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Feasibility of Using Topographic Data by TOPODATA Image in Urban Drainage Projects

Viabilidade de Uso dos Dados Topográficos por Imagem do TOPODATA em Projetos de Drenagem Urbana

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Abstract

In general, the urbanization process in cities increases the impermeabilization of the soil, increasing surface runoff, leading the population to suffer from risks of flooding. In this context, the design of the drainage system is fundamental, which depends on the terrain characteristics. The total station is one of the most used equipment in topographic survey in field service. With the technological advance, it is possible to obtain this information remotely, as through satellite image with the aid of geoprocessing software. Thus, the objective of this research was to carry out a feasibility study on the use of topographic data obtained by TOPODATA Project images generated by Instituto Nacional de Pesquisas Espaciais - INPE in an urban drainage project. The seat of the municipality of Ipixuna do Pará was adopted as study area, where altimetry information was obtained by total station and by TOPODATA images. The interpolation kriging method was used to generate the contour lines and the Digital Terrain Model (DTM). To evaluate the performance of the TOPODATA data, the Pearson correlation coefficient test (R) and the Root Mean Square Error (RMSE) were used. For the microdrainage project, an area of approximately 14 hectares was delimited within the municipality's seat. From the statistical analysis, satisfactory results were obtained with R of 0.81, a "very high" correlation; and the RMSE of 1.27 m in the project area. Therefore, it was verified that it is feasible to use the TOPODATA image in the altimetry survey for areas considered small, with good correlation, considering the agility in obtaining the data, allowing access to information in places of difficult access, in addition to the economic aspect.

Keywords: Satellite images; Total station; Delimitation of watersheds

Resumo

Em geral o processo de urbanização nas cidades aumenta a impermeabilização do solo, aumentando o escoamento superficial, levando a população sofrer com riscos de enchentes. Nesse contexto, o dimensionamento do sistema de drenagem é fundamental, o qual depende das características do relevo. A estação total é um dos equipamentos muito utilizado no levantamento topográfico em serviço de campo. Com o avanço tecnológico, há possibilidade de obtenção dessas informações remotamente, como por meio de imagem de satélite com auxílio de softwares de geoprocessamento. Assim, o objetivo desta pesquisa foi realizar estudo de viabilidade de uso dos dados topográficos obtidos por imagem do Projeto TOPODATA do Instituto Nacional de Pesquisas Espaciais-INPE em projeto de drenagem urbana. Adotou-se a sede do município de Ipixuna do Pará, onde as informações de altimetria foram obtidas por estação total e por imagem do TOPODATA. O método *kriging* de interpolação foi utilizado para gerar as curvas de níveis e o Modelo de Digital do Terreno (MDT). Para avaliar o desempenho dos dados do TOPODATA utilizou-se o teste do coeficiente de correlação de Pearson (R) e a Raiz do Erro Quadrático Médio (RMSE). Para o projeto de microdrenagem, delimitou-se, dentro da sede do munícipio, uma área de aproximadamente 14 hectares. A partir da análise estatística, obteve-se resultados satisfatórios com R de 0,81, uma correlação "muito alta"; e o RMSE de 1,27 m na área de projeto. Portanto, verificou-se que é viável utilizar a imagem do TOPODATA no levantamento da altimetria para áreas consideradas pequenas, com boa correlação, levando em conta a agilidade na obtenção dos dados, permitindo acesso de informações em locais de difícil acesso, além do aspecto econômico

Palavras-chave: Imagens de satélite; Estação total; Delimitação de microbacias

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1 Introduction

The soil impermeabilization caused by paving, due to urbanization, makes it difficult for rainwater to infiltrate and increases runoff, which leads the population to suffer from high flow peaks, making flooding more frequent, which can bring environmental damage, social and economic. Thus, the importance of adequate water flow through the drainage system is verified.

Urban drainage still does not receive the attention it deserves, even though it is one of the important components of sanitation (Tasca et al. 2017). And the absence or deficiency of this service contributes to the proliferation of disease-transmitting animals, it brings negative impacts to vehicle traffic, affects commercial activity, in addition to the inconvenience for residents (Krüger & Almeida 2019).

