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Geoprocessing and Health: Childhood Cancer Cases and the Relationship between the Population of the Cities

Geoprocessamento e Saúde: Casos de Câncer Infantojuvenil e Relação entre População dos Municípios

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ABSTRACT

This study is based on the following hypothesis: "Is it true that the larger the population of a municipality, the higher the number of cancer cases?" To investigate this question, a mapping of childhood and adolescent cancer cases by municipality was created, based on the cases assisted by the NGO Viver, with the goal of comparing the amount of cases to the number of inhabitants of the municipalities served. Through the QGIS software, the cases were superimposed on the map of Paraná to visualize the spatial distribution. In addition, comparative graphs between the population and the number of cases were generated to verify the existence of a correlation. Due to the prominent number of cases in the northern region of the state, municipalities outside of this area were discarded to minimize data variation. The data were equalized based on Londrina statistics, a major health hub, assuming that all cases from that city are treated locally. There was a variation in the results among municipalities, with some presenting up to 8 more cases than expected and others up to 4 fewer, based on the proportion of cases in Londrina. Although more populous municipalities generally present more cancer cases, some exceptions were identified which suggests the need for future investigations to understand these deviations.

keywords medical geography, childhood and adolescent cancer, northern Paraná

RESUMO

Este estudo baseia-se na seguinte hipótese: “É verdade que quanto maior o número de habitantes no município, maior o número de casos de câncer?”. Para investigar essa questão, foi realizado um mapeamento dos casos de câncer infantojuvenil por município, atendidos pela ONG Viver, com o objetivo de comparar a quantidade de casos com a população dos municípios atendidos. Através do software QGIS, os casos foram sobrepostos ao mapa do Paraná para visualização da distribuição espacial. Além disso, gráficos comparativos entre a população e o número de casos foram gerados para verificar a existência de correlação. Devido à concentração dos casos na região Norte do estado, os municípios fora dessa área foram descartados para minimizar a oscilação dos dados. Os dados foram equalizados com base nos números de Londrina, um importante polo de saúde, assumindo que todos os casos da cidade sejam tratados localmente. Houve uma variação nos resultados entre os municípios, com um apresentando 8 casos a mais que o esperado até outro com 4 casos a menos, baseado na proporção dos casos em Londrina. Embora municípios mais populosos geralmente apresentem mais casos de câncer, algumas exceções foram identificadas, o que sugere a necessidade de investigações futuras para entender esses desvios.

palavras-chave geografia médica, câncer infantojuvenil, norte do Paraná

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Introduction

The population growth in diverse regions of the world is a very clear reality (United Nations, 2022) and leads us to some reflections. The high concentration of people in a specific place can sometimes generate difficult life situations such as transport traffic, dificult to acquire goods, etc. Theoretically the bigger this concentration is the more problems can occur and to a bigger degree (Lu et al., 2023).Based on this idea, does the number of cases of childhood cancer increase with the increase in the number of inhabitants of a municipality?

Cancer is the name given to a group of diseases characterized by the uncontrolled growth of abnormal cells anywhere in the body. It is the second leading cause of death in the world, estimated at 9.6 million deaths in 2018. Around 400,000 children develop cancer each year in the world (World Health Organization [WHO], 2022).

Childhood cancer is the main subject of this study. Between 2014 and 2020 there were 18,318 deaths of children and teenagers in Brazil, among men and women, with 4,388 deaths being in the age group from 0 to 4 years, 3,942 in the age group from 5 to 9 years, 4,130 in the age group from 10 to 14 years, and 5,858 in the age group 15 to 19 years old. In the state of Paraná, there were 960 deaths, aged 0 to 18 years, between 2014 and 2020, 153 in 2014, 157 in 2015, 130 in 2016, 138 in 2017, 125 in 2018, 136 in 2019 and 121 in 2020 (Instituto Nacional de Câncer [INCA], 2014).

It is common for children and teenagers who are submitted to cancer treatment in hospitals to have a support institution that helps them and their families with some pertinent issues to provide some relief at such a delicate time. Among these institutions is the Non-Governmental Organization Viver (NGO Viver), a non-profit organization recognized as a charitable social assistance entity that provides services in education, social assistance or health areas, obtaining its resources through private companies, sale of products and the population in general (donations). A large part of the workforce is formed of volunteers.

The NGO was created in 2001, currently based at Rua Lucilla Ballalai, 391, Jd. Petrópolis, in Londrina – PR. It has no political-party or religious ties and its objective is to meet the needs of children and teenagers with cancer, hospitalized and/or undergoing treatment at the Londrina Cancer Hospital (HCL) and the Londrina University Hospital (HU). The service provided by the NGO Viver is aimed at patients treated by the Unified Health System (SUS) who do not have private medical insurance, emphasizing then low income families (Organização Viver, 2022).

Patients when traveling from their cities of origin to attend consultations or treatments at the hospital, while waiting for previously scheduled medical care attend services developed by NGO Viver such as: breakfast, lunch, donation of basic food baskets, medication assistance, recreation, arts workshop, overnight accommodations and nutritional, psychological and dental support.

