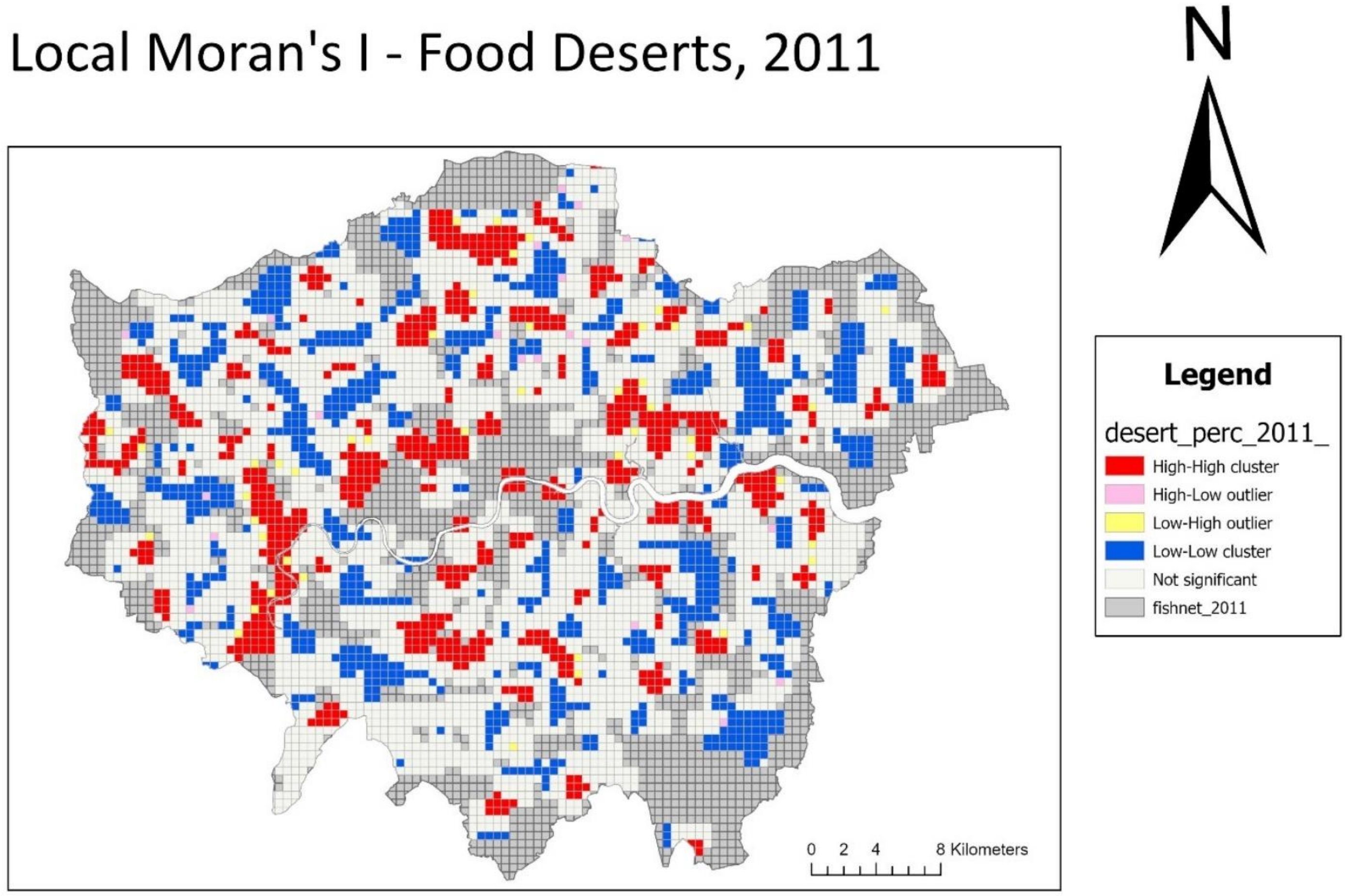


Figure 27: Local Moran’s I Map, Food Deserts, London, 2011

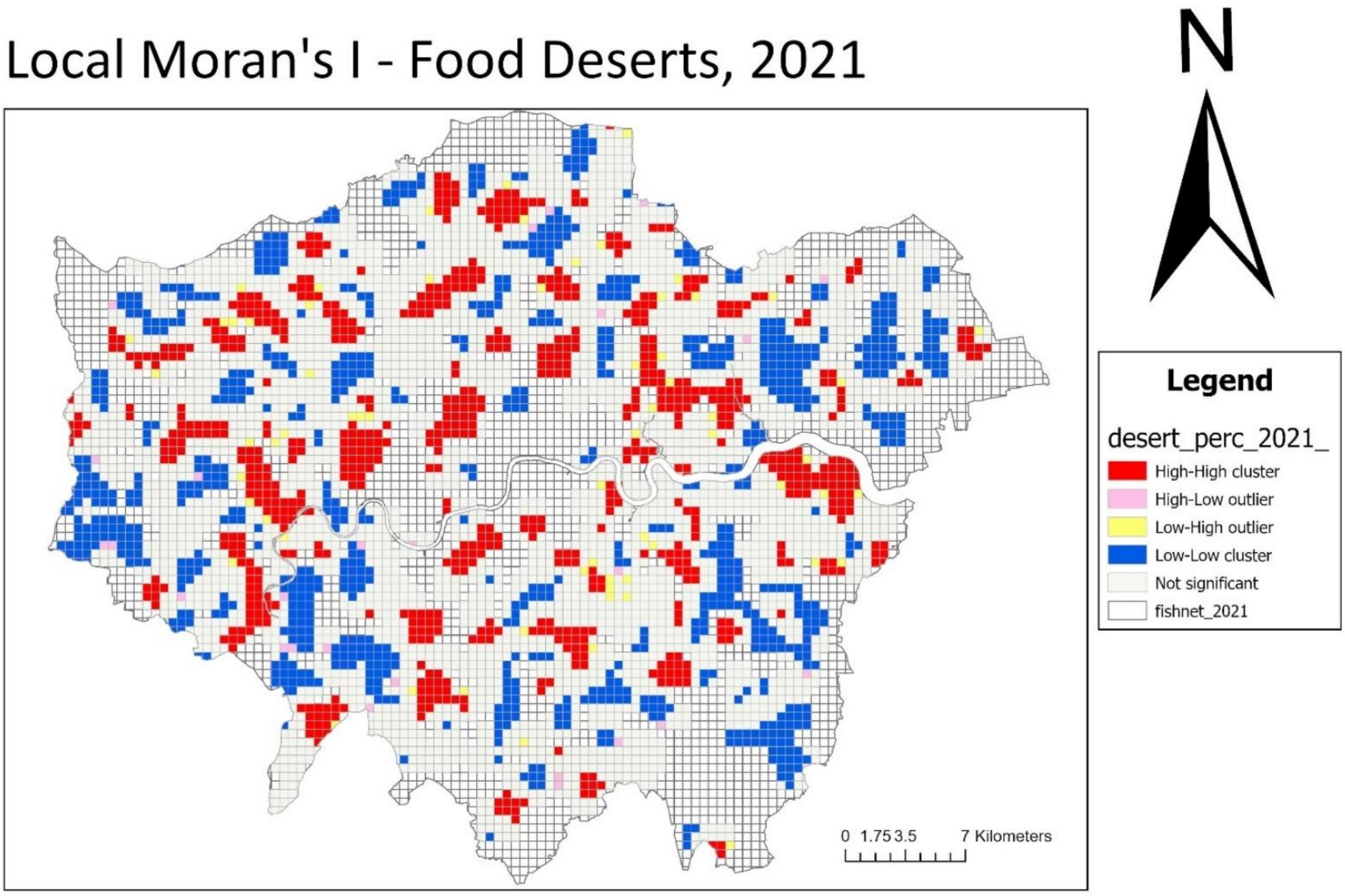


