



ISSN: 2447-3359

REVISTA DE GEOCIÊNCIAS DO NORDESTE

*Northeast Geosciences Journal*

v. 10, n° 1 (2024)

<https://doi.org/10.21680/2447-3359.2024v10n1ID31621>



## Area estimation for Union's cadastral land: a comparative study between the local geodetic system and cartographic projections

### *Estimativa de áreas para terrenos cadastrais pertencentes a União: um estudo comparativo entre projeções cartográficas*

Misael S. B. Junior<sup>1</sup>; Fabiano P. Freiman<sup>2</sup>; Ediana S. F. Conceição<sup>3</sup>; Fabíola A. Souza<sup>4</sup>; Cárita da S. Sampaio<sup>5</sup>

<sup>1</sup> UFBA, Escola Politécnica /DETG, Salvador/BA, Brasil. Email: misael.junior@ufba.br

ORCID: <https://orcid.org/0009-0006-3669-4907>

<sup>2</sup> UFBA, Escola Politécnica /DETG, Salvador/BA, Brasil. Email: fabiano.freiman@ufba.br

ORCID: <https://orcid.org/0000-0001-5878-4707>

<sup>3</sup> UFBA, Escola Politécnica/DETG, Salvador/BA, Brasil. Email: edianaфуza@gmail.com

ORCID: <https://orcid.org/0000-0001-5657-3471>

<sup>4</sup> UFBA, Escola Politécnica/DETG, Salvador/BA, Brasil. Email: fabiola.andrade@ufba.br

ORCID: <https://orcid.org/0000-0003-2475-4520>

<sup>5</sup> Ministério da Gestão e da Inovação em Serviços Públicos, SPU, Brasília/DF, Brasil. Email: carita.sampaio@economia.gov.br

ORCID: <https://orcid.org/0000-0002-9928-9996>

**Abstract:** This article discusses the problems related to the numerical determination of the area of territorial parcels. Several mathematical processes can be applied for this purpose, however, due to the complexity of the Earth's shape, the methods have limitations, especially in large territorial parcels, such as those existing in Brazil, as it is a country with continental dimensions. In this context, government agencies and companies constantly analyze values of areas related to territorial parcels in a national scope. However, a standard methodology to estimate the areas of these plots has not yet been defined. Thus, we seek to evaluate the numerical values of areas previously determined from the application of conventional methodologies used in Brazil. The process consists of comparing the values estimated by the application of the Local Geodetic System (LGS), Cartographic Projections with Equivalence property and areas based on the Universal Transverse Mercator (UTM). Based on the results of this study, it was observed that the estimated areas for each analyzed terrain did not present significant differences in relation to the application of divergent methodologies. However, it is recommended for applications at the national level, the use of the Albers PC adapted for the Brazilian territory, since its mathematical characteristics are determined specifically for the country and do not present subdivisions (zones), in addition, it presents the property of equivalence, a factor that minimizes the deformations of linear and angular quantities. This work consists of preliminary studies for the improvement of the PRISMA-SPU plugin.

**Keywords:** Local Geodetic System; Cartographic Projections; Equivalence property.

**Resumo:** Este artigo discute os problemas de determinação numérica da área de parcelas territoriais. Vários processos matemáticos podem ser aplicados para esta finalidade, entretanto, devido à complexidade do formato da Terra, os métodos apresentam limitações, principalmente em parcelas territoriais extensas, como as existentes no Brasil, por ser um país com dimensões continentais. Órgãos governamentais e empresas analisam constantemente valores de áreas relacionadas a parcelas territoriais em uma abrangência nacional. Entretanto, ainda não foi definida uma metodologia padrão para estimar as áreas dessas parcelas. Desta maneira, busca-se avaliar os valores numéricos de áreas determinados previamente a partir da aplicação de metodologias convencionais empregadas no Brasil. O processo consiste na comparação dos valores estimados pela aplicação do Sistema Geodésico Local, Projeções Cartográficas (PC) com propriedade de Equivalência e áreas baseadas na PC Universal Transversa de Mercator. Com base nos resultados desse estudo, observou-se que as áreas estimadas para cada terreno analisado não apresentaram diferenças significativas em relação a aplicação de metodologias divergentes. Entretanto, recomenda-se para aplicações no âmbito nacional, o emprego da PC de Albers adaptada para o território brasileiro, uma vez que suas características matemáticas são determinadas especificamente para o país e não apresentam subdivisões, além disso, apresenta a propriedade de equivalência, fator que minimiza as deformações de grandezas lineares e angulares. Este trabalho consiste em estudo preliminares para aprimoramento do plugin PRISMA-SPU.

**Palavras-chave:** Sistema Geodésico Local; Projeções Cartográficas; Equivalência.

Received: 02/27/2023; Accepted: 05/16/2024; Published: 05/06/2024

## 1. Introduction

In the geographical context, the process of determining the areas of territorial parcels is common, whether at a local or global level. To achieve this goal, mathematical equations are often used to relate metric measurements made on the physical surface of the Earth to its schematic representation, whether in analog or digital format. This task is supported by the designation of coordinate systems which are defined mathematically to allow a biunivocal relationship between a Reference Surface (RS) - for cartographic and topographic purposes, usually the ellipsoid of revolution - and a Projection Surface (PS) - flat or developable on a plane - which uses metric coordinates and allows the extraction and quantification of the elements represented (ROSA; BRITO, 2013).

