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THE RIVERS, THE CITY AND THE MAP AS AN OBJECT OF ANALYSIS OF LANDSCAPE DYNAMICS

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Abstract

Historical cartography has been increasingly important in understanding the landscape transformations, especially in the urban environment where different historical records are used. The present work aims at identifying and comparing, from historical and current records, the changes occurred in the three main rivers that cut the genesis area of the city of Petrópolis (Quitandinha, Palatino and Piabanha). The main research material consists of the Koeler Map (1846), a document that guides the urban planning of the city of Petrópolis, which was designed in line with the drainage network, produced in a 1: 5,000 scale and the most recent cartographic base of the city (1999) in scale 1: 10,000. The georeferencing and vectorization of the Koeler Map made it possible to perform different measurements, such as river width and winding. Later, the same procedures were performed on the most recent cartographic base of the city, in order to create comparative parameters for changes in the course of the rivers and their floods. The results show the suppression of four river islands and a decrease of sinuosity of the rivers with a variation of +0.575% to -2.436%. In the Quitandinha river were recorded the biggest changes and the largest flood record (97%), indicating that changes in the drainage network are significant elements in understanding flood dynamics.

Keywords: Landscape change. Drainage network. Koeler Map. Historical GIS.

Resumo / Resumen

OS RIOS, A CIDADE E O MAPA COMO OBJETO DE ANÁLISE DA DINÂMICA DA PAISAGEM

A cartografia histórica tem sido cada vez mais importante na compreensão das transformações da paisagem, especialmente no ambiente urbano, onde diferentes registros históricos são utilizados. O presente trabalho tem como objetivo identificar e comparar, a partir de registros históricos e atuais, as mudanças ocorridas nos três principais rios que cortam a área de gênese da cidade de Petrópolis (Quitandinha, Palatino e Piabanha). O principal material de pesquisa consiste na Planta Koeler (1846), documento que orientou o planejamento urbano da cidade de Petrópolis, que foi delineado em consonância com a rede de drenagem, produzida na escala 1:5.000, e na base cartográfica mais recente da cidade (1999) na escala de 1: 10.000. O georreferenciamento e a vetorização da planta Koeler possibilitou realizar diferentes mensurações, como largura dos rios e sinuosidade. Posteriormente, os mesmos procedimentos foram realizados na base cartográfica de mais recente da cidade, a fim de criar parâmetros comparativos para alterações do curso dos rios e sua a largura. Os resultados mostram a supressão de quatro ilhas fluviais e uma diminuição da sinuosidade dos rios com uma variação de + 0,575% a -2,436%. No rio Quitandinha foram registradas as maiores mudanças e inundações (97%), indicando que as mudanças na rede de drenagem são elementos significativos no entendimento da dinâmica das inundações.

Palavras-chave: Mudanças na paisagem. Rede de drenagem. Planta Koeler. SIG Histórico.

LOS RÍOS, LA CIUDAD Y EL MAPA COMO OBJETO DE ANÁLISIS DE LA DINÁMICA DEL PAISAJE

La cartografía histórica ha sido cada vez más importante en comprensión de los cambios en el paisaje, en particular en ambiente urbano, dónde distintos registros históricos son utilizados. La investigación tiene como objetivo identificar y comparar, a partir de registros históricos y actuales, los cambios ocurridos en los tres principales ríos que pasan por el área génesis de la ciudad de Petrópolis (Quitandinha, Palatino y Piabanha). Los principales datos de investigación son la Planta Koeler (1846), documento que orientó el plan urbano de la ciudad de Petrópolis siguiendo la red de drenaje, hecho en escala 1:5.000 y la base cartográfica más reciente de la ciudad (1999) en escala 1:10.000. La georreferenciación y vectorización de la planta de Koeler permitió realizar diferentes mediciones, como largura de los ríos y sinuosidad. Después, los mismos procedimientos fueron realizados en el mapa más reciente de la ciudad, para crear parámetros comparativos para los cambios del corso de los ríos y su largura. Los resultados muestran la supresión de cuatro islas fluviales y un regreso en la sinuosidad de los ríos con un cambio de +0,575% a -2,436%. En el río Quitandinha fueron listo los mayores cambios y llenas (97%), indicando que los cambios en la red de drenaje son importantes en la comprensión de la dinámica de las llenas.

Palabras-clave: Cambios en el paisaje. Red de drenaje. Planta Koeler. SIG Histórico.

INTRODUCTION

Dynamics are an important component in analyzing a landscape (Turner, 1989), and, therefore, studying them allows for understanding how certain processes evolve with time. A classic example is cited by Dunne and Leopold (1978), who demonstrate the raise in floods occurring in drainage basins after the covering and land usage, as well as draining network means, have been altered.

There are currently many academic papers that use methodologies which are set in geotechnologies that aim to analyze the dynamics in the drainage network of a landscape, whether it is a natural or a built one. However, when one looks to analyze these changes within a historical point of view, the available bibliography and methodology are rarer. In this sense, this article aims at analyzing the drainage network dynamics in the genesis area of the city of Petrópolis, in Rio de Janeiro State, comparing the recent spatial arrangement of the drainage network with the one in the 19th century, to be more exact on the year 1846, a settlement period in this area.

