REVISTA DE NUTRIÇÃO
Brazilian Journal of Nutrition

ORIGINAL

Epidemiology and Statistics

Editor
Lígia Amparo da Silva Santos

Conflict of interest
The authors declare that there are no conflict of interests.

Received
April 4, 2023

Final version
February 21, 2024

Approved
May 7, 2024

Spatial distribution of commercial food establishments in a Northern State of Brazil: do we have food deserts and swamps?

Distribuição espacial de estabelecimentos comerciais alimentícios em um estado da região Norte do Brasil: temos desertos e pântanos alimentares?

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How to cite this article: Borges Neto WS, Silva KC, Vegi ASF, Pinto SL. Spatial distribution of commercial food establishments in a Northern State of Brazil: do we have food deserts and swamps? Rev Nutr. 2024;37:e230058. https://doi.org/10.1590/1678-9865202437e230058

ABSTRACT

Objective
This study aimed to evaluate the spatial distribution of commercial food establishments in the state of Tocantins, in order to identify the presence of food deserts and swamps and its relationship with sociodemographic characteristics.

Methods
The present study is an ecological (observational) study of secondary state data. Sociodemographic and stablishment data were extracted from open government databases. After extracting the data, establishments were filtered according to CNAE, and a total of 4.202 establishments were distributed in 139 municipalities in the state of Tocantins. Each establishment was classified as unprocessed, mixed or ultra-processed. Since there is a high number of small-sized I municipalities, the density data of both types of establishments, associated relationships were calculated per 1000 inhabitants and then divided into quartiles. Lastly, maps were constructed for included establishments, using the QGIS software.

Results
In the north of the state, a tendency towards spatial clustering of municipalities in the first quartile of the distribution of healthy establishments was observed, indicating food deserts. Food deserts are spread across the whole territory of Tocantins, but food swamps are absent.

Conclusion
This study suggests that food deserts are present in Tocantins and food swamps could not be found, despite unhealthy stablishments being concentrated along BR highway 153.

Keywords: Built environment. Food deserts. Food insecurity. Geographic mapping. Spatial analysis.

RESUMO

Objetivo

Este estudo teve como objetivo avaliar a distribuição espacial dos estabelecimentos comerciais de alimentação no estado do Tocantins, a fim de identificar a presença de desertos alimentares e brejos pântanos e sua relação com características sociodemográficas.

Métodos

O presente estudo é um estudo ecológico (observacional) de dados secundários do estado. Os dados sociodemográficos e dos estabelecimentos foram extraídos de bancos de dados abertos do governo. Após a extração dos dados, os estabelecimentos foram filtrados conforme CNAE, e foram distribuídos um total de 4.202 estabelecimentos em 139 municípios do estado do Tocantins. Cada estabelecimento foi classificado como in natura, misto ou ultraprocessado. Visto que há um grande número de muitos municípios de pequeno porte, os dados de densidade de ambos os tipos de estabelecimentos e relações associadas foram calculados por 1000 habitantes e depois divididos em quartis. Por fim, foram construídos mapas dos estabelecimentos incluídos, utilizando o software QGIS.

Resultados

No norte do estado, observou-se tendência à aglomeração espacial dos municípios no primeiro quartil da distribuição dos estabelecimentos saudáveis, indicando desertos alimentares. Os desertos alimentares estão espalhados por todo o território do Tocantins, mas os pântanos alimentares estão ausentes.

Conclusão

Este estudo sugere que desertos alimentares estão presentes no Tocantins e que não foram encontrados pântanos alimentares, apesar dos estabelecimentos insalubres estarem concentrados ao longo da rodovia BR 153.

Palavras-chave: *Ambiente construído. Análise espacial. Desertos alimentares. Insegurança alimentar. Mapeamento geográfico.*

INTRODUCTION

The place where an individual lives and its aspects such as access to food (availability, quality and value) can influence food choices. It also forms part of the so-called food environment. This environment is composed of extensive factors such as policies, food industries, advertising and marketing among others, that can affect food purchase decision [1]. It serves as an interface of the consumer as regards food and beverage (availability, accessibility, convenience, promotion, quality and sustainability) in wild, cultivated and built spaces, being affected by sociocultural and political environments, and incorporated ecosystems [2].