The transformation of coordinates from a RS to a PS in a Geographic Information System (GIS) is materialized by Cartographic Projections (CP), implemented computationally, following specific rules according to the region analyzed and their respective purposes (representation in true magnitude of linear, angular or area aspects). CP is a mathematical process used in Cartography and allows the representation of a curved element, the RS, in a PS and to represent it by symbolizing geographical reality (BUGAYEVSKIY; SNYDER, 1995).

In Brazil, the Brazilian Institute of Geography and Statistics (IBGE) has officially adopted the Universal Transverse Mercator (UTM) CP for systematic mapping, and it is widely used in the country (IBGE, 1999). This projection is often used for the numerical determination of areas, however, due to its property of conformity, subdivision into partial zones of 6° amplitude and the deformations inserted in the projection process, the numerical values of areas can be increased ( $k > 1$ ) or reduced ( $k < 1$ ) and the results may not coincide with reality (SCHNEIDER *et al.*, 2014). Júnior, Brito and Schmidt (2017) discuss this problem and mention that the numerical result of the area calculation will be the closest to the physical surface reality according to the definition of the CP to be used, considering the characteristics of the distortions that each CP has. In addition, with advances in computing and geodesy, other modern concepts and processes have been introduced for area calculations, such as the adoption of the Local Geodetic System (LGS), suggested in the publication of the 3rd Technical Standard for Georeferencing Rural Property in Brazil (INCRA [b], 2013), to ensure the accuracy of numerical area values (SILVEIRA and ROCHA, 2016; SIMÕES *et al.*, 2017; SEGABINAZZI, 2018; MUZY, 2018).

For recent geodetic surveys using Global Navigation Satellite System (GNSS) technology, it is interesting to use LGS, as the user will have at their disposal all the geodetic parameters needed to determine the metric coordinates on a Cartesian system in the local topographic plane (INCRA [a], 2013). However, for old cartographic databases stored in vector format, this process becomes complicated due to the absence of these geodetic parameters and the difficulties of carrying out a new survey to renew the entire cartographic base. In these cases, CPs with the equivalence property are commonly used to calculate areas. Of course, there are a multitude of equivalent CPs, but choosing the one that suits the interests of the project is a desirable process to ensure consistency in calculations and minimize distortions.

In this context, the Secretariat for the Management of Federal Property (SPU), currently attached to the Ministry of Management and Innovation in Public Services, which is responsible for the management of federal domain areas (marine and marginal lands of federal rivers, according to Law No. 9,636 of 15 May 1998) and federal public properties, has been seeking to standardize the cartographic documents that are inputs for these federal public properties. This standardization process is important for ensuring compatibility between processes for characterizing, incorporating, and allocating properties, simplifying the exchange of information between agencies of different federal entities and society, as well as improving the quality of information, analysis and processing of spatial data belonging to the institution. Especially for processing its cartographic collection (two-dimensional digital data in vector format), SPU has developed a plugin for QGIS software called PRISMA.

One of the processes associated with PRISMA is the calculation and determination of areas for federal land. To this end, based on the assumption that SPU's cartographic collection is made up of historical geospatial data, originally analogue and later converted to digital media and stored in vector format for use in the GIS, coupled with the fact that there is no standardization for adopting an equivalent CP, the aim is to analyze methodologies for calculating areas that meet the institution's needs and can be used in a standardized way by PRISMA. The aim is to carry out tests with different equivalent CPs to identify the ideal analytical configuration for calculating areas on federal land. The tests were applied in three Brazilian states. In two of them, Sergipe and Paraná, field data using GNSS technology was used. The comparison parameter was the determination of the areas of each plot using LGS, since this is considered to be the process that allows areas to be obtained with greater geometric rigidity when compared to other analytical processes (JÚNIOR, 2017). In the state of Bahia, data from the SPU itself was used to estimate the differences between the projections used.

## 1.1 Plugin PRISMA - SPU

The experiments to be described in the following sections were part of studies to determine parameters to be used in the implementation of methodologies to automate and improve work that depends on geospatial data within SPU, in conjunction with the Geoinformation Center of SPU in Santa Catarina and Bahia. The SPU-PRISMA plugin was developed based on free tools, using the Python 3.0 programming language and QGIS software (Figure 1) to automate processes for overlaying areas belonging to the Federal Government, as well as carrying out preliminary spatial analysis and making maps in an automated way.