The city of Petrópolis, in Brazil, is located on the mountain region of Rio de Janeiro State, as has been dealing historically with environmental issues with various characteristics. Among them, the mass movements and the reoccurring flood events. This framework is directly linked to the occupation of the city as a whole, but mainly on the first district, since its first occupation on the 19th century. This city has a different history background from most Brazilian cities, since it was created after an imperial decree and it was defined by a map, the Petrópolis Map (1846) – also known as the Koeler Map – which served as a base for the plan of occupation of the future city. This imperial decree was signed by the Emperor Pedro II of Brazil and was registered in the Administrative book #155. The decree has allowed for the creation of a settlement and the construction of an imperial house where the old farm Córrego Seco was located, which was acquired by Dom Pedro II's father, the Emperor Dom Pedro I, thirteen years before (Ambrozio, 2012). This decree has become known as "Summer Palace Plan" our Koeler Plan. The plan has allowed for the leasing of the Imperial farm, formerly known as Córrego Seco farm and Corcórdia farm, to Major Júlio Frederico Koeler, a German immigrant who joined the military engineering sector of the Brazilian army. This decree has resulted in a document signed on July 26th, 1843 that was a part of the prior, original decree. Ever since the signing of this document, the renter, Júlio Federico Koeler, was obliged to prepare the future map of Petrópolis, dividing the imperial lands into lots or numbered points which were to be conceded. In addition, he had to plan the Emperor's Palace and his rooms (Paula Buarque, 1940).

The Koeler Map contain different cartographical elements such as hydrography, streets, public parks, land installments in which blocks were divided and plots reserved to public and religious buildings (Sá Earp, 1996; Souza, 2013). It is worth noticing that this map was in an advanced stage of degradation and was restored in 2016 (Neves and Zanatta, 2016) (figure 1).

Figure 1 - Koeler Map (1846) restored (Neves; Zanatta, 2016)

Currently, the municipality is divided into five districts. The city was founded, and its origins were set in the first district, called Petrópolis, where the area covered by the Koeler Map is located. The area the map covers (of 15.91 square kilometers) represents 12% of the current first district of Petrópolis and 2% of the whole current city. The image 2 shows the perspective of the research study, which coincides with the area in the Koeler Map.

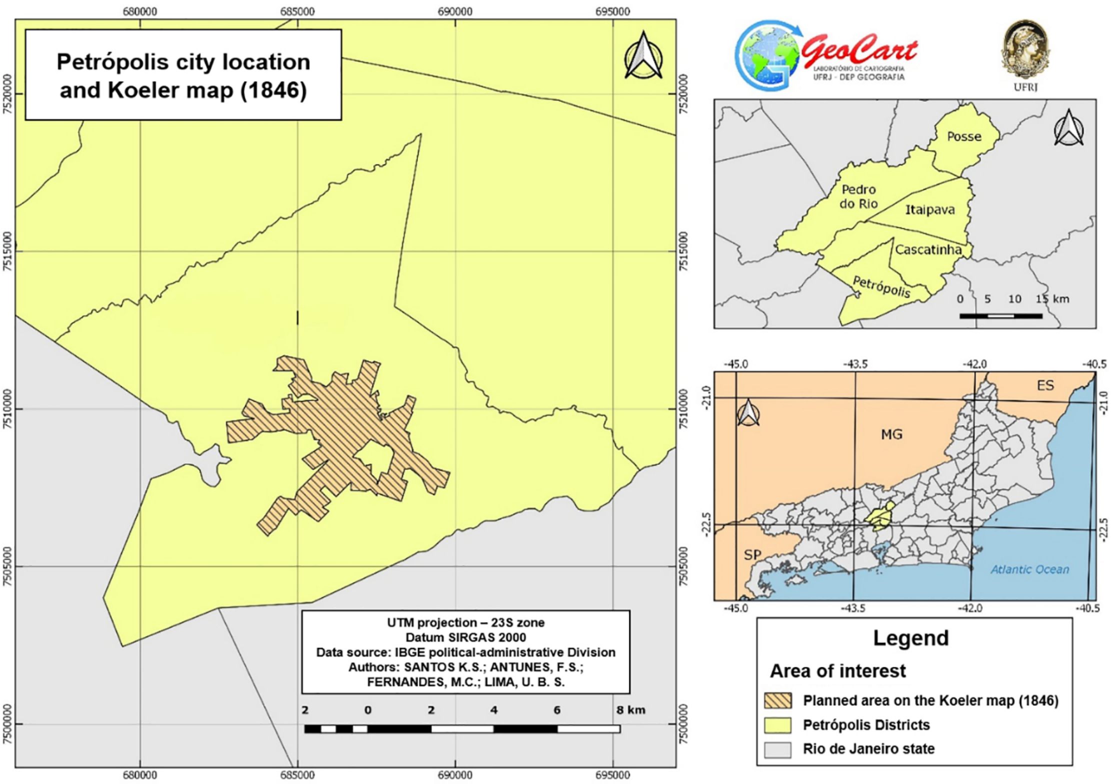

Figure 2 - The first district of Petrópolis and Koeler Map planned area (1846)

An important characteristic of the Koeler Plan is that it can be understood as a project that was worried about the responsible use of resources and the environment. Rabaço (1985) goes on about important aspects that characterize the Koeler Plan as a project that had a preoccupation with the responsible usage of the environment. This plan is considered the first building law of the city of Petrópolis, forbidding constructions on top of hills and horizontally subdividing lots, that is, making them parallel with the front line. The plan also established that the front of all houses should face the rivers, and that the sewage should be directed to the pits at the back of the uncultivated lands. This characteristic is seen by Rabaço (1985) as one of the most original in the Koeler Plan, given that it exempted the building to be constructed in the traditional colonial style in which the houses were erected facing backwards to the rivers, that were functioning as a place for discarding waste. Finally, the planning of the green areas that would contain avenues filled with trees and gardens with hydrangeas, magnolias and silk floss trees.