In order to design a drainage system, it is necessary to collect three basic parameters: topography, in order to identify the main basins and define the flow path; the proposed or existing urban layout; and rainfall (Miguez, Rezende & Veról 2015). One of the ways to characterize precipitation is through equations of intensity-duration-frequency (IDF), also known as intense rainfall equation (Pruski et al. 2006).

The slope is one of the components that interferes in the elaboration of the project, as it directly influences the flow speed and, consequently, the time of concentration of the whatershed; in the design flow; in addition to being essential in the delimitation of contributing drainage basin (Rodrigues et al. 2016). Therefore, an adequate topographic survey must be carried out.

To obtain topographic data information, the traditional field survey equipment are the electronic theodolite and the total station (Segantine & Silva 2015). With the advancement of technology, this data can be obtained remotely through RPAS (Remotely- Piloted Aircraft System) - commom known as drones - and by satellite signals (Daibert 2018) as an alternative to optimize the topographic survey work.

As for satellite signals, they generate an image, which is a set of coded information, so it is necessary to treat it, a procedure that takes place in a Geographic Information System - GIS environment, through the application of geoprocessing software, such as QGIS, ArcGIS, ERDAS and ENVI, or in programming environments such as Python, R, MatLab (Barbosa et al. 2019).

One of the main source data of widely developed and consolidated radar image data is the base generated by the SRTM (Shuttle Radar Topography Mission), led by NASA (National Aeronautics and Space Administration) and NIMA (National Imagery and Mapping Agency). These data are available for free (Da Silva et al. 2018). After processing the images, several products can be generated on the terrain, such as the Digital Elevation Model (DEM), the delimitation of watersheds and the extraction of the drainage area (Brasil 2016).

In Brazil, the Instituto Nacional de Pesquisas Espaciais – INPE has proposed another DEM called TOPODATA, obtained by resampling the SRTM DEM to create a 1 arc second (~30 m) grid with a geostatistical interpolation approach (Valeriano & Rossetti 2012).

Such alternatives for obtaining information provide a reduction in data acquisition expenses (Silveira 2014) and reduce the work costs of field professionals (Zerbielli et al. 2015). INCRA, for example, adopted the use of RPAS to carry out the georeferencing of rural properties.

Thus, the objective of this research was to carry out a feasibility study of using topographic altimetry data acquired by TOPODATA images, in an urban drainage project, having as reference altimetric points surveyed by total station. The sub-basins of the study area were delimited using the two digital terrain models. Then, the statistical method was used to verify the correlation of the altimetric points obtained by TOPODATA with the total station points.

2 Methodology and Data

With the acquisition of data by total station and by TOPODATA, mathematical statistical methods were applied to evaluate the relationship of these data in order to verify the feasibility of using altimetry by satellite image in an urban drainage project. To achieve this goal, a sequence of methodological steps was carried out that include the description of the study area with the obtaining of topographic data and the statistical analysis.

2.1 Study Area

The study area is part of the Citizen Housing extension project, whose objectives are the technical studies of topography, urbanism, information technology, environment and social service, aimed at the land tenure regularization of housing.

The seat of the municipality of Ipixuna do Pará is the study area and it has a territorial extension of 173 hectares (Figure 1). Access to the necessary information for this research occurred through the Land Regularization Commission of UFPA, through the Citizen Housing Project.