The elevated disponibility of ultraprocessed food in conjunction with limited access to unprocessed/minimally processed foods in various food environments, be it in communities or for individual consumers, holds the potential to significantly impact dietary choices leads to food insecurity and increases the probability of overweight and obesity in all stages of the human life cycle [3]. This is due to the fact that individuals who are food insecure excessively consume unhealthy foods motivated by their relatively cheaper prices compared to healthier foods [4]. This imbalance may contribute to a syndemic interplay, fostering both overweight conditions and issues related to food insecurity [5].

Food environment is one of the crucial factors related to access to food and formation of eating habits [6]. Geographic access to food is considered a complex sociodemographic factor which can determine the nutritional status of individuals. For instance, traveling long distances to retail establishments that sell healthy food (unprocessed and minimally processed) or high prices can decrease healthy food consumption [7]. Retail establishments are part of the built environment, which include formal or informal markets [2]. Regions with low socioeconomic status often have a

low density of establishments that sell healthy foods and a high density of small retail establishments that either sell mostly unhealthy foods (processed and ultra-processed) or healthy foods with high price [8,9].

In this sense, the concept of food deserts is introduced as territories with little or no supply of healthy food [6]. In these places, individuals who want to maintain healthy eating habits have no option but to travel long distances or pay more. Another concept is food swamps characterized by territories whose neighborhoods have a high concentration of ultra-processed food sales which "flood" healthy alternatives. This classification is highly related to the prevalence of obesity in a given region [10], higher hospitalization rates and complications in adults with diabetes [11]. Studies that evaluated eating environments show positive associations between healthy eating environments and high-quality diets. For example, a study carried out in Latin America found that physical access to healthy foods directly affects individual eating habits [12]. Similarly, another study showed that lower Body Mass Index (BMI) and obesity rates among women in the United States of America (USA) were associated with greater availability and proximity of grocery stores and supermarkets to residence. On the other hand, greater availability of fast-food restaurants was associated with higher BMI and obesity rates [13], thus promoting the prevalence of overweight among adolescents and obesity among adults [14,15]. The same outcome was associated with lower availability of supermarkets and grocery stores [16].

The prevalence of obesity decreased as the socioeconomic status of the studied population increased [13]. Regions with greater socioeconomic deprivation can promote unhealthy habits, consequently increasing the prevalence of obesity [15]. Furthermore, low income neighborhoods have been associated with greater availability of unhealthy foods and higher probability of increased obesity prevalence [17,18].

Given the above considerations, this study aims to encourage the analysis of food environments in Tocantins, where there are no studies on food environments. Thus, it evaluated the spatial distribution of establishments that sell food in the state of Tocantins, and identified the presence of food deserts and swamps and its relationship with sociodemographic characteristics.

METHODS

The present study is an ecological (observational) study. It is under a large project entitled *Enfrentamento e Controle da Obesidade no Âmbito do Sistema Único de Saúde (SUS) in Tocantins*, Project ECOA/SUS-Tocantins, approved through the 28/2019 public call of the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and Ministry of Health.

The methodology of this research was based on a study by the Câmara Interministerial de Segurança Alimentar e Nutricional (CAISAN) [6]. Data on number of establishments were extracted from the database of the Secretariat of Finance of the State of Tocantins (SEFAZ/TO), which contains the number of active taxpayers according to the *Classificação Nacional das Atividades Econômicas* (CNAE, National Classification of Economic Activities) and municipality. Subsequently, the establishments were filtered according to CNAE. Using such a database doesn't permit the evaluation of informal trade. After extracting the data, a total of 4.202 establishments were distributed in 139 municipalities in the state of Tocantins. Each establishment was classified as unprocessed, mixed or ultra-processed according to the subclassifications proposed by CAISAN. Mixed and unprocessed establishments were classified as healthy and ultra-processed establishments were classified as unhealthy [6].