The map was projected in a scale of 1:5,000 (Fernandes et. al., 2007) and shows a planned occupation following the drainage network, with the streets and avenues running along the rivers (figure 3). The Koeler Plan can be seen as an urban plan whose spatial reference element is the Petrópolis Map or Koeler Map (1846), which also functions as a guide for handling and looks to minimize the effects of landslides and flooding.

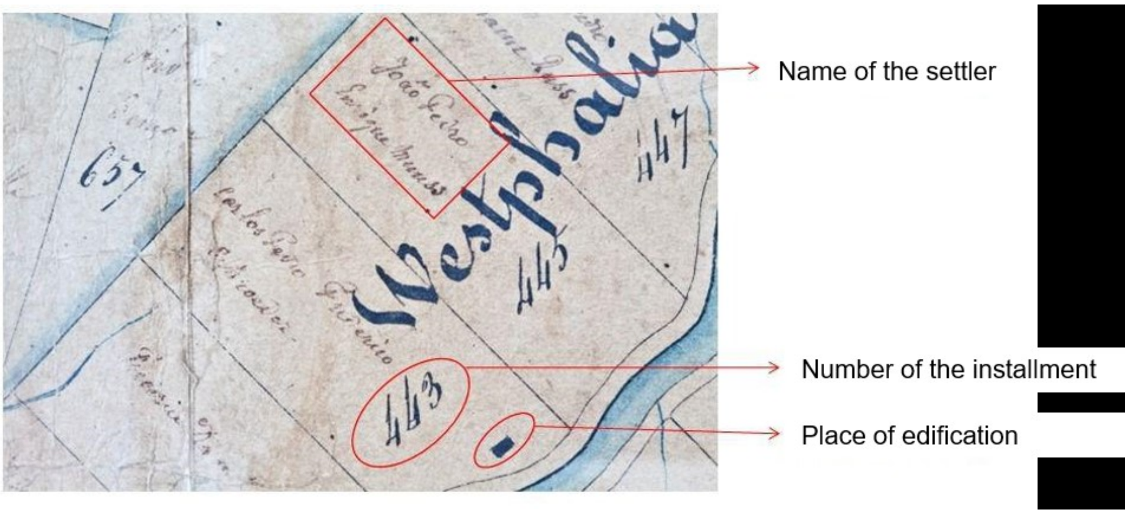

Figure 3 - Part of the Koeler Map identifying its inscriptions.

The map was projected in a scale of 1:5,000 (Fernandes et. al., 2007) and shows a planned occupation following the drainage network, with the streets and avenues running along the rivers (figure 3). The Koeler Plan can be seen as an urban plan whose spatial reference element is the Petrópolis Map or Koeler Map (1846), which also functions as a guide for handling and looks to minimize the effects of landslides and flooding.

In the projections drawn in the Koeler Map (1846), the straight segmentation of the three main rivers that cross the city was proposed as a facilitating way of occupying the area. Thus, the rivers (Piabanha, Palatino and Quitandinha) suffered modifications on their courses ever sing the upraise of the city, and, along with the occupation of its soil, which modified aspects of its covering, contributing to the alteration of the watershed's dynamics of the area. Studying the alterations that took place in this period is a fundamental task in order to comprehend the flooding problem that devastates the city since its formation.

In this sense, the main questions that guide this article are: Were the canals of the drainage network in the genesis area of Petrópolis modified in their width and sinuosity? Are the registered floods in areas where the canals and soil covering were more modified? While searching for answers to the aforementioned questions, the work methodology uses an approach that integrated the usage of GIS (the Geographical Information System), supported in both historical and current data, the measurement of physiographical parameters of the drainage network, the use of satellite images to map the soil covering and data of flooding in the period of 2011 to 2018.

MATERIALS AND METHODS

The article was developed following different steps in which various materials and methods were used, ever since surveying and structuring cartographical data, images and inventory of floods, to manipulating methods and data structuring, as well as their spatial analysis. These phases are shown as follows.

Data acquirement

In the first phase of the research, the Koeler Map, the digital cartographic base of Petrópolis and Worldview 2's image. The process of georeferencing was carried out directly on the restored version of the Koeler Map (Neves and Zanatta, 2016). This process has led to the collection of 30 inspection points in the digital cartographic base, which should necessarily be found on the historical map. The calculation of the Standard ofCartographicAccuracywas made according to the reference values on the Decree #89,817 of June 20th, 1984 (BRASIL, 1984). Out of the gathered results, the georeferencing has framed the Koeler Map as pertaining to Class A in the scale of 1:50,000, which grants it positioning errors of less than 25 meters. In this process, the cartographic base in the scale of 1:10,000 was crucial for obtaining the coordinates of known features and, thus, in giving them the same features in the historical map.

Aiming to map the soil covering and to quantifying the level of the edifications in the watershed area, an image of was acquired on earth explorer site of USGS, taken with an MSI instrument, by the Sentinel-2 mission. The table 1 shows the characteristics of the satellite bands of Sentinel-2 that were used.

