Real Surface Observations in the Analysis of Slums Situated on Hilly Terrain

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Abstract

The main goal of this study is to evaluate how area calculations on the real surface differ from the results on a planimetric reference surface, while alternating the analysis of variables in slums located on a mountainous area known as the Tijuca massif in Rio de Janeiro (Brazil). The study area was chosen from disordered urban expansion areas, which resulted in the construction of irregular settlement, known as slums on the massif, usually in steeply sloped areas. Researchers used some information acquired from the Pereira Passos Institute (IPP): data on slums included in the study area; hypsometry and the drainage to the construction of the associated Digital Elevation Model. The results indicated major differences between the real surface observations and the planimetric surface, generating an increase of around 0.79 km², and a reduction of around 2417.25 people/km² and 691.94 homes/km².

Key Words: Real Surface, Slums, Geoprocessing.

1. Introduction

The operationalization of geomorphological analyses was always a complex challenge involving a series of different techniques. Seeking to both improve and make the operationalization easier, a series of authors including Hutchinson (1989), Guimaraes (2000), Coelho Netto , Avelar, Fernandes and Lacerda (2007), Wilson and Gallant (2000) use geoprocessing technologies in the development of geomorphological analyses. However, a series of questions about the use of geoprocessing should be taken into account to avoid problems in the final results. To do this, it is important to conduct scientific studies. These series of questions are basically reflections of the computational construction and representation of reality, in other words, they are conceptual models that seek to paint a portrait of the landscape to be studied. One of these is the lack of consideration of the dimensionality of the data and information to be analyzed, which are evaluated based on the planimetric (projected) surface and on the real surface, making it possible to mask the interpretation of the structure, functionality, and dynamic of geomorphological elements, principally in landscapes with hilly terrain.

Even though it has a series of alternatives to work with the dimensionality of elements of a particular landscape, such as the Digital Elevation Models (DEM), geoprocessing has a limitation established by its lack of consideration of the irregularity of the space being analyzed (Fernandes and Menezes, 2005). Supporting this idea, Fernandes (2004) offers evidence that observations on the flat surface, especially in areas with large slopes in the terrain, mask the actual area and linear measurements, such as a slum area, an area of hydrographic basins and drainage canals (Fig. 1).

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In this sense, this paper attempts to present comparisons between real surface and planimetric surface observations from some of the variables of the slums such as total area, population density, and housing density. Through this comparative method, one can understand to what extent the real surface observations differ from the results of the planimetric surface while alternating between the analyses of variables for slums situated in hilly terrain such as those on the Tijuca massif in Rio de Janeiro. The goal is to also evaluate how the morphological conditions of a certain area, if well evaluated, can interfere in the reading of a particular phenomenon.

2. Area of Study

This research was conducted on the Tijuca massif. Situated in the city of Rio de Janeiro (RJ), this geomorphological formation has a hilly terrain, where the analysis of real surface observations becomes very pertinent. The Tijuca massif is a geomorphological unit that, along with the White Rock and Gericino-Medanha massifs, composes the compartment of coastal massifs of the city of Rio de Janeiro. This massif has an area of approximately 119.2 km², delimited above the quota of 40 meters, occupying an eastern portion of the municipality of Rio de Janeiro, RJ, between the parallels, 22º 55’ e 23º 00’ S; and the meridians, 43º 20’ e 43º 10’ W (Fig. 2).

According to Abreu (1992), one of the limiters of the process of expansion of the city is the sea and the Tijuca massif. In general, the Tijuca massif has been altered due to degradation over time through various transformative events such as deforestation, fires, and disordered urban occupation. According to Fernandes and Coelho Netto (1999), it is urban expansion, which had a 20.6% increase in its total area between 1966 and 1990, that serves as both the oldest and most central transformative event in the landscape structure of the massif. This urban pressure on the massif is due to the increased population density of the city, which remained constant until the 1990s (Fernandes and Coelho Netto, 1999). As such, the urban expansion on the massif manifests itself especially through slum occupations, that were located, in large part, in areas of steep slopes. It is exactly in these areas that the difference between the area of the real surface and the planimetric surface tends to be higher. In this sense, it is important to study the variables of slums situated on mountainous terrain in consideration of the ruggedness of the topography, in other words, through the analysis on the real surface, instead of on the flat surface, which could under or over estimate the calculations related to the area of the slums (Fig. 3).