Figure 28: Local Moran's I Map, Food Deserts, London, 2021

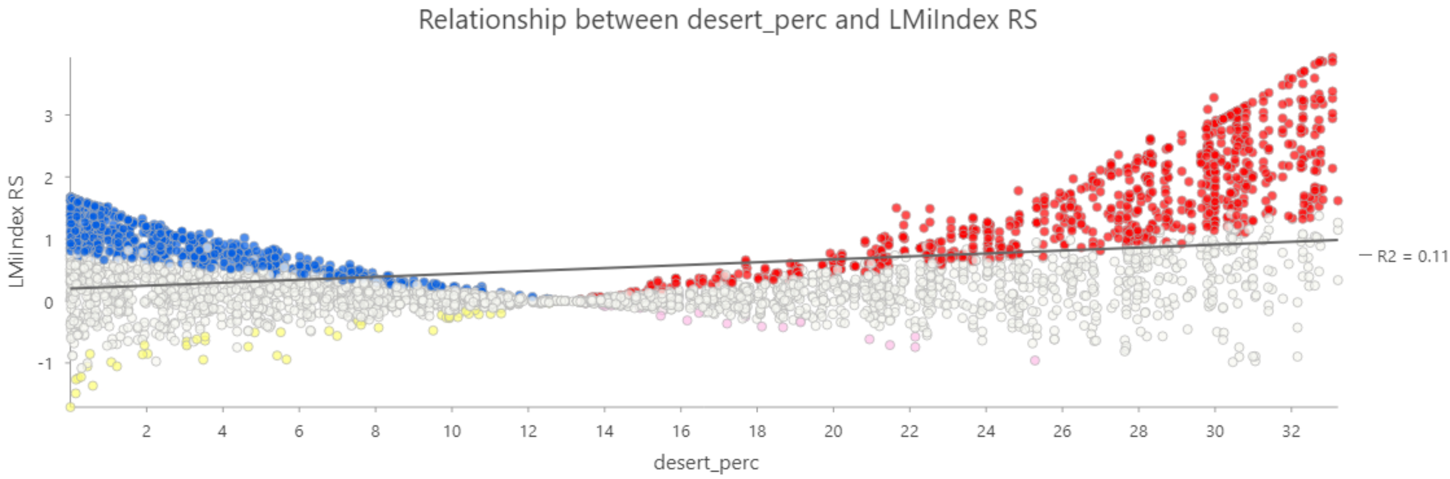


