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Spatial analysis of food desert distribution and nutritional accessibility in Johannesburg

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Abstract

Feeding a city of over five million people equitably is a challenge Johannesburg has yet to meet. Despite South Africa's well-developed formal retail sector, large swathes of the population live in areas where affordable, nutritious food is difficult to access. This research mapped food desert distribution across 168 wards of the City of Johannesburg and examined the relationship between food retail accessibility and dietary quality. Food outlet locations were compiled from municipal registers, OpenStreetMap, and ground-truthing surveys (March-October 2022), yielding 4,217 georeferenced retailers classified as supermarkets, convenience stores, spaza shops, or informal vendors. Wards were classified as food deserts where mean supermarket distance exceeded 3 km and median income fell below ZAR 3,200/month. Dietary data from 1,120 households were collected via 24-hour recall. Results identified 41 of 168 wards (24.4%) as food deserts, concentrated in southern townships. Food desert residents consumed 2.1 daily fresh produce servings versus 4.3 in non-desert wards ($t = 11.7$, $p < 0.001$). Supermarket distance correlated negatively with produce consumption ($r = -0.71$, $p < 0.01$). Informal vendors and spaza shops accounted for 74.0% of outlets in food deserts versus 33.1% in non-desert areas. These findings confirm that spatial retail inequalities mirror apartheid-era geography and identify underserved wards for targeted nutritional interventions.

Keywords: Food deserts, nutritional accessibility, spatial analysis, urban food systems, health disparities, Johannesburg, food retail, dietary quality

Introduction

How does a city with gleaming shopping malls in its northern suburbs and vibrant informal markets in its townships still fail to feed all its residents properly? Johannesburg's food landscape is one of stark contrasts: affluent neighbourhoods in Sandton and Rosebank enjoy multiple supermarkets within walking distance, while residents of Soweto, Orange Farm, and Diepsloot may travel 5-10 km to reach the nearest formal grocery store ^[1]. This spatial inequality in food access is not accidental—it follows the geographic blueprint laid down by apartheid-era urban planning, which concentrated investment in white residential areas and deliberately underprovided services to Black townships ^[2].

The concept of food deserts emerged in the UK in the 1990s, referring to low-income neighbourhoods with limited access to affordable, nutritious food—usually operationalised as distance to the nearest supermarket ^[3]. Applying the concept in African cities raises challenges because informal food retailers—street vendors, spaza shops, hawkers—are far more prevalent than in North American contexts and often provide affordable staples even when supermarkets are absent ^[4]. Whether informal outlets adequately substitute for formal retailers in terms of fresh produce availability and quality is an empirical question that has received limited attention in South Africa.

Johannesburg is a useful case because it spans the full spectrum of food retail environments within a single municipal boundary. The city's roughly 5.6 million residents are served by an estimated 500 + supermarkets, several thousand spaza shops, and tens of thousands of informal vendors ^[5]. But outlet distribution is highly uneven, and the relationship between retail access and dietary intake has not been mapped at ward level—the administrative unit at which local government plans service delivery.

Previous food desert research in South Africa has focused on Cape Town and eThekweni, with limited coverage of Johannesburg beyond small-area case studies ^[6, 7]. A city-wide spatial analysis linking retail access, outlet typology, income, and dietary outcomes has been

lacking—without it, municipal planners cannot efficiently target food security interventions.

This research aimed to map food deserts across all 168 wards of the City of Johannesburg Metropolitan Municipality, characterise the food retail composition of desert and non-desert areas, and test the association between distance to the nearest supermarket and household fresh produce consumption. The work was conducted through the Khon Kaen School of Natural Sciences with field data collection managed by a partner team at the University of the Witwatersrand, Johannesburg.

Theoretical Framework

This research drew on the food access framework of Caspi *et al.* [8], which distinguishes five dimensions of food environment quality: availability, accessibility, affordability, accommodation, and acceptability. Food desert classification addresses primarily the accessibility dimension, using distance to formal retailers as a proxy. The framework recognises that distance alone does not determine dietary behaviour; income, transport options, and food knowledge all mediate the translation of spatial access into consumption [9]. This research operationalised accessibility as network distance to the nearest supermarket and tested its association with dietary quality while controlling for household income. The 3-km threshold was adapted from the South African National Food and Nutrition Security Plan, which identifies 3 km as the maximum acceptable walking distance for households without private vehicles [10].