3. Materials and Methods

All the cartographic data used in the research were acquired from the topographic cards of the Pereira Passos Institute (IPP/1999) at a 1:10.000 scale and UTM projection, fusion of 23 S and datum SAD 69.

First, researchers analyzed all slums of the City of Rio de Janeiro, from which 148 were selected that were inserted into the Tijuca massif, or that at least touched (defined here as extending 40 vertical meters up the hill formation, see Fig. 4). Following this, researchers searched the total population data and the number of households in each slum, obtained through the SABREN site of the Rio de Janeiro Prefecture (municipal government). It is important to highlight that, according to the source, the data on population and households are estimated based on the Demographic Census of 2000 conducted and published by the Brazilian Institute of Geography and Statistics (IBGE). As such, they are a combination between the limits of the IPP slum registry and those of the census sectors of IBGE.

To obtain real surface area values, researchers constructed a Digital Elevation Model (DEM) (Fig. 5) based on the hypsometric data of the topographic cards (quoted points and contour levels in contact with the slums – equidistance of 5 meters) and drainage. This model was constructed based on the method of interpolation of Delaunay with restrictions, from the irregular network of triangles (TIN), that preserves the topographic characteristics, utilizing maximum (hypsometry) and minimum (drainage) lines. That process was conducted through the 3D Analyst extension of the ArcGis 9.3 software and was discussed by Fernandes and Menezes (2005) as being the most recommended for this type of analysis.

The values of real surface and planimetric surface area were reached through the Surface Tools extension of the ArcView 3.2 software (Jenness, 2001). Using Surface Tools, it was possible to compare the results of this process, allowing for the incorporation of new variables that are influenced by these readings in slum areas such as area, population density and household density.

3. Results and Discussion

The slum areas are very characteristic elements of the process of disordered occupation of the Tijuca massif. These elements slosh ashore the sides of the massif, occupying steeply sloped areas, where the difference between the real and planimetric surface areas tends to be greater, allowing in some cases to rise to approximately 1 km² of difference. Through the comparison of the total area of slums on the real and planimetric surfaces, one can see that the planimetric surface area is approximately 7.52 km², however, when calculated on the real surface this area increases to 8.31 km², which represents an increase of 0.79 km² or 9.55% (Fig. 6). These values directly influence the definition of population density, which presents a difference of -9.55% between the real and planimetric surfaces (Fig. 7). This variable on the planimetric surface presents a value of 25.322.20 inhabitants/km², but when calculated on the real surface this value decreases to 22,905.20 inhabitants/km², demonstrating a reduction of 2.417.25 inhabitants per km². The tendency to reduce the value of the population density for the collection of slums included in the study, when defined based on the measurement of the area on the real surface, repeats itself in the definition of household density per km² on the real and planimetric surfaces (Fig. 8). One can see that this variable when calculated on the flat surface estimates 7.248.59 households per km², yet when the same variable is calculated on the real surface, it presents a reduction of -9.55% making up at least 691.94 households/km². All of this tendency towards differentiation between observations conducted between the real and planimetric surface is directly related to the interpretation of the formations analyzed as a function of the morphology of the terrain and its occurrence. As such, the steeper the slope in the areas analyzed, the larger the difference in the proposed readings.

From Fig. 7, one can see that there is a strong correlation between average slope in the slum areas and the percentage of difference of the population and household densities between the real and planimetric surfaces. In this sense, the extent to which there is an increase in slope, there is a diminishing of the population density of the slums, when evaluated on the real surface. As such, the real values are masked, affecting the statistical and populational inferences that can be made from the results. After the development of the analyses that work with the total alterations of the selected variables in the study, researchers attempted the same method again, to verify how these variables behave in a specific manner in each slum. Table 1 illustrates the slums that were most representative in the variable analyses. The four slums that presented the largest and smallest percentual differences between the observations on planimetric and real surfaces. The slum that presented the largest percentual difference between planimetric and real surfaces in all the variables as the Francisco de Castro slum, with 37.31% difference in area and -27.21% in population and household density. In the calculation of the area, the slum obtained, on the real surface, an increase of 0.0004 km² or 441.57 m². However, it is worth noting that, in absolute numbers, the slum that showed the largest difference in area was the Rocinha slum, with an increase of 0.97 km², representing 12.68%.

