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MAPPING OF RIO PIRAPÓ'S HYDROGRAPHIC BASIN THROUGH GOOGLE EARTH ENGINE - CODE EDITOR

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ABSTRACT: This works objective consists in the mapping of the Pirapó River hydrographic basin vegetation, for this, remote sensing techniques were employed through Google Earth Engine - Code Editor, having as a base the Normalized Difference Vegetation Index (NDVI), through the Landsat 5 and 8 satellite images, available in 2005, 2010, 2015 and 2018. It was possible, through the results, to identify some dynamics regarding the hydrographic basin vegetation, as the fact that the in the year analyzed the biggest vegetation presence could be found in the river upper course area, possibly thanks to the area slope index that shows a steep relief and the observation of the environmental legislation in the last years. Lastly, it is important to highlight that Google Earth Engine emerges as a new tool for remote sensing, ensure a greater ease in the image processing for monitoring and environmental analysis.

Keywords: NDVI. Remote sensing. Permanent Preservation Areas. Pirapó River. River Basin

MAPEAMENTO DA VEGETAÇÃO DA BACIA HIDROGRÁFICA DO RIO PIRAPÓ ATRAVÉS DO GOOGLE EARTH ENGINE - CODE EDITOR

RESUMO: Este trabalho teve como objetivo o mapeamento da vegetação na bacia hidrográfica do Rio Pirapó, para isso, utilizou-se técnicas de sensoriamento remoto através da plataforma Google Earth Engine - Code Editor, tendo como base o índice de vegetação da diferença normalizada - NDVI, através das imagens do satélite Landsat 5 e 8 disponíveis no período de 2005, 2010, 2015 e 2018. Através dos resultados foi possível identificar algumas dinâmicas a respeito da vegetação da bacia hidrográfica, como o fato de que nos anos analisados a maior presença de vegetação se encontra na área da alta bacia, possivelmente devido a declividade da área que apresenta relevo íngreme e observação da legislação ambiental nos últimos anos. Por fim, é importante ressaltar que a plataforma Google Earth Engine surge como uma nova ferramenta para o sensoriamento remoto, garantindo maior facilidade no processamento de imagens para monitoramentos e análises ambientais.

Palavras-chave: NDVI. Sensoriamento remoto. Área de preservação permanente. Rio Pirapó. Bacia hidrográfica.

MAPEO DE LA VEGETACIÓN DE LA CUENCA HIDROGRÁFICA DEL RÍO PIRAPÓ A TRAVÉS DE GOOGLE EARTH ENGINE - CODE EDITOR

RESUMEN: Este trabajo tuvo como objetivo el mapeo de la vegetación en la cuenca hidrográfica del Río Pirapó, para ello, técnicas de sondeo remoto fueron utilizadas a través de la plataforma *Google Earth Engine - Code Editor*, basándose en el índice de vegetación de la diferencia normalizada - NDVI, a través de las imágenes del satélite *Landsat 5* y *8* disponibles en el período de 2005, 2010, 2015 y 2018. Fue posible identificar que en los años analizados la mayor presencia de vegetación está situada en el área de manantial, posiblemente debido al declive del área que presenta relieve escarpado y observación de la legislación ambiental en los últimos anos. Por fin, es importante resaltar que la plataforma *Google Earth Engine* surge como una nueva herramienta para el sondeo remoto, garantizando mayor facilidad en el procesamiento de imágenes para monitorización y análisis ambientales.

Palabras clave: NDVI. Sondeo remoto. Área de preservación permanente. Río Pirapó. Cuenca Hidrográfica

Introduction

Pirapó River Basin plays an important role in the regional context of the state of Paraná, in addition to being the water source that supplies the city of Maringá-PR. Currently, environmental degradation has been increasing due to the vegetation removal near this river. This article aims at showing the results of a mapping of the changes that have occurred in both, the river basin and the environmental preservation areas of Pirapó River in 2005, 2010, 2015 and 2018, considering the Brazilian environmental legislation. Remote sensing techniques were used.

The vegetation has a great influence on the conservation of soil and water, and Neves (1987) says that, one of the main functions is its action for soil fertilization that results from the decomposition of leaves, branches, fruits, seeds and flowers. Another important factor related to the vegetation is avoiding that rivers, streams and lakes decrease the amount of water, which minimizes their siltation process. In addition, by absorbing water trough the roots, they feed the water tables, which control the balance between infiltration and superficial outflow.

Considering their role as either a barrier or a filter, the riparian forests are important to avoid that sediments, organic matter, soil nutrients, fertilizers and pesticides used in agricultural areas reach the rivers in large proportions. Favoring water infiltration into the soil, recharging aquifers, and protecting the soil at the watercourse banks prevent erosion and siltation, in addition to creating conditions for the gene flow of flora and fauna, food supply for the maintenance of fish and other aquatic organisms, besides the refuge of pollinators and natural enemies of crop pests.

The Brazilian environmental legislation provides standards for protecting water resources, soil and vegetation, such as Law nº. 6.902 of April 27th, 1981 on the Environmental Protection Area; Law nº. 7.802 of July 10th, 1989 on the Agrochemicals; Law nº. 9605 of February 12th, 1998 on Environmental Crimes; and the Forest Code, Law nº. 12.561 of May 25th, 2012. The latter establishes a minimum limit for the Permanent Preservation Areas - APPs.

Pirapó River basin is located in the northern region of Paraná (PR) state and has a drainage area of 5.023km² (Figure 1). According to Cassaro; Carreira (2016), its source is located in the municipality of Apucarana / PR, and it has a length of 168km up to its mouth in Paranapanema River. The vegetation areas of this basin should be protected, however, this does not happen to a full extent.