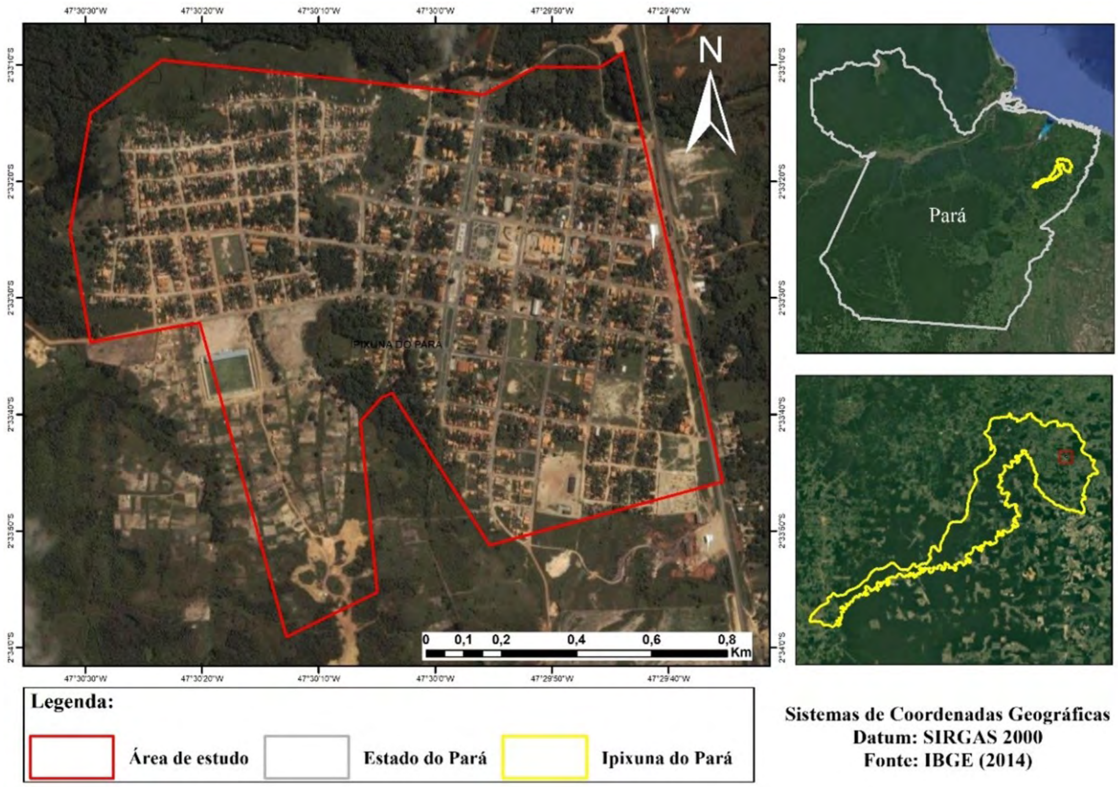

Figure 1 Study area localization. Source: Authors (2022).

The seat of municipality of Ipixuna do Pará, is subdivided from the political-administrative point of view into 05 sectors, including the districts Vila Nova, Berro D'água, João Paulo II, Paraúba and Centro, which are the focus on the regularization area and present consolidated road structure, skirted by the river and by the stream that enters the urban space, dividing it in Half (Santos 2019).

According to the IBGE, the estimated population in 2021 was 67,170 inhabitants, with the resident population being predominantly rural, around 76%. According to FAPESPA (2022), the municipality has a hydrography of 26 km² and a forest area of 2,327 km². The climate is "Am" – tropical monsoon climate, according to the Köppen classification (Cordeiro et al. 2017), which has two well-defined seasons, a period with a brief dry season and another period with intense rains.

According to the IBGE (2010), the municipality has 25% of households with adequate sanitation, 22.2% of urban households on public roads with trees and 4.6% of urban households on public roads with adequate urbanization (presence of manhole, sidewalk, paving and curb). According to the research by Mesquita (2019), after visiting the area, he reported the concentration of services in the most central areas, which is the case of the Centro district, which has a consolidated area, with paved roads, flat topography, and terrain with a soft slope.

On the other hand, in other areas the provision of services is scarce, with problems arising from the absence of drainage systems, sewage, paving and water supply, as occurs in the João Paulo II district, which is a hilly region, lacks adequate infrastructure, most of the roads are not paved, making access difficult.

2.2 Topographic Survey

To analyze the feasibility of using topographic altimetry data in a drainage network project, a necessary piece of information is the topography of the site, thus data acquired in two different ways were used to obtain altimetric data: by TOPODATA images; and by Total Station.

For the survey through the total station, topographic data was provided by the Land Regularization Commission - CRF, referring to the project "Citizen Housing: Urban and Land Regularization in the State of Pará". The data contained 9,675 altimetry points, in addition to other information, such as the streets, the water body, the residential and commercial areas, among others.