MSI Sentinel-2 (µm)	Description	Spatial Resolution (m)
Band 2 (0.458-0.523)	Blue	10
Band 3 (0.543-0.578)	Green	10
Band 4 (0.650-0., 680)	Red	10
Band 8 (0.785-0.900)	Nir	10

Table 1- Information from a satellite image used on the research.

The flood data were obtained from data of four rainfall or gauging stations run by Instituto Estadual do Ambiente (INEA/RJ) and distributed by the three drainage basins that are part of the genesis area of the city (Piabanha, Palatino and Quitandinha). The data encompasses continuous data surveys of limnometric quota from 2011 to 2018.

Manipulation and structuring of data

On the second phase, the Koeler Map was submitted to a vectorization process of the features that reference hydrography. All watercourses were vectorized in the ArcMac 10.4.1 program, however, only the three main canals were reworked in a later step. The information contained in the vectoral file in shapefile format were: the name of the feature, length and sinuosity rate. This information holds the identification of a stream of water through its official name and information on their measuring.

An atmospheric correction of the bands 2, 3, 4 and 8 was carried out so that the image could be used, in QGIS software, through the Semi-Automatic Classification Plugin (SCP) and then, the spectral signatures of many targets of the image were compared as to assure and visually evaluate the result that was obtained in the atmospheric correction of the bands that were utilized.

The gauging data were analyzed in relation to the quota of stream overflow established by INEA/RJ, allowing for the identification of all the flooding events to the four stations. These data allowed for the spatial evaluation of the phenomena, identifying the distributing of floods through the three different water basins of interest.

Construction of the analysis model

The measurement of the width and of the sinuosity rate of the canals were used to identify the modifications occurred through the courses of the rivers Piabanha, Quitandinha and Palatino. The width was measured through the Euclidean distance between the two margins, associating a constant width value to the whole canal. The figure 4 below summarizes this process that was carried out in ArcMap 10.4.1 software, through the Euclidean distance tool. To each margin one matrix file was created, where the pixel value corresponded to the distance to the margin. In order to obtain the constant distance between both margins it was necessary to sum the two files (map algebra), cutting the values to the inside of both margins.

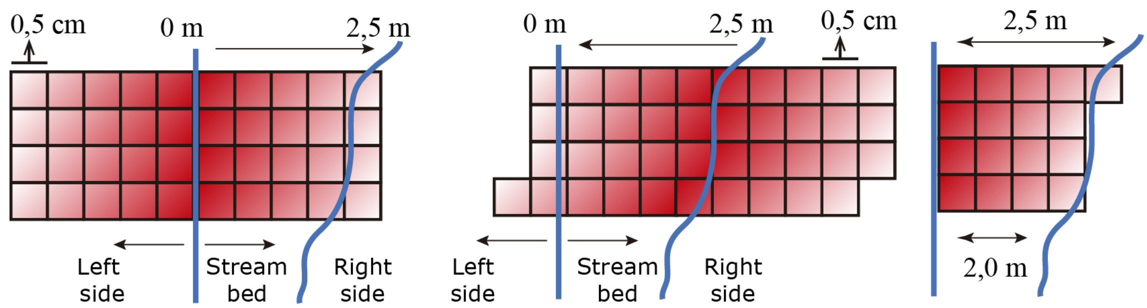

Figure 4 - Scheme of the calculation of the width distance on the rivers done through Euclidean distance.

The analysis of the stream sinuosity took into account, in turn, the shape dynamic of the main canals of the studied area. The shape of the canals can be considered straight, anastomosed, intertwined and meandering, forming the canal pattern (IBGE, 2009). The distinction between the straight, the sinuous, meandering and tortuous reflects itself in using qualitative and nominal criteria. By its own turn, when using quantitative criteria, one is drawn to problems that involve the adoption of limiting values, as in the proposition of Leopold and Wolman (1957) and of Leopold et al. (1964), indicating that the sinuosity rate is justifiable when it implies another typical element of the kind of canal found in the three river basins. The sinuosity rate is obtained [through] "[…] dividing the length of the canal a in a determined section by the length of this section measured along the valley" (Christofoletti, 1981). The described formula can be equated in .

Where Is is the sinuosity rate, Cc is the length of the main canal and Cv is the vectoral distance between the initial and final points of the canal in the considered section. These values were raised to the main canals of each of the three currently analyzed basins. They were framed in the classification by Leopold and Wolman (1957), that is: to levels under 1.5, the canal was considered straight; and, to those equal or over 1.5 were attributed the classification of meandering. Starting from the measurement of these two parameters, both in the historical map as well as in the current cartographic base, the aim is to evaluate modifications occurred on the course of the sections of the analyzed canals.

Soil covering and edification level

With the goal to analyze the urban landscape of Petrópolis' structure, a mapping o the soil covering was carried out, aiming to find the classes of "vegetation" and "non- vegetation". The classification was done on InterIMAGE open source software, which classifies satellite images using an object-oriented classification technique (GEOBIA), in which the objects of interest are identified and classified in accordance to a series of pre-established parameters, which differentiate them from traditional pixel to pixel techniques, and avoid the "salt-and-pepper" effect (Blaschke et al., 2014). After being classified, areas of both classes were calculated, allowing for the analysis of the landscape modification levels on the river basins.