Since Tocantins has a high number of small-sized l municipalities (up to 20,000 inhabitants), density was estimated per 1,000 inhabitants instead of 10.000 inhabitants normally utilized by CAISAN. The population data were extracted from the Atlas Brasil website of the Brazilian Institute of Geography and Statistics [19]. With these, the density of establishments was calculated and then divided into quartiles. Municipalities below the 25th percentile (1st quartile) of density of establishments classified as healthy were defined as food deserts, places with the worst access to healthy food within the state.

For density of unhealthy establishments, the division of data into quartiles was impossible due to the null density of 77 municipalities. These municipalities were placed in a specific category (density = 0) and the remaining 62 municipalities were divided into quartiles.

Using the estimated values, the relationship between the density of unhealthy and healthy establishments was determined. Accordingly, the trend of the number of unhealthy establishments for each healthy establishment within each municipality can be analyzed. If the ratio of unhealthy establishment ratio was greater than healthy, food swamps (values greater than 1.0) are present.

Based on the densities of healthy and unhealthy establishments and the relationship between them, choropleth maps were constructed using the QGIS 3.22.0 software. For this purpose, the state of Tocantins was geopolitically divided into 8 health regions, namely: Capim Dourado, Ilha do Bananal, Cantão, Amor Perfeito, Sudeste, Médio Norte Araguaia, Bico do Papagaio and Cerrado Tocantins Araguaia [18]. This division/format directly interferes in healthcare decisions/policies as regards planning, organization and management of actions. In addition, the presence of BR highway 153 in the geographic space of Tocantins was analyzed, given that it is an important highway which runs through several cities in the state and could have an impact on the number and type of establishments.

For income analysis, the data were extracted from the Instituto Brasileiro de Geografia e Estatística database [19]. Thus, the average income of the municipalities was separated into quartiles, and for each quartile the following data were presented in a table: average income, the mean density of healthy establishments and the mean density of unhealthy establishments.

RESULTS

The map of municipalities classified by density of healthy establishments (Figure 1) showed some trends in spatial clustering and allowed a better identification of food deserts. The municipalities classified as food deserts, that is, in the 1st quartile, are concentrated in the north and northeast health regions of Tocantins, specifically Bico do Papagaio and Médio Norte Araguaia, respectively. Mid-south regions of Tocantins, closer to the capital and having an intersection between health regions of Capim Dourado, Cantão and Amor Perfeito, presented a higher concentration of municipalities in the 4th quartile.

In relation to the density of unhealthy establishments (Figure 2), the 77 that did not present are presented in white, and the others 62 have densities between 0.06 and 0.97. The municipalities with the highest number of unhealthy establishments are mainly in the mid region of the state, in the intersection region between the health regions of Capim Dourado, Cantão and Amor Perfeito, as shown in Figure 2. In the northern region of the state, in the health regions of Médio Norte Araguaia and Cerrado Tocantins Araguaia, there is a subtle concentration of municipalities classified in the 4th quartile with neighboring municipalities in the 3rd quartile. We also note that unhealthy establishments are concentrated around BR highway 153.