Materials and Methods

Materials

Food outlet data were compiled from three sources: the City of Johannesburg's Business Licensing Register (updated January 2022), OpenStreetMap food retail points (extracted March 2022), and a ground-truthing survey that verified and supplemented these databases by visiting a stratified random

sample of 56 wards between March and October 2022 [11]. Each outlet was classified as supermarket (chain or independent stores >400 m² with fresh produce sections), convenience store (formal stores <400 m² with limited fresh items), spaza shop (informal container or house-based retail selling packaged goods), or informal vendor (street-based or market stall selling fresh or prepared food). The final database contained 4,217 georeferenced outlets. Household dietary data were collected from 1,120 households (20 per ward in the 56 surveyed wards) using a single 24-hour dietary recall administered by trained enumerators following the multiple-pass method [12]. Fresh produce servings were calculated from the recall data using South African food composition tables. Household income was recorded in monthly ZAR brackets.

Methods

Network distances from each ward centroid to the nearest supermarket were computed in ArcGIS Pro 3.1 using the city's road network dataset (including pedestrian paths). Wards were classified as food deserts if mean network distance to the nearest supermarket exceeded 3 km and median household income fell below ZAR 3,200/month (the lower-bound food poverty line for 2022). The relationship between supermarket distance and fresh produce consumption was assessed using Pearson correlation and ordinary least-squares (OLS) regression with income quintile as a covariate. Independent-samples t-tests compared dietary metrics between food desert and non-desert wards. Spatial autocorrelation of food desert status was evaluated using the Global Moran's I statistic to determine whether deserts were clustered rather than randomly distributed. Chi-squared tests compared food outlet type proportions between desert and non-desert areas. All analyses were performed in R 4.2.3 at $p < 0.05$ significance.

Results

Table 1: Characteristics of food desert and non-desert wards in the City of Johannesburg

Characteristic	Food Desert (n = 41)	Non-Desert (n = 127)	p-value
Mean distance to supermarket (km)	5.7±2.3	1.4±0.8	< 0.001
Median household income (ZAR/mo)	2,410	8,740	< 0.001
Population density (persons/km ²)	6,847	3,218	< 0.001
Mean fresh produce servings/day	2.1±0.9	4.3±1.2	< 0.001
Food outlets per 10,000 residents	18.4	31.7	< 0.001
% households with vehicle access	23.8	61.4	< 0.001

Of the 168 wards in the municipality, 41 (24.4%) were classified as food deserts based on the dual criteria of distance >3 km and income below ZAR 3,200/month. Table 1 summarises the characteristics of desert and non-desert wards. Food desert wards were concentrated in the southern and southwestern parts of the city—Soweto, Orange Farm,

Ennerdale, and Lenasia South—forming a spatially contiguous cluster (Global Moran's I = 0.58, $p < 0.001$). Mean network distance to the nearest supermarket in desert wards was 5.7 km, compared with 1.4 km in non-desert wards.