To finance its operation, the NGO Viver accepts contributions through deposits and bank transfers, donations of basic food baskets, nutritional supplements, clothing, toys and medicines, in addition to the help of volunteers to carry out its actions.

In this voluntary spirit, it was decided to create a map of cancer cases treated by the NGO Viver in order to generate an illustration showing the area of reach and consequently the seriousness of the work. Therefore, there was a need to use Geoprocessing tools, a technology in a computational environment that allows the overlay and analysis of maps and information that were not previously possible when information was only stored and viewed in charts.

One of the tools used in Geoprocessing are Geographic Information Systems (SIG), which refer to the “acquisition, storage, manipulation, analysis and presentation of georeferenced data, that is, a spatial information processing system” (Moura, 2005), through the use of software that makes it possible to spatialize any type of information that is related to space, providing analysis and manipulation of data (both cartographic and alphanumeric) (Barbosa & Fonseca, 2017).

At the moment this technology emerges, the main studies carried out were directed to areas of environmental studies, such as monitoring the dynamics of land use (Mas, 2004; Zhang et al., 2021) and urban analyzes (Ren et al., 2012). Subsequently, several fields of study were opened as in the health area, such as mapping diseases cases (Almeida et al., 2009; Curriero et al., 2021; Jayme et al., 2015; Melo et al., 2017).

The objective of this work is to map the cases of childhood cancer by municipality, attended at the NGO Viver, located in the city of Londrina, Paraná, and evaluate the correlation between the number of inhabitants versus cases of childhood cancer. Research on diseases commonly correlates the cases of the disease with the entire population of the studied area, without division by gender or age group (Barros et al., 2024; Jayme et al., 2015; Malta et al., 2020).With this study we aim to propose a new analysis, correlating an age group of the disease with the entire population of the studied area.

Based on the hypothesis of a direct correlation between inhabitants and cases of childhood cancer, a proportional result between the variables is expected, a priori. However, if a municipality presents a number of cases that is not proportional to its population, it may be a situation of improvement, depending on whether the cases are lower than expected, or an alert situation, if higher. This would provide material for more detailed future investigations by health professionals, aiming to understand this improvement, to replicate it, or to look for the reason for the alert, and mitigate it.

Methods

The database on childhood cancer cases treated by the NGO Viver, between 2011 and 2022, was provided by the NGO itself, respecting all data protection law protocols and research ethics codes. Of the data provided, only the patients' municipality of origin and their oncological disease were used. We clarify that this project was presented to the Human Research Ethics Committee, under CAAE No. 40623620.7.0000.5231 and approved by Review No. 5,897,854.

The cartographic database was obtained by downloading the municipal limits of the state of Paraná from the IBGE website (Instituto Brasileiro de Geografia e Estatística [IBGE], 2022), in shapefile format. Also from IBGE, it was obtained information about the population of each municipality involved in the study.

QGIS software was used, a Geographic Information System (SIG) supported and administered by the Open Source Geospatial Foundation (OSGEO), a free open source software licensed under the GNU General Public License. It is developed for several operating systems and supports several vectors, rasters and database file formats. It offers a wide range of plugins in constant development to visualize, manage, edit, analyze data, and create maps for printing (Santos, 2018).

The cartographic base for the state of Paraná was imported into QGIS, as well as the data table from the NGO Viver with data on childhood cancer cases. Then, each cancer case was identified as a point on the patient's municipality of residence and the association between the data chart and the map of municipalities was carried out using the join command.

A graph of the population of each municipality was created in a calculation spreadsheet, in descending order. In this order, the first municipality was Londrina, with the largest population among the municipalities in the study. Subsequently, following the sequence of municipalities established by this graph, another graph was generated with the number of cancer cases per municipality. Finally, the two graphs were compared to analyze whether the trend in population numbers follows the number of cancer cases.

To reduce the large fluctuation in the data, municipalities located far from the northern region of Paraná were discarded, generating a new population graph and a new graph of cancer cases. Patients from municipalities further away from Londrina can choose to seek treatment and support in other municipalities that also have excellence in pediatric oncology health such as Curitiba, Cascavel and Umuarama.

At last, in order to compare the different municipalities data the number of cancer cases was equalized, based on the population and cancer cases in Londrina. These comparisons are usually made based on the rate of 100,000 cases per inhabitant (Centro de Oncologia Monte Sinai, 2025; Gandra, 2023; Luizaga & Buchalla, 2023; Santos et al., 2023), this study presents a new comparison proposal, based on data from a representative regional institution in order to obtain a regional index as well. This suggestions is made according to the following equation, given by the "rule of three":

$$\mathrm{CCC} = \frac{\mathrm{POPMUNIC} \times \mathrm{CASESLDA}}{\mathrm{POPLDA}}, \tag{1}$$