Figure 29: Scatter Plot Local Moran's I, Food Deserts, London, 2011

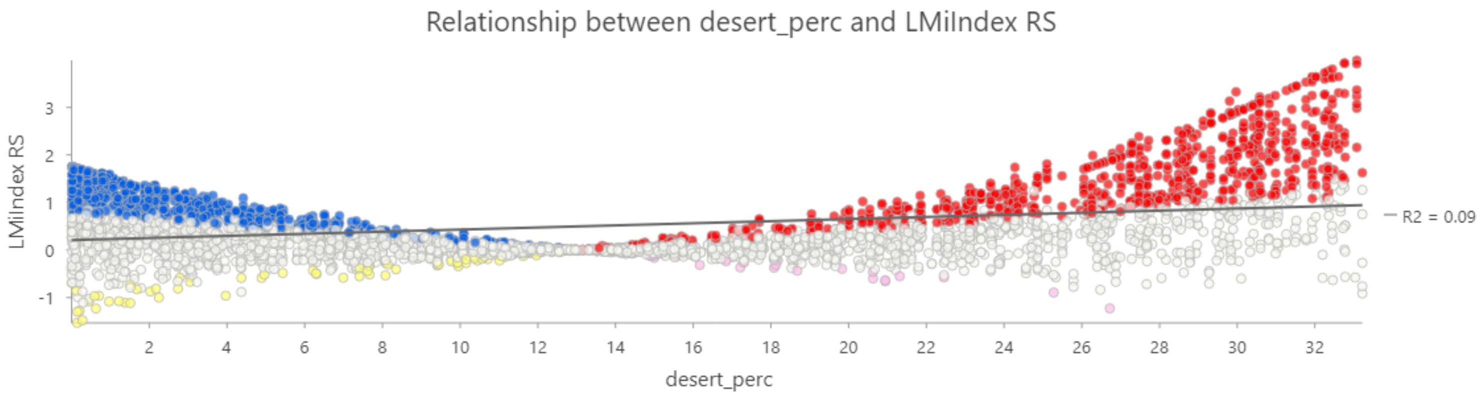
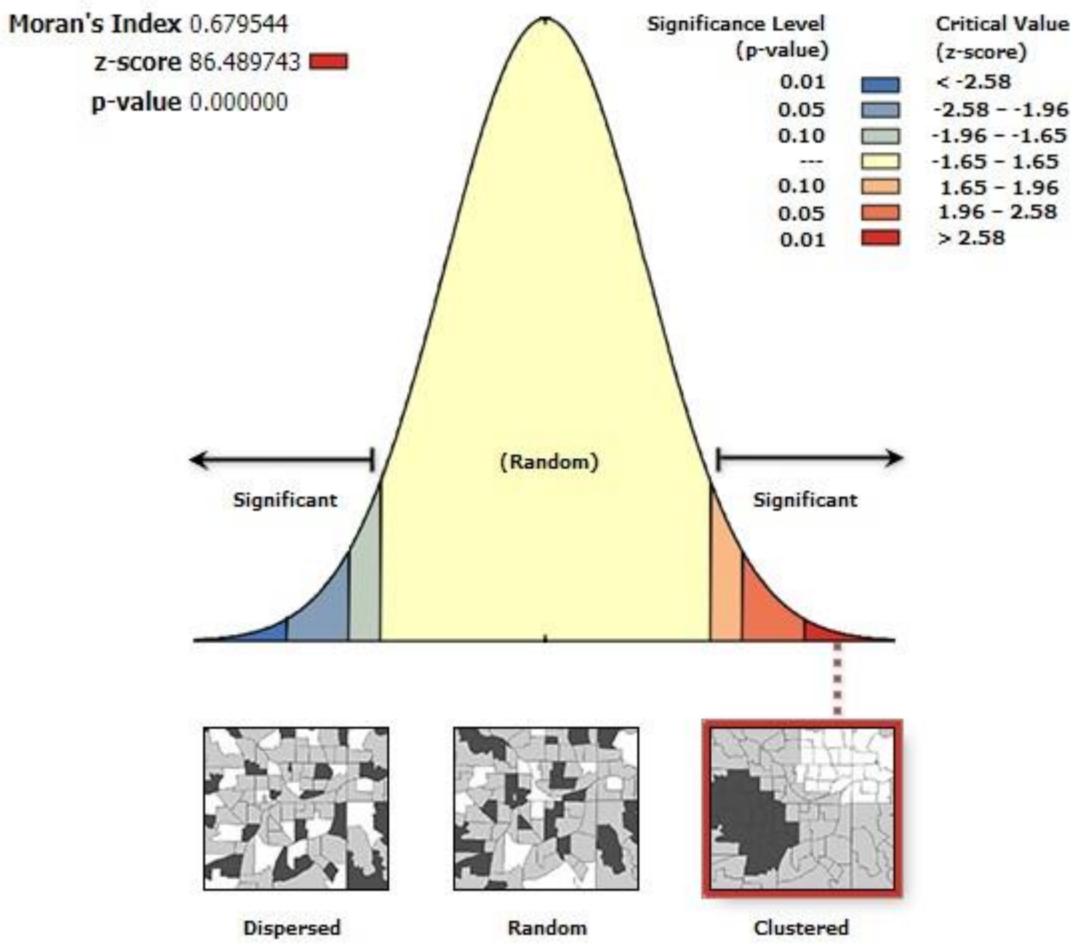