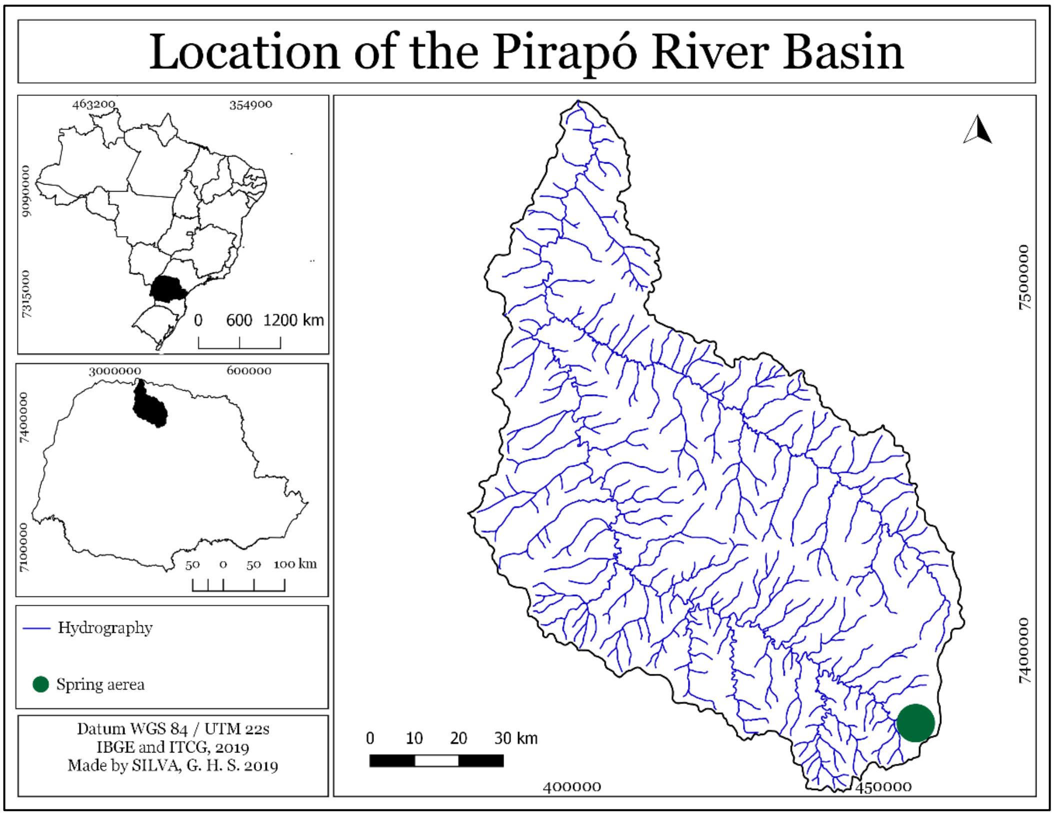

Figure 1 – Map of the location of Pirapó River basin/PR.
Font - Elaborated by the writers

Therefore, this article aims at showing the results of mapping the vegetation of Pirapó River basin by associating its importance and considering the environmental legislation.

Methodological Procedures

It is known that for understanding the changes in the landscape it is important to analyze some aspects and elements, for example, the vegetation removal in the preservation areas, and the lack of inspection in these areas may compromise the environmental quality and the preservation of rivers, streams, lakes, etc.

However, analyzing some of these aspects may be difficult, such as the enforcement of environmental standards. On the other hand, through a multitemporal analysis and using remote sensing techniques, it is possible to map the vegetation in the APPs in order to verify the changes that have occurred in these areas during a certain period, in addition to understanding the social, economic and environmental dynamics in the landscape.

In this context, the transformations and changes of the vegetation in Pirapó River basin were assessed in 2005, 2010, 2015 and 2018 by using remote sensing techniques and including both, the visual interpretation of the images and their digital processing.

In order to analyze the Pirapó river basin, we applied the Normalized Difference Vegetation Index (NDVI) for the four years covered by the study. According to Melo, Sales and Oliveira (2011), the NDVI is an enhancement process among satellite bands, and it is especially used for identifying biomasses and also for estimating vegetation coverage.

Jensen (2011) states that the formula for applying the NDVI is (Pnir – Pred)/(Pnir + Pred), in which "Pnir" is the reflectance of the near infrared wavelength, and "Pred" is the reflectance of the red wavelength.

Melo; Sale; Oliveira (2011) add that the vegetation is characterized by intense absorption in the red region (0,63 – 0,69 μm) and intense reflectance in the near infrared region (0,76 – 0,90 μm). That is the reason why the index relies on both reflectance ranges, thus enabling a high contrast in the vegetated area.

Finally, the NDVI result is expressed as a value that ranges from -1 to 1. The closer it is to 1, the greater is the density of vegetation coverage.

For that reason, taking into account the NDVI results, in order to map the vegetation of the Pirapó river basin, only values higher or equal to 0.6 were selected for they represent a broad vegetation coverage.

The process was carried out with the Google Earth Engine – Code Editor, through which we selected all the images of each year. We used median calculation per pixel of the images from each period. For 2005 and 2010 we used images from the Landsat 5 TM Collection 1 Tier 1 TOA Reflectance satellite. As for 2015 and 2018, images were obtained from the Landsat 8 Collection 1 Tier 1 TOA Reflectance satellite.

We used 14 images for 2005, 11 for 2010, 18 for 2015 and 18 again for 2018. They all had a cloud cover index lower or equal to 2%. The median allowed us to transform all the images into a single one, resulting in the best operation for elaborating the NDVI.

The statistical measure chosen, namely median value, enables the separation of the data set (which consists, in this case, of the satellite images) into two equal parts with the same number of elements, in a way that the number of elements that are inferior and superior to the median will be the same (CORREA, 2003).