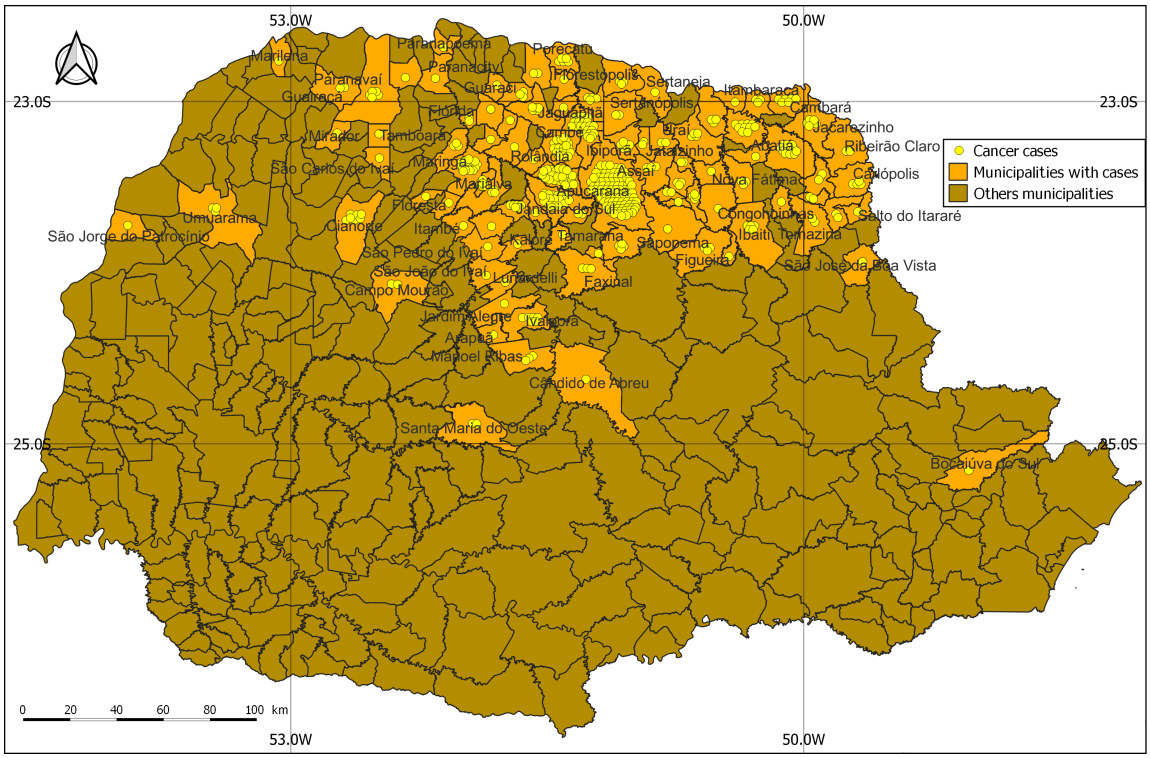
where the variable CCC is the calculated cancer cases, POPMUNIC is the population of each municipality, CASESLDA is the number of cancer cases in Londrina, and POPLDA is the population of Londrina.

With the new data generated using equation (1), a new graph of “calculated” cancer cases was created. Superimposing this on the graph of real existing cases made it possible to observe municipalities with more or fewer cancer cases than expected.

Results

NGO Viver treated cancer cases during the study were superimposed to the municipalities of Paraná map for spacial distribution visualization, resulting in an association map between number of cases and patients’s origin. This map is presented in Figure 1.

Figure 1 - Distribution of cancer cases childhood per municipality, assisted by the NGO Viver, between 2011 and 2022, IBGE database 2020.



From the map, Figure 1, it can be seen that the large concentration of cases assisted by the NGO Viver is in the North region of Paraná, which includes Londrina, and in the region called Norte Pioneiro, located east of Londrina. The municipalities, population and NGO Viver treated cancer cases are detailed on Table 1, adding up to 95 municipalities.

The other scattered municipalities in the Northwest and Central regions, in addition to a municipality close to the state capital, are sporadic cases that can sometimes occur. These are cases of families seeking medical care in Londrina, instead of closer locations. With this, it is understood that in these municipalities the number of cases may be higher, in addition to the fact that there may be cases in municipalities that are not included in the records of the NGO Viver because they sought other locations.

With this amount of cancer cases per municipality, a graph was created associating the population of each municipality, in descending order, with the respective number of cases, Figure 2.