In relation to the population density, the Fransico de Castro slum showed a reduction of 10.562.7 inhabitants per km², representing 19.95%. And finally, in the analysis of household density, the same slum presented a percentage fall of around 2.296.23 households per km²; in absolute numbers, the most outstanding is the Ladeira Santa Isabel slum, with a reduction of 3.267.21 households km², in other words, 20.10%. A the other extreme, the slum that presented the smallest differences, as much percentual as absolute, between the planimetric and real surface observations in all the variables was the Torres de Oliveira slum, with only 0.32% difference in area and -0.32% in population and household density. With relation to the area, this percentage represents an increase of 9 m², with relation to the population and household densities, this percentage signified a reduction, respectively, of 60.65 inhabitants per km² and 17.97 households per km².

5. Final Considerations

The analyses presented in this paper illustrated that real surface observations showed themselves to be quite different in relation to the results on the planimetric surface. The slums of the Tijuca massif, characterized by disordered occupation, and generally located in areas of steep slopes, had relevant alterations in their values for area, and population and household density. With relation to the area, there was an expressive increase on the real surface, representing a difference of approximately 800.000 m². On the other hand, the population and household densities presented a reduction of their values on the real surface respectively, of 2.417.25 inhabitants per km² and 691.94 households per km². The results obtained indicated that flat surface observations end up generating a sub-estimation of the slum areas and an over-estimation of the density of inhabitants and households inside of them.

This confirms the importance of the three-dimensional study of the landscape, in other words, taking into consideration the morphology of the terrain, especially in areas of hilly relief, the extent to which the real surface observations represent the structure of these areas most accurately. Another finding that reinforces this idea is the strong correlation demonstrated between the average slope and the difference between population density on the real and planimetric surfaces, where the larger the first, the larger the second, suggesting, once more, the importance of this study in areas with steep slopes. And still, despite the fact that the averages of alteration of the variables in the slums analyzed resulted in around ± 9.55%, it is Worth highlighting that the singular analysis of slums showed that the variation of this percentage of alteration can oscillate from de ±0.32%, as in the Torres de Oliveira slum, spanning values of -27% to 37%, in the Francisco de Castro slum. One should note the large margin of difference, which is subject to an analysis of values obtained from flat surface observations, not taking into account the morphology of the terrain. As such the adoption of real surface observations should always be considered, principally, when evaluating elements in distinct morphological situations. This is because elements in homogeneous morphological conditions with low slopes do not present significant variations when analyzed either on the real or planimetric surfaces, which does not occur with elements in areas of steep slopes.

Finally, the analyses conducted tree-dimensionally, in other words, taking into consideration the morphology of the area of analysis, seek to refine the observations made on the flat surface. However, still as such, they are based on the representations of reality, being subject, therefore, to imprecisions during the process of elaboration and should be used with necessary caution. It is important to stress the methodology to obtain real surface observations should still be submitted to more scientific investigations, seeking to improve even further the proposed observations. One of these is the discussion of the type of digital elevation model to be used, which should be evaluated according to the morphology of the terrain, the topographic data available and the spatial scale of the assumed analysis. It is worth highlighting that real surface observations is a possibility that demonstrated a new reading of the structure of landscape elements. However, this type of analysis can be employed in a series of analyses that take into consideration the morphology of the terrain, such as geomorphological analyses. In this type of analysis, the use of real surface observations can present different results in relation to the understanding of the structure of evaluated elements, in relation to the functionality of these, generating a new reading of geomorphological variables. A direct example of this would be the utilization of real surface observations in the evaluation of geomorphological indices that take into consideration values of area and length, as in the calculation of drainage density.