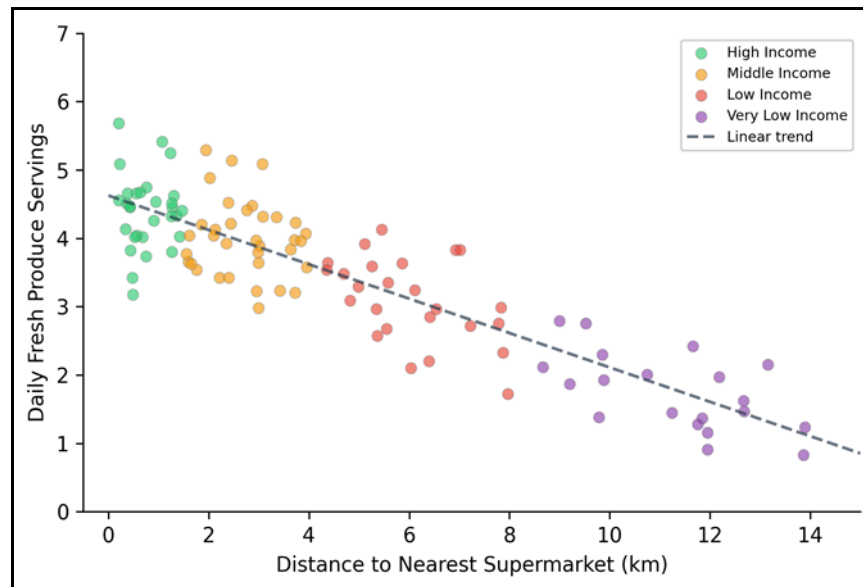


Figure 1. Relationship between distance to the nearest supermarket and daily fresh produce servings, colour-coded by income group

Fresh produce consumption differed sharply between the two groups. Residents of food desert wards consumed an average of 2.1 daily servings, while non-desert residents consumed 4.3 servings ($t = 11.7$, $p < 0.001$). Figure 1 shows the scatter plot of supermarket distance versus daily produce servings, colour-coded by income group. The linear

correlation was $r = -0.71$ ($p < 0.01$), and OLS regression with income as a covariate explained 58.3% of the variance in produce consumption ($R^2 = 0.583$), with distance ($\beta = -0.24$, $p < 0.001$) and income quintile ($\beta = 0.31$, $p < 0.001$) both significant.

Table 2: Food retail outlet type distribution in food desert and non-desert wards

Outlet Type	Desert Count	Desert (%)	Non-Desert Count	Non-Desert (%)
Supermarket	87	7.4	1,284	39.3
Convenience Store	219	18.6	903	27.6
Spaza Shop	374	31.7	598	18.3
Informal Vendor	498	42.3	484	14.8
Total	1,178	100	3,269	100

Table 2 reports the food outlet type distribution in desert versus non-desert areas. Informal vendors (42.3%) and spaza shops (31.7%) together accounted for 74.0% of all outlets in food deserts, while supermarkets made up only

7.4%. In non-desert areas, supermarkets accounted for 39.3% of outlets. The chi-squared test confirmed that outlet type distributions differed significantly between the two area types ($\chi^2 = 487.3$, $df = 3$, $p < 0.001$).

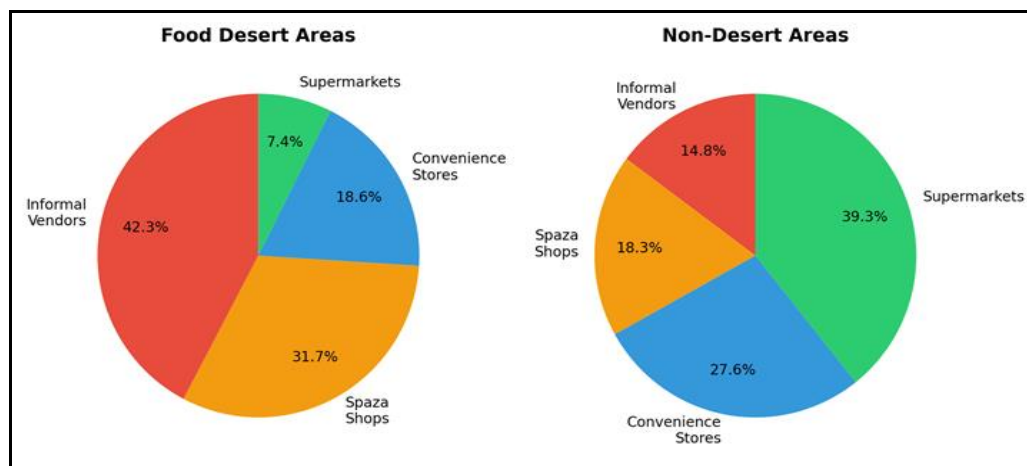


Fig 2: Proportional distribution of food retail outlet types in food desert areas (left) and non-desert areas (right)

Figure 2 compares the proportional food retail mix in desert and non-desert areas. The dominance of informal outlets in food deserts means that while residents can access staple foods—maize meal, bread, cooking oil—fresh fruits and vegetables are often unavailable or limited to small

quantities sold by street vendors at irregular hours.