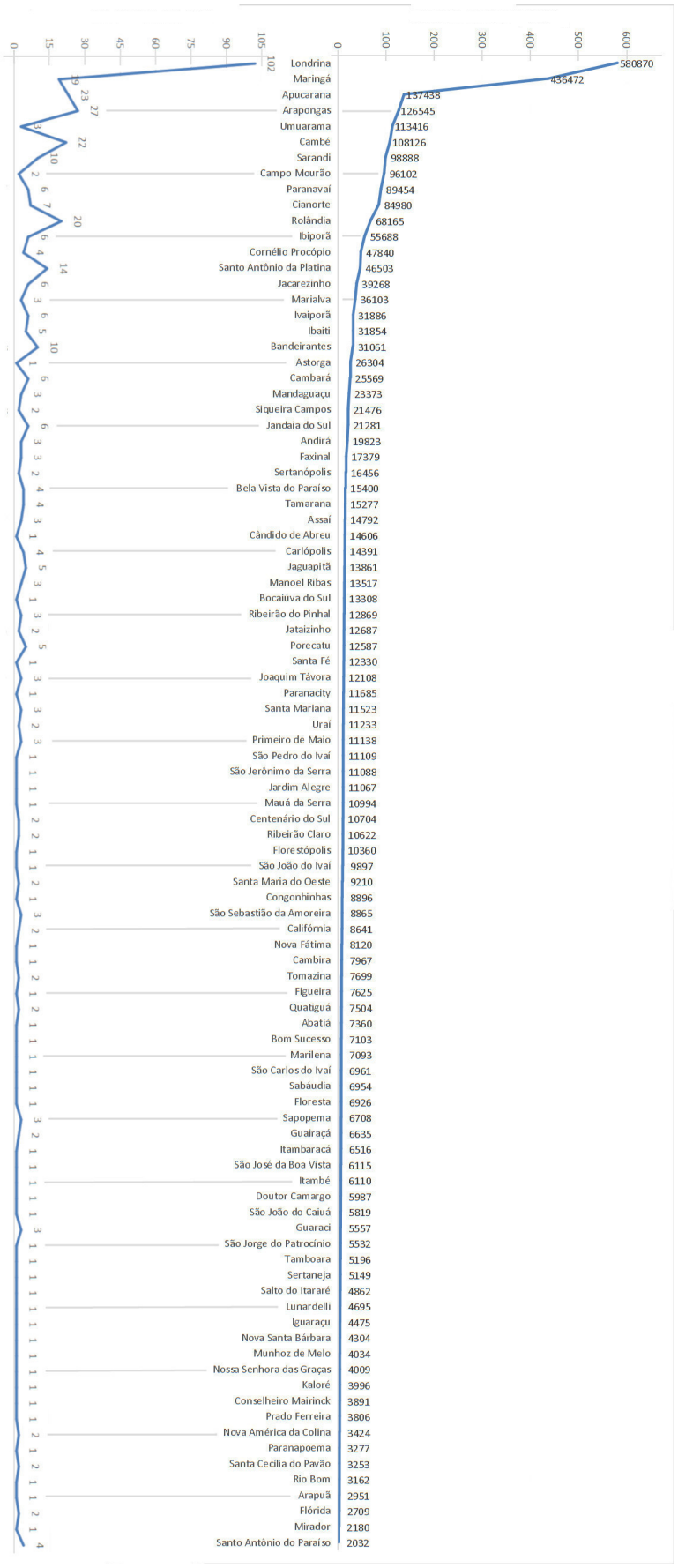
As expected, the first two municipalities are Londrina and Maringá, the two largest cities in the countryside of Paraná, with populations of 580,870 and 436,472 inhabitants, and 102 and 19 cases, respectively.

Pursuing the hypothesis that “the more people, the more problems”, it was expected that the graph curve of childhood cancer cases treated by the NGO Viver would show a similar trend to the population curve. However, it was noted that the first municipalities showed a very irregular distribution in the graph of cancer cases.

Table 1 - Population and childhood cancer cases per municipality, assisted by the NGO Viver, between 2011 and 2022.