The TOPODATA images, with a spatial resolution of 30 meters, was obtained free of charge from the website: http://www.webmapit.com.br/inpe/topodata/. The map is structured in squares, thus, it was necessary to locate the grid where the municipality of Ipixuna do Pará was inserted, to download it with altitude data.

2.3 DTM and Contour Lines: Total Station and TOPODATA

To generate the DTM, geoprocessing software QGIS was used. The total station altimetry data were provided by the CRF in *dwg file format, but this format is not read in QGIS, so the file needed to be converted to *dxf file format. After that, the file was then converted to shapefile (*shp). Thus, the DTM and the contour lines were generated through the Kriging interpolation method. Such procedures were performed within the software itself.

The TOPODATA images also needed some steps to reach the intended result: do the grid cut to obtain only the area of interest and to define the Geodetic Reference System (SGR) for SIRGAS2000, and the UTM projection according to the location of the study area.

After the image treatment, the MDT was generated in the software. As for the altimetry points of the TOPODATA images, these were extracted based on the georeferenced points of the Total Station.

The contour lines by TOPODATA were generated in the geoprocessing software, with 1-meter equidistance plans.

2.4 Delimitation of Microwatersheds and Statistical Analysis

The delimitation of the watersheds was defined by the generated contour lines, where the highest level defined the watersheds, thus delimiting the area of contribution of the drainage network, this procedure was carried out in AutoCAD software.

To evaluate the altitudes obtained by TOPODATA in relation to the Total Station, descriptive statistics were applied. First the data were organized in spreadsheets, and later amplitude, arithmetic mean, variance, standard deviation were calculated, this process was performed in *Microsoft Office Excel*.

Furthermore, for performance analysis, Pearson's correlation coefficient test (R) and Root Mean Square Error (RMSE) were used to verify the error and trend of the data (Table 1). The classification of (R) values is described in Table 2.

3 Results and Discussions

3.1 Altimetric Data

After processing the plant data provided by CRF, with the altimetry points evenly distributed in the study area of approximately 173 hectares. The distribution of points is shown in Figure 2. To access the TOPODATA image with altitude data, it was identified that the study area was inserted in the grid (02S48).

Table 1 Statistical Formulation.

Parameter	Equation	Interval	Optimum Value	Equation Number
R	$R = \frac{\sum(A_e - \bar{A}_e)(A_i - \bar{A}_i)^2}{\sqrt{\sum(A_e - \bar{A}_e)^2}\sqrt{\sum(A_i - \bar{A}_i)^2}}$	-1 a 1	1	(1)
RMSE	$RMSE = \left[\frac{1}{n}\sum(A_e - A_i)^2\right]^{1/2}$	0 a ∞	0	(2)

Note: A_e is the total station altimetry, A_i is the TOPODATA altimetry.

Table 2 Classification of Pearson´s coefficient values (R).

Correlation Coefficient (R)	Classification
0.0 a 0.1	Very low
0.1 a 0.3	Low
0.3 a 0.5	Moderate
0.5 a 0.7	High
0.7 a 0.9	Very High

Source: Hopkins (2000).