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Major Differences

Slums	plan. area	real area	difference	%	plan. dens.	real dens.	difference	%	plan. hous.	real hous.	difference	%	deg. aver.
Francisco de Castro	0.0012	0.0016	0.0004	37.31	38870.72	28308.04	-10562.68	-27.17	8450.16	6153.92	-2296.23	-27.17	37.61
Morro do Bananal	0.0125	0.0152	0.0028	22.18	33752.53	27625.03	-6127.49	-18.15	8177.57	6693.00	-1484.57	-18.15	32.71
Vila Santa Bárbara	0.0030	0.0036	0.0006	21.16	20434.69	16865.32	-3569.37	-17.47	7034.89	5806.09	-1228.80	-17.47	31.82
Cotia Velha	0.0050	0.0060	0.0010	20.34	14526.79	12071.77	-2455.02	-16.90	4035.22	3353.27	-681.95	-16.90	32.84

Minor Differences

Slums	plan. area	área real	difference	%	plan. dens.	real dens.	difference	%	plan. hous.	real hous.	difference	%	deg. aver.
Parque Araruna	0.016217	0.016348	0.000132	0.81	12517.97	12417.17	-100.80	-0.81	3638.23	3608.93	-29.30	-0.81	4.80
Rua Rodrigo da Silva	0.001912	0.001927	0.000015	0.78	63271.94	62781.48	-490.46	-0.78	20916.35	20754.21	-162.14	-0.78	6.36
Avenida Menezes Cortes	0.002276	0.002291	0.000015	0.68	33394.41	33169.96	-224.45	-0.67	9227.40	9165.38	-62.02	-0.67	5.99
Rua Torres de Oliveira	0.002826	0.002835	0.000009	0.32	19107.13	19046.48	-60.65	-0.32	5661.37	5643.40	-17.97	-0.32	3.60

plan. area = Planimetric surface area (Km²). real area = real surface area (Km²)

plan. dens. = Population density on planimetric surfaces (inhabitantes/Km²). real dens. = Population density on real surfaces (inhabitantes/Km²)

domplano = Household density on planimetric surfaces (households/Km²). dom real = Household density on real surfaces (households/Km²)

deg. aver. = Degrees of Average Slope

Tables

Tab. 1: Slums with the largest and smallest differences between planimetric and real surfaces

Fig. 1 – Real and planimetric surface representation of the Hill of the Ant, Rio de Janeiro.