The NDVI allowed the elaboration of the river basin mapping for each of the four years. In this case, we considered only the areas whose value is higher or equal to 0.6, thus depicting dense vegetation areas.

For analyzing the APPs, a buffer (areas created from a reference point to a certain distance) was generated, which is an important tool to delimit areas of influence by having the distance of 50m of Pirapó River as a basis. Rigon; Passos (2014) says that, this distance considers the river width that varies from 200 to 300 meters. Concerning the rules of the Forest Code, the rivers with this characteristic must have a minimum of 50 meters of APPs. This procedure enabled to approximately verify the limits of what would be the APPs of Pirapó River.

In order to calculate the extension of the vegetated area of the river basin, we made use of the GRASS GIS r.report with the QGIS 2.8.3 software. The NDVI was used as the basis of each period. Values were obtained as km², and only those higher or equal to 0.6 of the index were considered. In order to calculate the extension of the vegetated area of the river basin's permanent preservation areas (PPAs), the method applied was the same previously described. Yet, it was based on the NDVI only for the PPAs.

Identification of the total extension of the river basin and the PPAs relied on the use of a QGIS 2.8.3 field calculator, through the 'area' geometry tool. Since the given value is expressed as m², it was converted into Km².

In order to assist the analysis and understand the influence of the slope in the basin, a slope map was generated in the QGIS 2.8.3[1] software with the TOPODATA vector base, which is a digital model for elevating the national coverage; elaborated based on the SRTM data (Shuttle Radar Topography Mission), and provided by the USGS (United States Geological Survey).

Afterwards, with the purpose of understanding the dynamics of the basin landscape, a field work was carried out to obtain a qualitative analysis based on the information about the land use, in addition to the river and vegetation characteristics along its banks (PPAs).

Based on the results of the analysis and the use of remote sensing, it was possible to verify the situation of the PPAs in Pirapó River, as well as the changes that occurred in the period herein analyzed.

Remote sensing, definition and application

The remote sensing techniques, such as visual interpretation and digital image processing, have been increasingly used in research, considering that this has become an important tool for obtaining data to assist in the planning and monitoring of the landscape elements, for example, the vegetation.

Historically, human beings seek to know their territory, their living area and even distant places. With the advancement of cartography and technologies, this possibility has increased. During huge wars, a lot of technologies were developed, mainly the infrared film and aerial photographs, with the main purposes of knowing and mapping the territory, especially that of the enemy.

Over time, the technologies to analyze the territory were improved, such as the aerial photographs, which, through specific equipment, enabled to capture images of the surface with the possibility of differentiating the characteristics of the objects and the landscape elements.

According to Jensen (2011), during World War II, the space race began, and in 1957 the former Soviet Union launched its first satellite, which is known as Sputnik. The United States, in turn, launched the Explorer l in 1958. In the early 1960s, the Office of Naval Research group introduced the term referred to as remote sensing as a way of classifying the use of orbital images.

Since the first satellite to the present, the remote sensing has been constantly evolving, with new techniques, equipment, studies, etc. There are numerous definitions of remote sensing, for example, ‘acquisition of information about the ultraviolet, visible, infrared and microwave of the electromagnetic spectrum in some regions without making physical contact’ by means of instruments located on platforms, such as aircraft or satellites. In addition, the analysis of acquired information can be performed through visual interpretation or digital image processing (JENSEN, 2011).

The main instrument of remote sensing is referred to as sensor that is responsible for recording the EMR (electromagnetic radiation), which has a very fast response between the sensor and the remote phenomenon. One of the main uses of the remote sensing is focused on environmental analysis through an interaction among the satellite sensor and the objects of the land surface.

Considering vegetation, all plants go through the photosynthesis process, that is, they store energy for their survival. This occurs in the presence of light through the leaves and other green parts of the plants. When a plant receives electromagnetic energy, it absorbs one part and reflects another, that is, a green plant absorbs the wavelengths of the visible spectral region, which ranges from 0.35 µm - 0.70 µm, mainly in greater proportions; the wavelength is responsible for the blue and red colors.

According to Jensen (2011), when dealing with the reflectance of healthy canopies, the near infrared is the most indicated one because the plant has a spongy mesophyll inside it that is responsible for the reflectance of 40% to 60% of the energy.

The assessment of vegetation by using the remote sensing became very important in the 1960s; scientists extracted biophysical parameters from the vegetation, which enabled the development of new vegetation indices. Such indices are radiometric measurements that indicate the activity of green vegetation, such as percentage of green cover, chlorophyll content, green biomass, absorbed radiation, etc. (JENSEN, 2011).

Jensen (2011) completes, the first vegetation index appears with Cohen in 1991; it is known as Simple Ratio (SR), and it is the ratio between the value reflected in the near infrared (Pnir) and the value reflected in red (Pred): SR = Pnir / Pred

The Normalized Difference Vegetation Index is another example, which is a non-linear form of the simple ratio. This index enables to monitor seasonal and interannual changes concerning the vegetation development and activity. Moreover, this index reduces the forms of noise in the differences of solar illumination, cloud shadows, among others, which are present in the bands of the images.

The NDVI formula is based on the gain and ratio between the near infrared band and the red band, as it follows:

NDVI = Gain * [(A-B) / (A + B)] + OffSet
A = Near infrared band
B = Red band
The Gain and Offset parameters must be tested as there are no defaults for them.

In addition to the digital image processing and the use of the NDVI for mapping the several elements of the images so that they can subsequently help in the analysis, the use of image visual interpretation techniques based on their elements is necessary, that is, texture, shape, size, color, pattern, among others (FLORENZANA, 2002).

Color as a basic element of analysis is also of great importance. Figure 2 is a false color composition of bands 3, 4 and 5 of the Landsat 8 satellites of an area of the Pirapó River Basin. In this composition, the vegetation appears in red due to the influence of the high reflectance of these elements in band 5.