Figure 30: Scatter Plot Local Moran's I, Food Deserts, London, 2021

3.2.2 *Food Swamps*

Spatial Autocorrelation Report

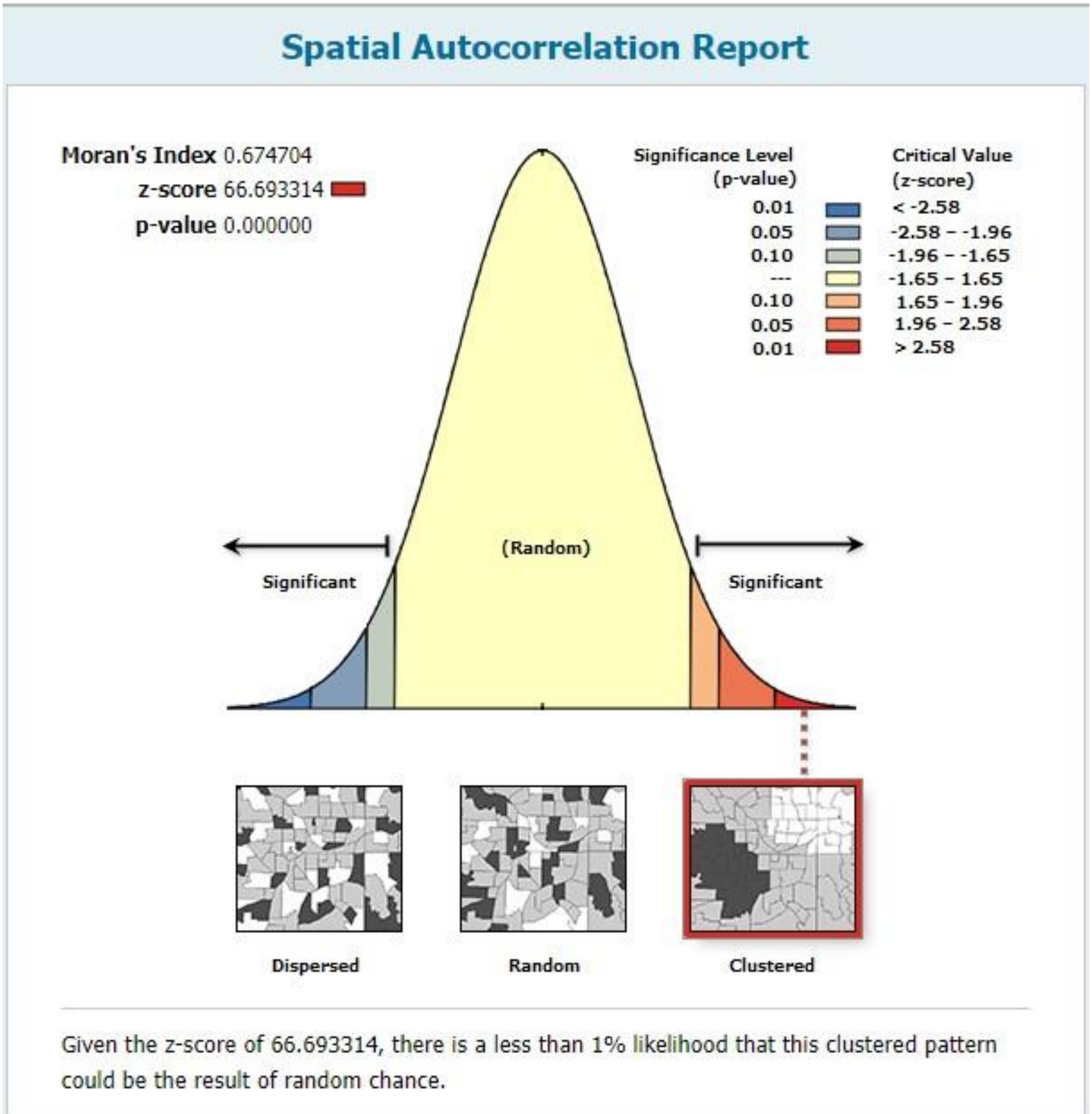


Given the z-score of 86.489743, there is a less than 1% likelihood that this clustered pattern could be the result of random chance.

Global Moran's I Summary

Moran's Index	0.679544
Expected Index	-0.000198
Variance	0.000062
z-score	86.489743
p-value	0.000000

Figure 31: Global Moran's I Report, Food Swamps, London, 2011



Global Moran's I Summary

Moran's Index	0.674704
Expected Index	-0.000244
Variance	0.000102
z-score	66.693314
p-value	0.000000