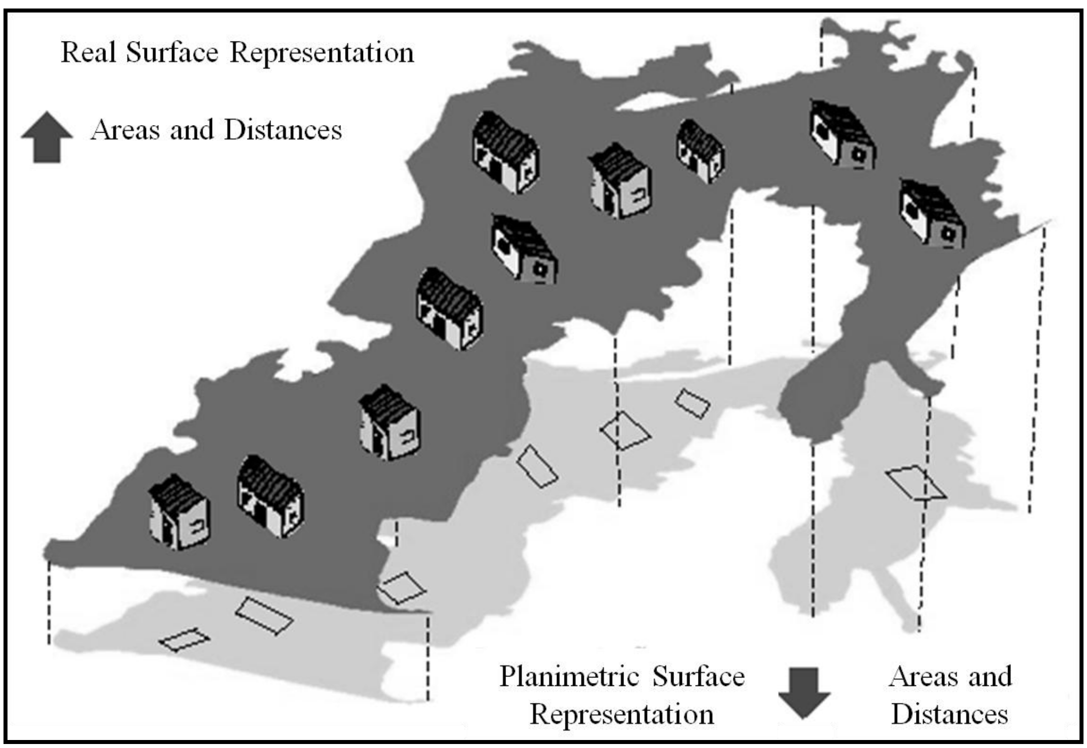
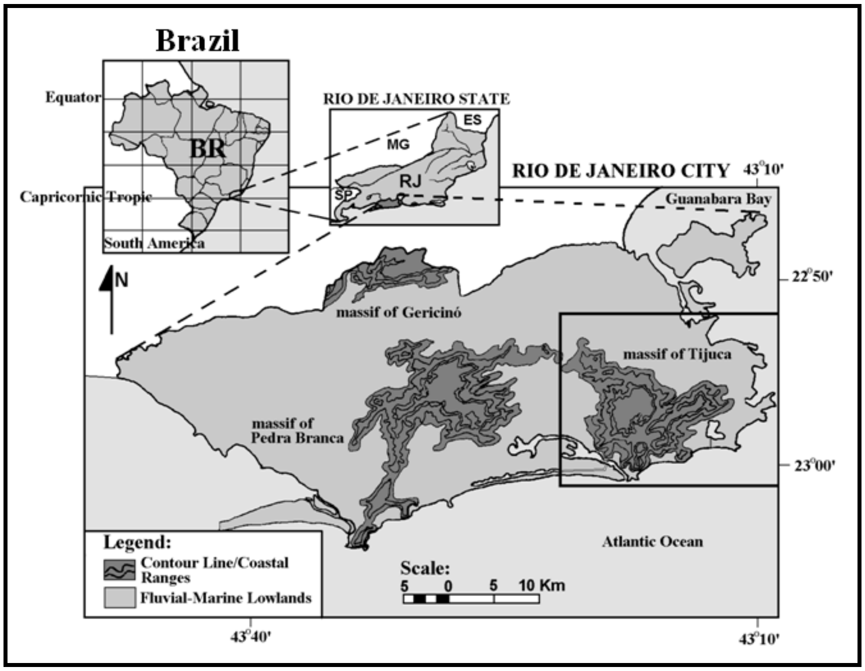


Fig. 2 – Location of the study area



Source: Image bank of the Geo-hydroecology laboratory (GEOHECO)

Fig. 3 – Distribution of some slums throughout the mountainous terrain of the Tijuca massif