The texture can be smooth or rough, which facilitates the understanding of the type of vegetation in the area analyzed. A rough texture may be a forest area, whereas a plantation may have a smoother texture in the image. Size and shape may help to identify the plantation type, for example, the rectangular shapes of same size and shape in sequence; with the presence of plots, they may indicate a sugar cane plantation.

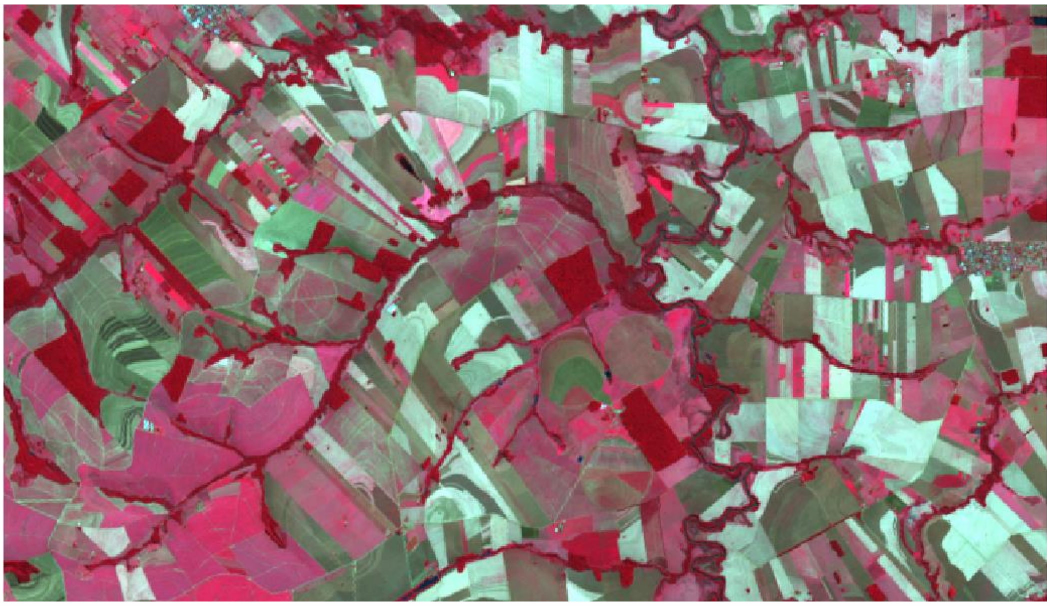

Figure 2 - Landsat 8 image in 2015, area of the Pirapó basin. Band5 (R); Band4 (G); Band3 (B).

Font - Elaborated by the writers

The use of orbital images and remote sensing techniques, including the NDVI, enabled to map the vegetation and to verify the changes that occurred in Pirapó River basin in 2005, 2010, 2015 and 2018, in addition to ascertaining the importance of the rules of the Forest Code.

The importance of vegetation and the Forest Code

Vegetation plays an important role for protecting soil and water courses in river basins, and it should be present in much of the extension of this system, especially in PPAs. Therefore, besides the conservation of the soil, considering its quality and composition, the vegetation helps in its structure.

According to Santos (2007), the area of a river basin shall be limited to a territory drained by a main river, its permanent or intermittent tributaries and sub-tributaries. Its concept is associated with the notion of system, sources, watersheds, hierarchical water courses and mouth.

The water basins are open systems, which receive energy through climatic agents and lose energy through the flowing. Teodoro et al, (2007) says that, these basins can be described in terms of interdependent variables, which oscillate around a standard and, thus, even when disturbed by anthropic actions, they are in dynamic equilibrium.

The vegetation influences the soil, such as the interception made by foliage that absorbs energy from the rain; the roots of the plants increase the soil roughness, which delays the erosion process. It influences the water quality, in addition to contributing to the increase of storage capacity in rivers and streams, and it is used as an ecological corridor for the fauna crossing.

In order to preserve the vegetation, the Forest Code was established in the country in 1934. Considering the changes in government, the transformations related to society and economy, among other factors, the Forest Code of 1934 was reformulated in 1965. Such reformulations brought great advances for the preservation and recovery of natural resources; among them, the increase of areas of permanent preservation along rivers and lakes, both natural and artificial ones, should be highlighted. These have become priority areas for the preservation of native vegetation.

The Forest Code has undergone new reformulations and changes that were published in 2012, under Law nº 12.561 of May 25th, 2012. This new version has been criticized for having elasticized some points that would compromise the preservation of vegetation and rivers, such as, the accounting of Legal Reserve (RL) areas, the difference in the way to measure PPAs, and new forms of RL compensation.

The Forest Code establishes a minimum limit for the APPs. According to article 3, item II of this code, the permanent preservation areas are 'those present on the banks of water bodies, which have the environmental function of preserving them and the landscape, as well as a geological stability by protecting the soil and the water'. These areas must be maintained intact by the owner of a rural property, irrespective of any other provision or condition due to its natural environmental function for preserving water resources and biodiversity.

Currently, with the availability of remote sensing products, for example, the aerial photographs, orbital images, and radars, it is possible to monitor areas for supervision purposes through monitoring. Other purposes can be highlighted, such as the mapping of environmental impacts, deforestation, and river siltation, among others. This is possible by the improvement of the spatial, spectral and radiometric resolution of the sensors in the last years, and the temporal resolution as well.

Mapping the vegetation in the Pirapó River Basin

Analyzing the vegetation of the Pirapó river basin demanded a multitemporal assessment of the basin itself. Therefore, Figure 3 shows a chart with the NDVI results for all periods.