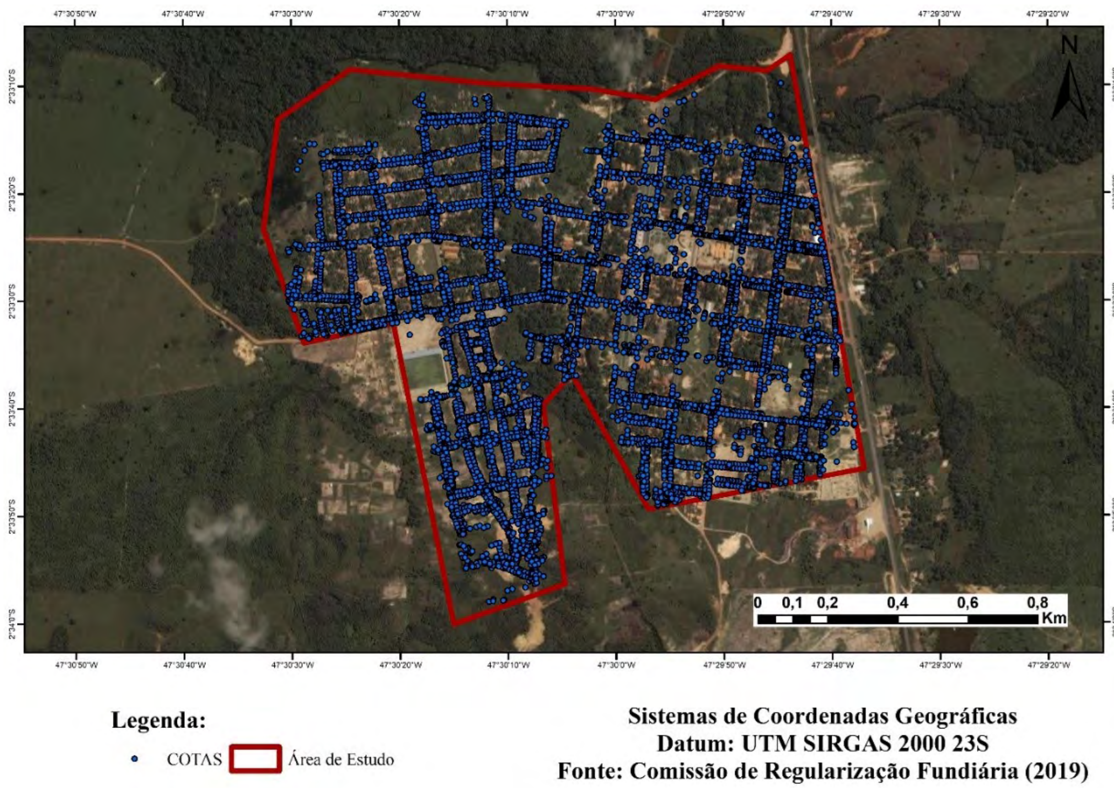

Figure 2 Spatialization of point at the municipality seat. Source: Authors (2022).

3.2 DTM and Contour Lines

Although the datafile by Total Station contains various information about the location, such as street layout, water body, residential and commercial areas, among others, to generate the DTM only altimetry information was needed, in which the datapoints were exported to *shp format.

For better visualization of the topography of the area, the DTM and the contour lines were generated, Figure 3A, using the kriging interpolation method.

The DTM and the contour lines generated by the survey of the total station, have a good precision and accuracy of the data, because it is a survey carried out in loco. Since these points collected by the total station were referring to the alignment of the block, position of the power poles and the existing road system, thus, most of these points were not close to trees and roofs (Mesquita 2019).

To generate the DTM by TOPODATA, from the radar image, cut the area and obtain only the study area. Then the SGR was defined for SIRGAS2000, and the UTM projection, 23 South zone, due to the location of the study area.

After such procedures, the DTM of the TOPODATA was elaborated; and, determining an interval of 1 meter, the contour lines were generated (Figure 3B).

Note that the highest region is the southern portion of the study area, and the elevation decreases towards the northern and central portion of the study area, which coincides with the location where the water body passes.

The TOPODATA image is susceptible to some distortions due to the presence of roof coverings and green areas, but as the survey of points per total station occurred mostly at points far from these locations that could cause such distortions, the result presented by TOPODATA becomes even more satisfying.

In addition, the use of data provided by TOPODATA (INPE, 2011) for the study of digital elevation in Brazil is recommended because they are images that have undergone treatment, to correct grid flaws, and thus improve these images (INPE, 2011). These images are disseminated for various purposes, such as planning and environmental management, in management projects and watersheds, delimitation of watersheds (Corrêa et al. 2017).

3.3 Delimitation of Microwatersheds

With the generated contours, they were exported with the elevation data to the CAD environment. The "feature to 3D" tool was used within QGIS, which generated a new file and with the use of "Export to CAD", it was exported to be treated in the AUTOCAD software. Through these curves with elevation information, it was possible to delimit the watersheds (MB) in the study area by total station and TOPODATA.