Figure 32: Global Moran’s I Report, Food Swamps, London, 2021

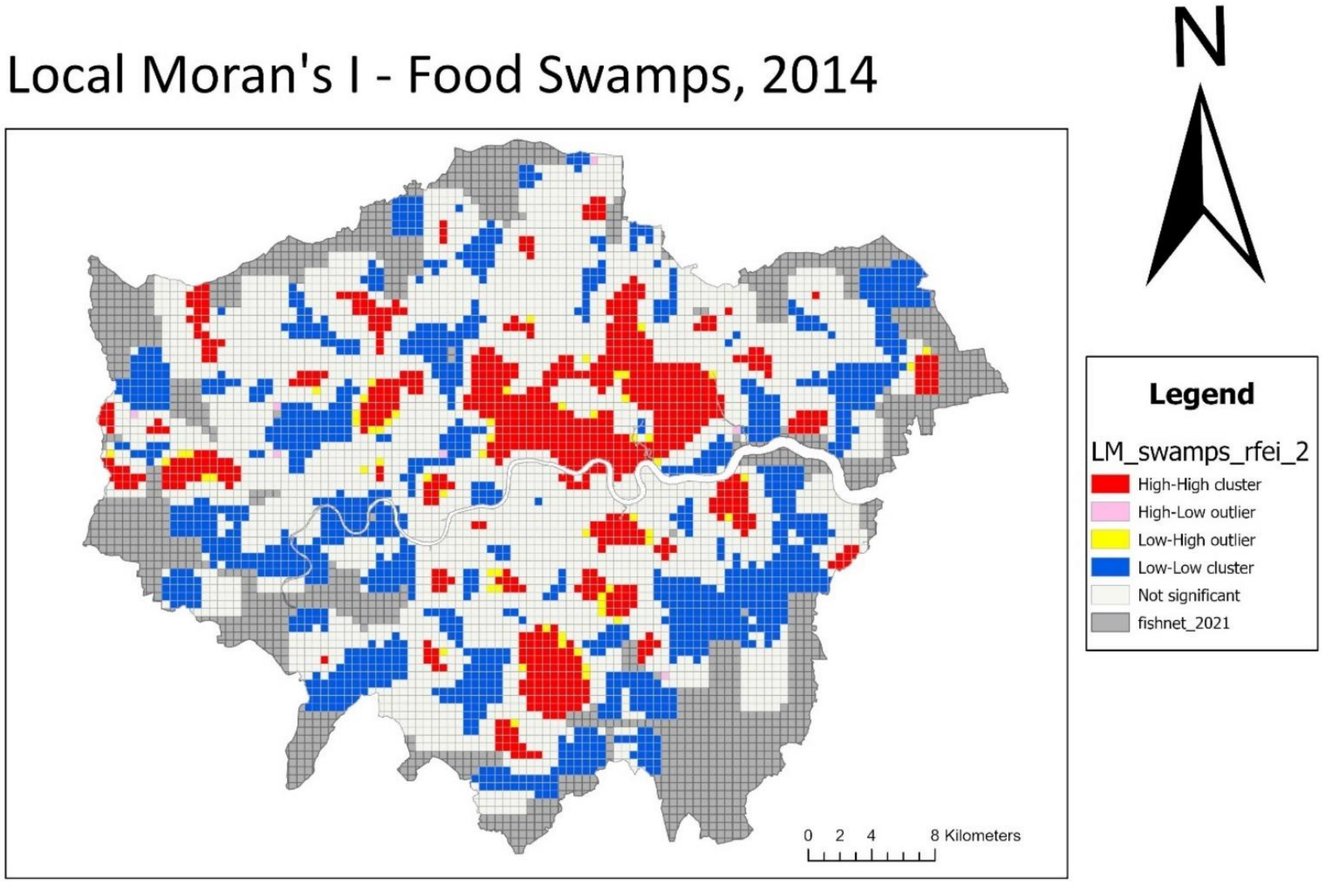


Figure 33: Local Moran’s I Map, Food Swamps, London, 2011

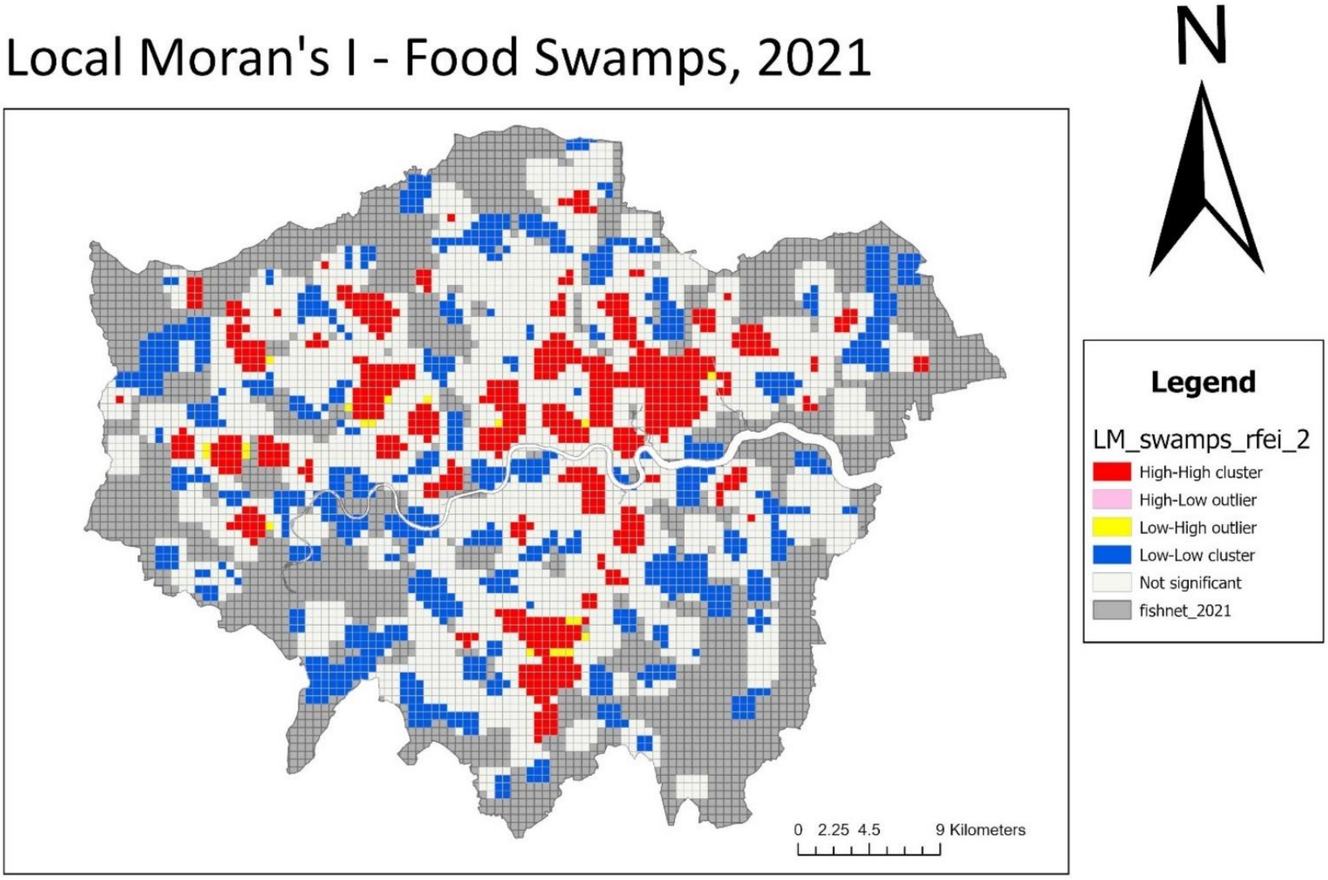


Figure 34: Local Moran’s I Map, Food Swamps, London, 2021

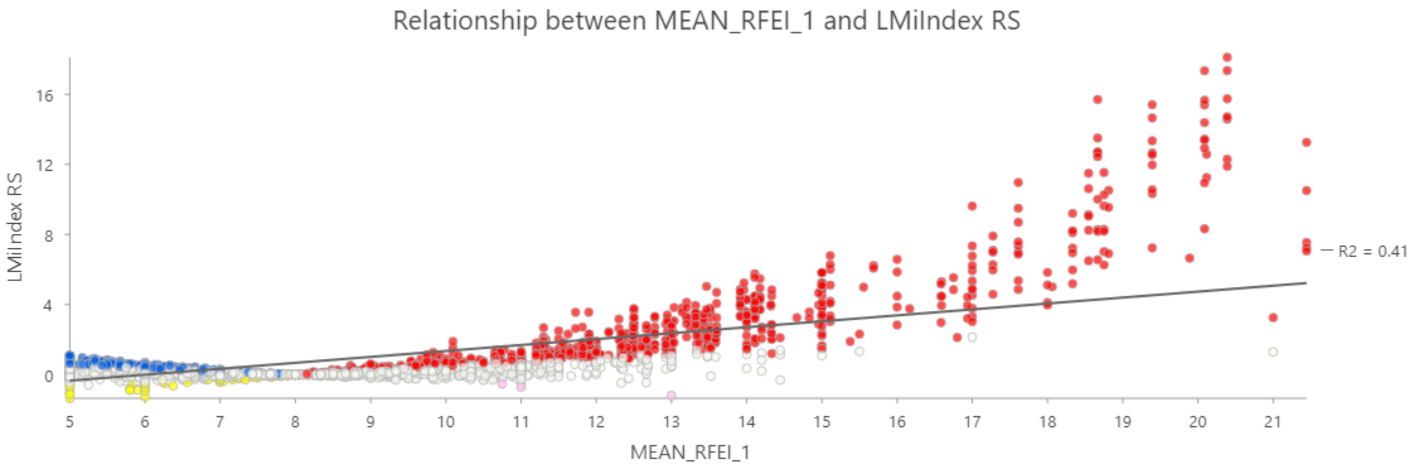


Figure 35: Scatter Plot Local Moran’s I, Food Swamps, London, 2011

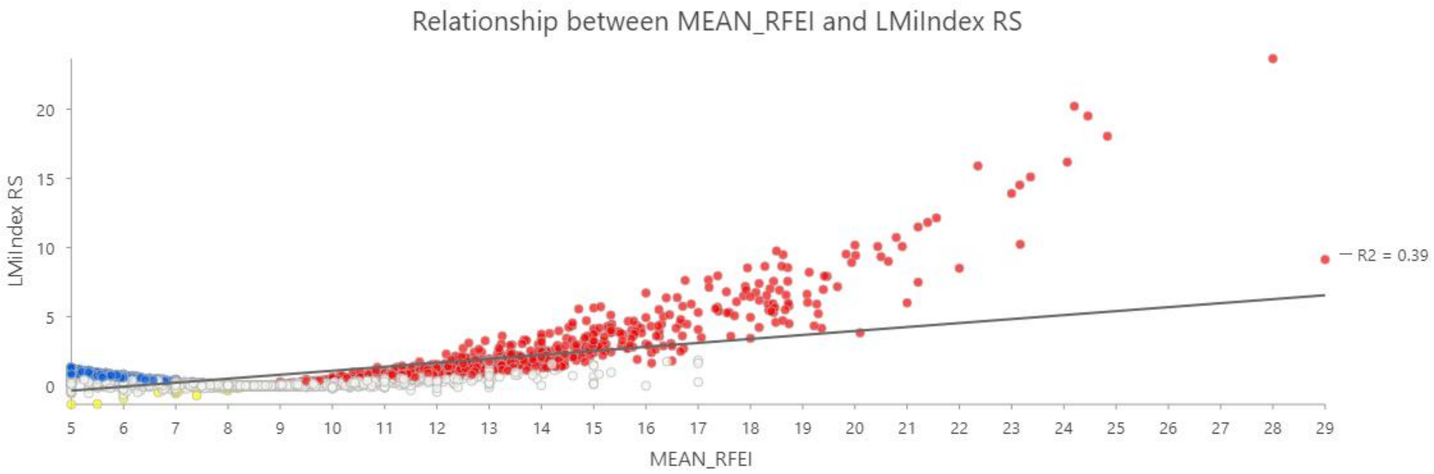


Figure 36: Scatter Plot Local Moran’s I, Food Swamps, London, 2021

Taking into account the 95% confidence interval while carrying out the Global Moran’s I, both the categories for the two years had a p-value of 0, in which case the null hypothesis that the clustering is due to chance can be rejected. This is also confirmed by the high z-score values for all the four tests. Moreover, high positive Global Moran’s index values indicate strong positive clustering in all the cases, which is confirmed by the Local Moran’s I maps. The scatter plots have their axes reversed, which is a mistake in the creation of the plots.

The H-H clusters in the food swamp tests in the central part of London may be explained by the sheer amount of fast-food outlets present there. Nevertheless, there is a change between the two years, and the clusters are more dispersed and more in number, albeit smaller in size.