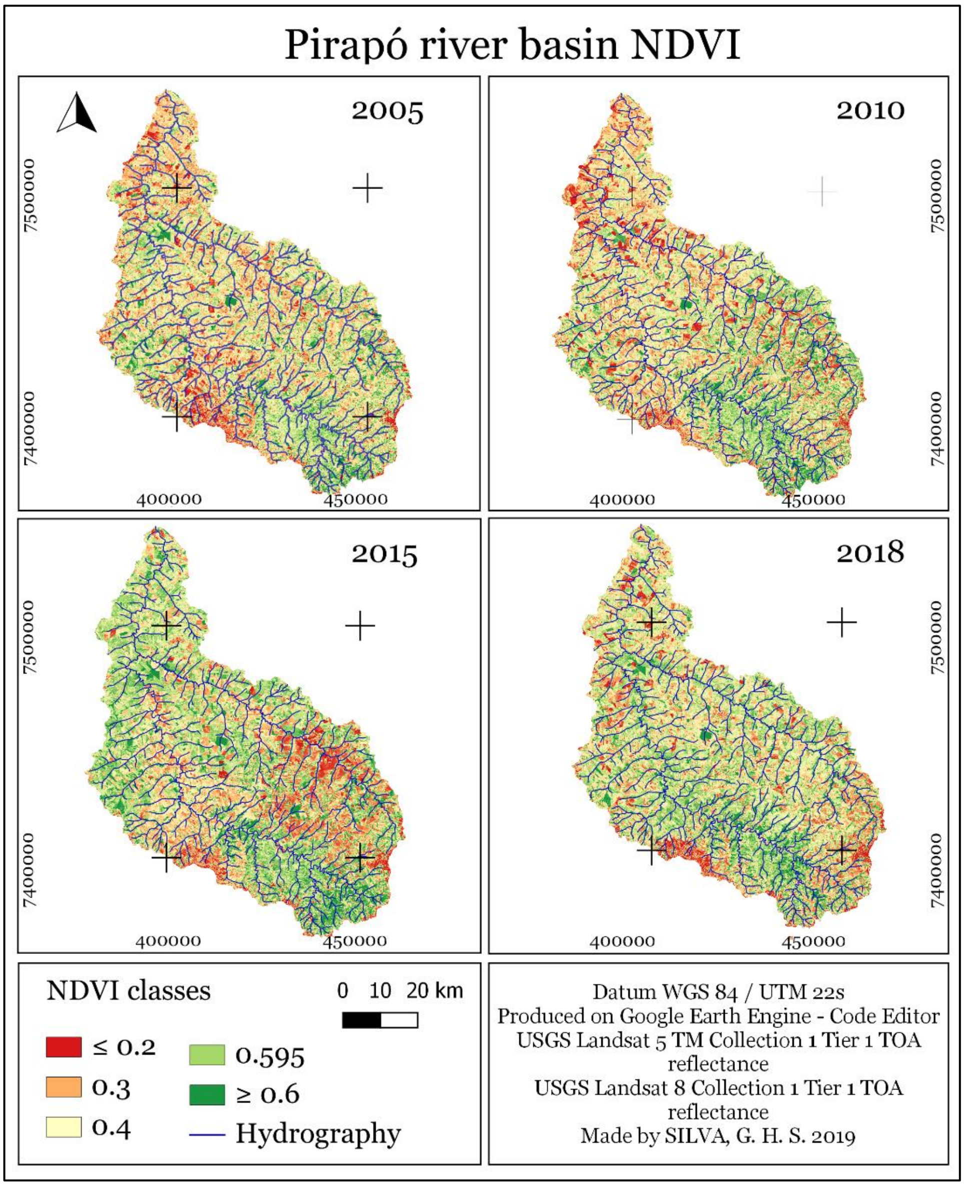

Figure 3 – Chart containing the NDVI of the Pirapó river basin
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By analyzing the chart, it is possible to stress that in the four periods, the source of Pirapó river presents significant areas covered by vegetation, with the highest NDVI values, differently from other areas of the basin. In that area, declivity is more considerable (Figure 4), which hinders the access of agricultural machinery. It also points to an increase in the preservation efforts by land owners, which is boosted by environmental awareness and, mainly, by government inspection in such areas.