From the elevation per total station, 5 watersheds were generated (Figure 4A), all MB (microwatershed in portuguese) flow towards the Ipixuna River. The largest basin is the MB1, and its delimitation passes through all the neighborhoods of the study area, ranging from the highest point in the João Paulo II sector, where it is the source of the river that runs through the middle of the MB1, to the lowest point of MB1, according to this morphometry this watershed has a marked slope.

From the TOPODATA image, 6 watersheds were delimited, one more compared to the total station. However, this scenario presented the MB1 with characteristics similar to the MB1 of the total station, being the largest basin, with accentuated slope and passing in all sectors (Figure 4B).

Practically all MB by TOPODATA had their flow towards the Ipixuna River, except for MB5, which is located between the Centro and Vila Nova sectors, which has a valley region, susceptible to flooding. The MB areas can be seen in Table 3, the MB1 per TOPODATA, practically coincides in size with the MB1 per total station.

3.4 Statistical Analysis

Statistical analysis was performed comparing the altitude surveyed by total station and by TOPODATA image. For this analysis, altimetry points from the TOPODATA were extracted, based on the georeferenced altimetry points from the Total Station imported into QGIS, where they were superimposed on the TOPODATA image and the altitude of each point was determined.

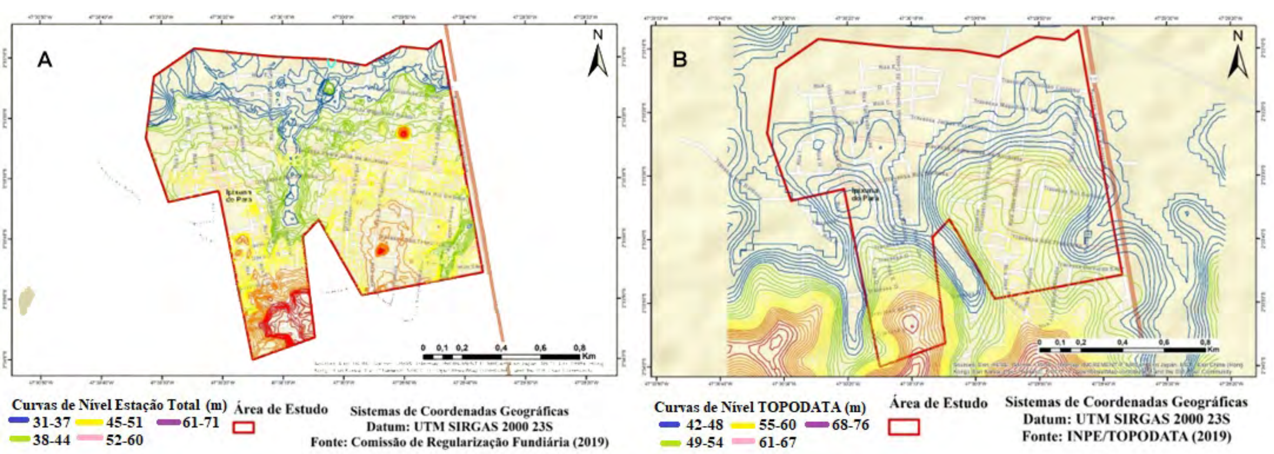

Figure 3 Contour lines: A. Total station; B. TOPODATA. Source: Authors (2022).