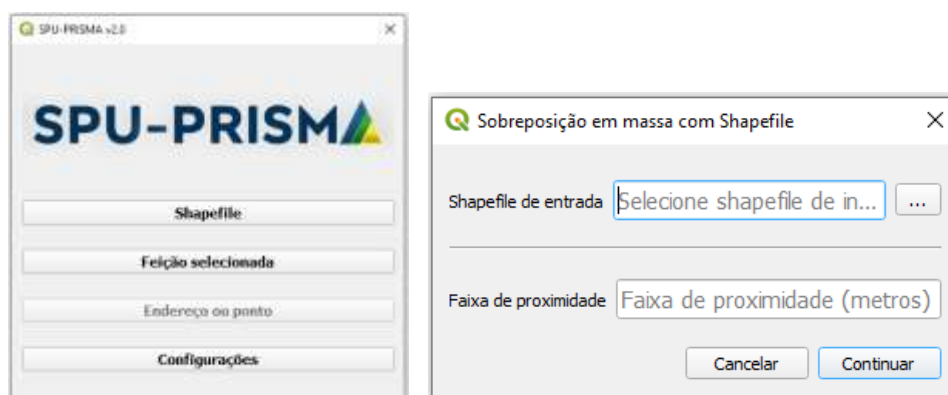


Figure 1 – PRISMA – SPU (in portuguese)

Source: Authors (2024)

This plugin was not used in the tests described in this article, as will be seen in the methodology, however, the results presented aim to define the most appropriate CP to be applied in the area calculations used by it and consequently to help in the spatial analysis of properties that overlap with areas that belong to the Government, defining the area of overlap as close as possible to reality. This is one of the initiatives to modernize the management of the institution's geospatial database, based on the installation of the corporate Spatial Data Infrastructure (SDI-SPU), which includes the Technical Specifications for Structuring Vector Geospatial Data - SPU, version 3.0 (ET- EDGV - SPU 3.0). This plugin is already available for installation and use in the QGIS software as an experimental plugin, and the definition of the default CP to be applied in the calculations will be updated based on the results of this study.

## 2. Methodology

To analyze the calculation of areas using different CPs, it was first necessary to carry out field surveys using GNSS receivers to obtain the geodesic coordinates of each vertex that materializes a territorial parcel. As the aim is to analyze the results in terms of Brazilian territory, we opted for areas surveyed in the state of Paraná (municipality of Curitiba) and the state of Sergipe (municipality of Aracaju). The on-site survey was important for determining comparison parameters. Following the premises of Prina (2018), the LGS is the system that allows area values to be obtained that are closest to reality compared to the UTM projection, so the areas calculated using this system were used as a control group.

To use LGS, it is necessary to determine the geodetic information obtained and calculated by means of observations acquired in the field. To this end, dual-frequency GNSS receivers and the fast static geodetic positioning method (20 minutes of tracking) (IBGE, 2008) were used to acquire observations and determine the coordinates of each vertex that materializes the land boundaries, which were processed using TopconTools software. The vertices of the Brazilian GNSS Continuous Monitoring Network (RBMC) located in Curitiba and Aracaju were used as source data. Finally, QGIS software version 3.18 and LibreOffice Calc were used, respectively, to compile maps and calculate polygon areas using the Gauss method. In the areas located in the state of Bahia (different municipalities in the coastal region), only vector data from the SPU collection was used, these originals in CAD format which were structured, treated topologically, and converted to a database according to the ET-EDGV SPU 3.0 model, in the context of the implementation of SDI-SPU, for manipulation in a GIS environment.

## 2.1 Methodological Flow

The methodological flow consists of 4 stages (Figure 2). Firstly, field data was acquired to determine the geographical coordinates of the vertices that materialize the land using GNSS positioning, as shown in Subsection 2.1.1.



Figure 2 – Methodological Flow  
Source: Authors (2024)

Based on the geographic coordinates defined, mathematical procedures were carried out to reference them to the LGS (Subsection 2.1.1). With the aid of the QGIS software, the data was projected onto this same set of coordinates according to the CP chosen because of its equivalence property (Subsection 2.1.2), as well as using the UTM projection in their respective zones. The areas were then calculated using the Gauss method (Subsection 2.1.3). For the areas located in the state of Bahia, only the last two stages were used, determining the projected plane coordinates, and calculating the area.

### 2.1.1 Determining coordinates in LGS

LGS is a Cartesian system made up of three mutually orthogonal axes (e, n, u), in which the “n” axis points towards geodesic North, the “e” axis points eastwards and is perpendicular to the “n” axis, both contained in the topocentric plane, and the “u” axis coincides with the normal to the ellipsoid that passes through the vertex chosen as the origin of the system. The coordinates referenced to the LGS differ from those determined by GNSS positioning, which have a geocentric concept, i.e. coordinates referenced to three orthogonal axes originating from the Earth’s center of mass, with the Z axis oriented in the direction of the Conventional Earth Pole, the X axis in the mean direction of the Greenwich meridian and the Y axis in such a way as to make the system dextrographic, determining geocentric coordinates (X, Y, Z) of a point, whose geodetic coordinates (latitude and longitude) are known ( $\varphi, \lambda$ ) (MONICO, 2008). Based on the geocentric coordinates of a given vertex, it is possible to obtain the local geodetic coordinates (e, n, u) which correspond to the Cartesian coordinates defined in a local topocentric plane perpendicular to the normal and tangent to the ellipsoid elevated above the earth’s surface at the origin point of the LGS using the method of rotations and translations recommended by INCRA (2013 [b]) (Equation 1).