When using a map of soil covering in the analysis of the draining network in the original occupation area of Petrópolis in the face of the flooding events. Thus, the level of alteration of the soil covering can help us understand in which way do the landscape modifications interfere in the floods that happen in the studied area.

RESULTS AND DISCUTION

The results gathered by this research can be divided in two parts and contribute to reinforcing the importance of Historical Cartography as a tool for integrated landscape analysis using GIS. The first part is directly about the canals' width and its sinuosity, both measured in the historical map and in the current cartographic base; the second part, on its turn, presents more recent data that follow the direction of observing the impact of landscape transformation as partly responsible for recurring problems of flood in the river basins of the Piabanha, Quitandinha and Palatino rivers.

The shapes of the canals: sinuosity rate

The application of the aforementioned methodology has allowed for the demonstration of the results about the length of the canals, the vectoral extension in the extremes of the rivers section and sinuosity rates in both of the utilized bases. The table 2 presents the values obtained to the three main canals of each analyzed basin.

River Canal	Length (m)	Extension (m)	Sinuosity rate
Quitandinha (Koeler Map)	7.672,24	5.036,84	1,523
Quitandinha (1999 base)	7.474,25	5.025,19	1,487
Difference	-197,99	-11,65	-2,436%
Palatino (Koeler Map)	4.828,78	2.813,89	1,716
Palatino (1999 base)	4.805,87	2.859,13	1,680
Difference	-22,91	+45,24	-2,142%
Piabanha (Koeler Map)	7.327,10	4.712,09	1,555
Piabanha (1999 base)	7.373,08	4.711,25	1,564
Difference	+45,98	-0,84	+0,575%

Table 2 - Measurement of the sinuosity parameters to each of the three main canals.

The Quintandinha river was the one that presented the greater variation in the calculated sinuosity rate, when comparing the Koeler Map and the cartographic base of the year 1999. The sinuosity rate in this river has diminished from 1,523 to 1,487, which shows a greater rectilinear shape progressing in this section of the canal. This diminishing is a reflex of the modification of length values at the section of the canal (Cc), which has reached the value of 197,99 meters, and of the vectoral length (Cv), much smaller, reached around 11,65 meters. Along with other results obtained, this is an important index that helps understanding the flooding problems at the region. For the values obtained in the Palatino river, the length (Cc) has modified in 22,91 meters and raised in 45,25 meters for the vectoral length (Cv). The considerable difference in the vectoral length can be due to the positioning of the map in a known system of coordinates. Last, the Piabanha river is the one which presented the least variation in the sinuosity rates (+0,575). The length values of the canal section (Cc) have raised 43,98 meters and the vectoral length has had a small variation in the vectoral distance (Cv) of -0,84 meters.

The results of sinuosity rates show that there were alterations to the three main canals of different proportions. It is necessary to take into account that the Koeler Map holds positioning and precision errors linked to its elaboration and manipulation in a GIS environment. Thus, when thinking about quantitative measurement, the variations can be greater or smaller than the presented values. However, they are not very significant in the face of the cartographic criteria used to evaluate them, which meet the parameters of the class A of 1:50,000 scale (BRASIL, 1984). On the other hand, when taking qualitative aspects into account, when making a comparison, it is possible to note variations on the sinuosity of the rivers, and they thoroughly meet the quantitative data gathered.

The canals shape: canals width

The canals width was measured using the Euclidean distance measuring and, thus, an option was made to show the maximum, minimum and medium results of each of the scenarios. The table 3 presents the results.

River Canal	Max. (m) width	Min. (m) width	Medium (m) width
Quitandinha (Koeler Map)	33,92	4,27	9,88
Quitandinha (1999 base)	14,08	0,0	8,27
Difference	**-19,84**	**-4,27**	**-1,61**
Palatino (Koeler Map)	22,48	0,0	8,37
Palatino (1999 base)	12,90	0,0	7,24
Difference	**-9,58**	**0,0**	**-1,13**
Piabanha (Koeler Map)	29,5	0,5	16,41
Piabanha (1999 base)	17,12	0,5	9,37
Difference	**-12.38**	**0**	**-7.04**

Table 3 - Measurement of the width of main canals

The greater variation found in the maximum width of the canal are on the Quitandinha river, with differences of 19,84 meters. Along all analyzed canals, comparing both documents used, one can notice the suppressing of features, river islands, as it was mentioned by Fernandes et al. (2017). Another relevant aspect about Quitandinha river is that the medium value of width in the canal has suffered a variation of only 1,61 m. One can say that the sharpest width variation occurred in an occasional manner and they were concentrated in some sections of the Quitandinha river. The Piabanha river presents the greater variation in medium width amongst all (7,04 m) and the Palatino the smallest (1,13 m). With respect to the maximum width, its value was 12,38 m and 9,58 m respectively.

Some sections present great discrepancies when the map of 1846 and the cartographic base of 1999. There is a reference to the existence of river islands in the Koeler Map, where such references have ceased, due to the modification of the rivers course and its rectilinization process. Figures 5 and 6 present four sections where the cited alterations in respect to the measurements and the suppression of islands are more evident.