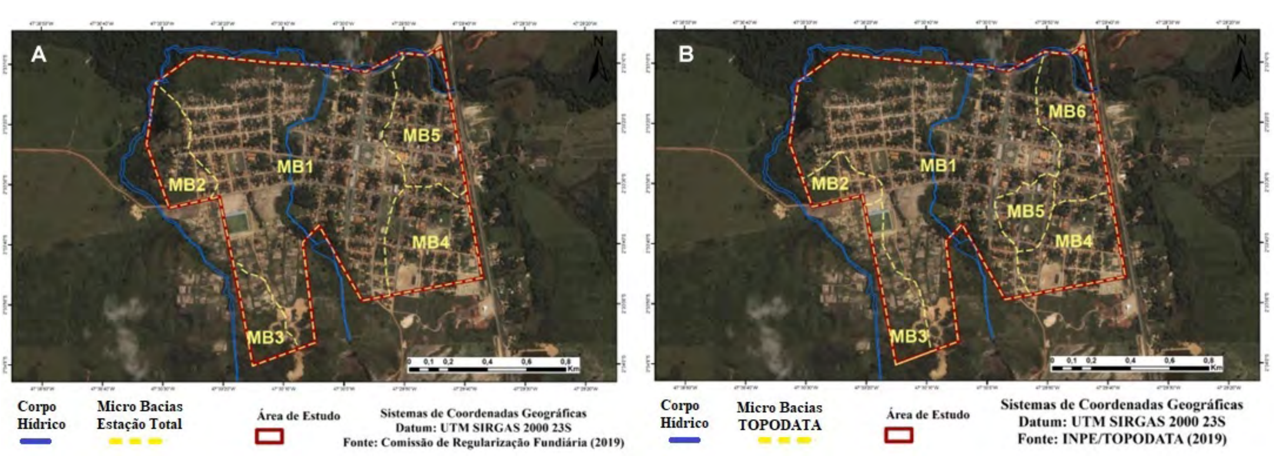

Figure 4 Delimitation of microwatersheds: A. Total station; B. TOPODATA. Source: Authors (2022).

Table 3 MB areas (ha).

	MB1	MB2	MB3	MB4	MB5	MB6
Total Station	109.54	12.24	8.61	22.07	20.89	–
TOPODATA	109.40	6.63	10.79	18.94	8.06	19.53

Source: Authors (2022).

Thus, it was possible to analyze and compare the values obtained with the application of descriptive statistics in the entire area, for each sector. In Table 4, the values of maximum, minimum, amplitude, average, standard deviation are presented for each source of the survey, considering the seat of the municipality.

Table 4 Descriptive statistics.

Statistics Parameters	Total Station	SRTM
Sample size	8375	8375
Maximum	71.35	69.13
Minimum	30.78	41.95
Amplitude	40.57	27.18
Arithmetic mean	45.29	47.91
Variance	54.10	38.82
Standard deviation	7.35	6.23

Source: Authors (2022).

We worked with 87% of all points that were uniformly spatialized in the study area. For the minimum and maximum altitudes, they were, respectively, 30.78 and 71.35 meters with the total station, and 41.95 and 69.13 meters with the use of the TOPODATA image. The biggest difference was in the minimum height, which in the DTM of the Total Station the quoted value was 30.78 meters and in the DTM of TOPODATA, the value was 41.95 meters, this consequently affected the other results, such as the arithmetic mean with 45.29 and 47.91 for Total Station and TOPODATA, respectively. In the case of standard deviation, the result was closer, 7.35 and 6.23, for Station and TOPODATA, respectively.

This discrepancy in the minimum level may have occurred due to several factors, such as the presence of clouds, the presence of trees due to the locations of this lower level being closer to the city's river, in addition, Chagas et al. (2010) cites noise in the acquisition processes and data transfer, errors in orbit geometry.

Despite this, the standard error of the sample was 2.47, not being treated an outlier for analysis, considering the sample size. Using Pearson's correlation coefficient, a result of 0.92 was obtained. According to the classification of Hopkins (2000) the correlation is "almost perfect". Regarding the error, it obtained the RMSE 2.47m. A satisfactory result, presenting a good relationship between the two survey sources, which allows the application in engineering projects (Elkhrachy 2018).

The amplitude was 40.57 for the Total Station and 27.18 for the TOPODATA, such values mean that there is uneven terrain. This amplitude shows that the difference is greater per total station compared to TOPODATA. This promotes the importance of evaluating the study area by dividing it, and this analysis will start from the division that it already has: 5 political-administrative sectors. Thus, it is intended to verify where there is the best correlation of the quoted points, if in flat terrains or with accentuated declivity.

The result of the descriptive statistical analysis for each sector is presented in Table 5. In this table, the João Paulo II sector has a greater amplitude and the variance of the quoted points is also the largest in relation to the other sectors, representing the largest dispersion of data around the arithmetic mean. In this case, characterizing the area of greater slope.