Therefore, for each vertex of the analyzed plots, the geocentric Cartesian coordinates were converted to local Cartesian coordinates referenced to the LGS using an electronic calculation table. These coordinates were used to calculate the areas of the plots and were used as control values for comparison with those obtained using the CP.

$$\begin{bmatrix} e \\ n \\ u \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \sin(\varphi_0) & \cos(\varphi_0) \\ 0 & -\cos(\varphi_0) & \sin(\varphi_0) \end{bmatrix} * \begin{bmatrix} -\sin(\lambda_0) & \cos(\lambda_0) & 0 \\ -\cos(\lambda_0) & -\sin(\lambda_0) & 0 \\ 0 & 0 & 1 \end{bmatrix} * \begin{bmatrix} X - X_0 \\ Y - Y_0 \\ Z - Z_0 \end{bmatrix} \quad (1)$$

Where:

e, n, u = are the local Cartesian coordinates of the vertex of interest;

X, Y, Z = are the geocentric Cartesian coordinates of the vertex of interest;

$\varphi_0, \lambda_0$  = are the latitude and longitude adopted as the origin of the system;

$X_0, Y_0, Z_0$  = are the geocentric Cartesian coordinates adopted as the origin of the system.

### 2.1.2 Determining projected plane coordinates

Within the scope of Cartography and Geodesy, calculating polygon areas is a basic task performed by geoscience professionals. In the context of adopting a flat or spherical surface, it is relatively simple to carry out this task; however, when using more robust geodesic aspects, such as adopting the ellipsoid of revolution, this task becomes challenging due to the uncertainties associated with mathematical approximations.

To get around this problem, CPs are commonly used (SNYDER, 1987). The most important factor in this context is the use of the appropriate mathematical method for a given area of interest. The elements represented are naturally distorted, while some metric quantity is preserved (angles, distances in relation to a family of lines - direction of latitude or longitude - or areas) (ÁBRAHÁMOVÁ, 2022). In the context of estimating area values, the projection of a polygon in relation to a plane coordinate system is subject to a significant area error, which may or may not occur. The source of errors is related to the inappropriate choice or incorrect parameters for a given CP associated with algorithmic errors in GIS software (USERY, SEONG, 2001).

In this work, we sought to select the main properties of the Equivalent CPs chosen, as listed in Table 1.

Table 1 – Equivalent Cartographic Projections used

General parameters of the Cartographic Projections used			
Projection	Datum	Standard Parallel	Concept
Lambert Equivalent (EPSG: 54034)	WGS84	Tangent Projection (0°)	Global
Equivalent for the Americas (EPSG: 8858)	WGS84	Tangent Projection (0°)	Regional
Albers Equivalent Conic Projection (EPSG: 102033)	SAD69	Secant Projection (-5°; -42°)	Regional
Albers Equivalent Conic Projection (EPSG: 7823 adapted for Brazil according to IBGE)	SIRGAS2000	Secant Projection (-12°, -54°)	Nacional

Source: Authors (2024)

The CPs shown in Table 1 have already been implemented in the QGIS software, except for the Albers CP recommended by the IBGE, which has been standardized individually by the software user. The projection adapted for Brazil has the property of secancy (two standard parallels), the others, tangency (SPATIAL REFERENCE, 2022). The surveyed areas were then projected using these mathematical resources and the numerical area values were then calculated using the Gauss method (INCRA [a], 2013). The values found were compared with those determined using the LGS and the UTM CP, since it is often used in Brazil for this purpose, even though it does not have the property of equivalence.

### 2.1.3 Calculating area

Para o cálculo da área das poligonais elaboradas através das coordenadas cartesianas locais e das coordenadas projetadas, foi utilizada a Fórmula de Gauss (Equação 2) (JÚNIOR, BRITO E SCHMIDT, 2017). Esse cálculo foi realizado através do uso do *software* LibreOffice Calc.

The Gauss Formula (Equation 2) was used to calculate the area of the polygons drawn up using the local Cartesian coordinates and the projected coordinates (JÚNIOR, BRITO E SCHMIDT, 2017). This calculation was carried out using LibreOffice Calc software.

$$A = \frac{1}{2} (\sum_{i=1}^n Y_i X_{i+1} - \sum_{i=1}^n X_i Y_{i+1}) \quad (2)$$

Where:

- A is the value of the calculated area;
- N is the number of vertices in the polygon;
- X and Y are the coordinates of the polygon vertices.

### 3. Results and discussion

Based on the on-site survey of the vertices that make up the plots analyzed in the states of Sergipe and Paraná, the area calculation analyses presented in Subsections 3.1 and 3.2 were carried out, followed by the analyses in the state of Bahia, in Subsection 3.3, which follows.

#### 3.1 Areas in the State of Sergipe

The vertices surveyed in the state of Sergipe were determined using GNSS receivers. In all, there are 4 plots of land located on the Aracaju waterfront, Atalaia (Figure 3). It should be noted that these territorial parcels, as well as those surveyed in the state of Paraná, are hypothetical and were used for comparison purposes only.