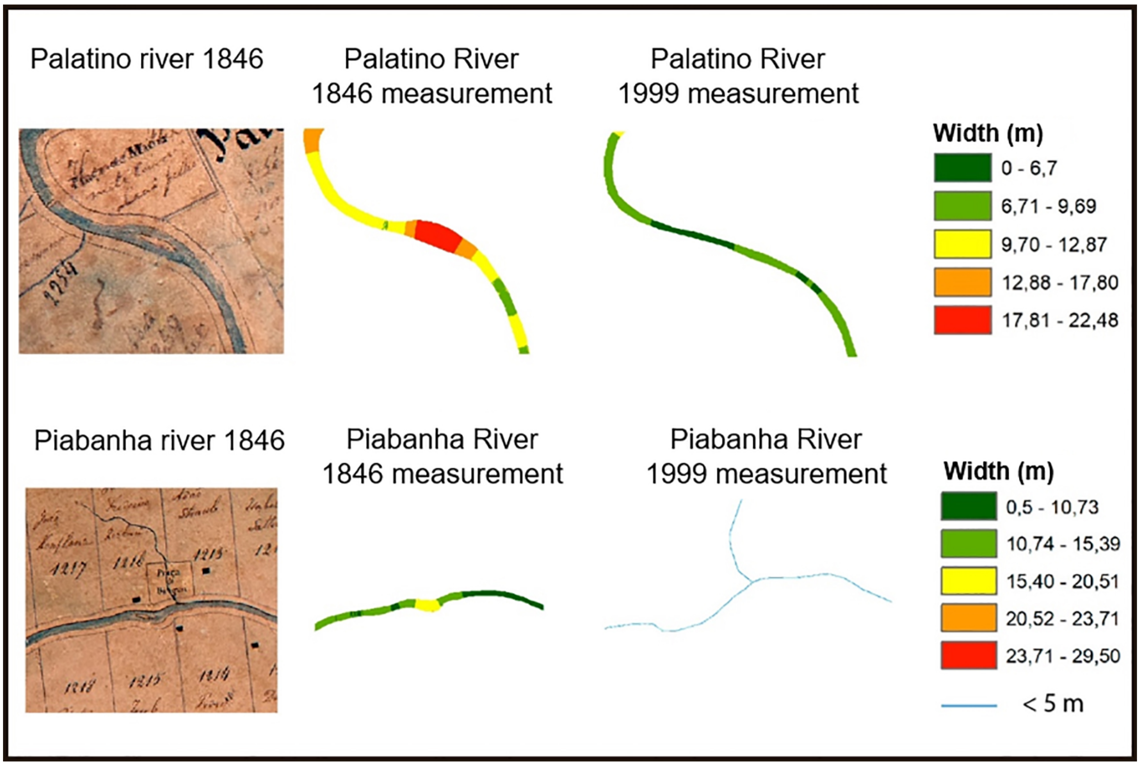

Figure 5 - Sections of the Palatino and Piabanha rivers with the suppressing of river islands.

The illustration above shows a section of the rivers Palatino and Piabanha with the suppression of river features, in this case, of islands. In these two rivers the suppression of one island in each river has been identified. It is possible to say that, due to that suppression, theses sections had a larger width in the Koeler Map than in the 1999 base. This same pattern repeats itself through the canals, even without the suppression of other river features. In figure 5, the caption indicates a 17,81 to 22,48 meters width to the section of the Palatino river, which was not the case through the course of the canal in the 1999 base. In the highlighted section at the Piabanha river, the width values have reached the value of 15,40 to 20,51 meters, and when the same section is analyzed in the cartographical chart of 1999, is possible to realize that the areas of greater width were suppressed, as well as the features of the river island themselves. For the Piabanha river, the highlighted section in the figure 5 was represented as a simple line, which, on the mapping scale of the 1999 base, indicates section with a 5 m width at max.