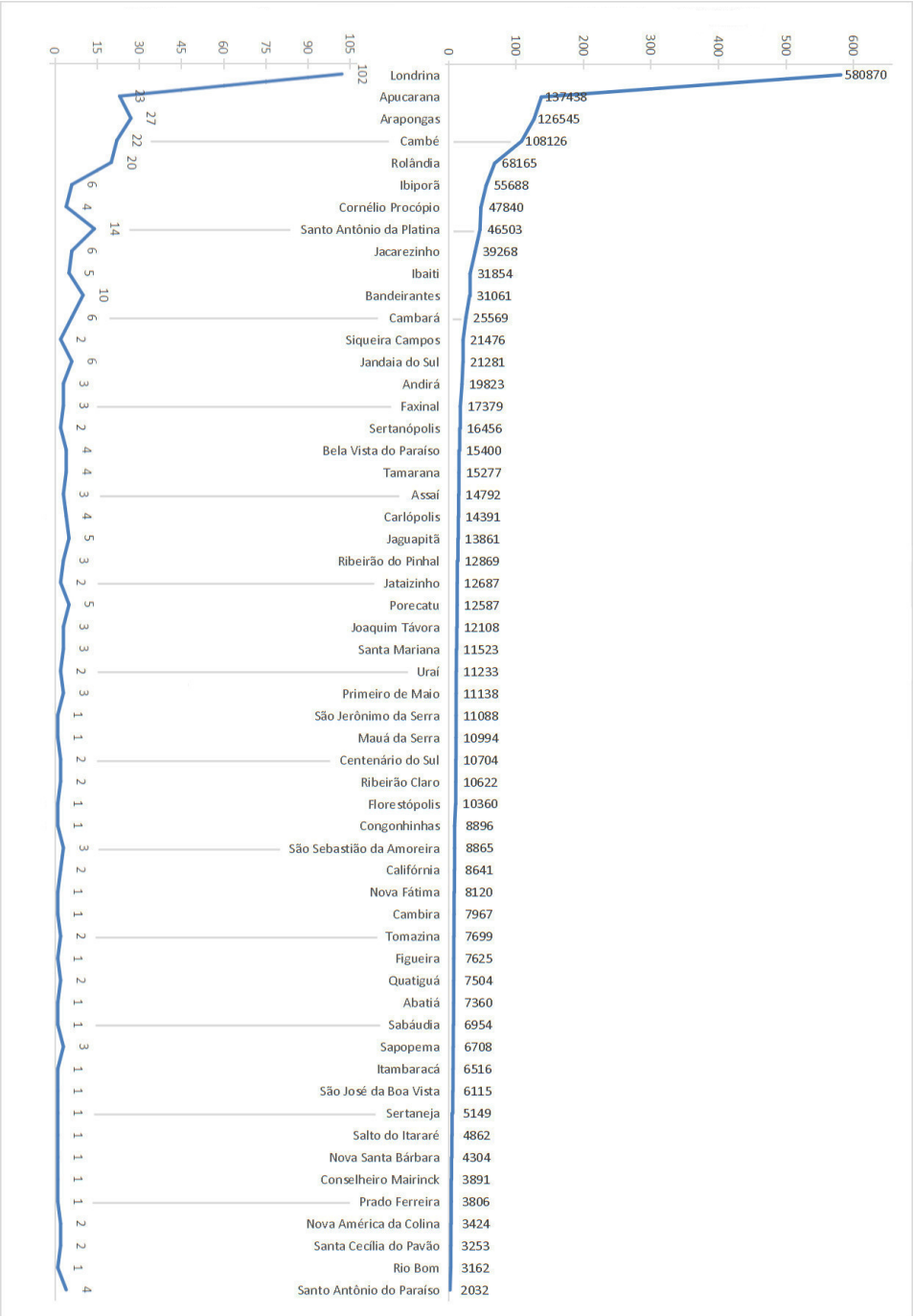
Municipality	Pop.	Cases	Municipality	Pop.	Cases	Municipality	Pop.	Cases
Londrina	580,870	102	Jaguapitã	13,861	5	São Carlos do Ivaí	6,961	1
Maringá	436,472	19	Manoel Ribas	13,517	3	Sabáudia	6,954	1
Apucarana	137,438	23	Bocaiúva do Sul	13,308	1	Floresta	6,926	1
Arapongas	126,545	27	Ribeirão do Pinhal	12,869	3	Sapopema	6,708	3
Umuarama	113,416	3	Jataizinho	12,687	2	Guairaça	6,635	2
Cambé	108,126	22	Porecatu	12,587	5	Itambaracá	6,516	1
Sarandi	98,888	10	Santa Fé	12,330	1	São José da Boa Vista	6,115	1
Campo Mourão	96,102	2	Joaquim Távora	12,108	3	Itambé	6,110	1
Paranavaí	89,454	6	Paranacity	11,685	1	Doutor Camargo	5,987	1
Cianorte	84,980	7	Santa Mariana	11,523	3	São João do Caiuá	5,819	1
Rolândia	68,165	20	Uraí	11,233	2	Guaraci	5,557	3
Ibiporã	55,688	6	Primeiro de Maio	11,138	3	São Jorge do Patrocínio	5,532	1
Cornélio Procópio	47,840	4	São Pedro do Ivaí	11,109	1	Tamboara	5,196	1
Santo Antônio da Platina	46,503	14	São Jerônimo da Serra	11,088	1	Sertaneja	5,149	1
Jacarezinho	39,268	6	Jardim Alegre	11,067	1	Salto do Itararé	4,862	1
Marialva	36,103	3	Mauá da Serra	10,994	1	Lunardelli	4,695	1
Ivaiporã	31,886	6	Centenário do Sul	10,704	2	Iguaraçu	4,475	1
Ibaiti	31,854	5	Ribeirão Claro	10,622	2	Nova Santa Bárbara	4,304	1
Bandeirantes	31,061	10	Florestópolis	10,360	1	Munhoz de Mello	4,034	1
Astorga	26,304	1	São João do Ivaí	9,897	1	Nossa Senhora das Graças	4,009	1
Cambará	25,569	6	Santa Maria do Oeste	9,210	2	Kaloré	3,996	1
Mandaguaçu	23,373	3	Congonhinhas	8,896	1	Conselheiro Mairinck	3,891	1
Siqueira Campos	21,476	2	São Sebastião Amoreira	8,865	3	Prado Ferreira	3,806	1
Jandaia do Sul	21,281	6	Califórnia	8,641	2	Nova América da Colina	3,424	2
Andirá	19,823	3	Nova Fátima	8,120	1	Paranapoema	3,277	1
Faxinal	17,379	3	Cambira	7,967	1	Santa Cecília do Pavão	3,253	2
Sertanópolis	16,456	2	Tomazina	7,699	2	Rio Bom	3,162	1
Bela Vista do Paraíso	15,400	4	Figueira	7,625	1	Arapuã	2,951	1
Tamarana	15,277	4	Quatiguá	7,504	2	Flórida	2,709	2
Assaí	14,792	3	Abatiá	7,360	1	Mirador	2,180	1
Cândido de Abreu	14,606	1	Bom Sucesso	7,103	1	Santo Antônio do Paraíso	2,032	4
Carlópolis	14,391	4	Marilena	7,093	1	-	-	-

Figure 2 - Population of 95 municipality graph (descending order), with the respective number of cases.