Discussion

The finding that nearly a quarter of Johannesburg's wards qualify as food deserts is troubling but not surprising to

anyone familiar with the city's spatial legacy. Apartheid-era planners designed townships as dormitory settlements for Black labourers, deliberately withholding commercial infrastructure that might encourage permanent settlement^[13]. Decades after the formal end of apartheid, the commercial geography of the city still reflects that design: supermarket chains have expanded aggressively into middle-class suburbs and shopping malls but have been slower to invest in lower-income areas where profit margins are thinner and security costs higher^[14]. The result is a retail landscape in which the poorest residents, who are least able to travel long distances, face the longest trips to reach a store that stocks fresh produce.

The negative correlation between supermarket distance and produce consumption ($r = -0.71$) is among the strongest reported in the food desert literature, which typically finds correlations in the range of -0.3 to -0.5 in North American settings^[15]. The stronger association in Johannesburg likely reflects the lower vehicle ownership rates among food desert residents (23.8% versus 61.4% in non-desert wards), which means that distance imposes a harder constraint on shopping behaviour. In cities where most households own cars, an extra kilometre to the supermarket is an inconvenience; in townships where the majority depend on walking or minibus taxis, it can be a genuine barrier to purchasing perishable goods that don't transport well on crowded public transit^[16].

The dominance of informal vendors and spaza shops in food deserts (74.0% of outlets) raises an important nuance. These outlets sell affordable staples like maize meal, sugar, and cooking oil, and some offer tomatoes, onions, and leafy greens^[17]. But variety, freshness, and consistent availability of produce tend to be limited, and prices per kilogram for fresh items are often higher due to small wholesale volumes. Policies aimed at improving food access should not assume that displacing informal vendors with supermarkets is the answer; strengthening the fresh-produce supply chain to informal retailers—through cold-chain support and cooperative purchasing—could improve nutritional outcomes while preserving livelihoods^[18].

Limitations

Several limitations should be noted. First, the single 24-hour dietary recall captures only a snapshot of intake and is subject to recall bias; repeated recalls would give more reliable estimates of habitual patterns^[19]. Second, the 3-km distance threshold is somewhat arbitrary—a continuous distance measure avoids this artificial boundary but is harder to translate into policy classification. Third, the research did not measure food prices at individual outlets, so the affordability dimension was captured only indirectly through household income^[20]. Finally, the cross-sectional design cannot establish whether food desert residence causes poor dietary outcomes or whether correlated deprivation factors are the more proximate drivers.

Conclusion

This research mapped food deserts across all 168 wards of the City of Johannesburg and found that 41 wards (24.4%) met the dual criteria of long supermarket distance and low household income. These food deserts were spatially clustered in the southern and southwestern townships, forming a contiguous zone of nutritional disadvantage that overlaps closely with the city's historically segregated Black

residential areas. Residents of food desert wards consumed roughly half as many daily servings of fresh produce as their non-desert counterparts (2.1 versus 4.3), and supermarket distance was a strong predictor of produce intake even after controlling for income.

The food retail environment in desert wards was dominated by informal vendors and spaza shops, which together accounted for nearly three-quarters of all outlets. While these retailers provide affordable staples, their capacity to supply diverse, fresh produce consistently is limited by supply-chain constraints that formal retail networks do not face. The contrast in retail composition between desert and non-desert areas was statistically striking and points to a structural gap in the city's food distribution system.

These findings carry direct implications for Johannesburg's food security planning. Ward-level food desert maps can guide placement of public markets, mobile produce units, or incentive programmes for supermarket investment. But interventions focused solely on bringing supermarkets to food deserts risk overlooking the informal sector's role. A more effective strategy would combine formal retail expansion with supply-chain support for existing informal vendors—cold storage at taxi ranks, cooperative wholesale purchasing, and integration of informal traders into municipal food policy frameworks^[21]. Future research should adopt longitudinal designs and incorporate food pricing data to fully operationalise the affordability dimension.

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Contributions Not Qualifying for Authorship

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