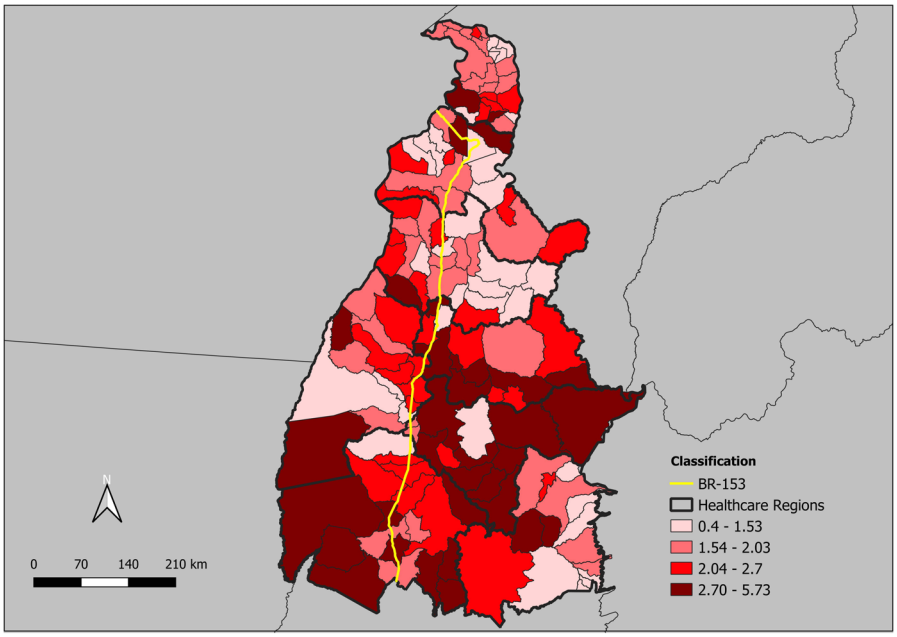

Figure 1 – Number of healthy establishments for every 1,000 inhabitants per municipality, in the state of Tocantins, 2019.

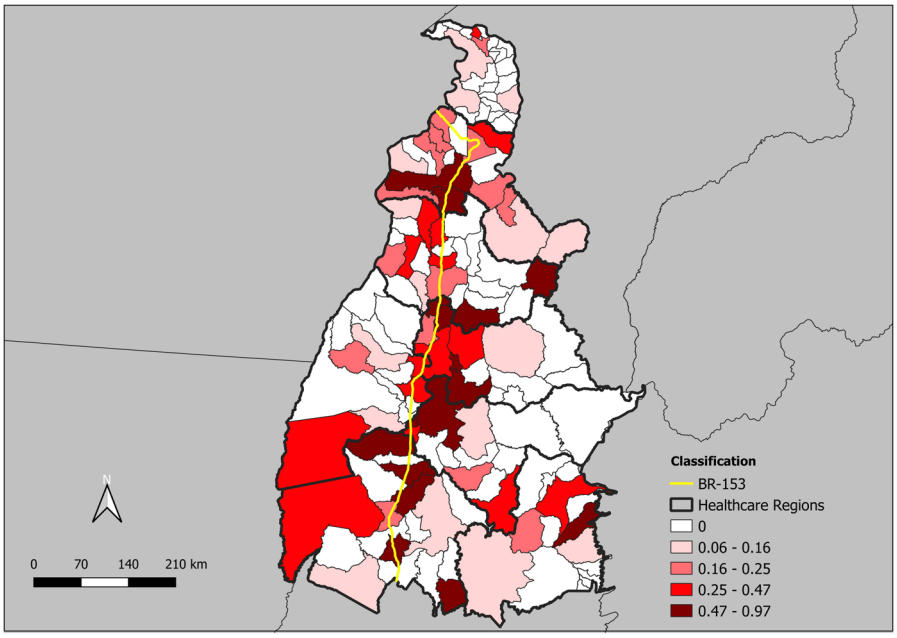

Figure 2 – Number of unhealthy establishments per 1,000 inhabitants by municipality, in the state of Tocantins, 2019.

The relationship between the densities of unhealthy establishments and healthy establishments (Figure 3) allowed a better identification of food swamps. In Tocantins, the maximum ratio is 0.67, all municipalities having less than one unhealthy establishment for each healthy establishment. The regions with concentration of establishments in the 4th quartile are similar to the regions in the ultra-processed map, with differences in only a few municipalities.

In relation to income (Table 1), the average income of the municipalities increased from 822.34 reais in the 1st quartile to 1232.63 reais in the 4th quartile, approximately a 50% increase. The average density of healthy establishments increases as income increases, up to the 3rd quartile. The density in the 1st and 3rd quartiles is 2.02 and 2.42, respectively, an increase of approximately 20%. The density in the 4th quartile is 2.17, a decrease of approximately 11%. Analyzing the average density of unhealthy establishments, it's possible to see an initial decrease of 33% (0.15 to 0.10) from the 1st to the 2nd quartile, followed by an increase with income, in this case from 0.10 in the 2nd quartile to 0.23 in the 4th quartile, representing a 130% increase.

Table 1 – Distribution of municipalities by income quartile, average income and density of healthy and ultra-processed establishments (Tocantins, 2019).