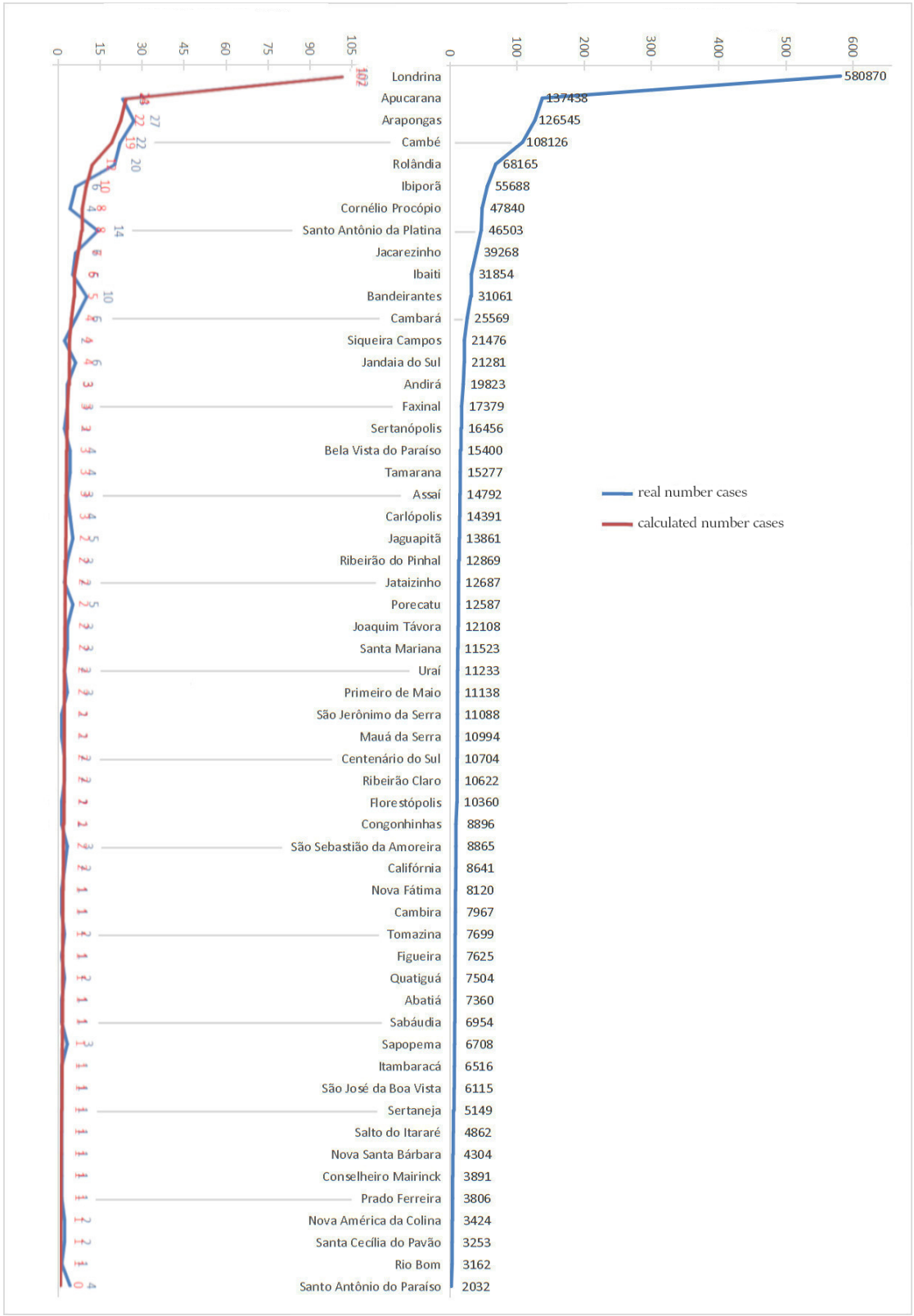
Observing these first municipalities, Figure 2, it is noted that some of them are municipalities scattered in the Northwest and Central region of the state, being Umuarama, Campo Mourão, Paranavaí and Cianorte, which, as previously stated, may not be presenting the total number of existing cases. In an attempt to reduce data fluctuation, another graph was created removing the 39 municipalities from these two regions with 56 municipalities remaining, resulting in Figure 3.

Figure 3 - Population of the 56 municipalities in the North and North Pioneiro regions graph (descending order), with the respective number of cases.