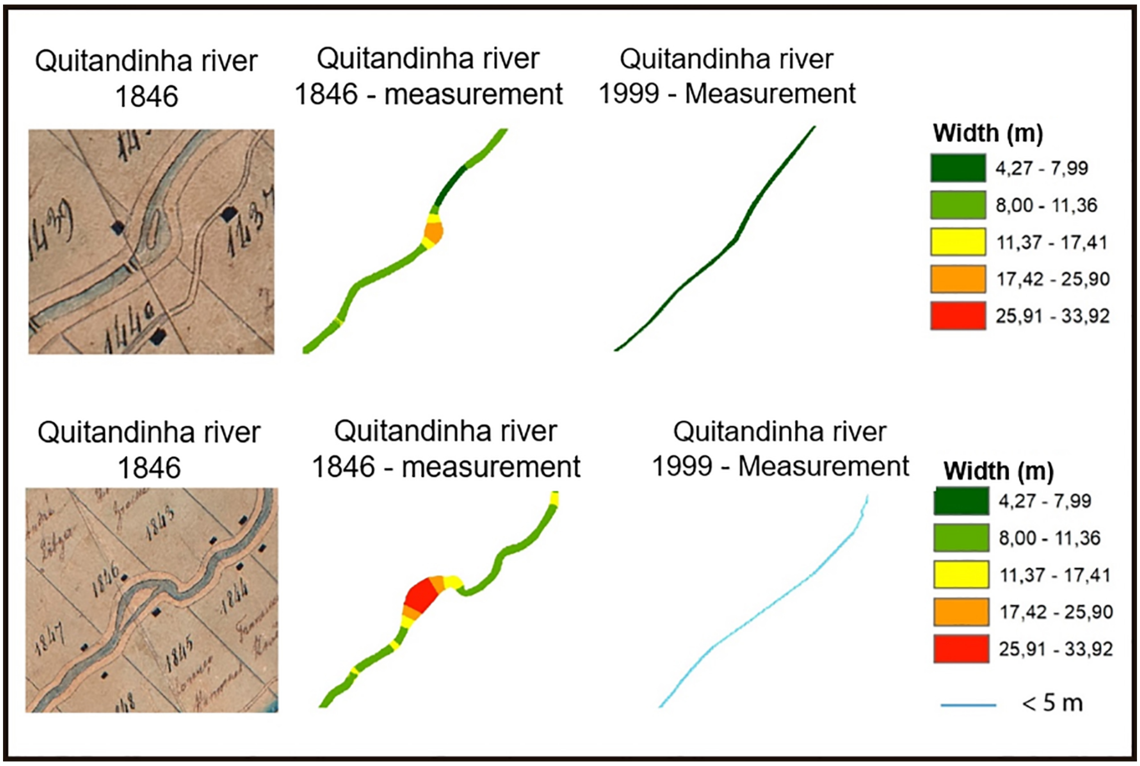

Figure 6 - Sections of the Quitandinha river with river islands suppressed.

The suppression of two river islands is identifiable, for both sections of the Quitandinha river presented on the figure 6, one in each presented section. To all of the area of analysis, the suppression of four river islands was identified, two at the Quitandinha river (measuring 847 and 132 square meters), one at the Piabanha river (218 square meters) and another at the Palatino river (195 square meters). The second section of the Quitandinha river, presented on the figure 6, was also mapped in the cartographic base of 1999 as a simple line, which hindered direct comparations with the 1846 map. However, through a field survey, it was possible to verify that the section was modified, holding a smaller than or equal to 5 m width.

When the data of sinuosity rates of the canal sections are confronted, some points are noticeable because of their behavior. The Quitandinha river has presented a diminishing in its length, a reduction on the sinuosity rate and a lot of difference in the value of maximum width measured on the two dates. This allows for the reading that the river has had a greater rectilinization and narrowing of the riverbed. The Palatino river presented a similar pattern, with a reduction of the canal's length and the reduction of the sinuosity rate but showing a low reduction on the maximum width and medium width. This encompasses the same reading of greater rectilinization and narrowing of the riverbed. Last, the

Piabanha river has presented the smallest variation on the sinuosity rate, allowing for the conclusion that it was roughly maintained. On the other hand, it is possible to deduce that the river has suffered few alterations in its sinuosity but had a reduction in the riverbed at the course of the considered time span.

Mapping of soil covering and flooding register

The mapping of soil covering aims at calculating the covering for the basins area. From the calculation of classes areas in each basin, one could observe the edification level of each one of them. The edification level can be understood as the percentage of anthropic areas, or non-vegetation coverings, such as rocky outcrops. It is important to notice that the variable level of change expresses how much of anthropic area is on the basin, therefore, we can thus define how much of this area was altered since the Koeler Map, when there was no effective occupation in the analyzed landscape. In the table 4 are shown the river basins and their respective percentage of edification.

River Basin	Vegetation (km²)	Non-vegetation (km²)	Total (km²)	Change Level (%)
Quitandinha	5,72	7,52	13,24	56,78
Palatino	6,60	3,48	10,08	34,51
Piabanha	16,77	7,76	24,53	31,62

Table 4 - Level of change in the river basins.

Analyzing the table 4, it is noticeable that the Quitandinha river basin holds the biggest level of change in the soil coverage. This result meets the values that refer to the rivers sinuosity. Thus, one can observe that the Quitandinha river, which presents least sinuosity, is a part of the river basin with the greatest level of change. This pattern is repeated on the other analyzed rivers and basins. Thus, the Palatino river holds the second smaller sinuosity rate and the second greater level of change in the landscape, and the Piabanha river presents the greater sinuosity rate and the smaller level of change in its basin.

This same behavior happens when the level of change is related to the width and the suppression of islands in the analyzed basins, creating the conditions to allow for understanding how the flood occurrences are distributed. These floods, identified in the period from 2011 to 2018, where mostly identified in the rainfall and gauging stations located on the basin of Quitandinha river (93,1%), followed by the basins of Palatino (5,7%) and Piabanha (1,2%), that is, the floods that are concentrated on the basin with the least sinuosity, greater modification on width, greater suppression of islands (in quantity and area) and greater level of change. The figure 7 presents the juxtaposition of the usage and soil covering map to the distribution of floods identified in the rainfall and gauging stations in the analyzed basins. In this figure it is possible to see that the river basin with less area of vegetation is the one to present a greater number of floods.

The genesis area of Petrópolis has developed in a mountain landscape filled with quite steep slopes and valleys surrounded by mountains bottoms. The usage and covering mappings has left clear that the areas with vegetation are concentrated in these largely steep slopes, and at the valley bottoms the non-vegetation features are spread, pressuring the river canals, which had their courses altered to fit the factory edifications that were building up in Petrópolis, as well as the growing demand for housing (ANTUNES, 2017; AMBROZIO, 2008). Therefore, analyzing the map on the figure 7, one can observe that the area with more flooding is set on the basin with larger levels of change in soil coverage, which, in its own turn, was also where the greater modifications in the river features have occurred. It is important to notice that these flooding conditions do not only limit themselves to the covering dynamics and river features, since many other elements that constitute the landscape and bare relations to the floods were not addressed. However, the analyzes at hand already greatly suggests the correlation between the analyzed elements in the face of the flooding phenomenon.