Figure 3 – Areas analyzed in the state of Sergipe – Aracaju  
Source: Authors (2024)

After surveying the vertices that make up the analyzed plots, the geodesic coordinates ( $\varphi$ ,  $\lambda$ ) of each point were first determined. These coordinates are the basic inputs for carrying out the tests related to each projection used in this work. They were converted to geodesic Cartesian coordinates and then to LGS and planes. Therefore, each vertex that materializes one of the plots analyzed was referenced to the coordinate system associated with the LGS to later determine the area of each plot using the Gauss formula. This step was required to provide a reference value for comparing the areas calculated using plane coordinates defined in relation to each projection used. The areas estimated using the Gauss formula are shown in Table 2.



Table 2 – Areas calculated for land located in the state of Sergipe

Areas calculated according to Gauss's formula (m)					
Area	LGS	UTM	EPSG: 102033	EPSG: 8858	ALBERS IBGE
01	66160,654	66179,961	66160,301	66160,707	66160,729
02	25946,288	25953,840	25946,160	25946,313	25946,295
03	30265,911	30274,754	30265,684	30266,020	30266,012
04	11454,736	11458,059	11454,664	11454,750	11454,742

Source: Authors (2024)

The calculated areas show a small average percentage variation of - 0.03% when the UTM projection is used. When the equivalent projections were used, there was a variation of +/- 0.0001% with the reference value, estimated using the LGS (Figure 4).

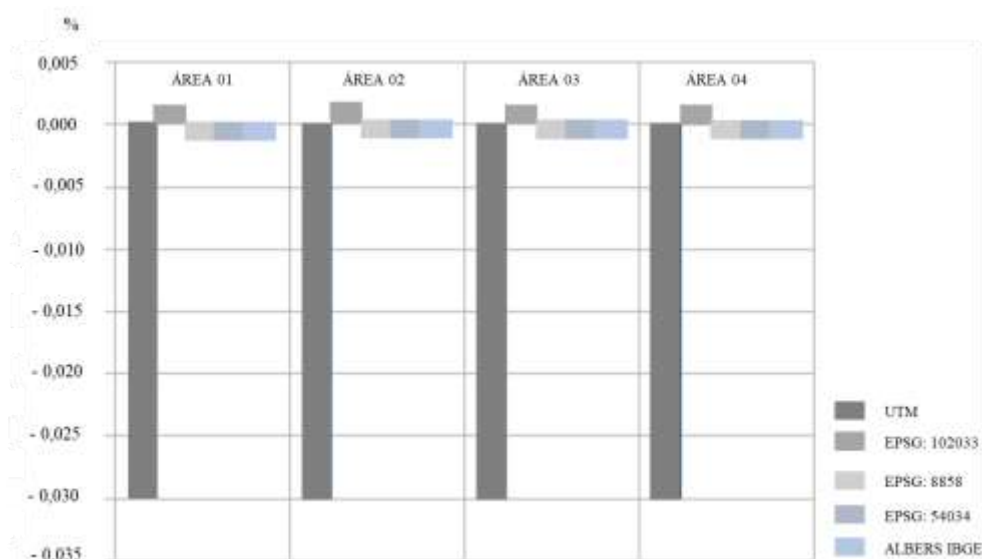


Figure 4 – Percentage Differences - areas analyzed in the State of Sergipe – Aracaju.

Source: Authors (2024)

### 3.2 Areas in the State of Paraná

In the state of Paraná, 4 areas were also surveyed, in the city of Curitiba, in the Guabirotuba neighborhood (Figure 5). The areas calculated for each plot are listed in Table 2. It can be seen that in both states there was a slight variation in the value of the estimated areas.

Table 3 – Areas calculated for land located in the state of Paraná

Areas calculated according to Gauss's formula (m)					
Area	LGS	UTM	EPSG: 102033	EPSG: 8858	ALBERS IBGE
01	3070,632	3069,683	3069,761	3069,762	3069,758
02	8790,263	8787,537	8787,765	8787,766	8787,762
03	37094,302	37082,809	37083,769	37083,781	37083,773
04	1897421,123	1896820,527	1896875,200	1896861,090	1896912,211

Source: Authors (2024)

The average variation observed for the areas located in Curitiba was 0.03% in relation to the reference area (calculated from the LGS). The variation in the calculation of areas with all the mathematical processes employed was constant, even with the use of the UTM CP to determine areas. This is mainly due to the size of the plots analyzed, since they are compatible with small plots or blocks in urban environments, so the deformations for areas equal to or smaller than those listed in Table 2 are not significant. However, in the Aracaju plots, there is a greater variation when calculating areas referenced to the UTM projection, which is mainly due to the position of the plots in relation to the spindle, which when positioned closer to the edge, increases (SCHNEIDER *et al.*, 2014). It is also associated with the property of the UTM CP itself, conformity.



Figure 5 – Areas analyzed in the state of Paraná – Curitiba  
 Source: Authors (2024)



The graph in Figure 6 shows the differences in the areas calculated for each plot of land in the city of Curitiba.