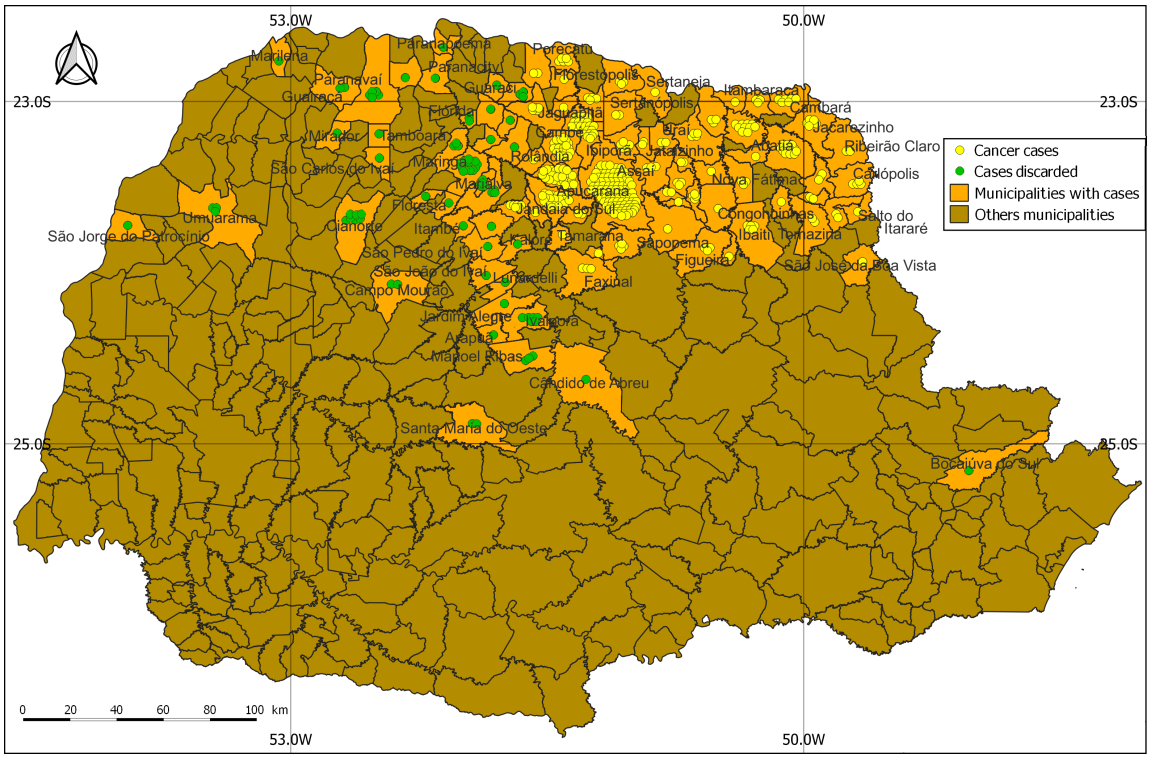
To start comparison between municipalities with more or fewer cases of childhood cancer, the municipality of Londrina was taken as a base for locating the headquarters of NGO Viver and because it is the regional center of excellence in health area, suggesting that patients close to Londrina do not go anywhere else. A new graph of cancer cases was generated, calculated by the equation (1) and superimposed on the existing one, resulting in Figure 4.

Figure 4 - Population of the 56 municipalities in the North and North Pioneiro regions graph (descending order), with the respective real and calculated number of cases.



To better visualize the 56 municipalities, that belong to the analysis, the general map in Figure 1 was enlarged, resulting in Figure 5.

Figure 5 - Cancer cases childhood distribution used in the analysis and those discarded, by municipality of origin, IBGE database 2020



Discussion

Regarding the graph in Figure 4, it is worth highlighting initially that many variables were not taken into consideration in this first general approach, the focus of this work, being material for future more detailed and precise work. Such variables, among others, would be:

- The number of cases reported may not be the actual total for each municipality;
- The age group relationship was not taken into account, as there may be municipalities with more patients than others;
- The temporality of the cases was not considered, that is, there are old and recent cases in the same set;
- The cases that were still alive and those that had already passed away were not separated;
- If the reported number of cases in Londrina is not the correct total, it would change the entire list made for the calculated cases. The average cancer incidence in Brazil is approximately 150 children and adolescents per million inhabitants (Feliciano et al., 2018). As Londrina has a population of around 600 thousand inhabitants, the average proportion of incidence would be, for Londrina, 90 cases, close to the 102 cases registered by the NGO, considering that the data is from 2018.

It is known that the number of cases of childhood cancer treated and reported by the NGO Viver may not be the total number of cases existing in the respective municipalities. Even so, this reported number exists and, therefore, the actual existing number will not be less than this reported number. Therefore, the analysis carried out in this work could only represent more worrying results, with more cases per municipality.

In Figure 4, in the red line, the number of cancer cases that the municipality should have, based on the number of cases in Londrina has been calculated, and in the blue line the actual number of cases existing in the NGO Viver database. What matters in the analysis is exactly the difference in position of these two

lines for each municipality. The most concerning municipalities would be those where the value in blue was greater than the value in red. Municipalities in normal situations would have the same values. And the best municipalities would have the values in blue lower than the values in red.