For the other sectors (Centro, Vila Nova, Berro D'água and Paraúba) the amplitudes were smaller, presenting sectors with smaller slopes. Berro D'água was characterized as the flattest sector, with a variance of 1.41 for the $TDM_{TOPODATA}$ and 2.99 for the $DTM_{Station}$, despite having a similar standard deviation in the two survey sources. When the correlation between the points was calculated, this sector presented the lowest (R), of 0.62. However, this did not happen with the João Paulo II and Centro sectors, which also obtained a similar standard deviation, but these two had the highest correlation index (R): 0.94 and 0.87, respectively.

This divergence can be explained by the limitation of the area for the use of the TOPODATA, which has a spatial resolution of 30 meters and ends up generating incoherent results in some parts (Graosque 2018), as it happened in the Berro D'água sector, area of 6.96 ha, and also in Paraúba, which had the second lowest correlation (R) of 0.71, and an area of 7.85 ha.

The classification of the sectors regarding the correlation of their points was as shown in Table 6. The João Paulo II sector, where the highest elevations were verified, obtained the best result, an almost perfect correlation.

Table 5 Descriptive statistics of Ipixuna do Pará municipality's sectors.

	Centro		Vila Nova		João Paulo II		Berro D'água		Paraúba	
Area (ha)	76.14		51.87		30.52		6.96		7.85	
Source	TOPODATA	Total Station	TOPODATA	Total Station	TOPODATA	Total Station	TOPODATA	Total Station	TOPODATA	Total Station
Sample Size	3198	3198	2096	2096	1994	1994	511	511	576	576
Maximum	55.79	55.08	47.76	47.70	69.13	71.35	57.01	57.94	57.01	55.37
Minimum	41.95	32.47	41.95	30.78	41.95	35.95	50.83	47.78	43.32	38.94
Amplitude	13.84	22.60	5.81	16.92	27.18	35.40	6.18	10.16	13.70	16.44
Arithmetic Mean	46.87	43.99	43.00	39.27	52.59	51.32	54.74	52.36	49.35	47.20
Variance	18.24	21.88	2.19	20.61	67.85	72.43	1.41	2.99	6.37	21.60
Standard Deviation	4.27	4.68	1.48	4.54	8.24	8.51	1.19	1.73	2.52	4.65

Source: Authors (2022).

Table 6 Pearson´s correlation (R) in the sectors.

Sectors	(R) Coeficient	Classification
João Paulo II	0.94	Almost Perfect
Centro	0.87	Very High
Vila Nova	0.78	Very High
Paraúba	0.71	Very High
Berro D'água	0.62	High

Source: Authors (2022).

4 Conclusion

In a microdrainage project, it is important to collect information from the site in loco, but there are some situations that require speed to deliver a proposal for a possible design. In situations like this, obtaining the characterization of the location can be obtained by satellite image or by other tools, such as the use of drones.

This research addressed the use of altimetry with TOPODATA image, with a spatial resolution of 30 meters, and the possibility of using this data source, available for free. Regarding the altimetric topographic survey at the total station, the TOPODATA images showed satisfactory results for designing a drainage network for small areas.

Using statistical methods, this satisfactory result was reached, with the validation of the correlation between the predicted and observed points in an area of 14.52 ha, referring to a watershed, resulting in a Pearson correlation index of 0.81, a "very high" correlation; in addition to presenting the RMSE of 1.27 m.

In this way, it was verified that it is feasible to use satellite image to survey the altimetry for small areas, not excluding the importance of the field survey, since the field survey provides more detailed characteristics of the place. For a microdrainage project, the integration of technologies with the on-site survey can achieve the necessary detail and guarantee the final quality.

Thus, the continuity of techniques, methods and technologies that help field work is of great importance, especially in locations lacking resources and technical staff. And the satellite image is an important advance in the agility of obtaining data, taking into account the economic aspect, as it allows satisfactory results at a distance.

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Author contributions

Lilian Paixão Aleixo de Sousa: conceptualization; methodology; writing-original draft; writing – review and editing. **Lindemberg Lima Fernandes:** methodology; supervision; visualization. **Germana Mesnescal Bittencourt:** supervision; visualization.

Conflict of interest

The authors declare no conflict of interest.

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