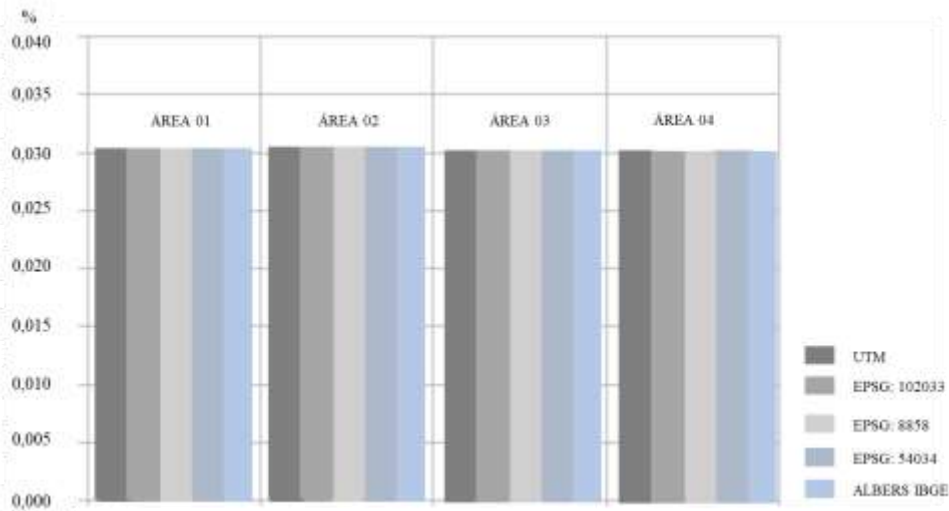


Figure 6 – Percentage Differences - areas analyzed in the State of Paraná – Curitiba  
Source: Authors (2024)

To statistically analyze these differences, we used the t-Student test for paired (dependent) samples using the JAMOVI software. The aim was to compare the value of the reference area associated with the LGS and the others calculated for all the regions analyzed using plane coordinates according to the CP. As the data does not follow a normal distribution, the most appropriate approach is to use a non-parametric test (FIRMINO, 2015), so the Wilcoxon test was used. The statistical results show that none of the values found differed significantly from the area calculated using the LGS, as illustrated in Figure 7.

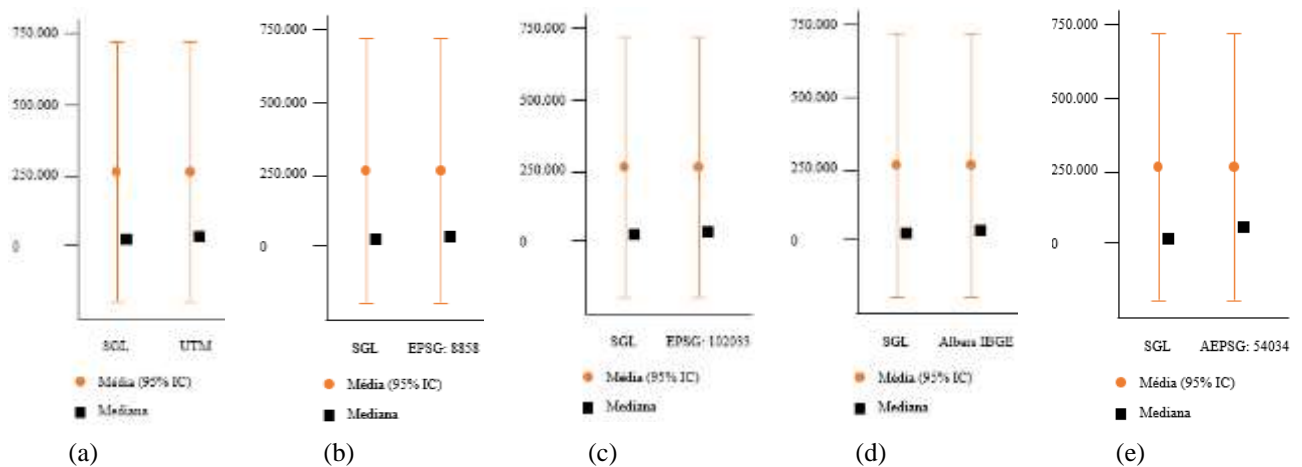


Figure 7 – Comparison among the areas calculated in relation to the LGS (a) UTM (b) EPSG: 8858 (c) EPSG: 102033 (d) Albers IBGE (e) EPSG: 54034  
Source: Authors (2024)

The same pattern of variation was observed for the areas located in the city of Aracaju, with no significant variations when compared to the areas calculated with coordinates projected according to the CP and defined from the LGS. This is mainly because the areas are small, however, other variables such as geographical position and the predominant direction of the area's extensions (north - south or east - west) can influence the results. To test the difference in larger areas, data from the SPU collection was used to identify differences in estimates in relation to the CP used, as Subsection 3.3.

### 3.3 Areas in the State of Bahia

To test the same processes in the SPU's geospatial repository, we used two marine lands (from the Preamar Line - LPM) located in the south of the state of Bahia (both in the UTM 24S spindle), which comprises the coastline of the geographical regions of Serra Grande, Uruçuca and Ilhéus. Specifically, it sought to test the same processes as in the previous sections in terrains that are larger than the other terrains surveyed and described in the previous sections. It should be noted that, as the area was not visited locally to acquire GNSS data on site for the calculation of coordinates in the LGS, only the calculation on CP in the QGIS software was tested in these areas. The area comprises more than one municipality and has a predominantly north-south layout in the state of Bahia. The geographical layout of the land is illustrated in Figure 8.