The municipality that has the highest number of cases than normal is Rolândia, as it was calculated that it would have 12 cases, based on the population projection, and has 20 cases, a difference of 8 more cases.

Santo Antônio da Platina comes in second place, with a difference of 6 cases, having 14 real cases, but should, by calculation, have 8 cases.

In third place are Arapongas (having 22 calculated cases and 27 real cases) and Bandeirantes (having 5 calculated cases and 10 real cases), with a difference of 5 more cases.

With a difference of 4 more cases, we have Santo Antônio do Paraíso, which has 4 real cases and, according to calculations, should not have any.

Next comes Cambé (19 calculated and 22 real), Jaguapitã (2 calculated and 5 real) and Porecatu (2 calculated and 5 real), all with a difference of 3 more cases than they should have.

Cambará (4 calculated and 6 real), Jandáia do Sul (4 calculated and 6 real) and Sapopema (1 calculated and 3 real) are municipalities with 2 more cancer cases than calculated.

With this separation, it is noted that Rolândia, Arapongas, Cambé and Jaguapitã, alongside with Londrina as a reference, are neighboring municipalities and concentrate a large part of the cases of childhood cancer treated by the NGO Viver. Future work could investigate whether there is any factor triggering this concentration, be it environmental, social, or whether it would be mere chance. Interestingly, when looking at Figure 5, a concentration of cases is also noted in the neighboring municipalities of Ibiporã and Apucarana and there is a tendency to visually classify them in the same alert situation. However, as discussed below, there is a satisfactory situation in these two municipalities.

Santo Antônio da Platina, Bandeirantes and Cambará are in a similar situation, which are nearby municipalities and also have a concentration of cancer cases, and the cause of this concentration could be investigated in the future. And looking at Figure 5, we also tend to visually group the municipality of Jacarezinho due to its number of cases; however, as seen below, this municipality is in a satisfactory situation.

With these two small analyses, grouping the municipalities neighboring Londrina and neighboring Bandeirantes, it is noted that the creation of the map showing the distribution of cases of childhood cancer treated by the NGO Viver is an important analysis tool, but that isolated may incur errors due to the mere absolute observation of the data. In other words, where there is “a lot” or “little” does not necessarily mean that something is “good” or “bad”. Observation regarding the population of the municipality leads to new reasoning.

Finishing the count, there are several municipalities with 1 additional case, which are: Bela Vista do Paraíso, Tamarana, Carlópolis, Ribeirão do Pinhal, Joaquim Távora, Santa Mariana, Primeiro de Maio, São Sebastião da Amoreira, Tomazina, Quatiguá, Nova América da Colina and Santa Cecília do Pavão.

Other municipalities are in a normal situation, with the equal real and calculated number of cases, which are: Andirá, Jataizinho, Uraí, Centenário do Sul, Ribeirão Claro, Califórnia, Nova Fátima, Cambira, Figueira, Abatiá, Sabáudia, Itambaracá , São José da Boa Vista, Sertaneja, Salto do Itararé, Nova Santa Bárbara, Conselheiro Mairinck, Prado Ferreira and Rio Bom.

Satisfactorily, municipalities are noted in which the actual number of cases is lower than the calculated one, showing that there are fewer cases of cancer than expected. These municipalities are:

- Ibiporã and Cornélio Procópio, which present a difference of 4 fewer cases, being the municipalities in a better situation;
- Siqueira Campos, with a difference of 2 fewer cases;
- Apucarana, Jacarezinho, Ibaiti, Sertanópolis, São Jerônimo da Serra, Mauá da Serra, Florestópolis, and Congonhinhas, with 1 case less than expected.

Here, as previously discussed, are Ibiporã, Apucarana and Jacarezinho, municipalities in satisfactory condition even though they are close to municipalities with a high concentration of cases. This situation should be studied in the future by trained health professionals to discover why this condition is better than proximity and, upon discovering, replicate it in other municipalities to improve the entire region.

Conclusion

The most populous municipalities have more cancer cases but there are exceptions, and these should be the focus of future research by health professionals, to investigate possible causes of the concentration of cancer cases or the desired lack of them.

The map showing the distribution of cancer cases is an important analysis tool but if isolated can lead to errors due to the mere absolute observation of the data. Relative observation, regarding the population of the municipality, for example, leads to new reasoning. In comparison, the municipalities with the least cancer cases are Ibiporã and Cornélio Procópio, while Rolândia has the higher number of cases.

Author contributions

I. H. de S. Palmar participated in formal analysis, methodology, visualization, writing – original draft, review, and editing. V. de Alvarenga participated in formal analysis, methodology, visualization, writing – original draft, review, and editing. O. C. Pereira Neto participated in conceptualization, data curation, formal analysis, investigation, methodology, administration, supervision, visualization, writing – original draft, review, and editing.

Conflicts of interest

The authors certify that no commercial or associative interest represents a conflict of interest concerning the manuscript.

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