Distribution of municipalities by income quartile	Average Income (Reals)	Average Density of Healthy Establishments	Average Density of Unhealthy Establishments
Less than p25 of income (1q)	R$ 822.34	2.02	0.13
Between p25 and p50 of income (2q)	R$ 929.63	2.03	0.10
Between p50 and p75 of income (3q)	R$ 1010.15	2.42	0.15
Greater than p75 of income (4q)	R$ 1232.63	2.17	0.23

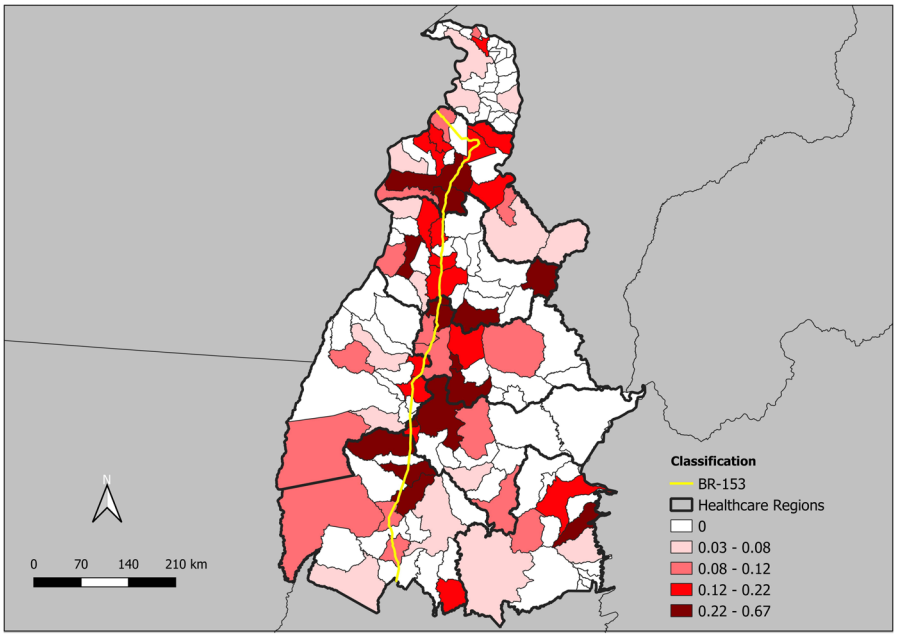

Figure 3 – Relationship between the density of unhealthy and healthy establishments per 1,000 inhabitants by municipality, in the state of Tocantins, 2019.

DISCUSSION

The state of Tocantins is located in the Northern region of Brazil, and is the youngest state in the federation created through the 1988 constitution [21]. It has 139 municipalities and Palmas as the state capital. Tocantins is a very young state that is constantly growing and developing. Thus, the maps presented in this study show the distribution of different types of food establishments in the state of Tocantins and their spatial configuration. It is important to emphasize that the

region analyzed in this study has the 4th lowest Gross Domestic Product (GDP) [22] and the 14th highest average income in the country [19]. Its population density is expressed in Figure 4, where the municipalities are demarcated and classified into quartiles. A remarkable highlight is that the highest population density is in the state capital, Palmas, with 128.76 inhabitants per km².