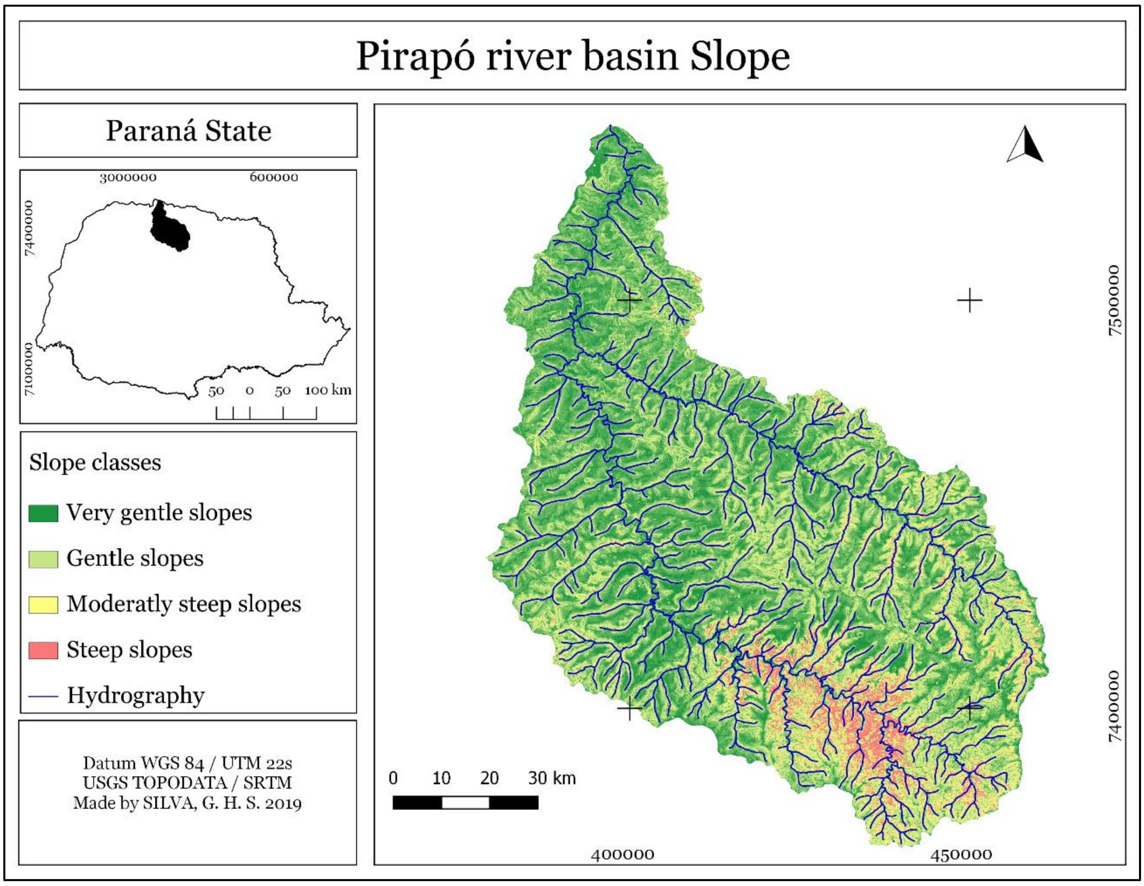

Figure 4 – Declivity of the Pirapó river basin
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The other areas showed a lower concentration of vegetation, mainly in the central and northern parts. However, especially in 2018, there was an increase in vegetation around the river. It is relevant to mention that, in this study, an analysis of the quality of these forest fragments was not carried.

To support the analysis, we devised maps based on the NDVI information whose values are higher than 0.6, thus representing only forest areas.

Figure 6 presents the vegetation of the Pirapó river basin corresponding to 2005, whereas Figure 6 refers to 2010.