The number of clusters being decreased in the case of food deserts may be explained by the fact that food deserts themselves have decreased in areas, and hence the relationship between neighbouring cells in more non-significant in 2021. The bigger H-H clusters may be explained by the fact that more people are being serviced by the grocery stores, and hence the percentage of people in those deserts is still higher, although being lower than the required 33% criteria for them to not be considered food deserts. Prevalence of L-L clusters is discussed before due to the lower number of resident residing in the outskirts of London.

Finally, the results may be analysed to discuss the answers to the research questions proposed initially in the study.

A) Is there a change in the number of food deserts and food swamps from the year 2011 to 2021?

For Food Deserts:

Since the number of grocery retail store locations have increased from 7290 in 2011 to 8865 in 2021, the landscape of the retail structure in London is expected to change. This is an increase of 21.60% and it shows in the calculations for the grid cell and population coverage by the buffer catchment area. The number of grid cells increased decreased from being 64.37% of the total grid cells to 59.98% of the total grid cells. This is a decrease in 6.8% and hence shows that food deserts in terms of area and accessibility have decreased, even though the population decrease in the food deserts may only be from 2.76% of the total to 2.70% of the total. In any case, the study cannot comment on the availability of nutritious food in the new locations, and the ease of access regarding other factors to promote more consumers to buy healthier food.