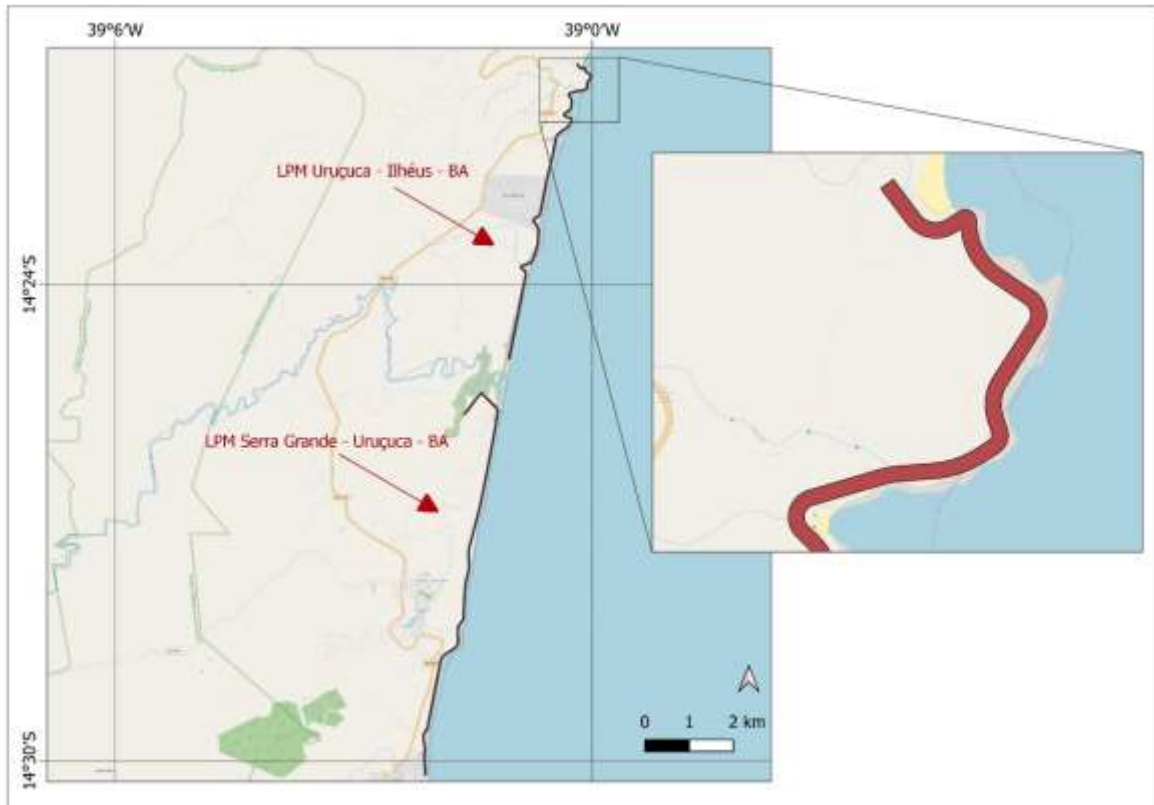


Figure 8 – Area of the SPU collection - State of Bahia  
Source: Authors (2024)

From the definition of the projections analyzed, the results listed in Table 4 were obtained. The same pattern and variation as in the previous tests was obtained, with no significant variations between the areas calculated by the equivalent projections and the UTM tested. However, the values estimated using the Albers CP adapted for Brazil showed smaller area values, with an average difference of 3.5 m<sup>2</sup>.

Table 4 – Areas calculated for land located in the state of Bahia

Areas calculated according to Gauss's formula (m)				
Area	UTM	EPSG: 102033	EPSG: 8858	ALBERS IBGE
LPM Serra Grande – Uruçuca – BA	330095,348	330093,218	330095,348	330090,885
LPM Uruçuca – Ilhéus - BA	269211,811	269210,065	269211,809	269208,162

Source: Authors (2024)

Although the results did not show a significant difference, with the advances in spatial tools and the possibility of reprojecting a layer in a GIS environment in a simple way, the Albers projection adapted for Brazil may present advantages due to the minimization of distortions in the representation of the territory, as well as having a continuous projection surface, without the subdivision into zones as occurs in the UTM projection (which makes it difficult to calculate areas in regions covered by more than one zone). These tests were initial studies to determine the most suitable projection to be used by the Prisma-SPU plugin for the QGIS software to manage federal territories, as outlined in Subsection 1.1.

#### 4. Final considerations

LGS was considered to be the system best suited to estimating the areas of land parcels. However, its use is conditional on carrying out geodetic surveys on site, which can be a limiting factor when dealing with large existing cartographic bases stored in vector format, as is the case with SPU and the use of the SPU-PRISMA plugin. Although the tests used in this work did not show any significant differences between the use of LGS and the other cartographic projections used in the experiments, it is interesting to adopt a CP with the property of equivalence. For a national data, the Albers CP adapted for Brazil is the recommended process due to its mathematical characteristics being determined specifically for the national territory, therefore, in addition to presenting the equivalence property, it minimizes deformations due to the adjustment of the CP parameters to the geographical location of Brazil.