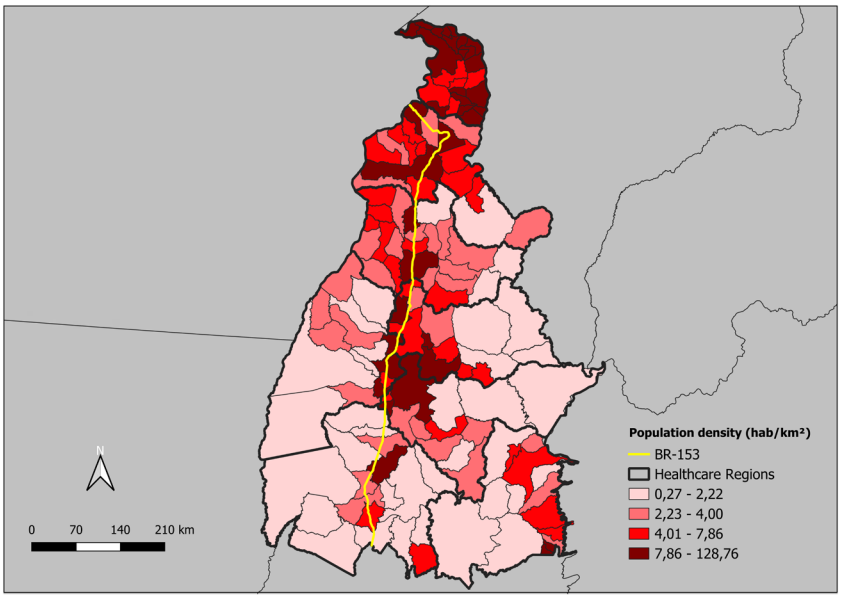

Figure 4 – Population density by municipality, in the state of Tocantins, 2019.

In this study, we observed that Tocantins has a high concentration of food deserts in its territory, however, no food swamps were found. In addition, unhealthy establishments were found to be concentrated along BR highway 153, which crosses the state from north to south. Average income increased by 50% from the 1st quartile to the 4th quartile. This value is not close to that of other Brazilian states such as São Paulo, Rio de Janeiro and the Federal District. Nevertheless, it is close to the Brazilian average, which is R$ 834.31 [19].

In the mid region of the state there is a cluster with a high density of healthy establishments, classified in the 4th quartile and some in the 3rd. Furthermore, the values for the third quartile (2.04 – 2.70) show that more than half of the municipalities in Tocantins have at least 2 healthy establishments for every 1,000 inhabitants. Small food stores, despite growing and disproportionate competition, are important points of sale for fruit and vegetables and still offer protection to the local community [23]. The lack of access to fresh food, such as fruits and vegetables, in low-income regions, while combined with the predominance of convenience stores over supermarkets, contributes to unhealthy food choices [24]. The result shows that physical access to healthy food is possibly facilitated, hence the local region can promote better health conditions and favor healthier food choices.

On the other hand, in the north of the state, there is a cluster of municipalities with a lower density of healthy establishments, with some municipalities having less than 1 establishment for every 1,000 inhabitants. With lower density, municipalities classified in the 1st quartile (0.40 – 1.53) indicate possible food deserts when compared to others.

It's important to mention that the food environment can have a strong influence on shaping individual health behaviors and health outcomes, but not the contrary [10]. A closer look at the community level indicates that the consumption of ultraprocessed foods on fast-food restaurants is significantly higher than on sit-down restaurants, leading us to think food environment exerts a strong influence both on food purchases and consumption patterns [25].

The concept of food deserts can vary widely, but it is generally defined as an area with no supermarket and has limited access to healthy foods [26]. Food deserts negatively influence individuals' food choices and health. In these places, access to healthy food is very limited and few options lead to high prices. In this context, diets poor in healthy foods hinder the local population from having a good health status [27].

The number of unhealthy establishments, on the other hand, presented tendencies of clustering, although not easily noticeable. This is because more than half of the municipalities do not have any establishment of this type. Even when considering a small number of municipalities, in the mid region of the state there is a small cluster of establishments within the 4th quartile, these same municipalities also have large densities of healthy establishments. As regards the municipalities in question, the capital and its neighbors are present. The high density can be explained by the fact that it is the state capital, which is the gateway to various types of food establishments.

In addition, along the main highway that runs through the state, BR-153, it is observed a concentration of municipalities with a high density of unhealthy establishments, from the north through the south regions. Besides municipalities highlighted in the 4th quartile, there are also municipalities in the 3rd quartile of density of unhealthy establishments. Based on the values of unhealthy establishments, none of the municipalities had more than 1 unhealthy establishment for every 1,000 inhabitants. This is an interesting result for Tocantins, since the high consumption of unhealthy foods is associated with Chronic Non-Communicable Diseases such as obesity, systemic arterial hypertension [28] and cancer [29].

The high prevalence of unhealthy foods is related to increased temptation to buy due to visual stimulation, the environment can generate frequent cravings, increasing the chances of the individual eventually succumbing to buying unhealthy foods [30]. The relationship between the two densities is a means of identifying swamps, it shows that municipalities within the first quartile have better rankings. Food swamps are often associated with unhealthy diets, as access to ultra-processed foods is greater than healthy foods, and possible overlap between food swamps and deserts [31,32].