For Food Swamps:

The number of fast-food joints has increased from 8334 in 2011 to 9685 in 2021. This is an increase of 16.21%, and is reflected in the food swamp calculations. The grid cells falling under food swamps have increased from 58.26% of the total to 61.53% of the total number of grid cells. This is an increase of 5.6%. Moreover, the total population coverage under food swamp buffers have increased from 85% of the total grid cells in London to 87%. This again, is an exaggeration since the calculation of food swamps is flawed and takes into consideration the whole of grid cell when intersected with the buffers. A more precise calculation would have been to mimic that of food deserts, while keeping the criteria of RFEI>=5 consistent. Nevertheless, there has been an increase in the availability of fast-food in London. Again, the nutritional value of the food introduced cannot be commented on, as some cases have shown that fast-food may be becoming healthier as people become more conscious of their food choices. (Lydall, 2016)

B) Is there a correlation between the existence of food deserts and food swamps with the Index of Multiple Deprivation score (quantiles) for the corresponding year?

Figures 15,16,21 and 22, which are pie charts showing the distribution of grid cells in the IMD quantiles for both years, may be referred to for this answer. Moreover, figures 13,14,19 and 20 may be referred to for the spatial scenario for this answer. The outermost parts of London, which generally contain lower population, the suburbs and sometimes green spaces like forested areas in the southeast and the northeast, have low IMD scores and thus fall in the lower quantiles – and are less deprived as compared to the central areas of London. The analysis showed that for the lowest quantile, or the less deprived areas, the proportion of food deserts was the highest – 30.30% in 2011 and 32.00% in 2021. The trend was reversed for food swamps, where the highest quantile, or the most deprived areas have the most food swamp grid cell proportions – 32.9% in 2011 and 31.6% in 2021.

Further study and analysis is required to answer the questions regarding the trends depicted above – whether the number of cells in each quantile are changing or the locations of the newly established retail and fast-food stores are the factors responsible for the changes. Furthermore, it would be useful to incorporate different measures on deprivation for calculations in further studies, as it is discussed above that the elderly and children are the most vulnerable to lifestyle diseases due to food habits.

C) Null Hypothesis: Food deserts from 2011 have disappeared and residents now (2021) have access to nutritional food – Either the food deserts are now food oases (normal) and/or have not been turned into food swamps.

While the number of grid cells which fall under both FD and FS have been calculated for both the years, and the fact that FS grid cells have increased and the FD grid cells have decreased, more work needs to be done in order to determine if the same cells which were FD before have either turned into FS or lie in neither category in 2021. Figures 23 and 24 may be referred to for this answer. Visually, the northeast and northwest have more blue grid cells which were before in both categories. This, however, is not an exact calculation and the present study could be helped with more analysis. For context though, the number of cells falling under both categories was 1,857 in 2011 and 1,813 in 2021 and the population in the same has decreased by 218,672 residents, but the population according to WorldPop data also has decreased in the 10 year period, so a certain answer to the question is not possible. However, there generally has been an increase in the availability of supermarket store locations serving nutritious food, but so has the fast-food locations.

One of the key limitations of this study has been the way in which the food swamps were calculated. Indeed, a process similar to the determination of food deserts would have provided more accurate results. Therefore, a direct comparison is difficult to answer certain questions. While the number of grid cells falling in either FD and FS were calculated, along with their respective IMD quantiles, a bivariate Local Moran's I would have provided a better spatial picture to the clustering process relating the food insecurity and deprivation scores. Other deprivation measures may have been included, and other popular indices like Carstairs index and Townsend index may have been incorporated in the study. Moreover, the postcode population counts for the year 2021 were not available, and thus a more realistic picture could not be evaluated for London. A network analysis study would have been more comprehensive; however, the data processing would involve a finer spatial extent. Nonetheless, this methodology is useful in further hotspot analysis, creation of land use surfaces etc. and covers the entirety of London, which is not possible due to the closeness in proximity of the postcode points. Since London is densely populated, and as covered in previous studies above that it is usually well connected, the 500m buffer catchment may be questioned. This study however, is the first of its kind for London and a basic one, and further analyses could help with more data, time and better techniques.

4. Conclusion

While studies have previously taken place to map and evaluate the relationships between food insecurity and the deprivation measures around the world and across the UK, this dissertation tries to bridge the gap by including the association between the availability of nutritious food and the rising concerns regarding generally unhealthy fast-food data in Greater London, while still considering the deprivation in the areas. Buffer analysis was carried out to assess the statistics regarding food deserts and food swamps considering the size of Greater London, while a more elaborate study could involve the use of Network Analysis for smaller areas. However, at the present spatial granularity, the buffer analysis provided an effective technique to gauge the food insecurity and deprivation measures, while also discovering spatial patterns in the data further down the process.

The results demonstrate that although there has been a rise in availability of more nutritious foods, there is a simultaneous increase in the abundance of fast-food that is readily available to the major population, especially the populace of central London. Area-wise, food swamps have increased by nearly 5%, while food deserts have shrunk by nearly 7% from the year 2011 to 2021. In terms of the population, the proportion of population in food swamps in has increased from being 85% in 2011 to 87% in 2021, while the proportion of population has shrunk in the food swamp from nearly 64% in 2011 to 60% in 2021. For the purposes of measuring the deprivation in the fishnet grid cells in the area, quantiles were used instead of absolute IMD scores. The analysis found that about 30% of the area in food deserts fell under the areas with the least deprivation scores, which are usually scarcely populated in the suburbs of London, while nearly 30% of the area in food swamps fell under the areas with highest deprivation scores, which happens to be centrally. There seems to be a high spatial autocorrelation amongst both food swamps and food deserts, for both 2011 and 2021, i.e. areas with high and lower percentages of population under catchment areas clustering respectively for food deserts, while the same can be said about the higher values of the RFEI in terms of food swamps.