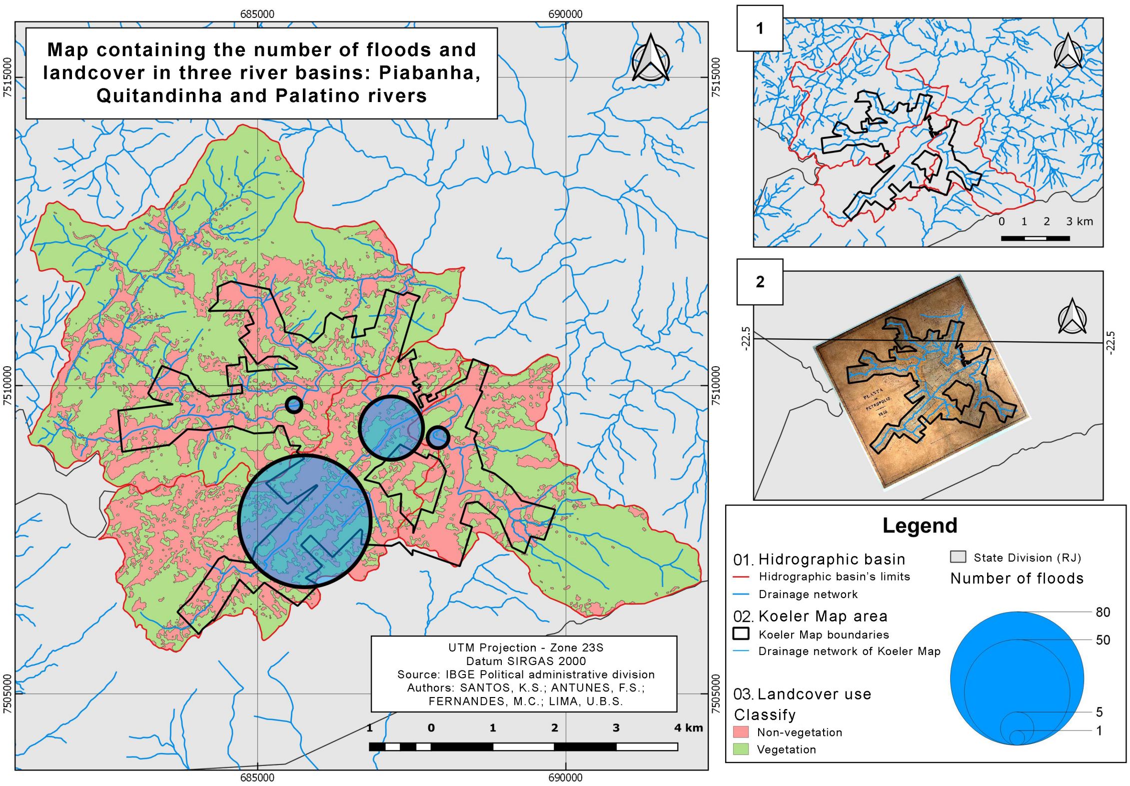

Figure 7 - Map compiling data on floods and soil covering in the area of the studied drainage basins, and its cropping by the Koeler Map

CONCLUSIONS

The Historical Cartography has had a growing participation in the studies for understanding the landscape dynamics and in the investigation of phenomena of different natures. Concerning research in Geography, the analysis of the dynamics of landscape is a quite consolidated approach. In so being, Historical Cartography has a great potential in contributing to this kind of approach, highlighting different aspects of the research. As was presented, using a historical document (Koeler Map, 1846) has helped obtaining a set of data about the study field. Using different techniques in an environment of Geographic Information System it was possible to extract, store, manipulate and analyze the dynamic of the sections of the canals in the studied area, with the goal of comprehending aspects that have modified in the course of time.

The employed methodology has allowed the presentation of a set of factors that contribute to the flooding problem in the genesis area of the city of Petrópolis, whose roots assent not only on current actions, but also on historical ones. The calculation of the sinuosity rate and of the width of the riverbeds has allowed us to compare and analyze the shape of the canals through the considered time period.

Answering the first posed question, the sinuosity of the canals has decreased, indicating a greater straight section of the canals. The width of the riverbed is also another measured aspect that can contribute to understanding the number of floods in certain sections. All investigated sections have suffered narrowing in different dimensions and, in some locations where river islands were once observed, it was possible to see that they were suppressed. Together with the first set of analyses, (sinuosity and width of the canals), the classification of the soil covering, and the data obtained in the rainfall and gauging stations installed at the canals have all allowed for the interpretation that number of floods in the considered rivers is due to different associated factors.

We could point out signs that the Quitandinha river section, which suffered the greater alteration in sinuosity and width, has lost the river islands as well as suffered the most degrading of the vegetation area, is the one that registers the greater number of floods. In an opposite direction, the section of the canal of the Piabanha river registers the smallest number of foods and holds the smallest alteration levels in the sinuosity rates and rivers width, as well as in the vegetation area of the river basin. This demonstrates that, in answer to the second raised question, that the floods occur in areas where there is greater modification of the shape of the canals and soil covering.

Based on the previous considerations, we can conclude that the article was able to show the participation of different landscape modification factors, which help in causing floods in the genesis area of Petrópolis. With the aid of historical maps and other analyses in GIS, it was possible to point out to signs that link the registered floods and the canals' shape modifications and soil covering.

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