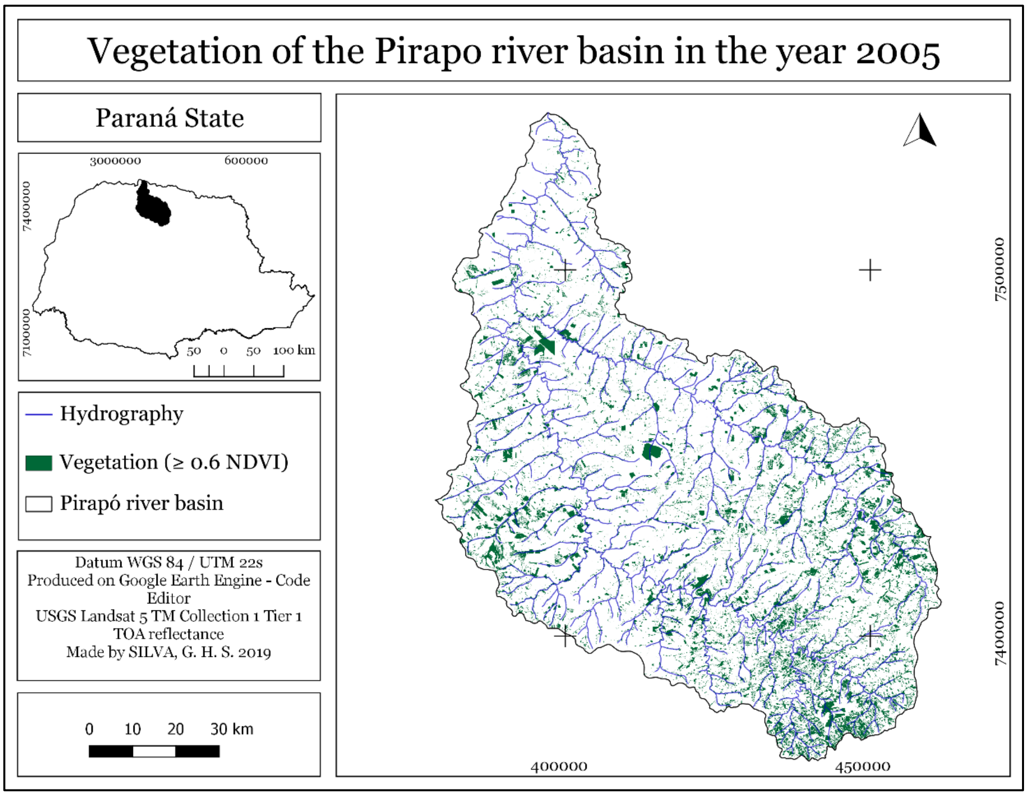

Figure 5 – Vegetation of the river basin (2005)
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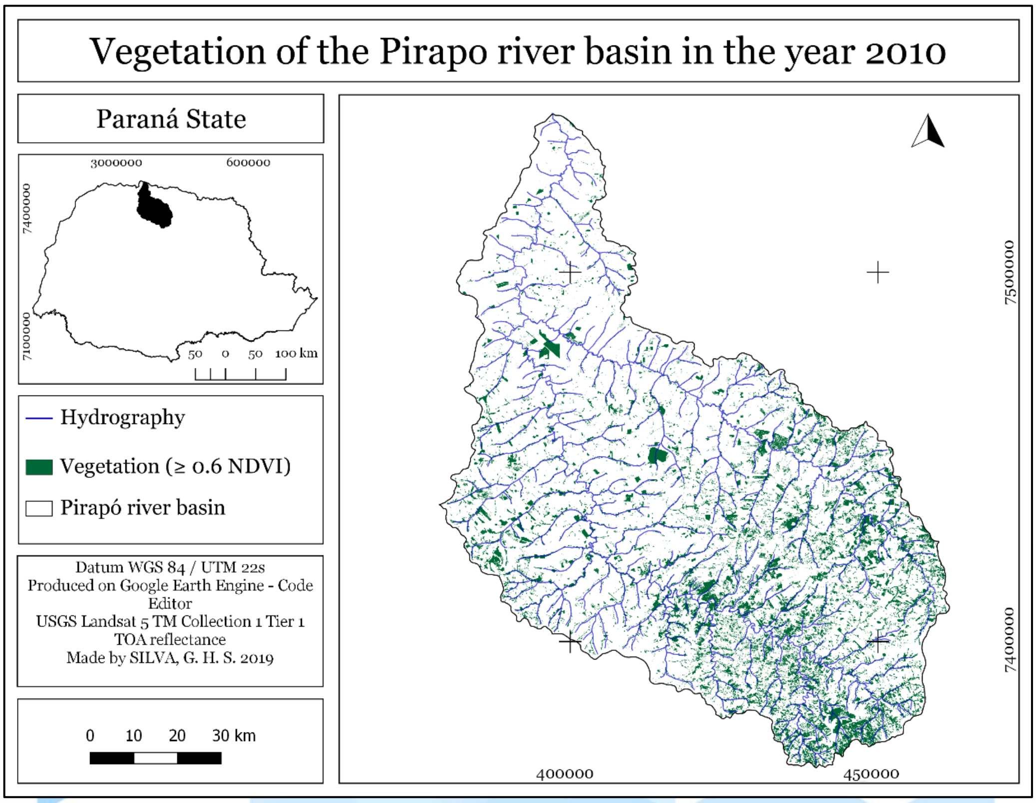

Figure 6 – Vegetation of the river basin (2010)
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Based on figures 5 and 6, we can identify a similar dynamic in the river basin within the periods aforementioned, during which the vegetation concentration was low, with emphasis on the upper course region.

Figures 7 and 8 present the vegetation of the river basin corresponding to 2015 and 2018, respectively. By analyzing them, it is possible to notice an increase in the river basin vegetation, especially comparing 2010 to 2015, and 2015 to 2018.