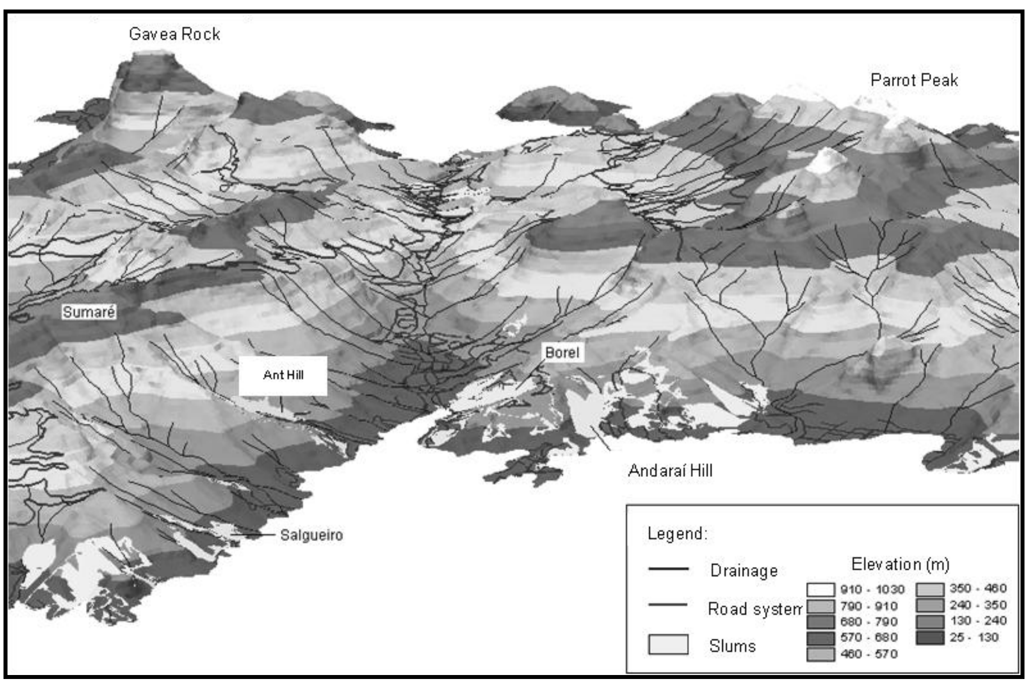


Fig. 4 – Location of the slums selected on the massif of Tijuca, RJ

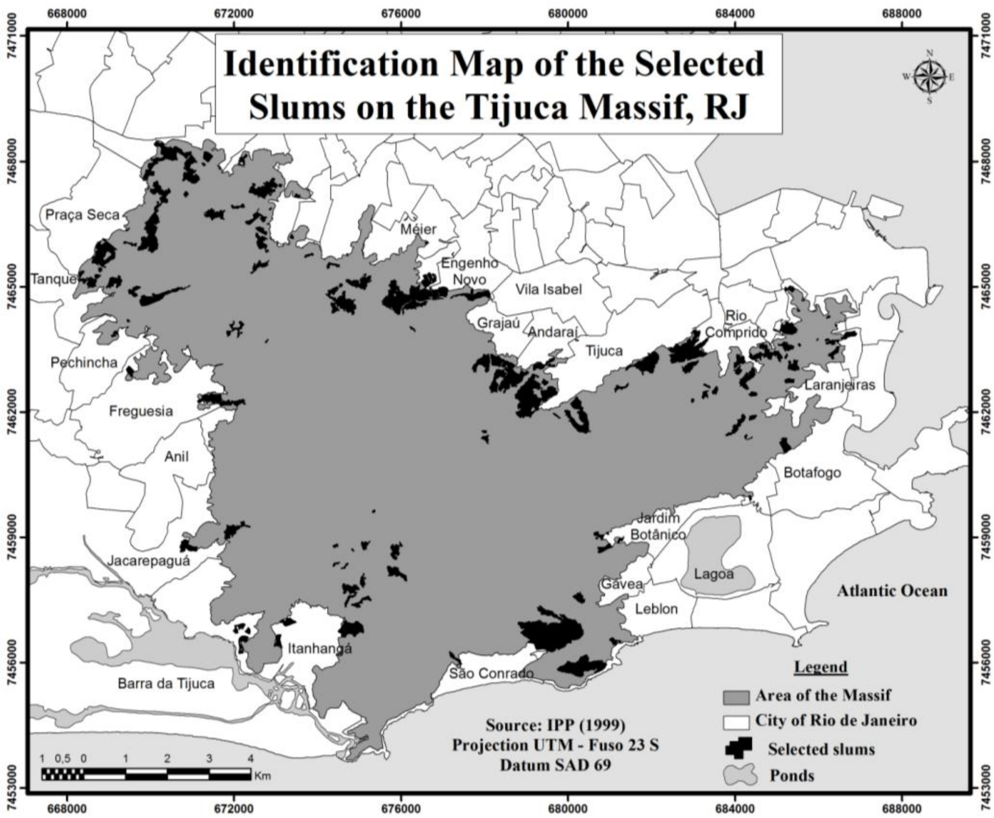


Fig. 5 – Three dimensional rendering of the Tijuca massif, RJ