While the primary objective of answering the research questions was achieved by the study, the reasons for those answers are beyond the scope of this study. For policy implementation and future research, more comprehensive techniques like network analysis, land use regression modelling, and so on, at a higher spatial extent may be necessary. A major refinement to the current study would be to improve the way the population in food swamps is calculated, and to employ bivariate Local Moran's I to discover spatial relationships between deprivation and food insecurity. While the area under the two is calculated in the study, the spatial clustering would answer more questions related to the association between deprivation and food insecurity. Moreover, the study uses a fishnet grid for the study area, which spreads out the population evenly. While this is an effective technique in carrying out statistical operations and making further surfaces for land use regression modelling, a more accurate picture in terms of absolutes would be painted with the use of postcode points data, if available. Furthermore, it would be essential to include more deprivation measures along with the IMD scores in following studies, in order to deduce the effects of vital social aspects like age, income etc. on the geography of food insecurity.

The Greater London Authority is moving towards improving accessibility throughout London. This includes plans to improve cycling infrastructure and walkability, which will not only ensure a healthier lifestyle amongst the people of the city, but also improve access to grocery stores where the availability of more nutritious food could be upgraded. Keeping that into consideration, fast-food chains have plans to improve the nutritional quality of the cheaper foods available to the public, the fight against lifestyle diseases due to calorie-dense fast-food is far from over. This can be ascertained by the sheer increase in the area under food swamps from 2011 to 2021, as found in this study.

5. Appendix

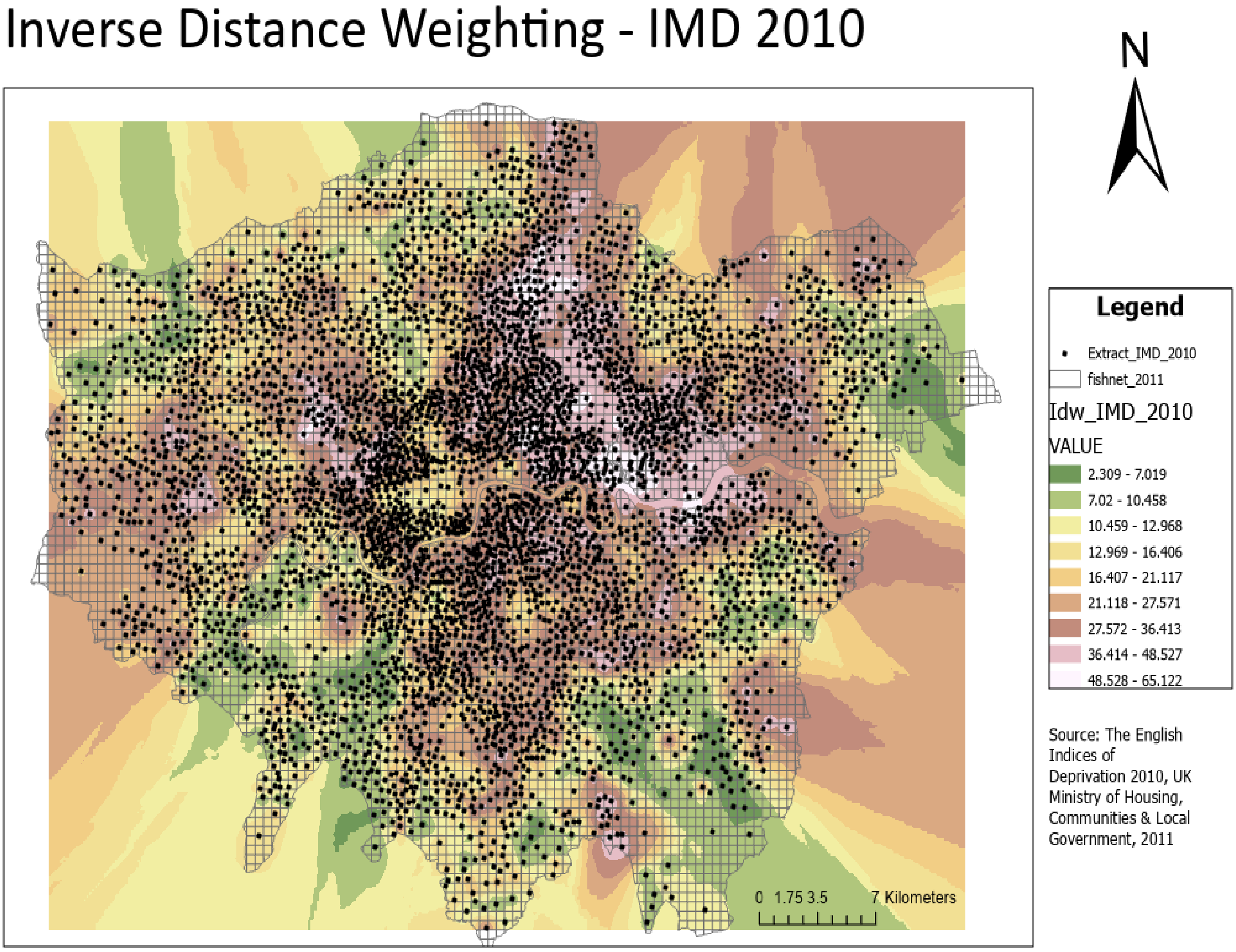


Figure 37: Inverse Distance Weighting to calculate Null values for IMD 2010 LSOAs

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