In Tocantins, there were no food swamps found. The highest density across the state was 0.67, which means that the worst scenario was 10 healthy establishments for approximately every 7 unhealthy establishments. This interesting feature can be observed throughout the state, showing that, possibly, physical access to unhealthy foods is more difficultated.

Regarding association with income, the density of healthy establishments increases as income increases, up to the 3rd quartile. This association corroborates other studies that show that food deserts are more present in low income regions, characterized by the dominant presence of small convenience stores having limited food choices with some degree of processing [33,34]. Despite the fact that food swamps are more likely to be present in low income communities [35,36], none were found in Tocantins, thus it is not possible to associate income with food swamps.

In Brazil, a study carried out in the state of Minas Gerais shows the relationship between food deserts, food swamp and social inequalities. Regions classified as food deserts have lower average per capita income than others, in addition to having values below average for variables

such as: total population, number of families and literates when compared to other regions that are not classified as food deserts. In addition, food deserts were mostly observed in neighborhoods with a high Health Vulnerability Index (IVS), while food swamps were mainly observed in regions with medium IVS. Regions classified as both food desert and swamp had lower average per capita income as well as neighborhoods with medium and high IVS. This shows that in order to implement successful interventions not only should the food environment be given attention, but also social conditions [37].

The analysis carried out in this study took into account the number of establishments in each municipality and its population. In addition, the database provided by the SEFAZ, which depends on factors such as the formal registration of the establishment, limits the analysis. Thus, future studies should focus on combining innovative strategies that enable the inclusion of informal establishments, avoiding underreporting. Also, the precise location of establishments can be used for the analysis of smaller regions, enabling more accurate results or new information about these regions. The mapping of important road sections can be useful for cases where available databases have limited number of establishments.

A potential limitation concerns the metrics used to study food deserts and food swamps in low and middle-income countries require further refinement, such as equations and methodological approaches to address mechanisms and causal links through these analyses. The quartiles of healthy foods show very close values. Therefore, it may be a methodological limitation to consider the first quartile as a food desert. However, this is the methodology proposed by CAISAN that allows comparability between locations in Brazilian territory. These improvements will support more in-depth inquiries into the link between food deserts, food swamps, and their effects on health outcomes. Furthermore, given the lack of studies that evaluate the quality of the SEFAZ database in this State, caution is needed when interpreting the data, as they are subject to factors such as the formal registration of the establishment.

It is important to note that food deserts are a contested concept, with constructs and methodologies continuing to emerge [10]. Various methodologies have been proposed for identifying and mapping food deserts. Some focused on the spatial and economic access to supermarkets, considering factors such as car ownership and driving distance [38]. Others have used geospatial techniques considering both physical and economic access [39]. It has been suggested that different methodologies can be applied for food deserts mapping, emphasizing the need for tailored approaches to suit specific geographical and socioeconomic settings [40]. In conclusion, the methodologies for studying food deserts encompass a wide range of approaches. This reflects the complexity to operationalize the concept in developing methodology for identifying food deserts.

CONCLUSION

This study suggests that, in Tocantins, there are clusters with low densities of healthy establishments, which can be characterized as food deserts, possibly affecting the shopping patterns of the local population and possibly their consumption patterns. Municipalities with high densities of unhealthy establishments are distributed throughout the state in a smaller proportion and have lower density values when compared to healthy ones, being a beneficial point for the health of the population of Tocantins. The analysis showed that unhealthy establishments do not dominate any region or municipality, as the analysis of the relationship shows no food swamps. Municipalities that are close to BR-153 have the highest densities of unhealthy establishments, which can be

explained by the high movement of people, generating continuous income for these establishments to sustain themselves. Future studies should evaluate the relationship of this spatial distribution with the presence of chronic disease, morbidity profile, and public policies that encourage healthy eating environments.

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ACKNOWLEDGMENTS

We would like to thank the institution that supported this study since the research leading to these results received funding from Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) through the 28/2019 public call.

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W.S. BORGES NETO, K.C. SILVA, A.S.F. VEGI, S.L. PINTO were responsible for the conception, design, writing, analysis and interpretation of data, review and final version approval of this article.