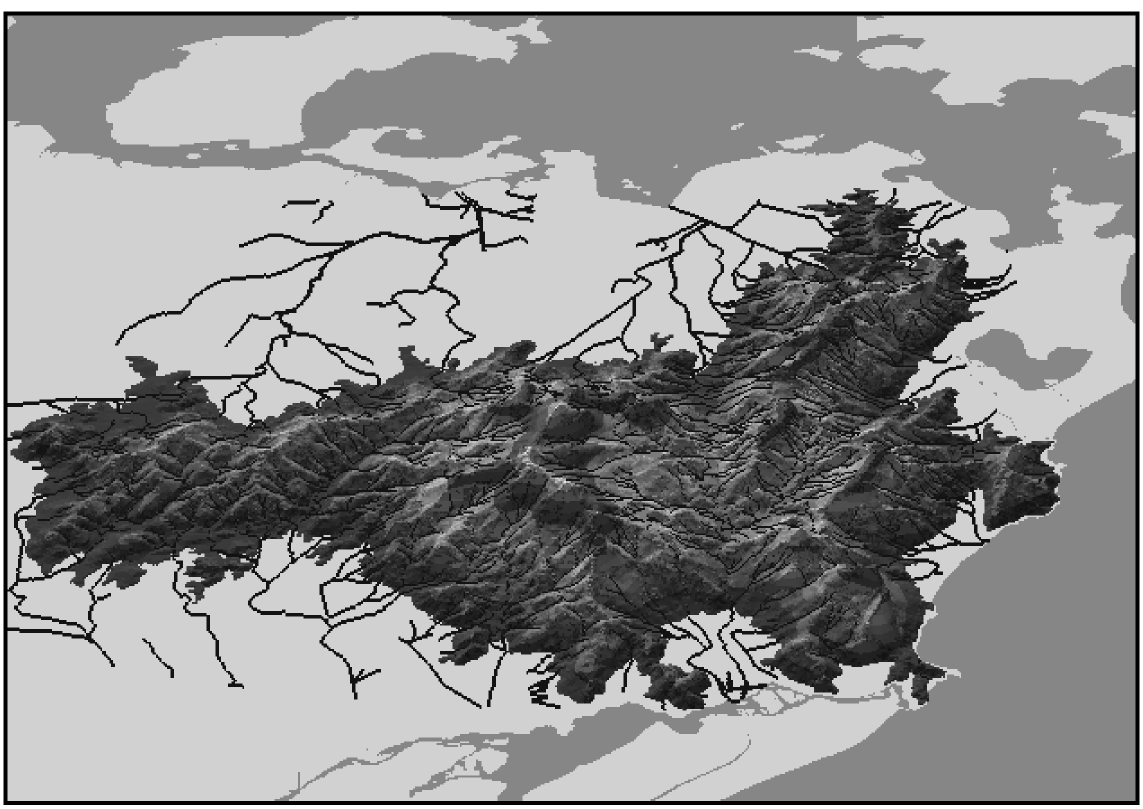


Fig. 6 – Comparative graph of the average area on real and planimetric surfaces

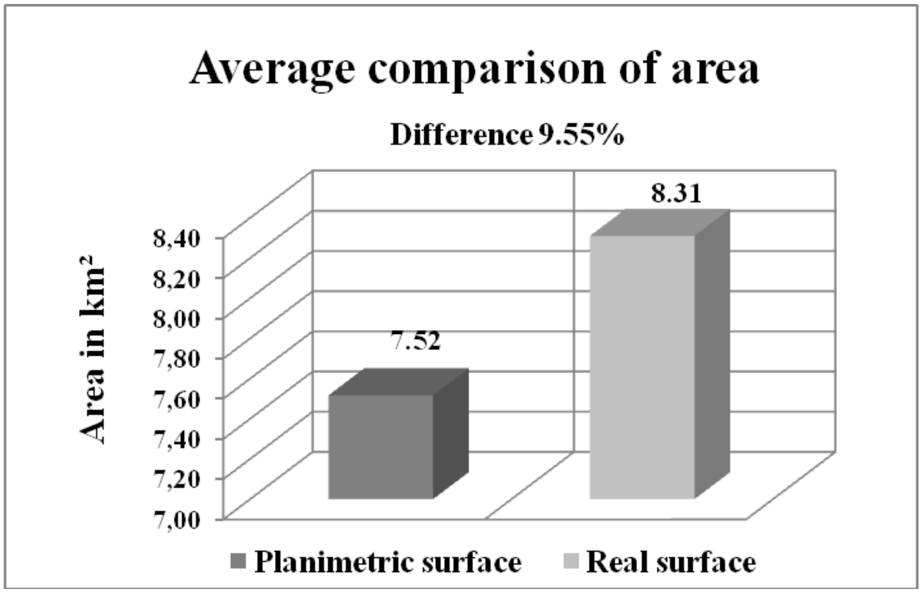


Fig. 7 – Comparative graph of the population density on real and planimetric surfaces