#### Acknowledgements

The authors would like to thank the Secretariat for the Management of Federal Property (SPU), specifically the Geoinformation Centers (BA and SC) and the Federal University of Bahia (UFBA) for carrying out the activities.

#### References

- ABNT, Associação Brasileira de Normas Técnicas. *NBR 13133: Execução de levantamento topográfico: procedimentos*. ABNT, 2021. 57 p.
- ÁBRAHÁMOVÁ, Andrea; VAJSÁBLOVÁ, Margita. *A Comparison of Variational Projection and Cartographic Projection by Ritz's Method*. Slovak Journal of Civil Engineering, v. 30, n. 2, p. 22-29, 2022.
- BUGAYEVSKIY, Lev M.; SNYDER, John. *Map projections: A reference manual*. CRC Press, 1995.
- IBGE, Instituto Brasileiro de Geografia e Estatística. *Noções Básicas de Cartografia*. v. 1. Rio de Janeiro: Fundação IBGE, 1999. 130 p. (Manuais Técnicos em Geociências, n. 8).
- IBGE. *Recomendações para levantamentos relativos estáticos - GPS*. 1 ed. Rio de Janeiro: IBGE, 2008. 25 p. Disponível em: [https://geoftp.ibge.gov.br/metodos\\_e\\_outros\\_documentos\\_de\\_referencia/normas/recom\\_gps\\_internet.pdf](https://geoftp.ibge.gov.br/metodos_e_outros_documentos_de_referencia/normas/recom_gps_internet.pdf). Acesso em: 27 out. 2023.
- FIRMINO, Maria José de Almeida Caetano de Sousa. *Teste de hipóteses: Uma abordagem não paramétrica*. Tese de Doutorado. Universidade de Lisboa, Faculdade de Ciências. 2015.
- INCRA [a]. Instituto Nacional de Colonização e Reforma Agrária. *Manual Técnico de Posicionamento: Georreferenciamento de Imóveis Rurais*. Brasília. 1ª Edição, 2013.
- INCRA [b]. Instituto Nacional de Colonização e Reforma Agrária. *Norma técnica para georreferenciamento de imóveis rurais*. Brasília. 3ª Edição, 2013.
- JÚNIOR, Carlos Roberto Borges; BRITO, Jorge Luís Silva; SCHMIDT, Marcio Augusto Reolon. *Estimativa de Área no Sistema Geodésico Local para Parcelas Rurais com Cálculo de Área Referenciado ao Sistema UTM*. Revista Brasileira de Cartografia, n. 69/7, p. 1411-1425, 2017.
- MONICO, João Francisco Galera. *Posicionamento pelo GNSS*. São Paulo: Editora Unesp, p. 477, 2008.

- 
- MUZY, Guilherme Augusto et al. *Influência da Deformação Linear em Mapeamento para Gestão Territorial e Projetos em Diferentes Sistemas de Projeção Cartográfica em Região de Fronteira entre Brasil e Argentina*. In: COBRAC 2018. 2018.
- PRINA, Bruno Zucuni; TRENTIN, Romario. *Cálculo de Área no Sistema Geodésico Local: Georreferenciamento de Imóveis Rurais/Brasil*. 2018.
- ROSA, Roberto; BRITO, Jorge Luis Silva. *Introdução ao geoprocessamento*. UFU: Apostila. Uberlândia, 2013. 143 p.
- SCHNEIDER, Gabriel; HILLEBRAND, Fernando Luis; SAMPAIO, Marco Ivan Rodrigues; DAL'FORNO, Gelson Lauro. *Análise das distorções do sistema de projeção cartográfica UTM em diferentes posições dentro do fuso e altitudes elipsoidais*. 5º Semana da Geomática, UFMS, Colégio Politécnico p. 62-68, 2014.
- SEGABINAZZI, Mariana da Silva et al. *Comparação entre Áreas nos Sistemas de Projeção UTM, TM-POA, PTL e Sistema Geodésico Elipsoidal para fins de Gestão Territorial Urbana no Município de Porto Alegre-RS*. In: COBRAC 2018. 2018. 20p.
- SILVEIRA, Leonard Niero da; ROCHA, Jonatan dos Santos. *Influência da altitude na deformação de áreas projetadas nos sistemas planos UTM, LTM e RTM*. Revista Tecnologia e Ambiente, Criciúma- Sc, v. 22, p.137-146, 2016.
- SIMÕES, Débora Paula; ALBARICI, Fabio Luiz; BORGES, Paulo Augusto Ferreira. *Análise comparativa das coordenadas no Sistema Geodésico Local e no Sistema Topográfico Local*. Revista Brasileira de Geomática, v. 5, n. 1, p. 62-81, 2017.
- SNYDER, John Parr. *Map projections--A working manual*. US Government Printing Office, 1987.
- SPATIAL REFERENCE, *Projection 7823*, Projeção: Conica Equivalente de Albers Brasil. Disponível em: <<https://spatialreference.org/ref/sr-org/albers-conical-equal-area-brazil-sirgas-2000/html/>>. Acesso em: 28 jul. 2022.
- USERY, Lynn E.; SEONG, Jeong Chang. *All equal-area map projections are created equal, but some are more equal than others*. Cartography and Geographic Information Science, v. 28, n. 3, p. 183-194, 2001.