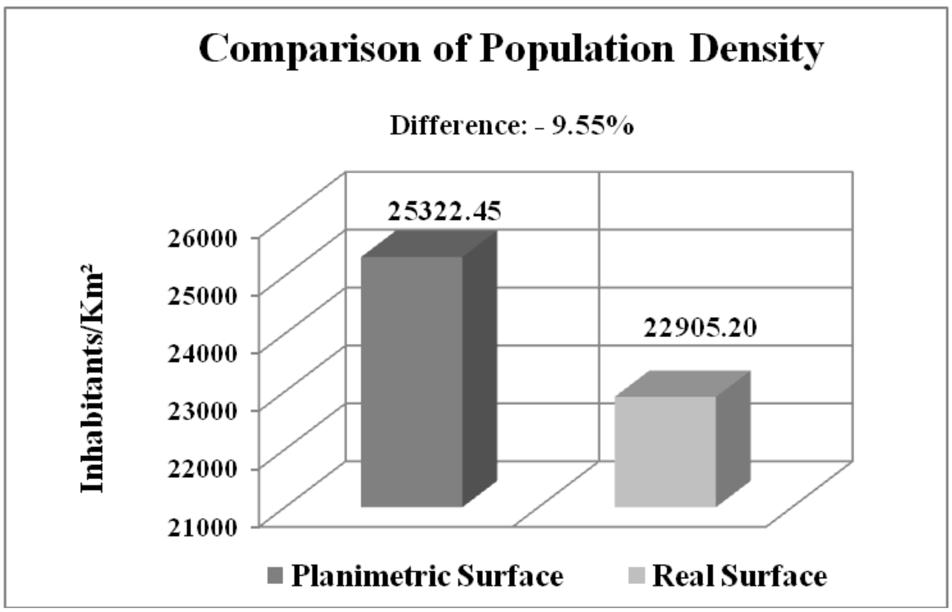


Fig. 8 – Comparative graph of household density on real and planimetric surfaces

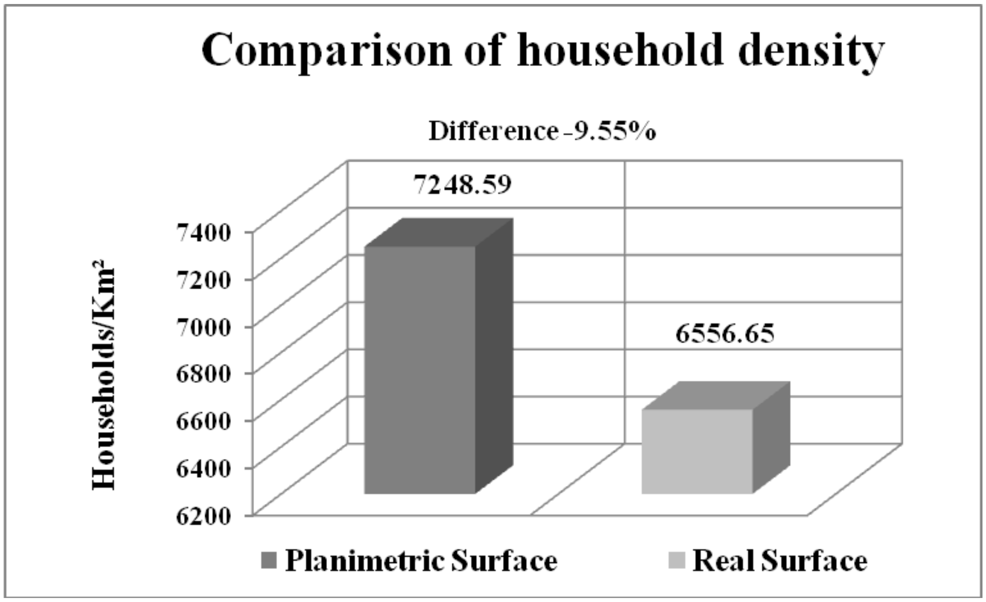


Fig. 9 – Graph of the relation between average slope and the percentual difference between population density on real and planimetric surfaces