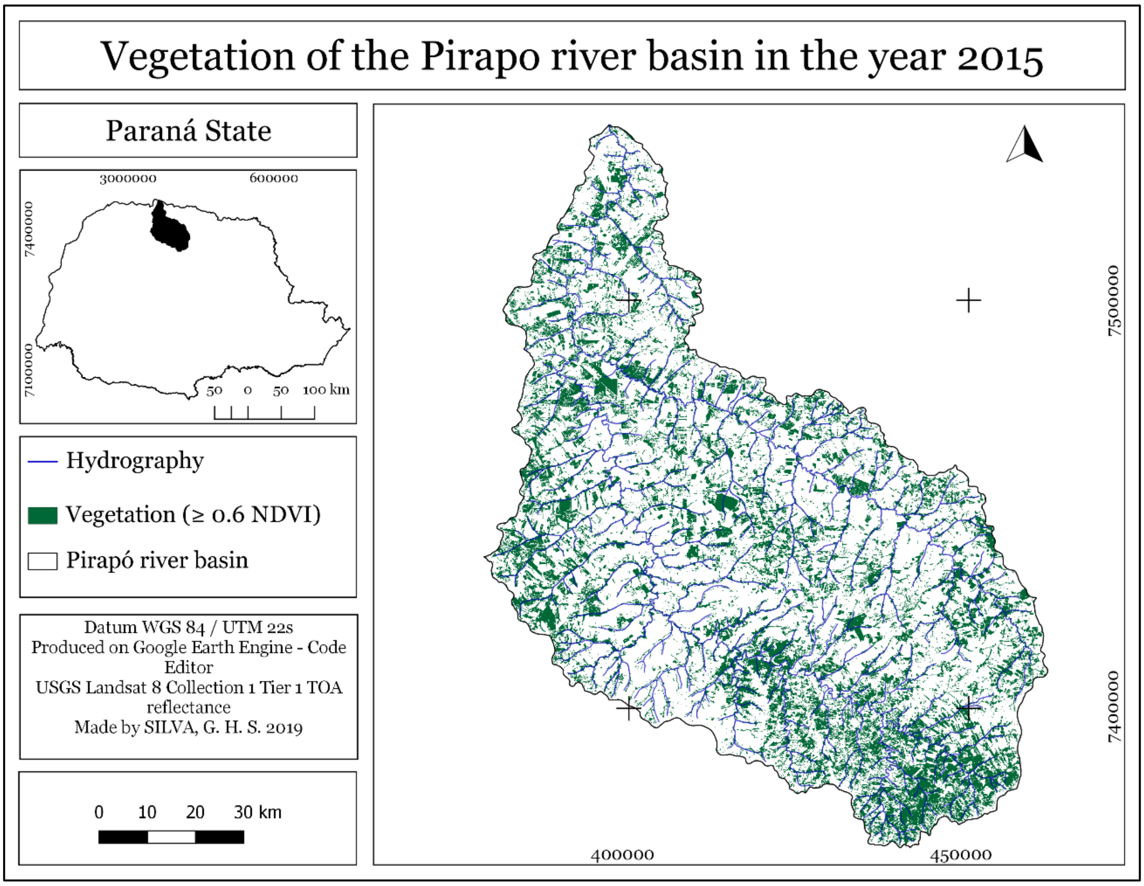

Figure 7 – Vegetation of the river basin (2015)
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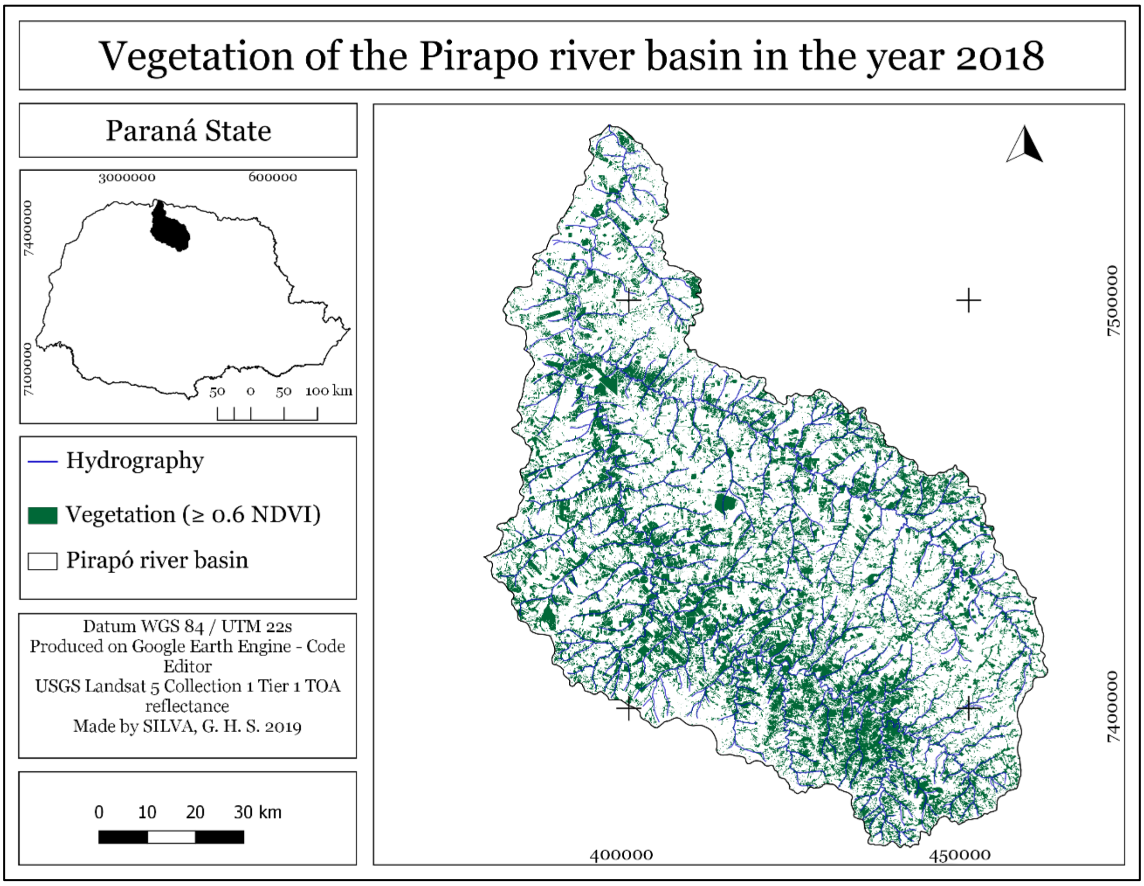

Figure 8 – Vegetation of the river basin (2018)
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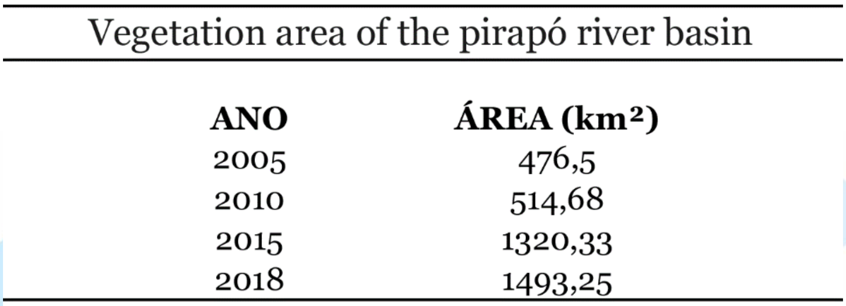
Based on the NDVI results, we conclude that, in 2015, the increase in vegetation occurred in a broad way, mainly in the northern and southern areas. Nevertheless, in 2018 the vegetation around Pirapó river was denser.

In order to support the analyses, we devised a table for the total vegetation amount in the basin expressed in km² (Table 1), and also for the permanent preservation areas (PPS) in particular (Table 2).



Vegetation area of the pirapó river basin

ANO	ÁREA (km²)
2005	476,5
2010	514,68
2015	1320,33
2018	1493,25

Table 1 – Vegetation area of the pirapó river Basin
Font - Elaborated by the writers

Vegetation of permanent preservation areas (PAA) of the Pirapó river basin

ANO	ÁREA (km²)
2005	38,44
2010	38,19
2015	90,84
2018	110,68

Table 2 – Vegetation of PAA of the Pirapó river basin
Font - Elaborated by the writers

By taking Table 1 into account, we can see that the river basin vegetation had an increase throughout the years. Since its total extension is 5.098 km², in 2005 only 9% of its total area were covered by vegetation. On the other hand, in 2018, the vegetated area corresponded to 29%.

There was also difference if we compare 2010 and 2015, since there was an increase in vegetated area of 156%, which means that it went from 514 km² to 1320 km².

Table 2 also shows an increase in vegetation of the PPAs. Even though there was a slight decrease corresponding to 0,25 km² in 2005 and 2010, vegetation coverage increased again in 2015. Considering that the river basin has 207km² of permanent preservation areas, in 2005 18% of such area were covered by vegetation, whereas, in 2018, the PPA vegetation coverage reached 53%. The comparison between 2010 and 2015 evidences an increase in vegetated area of 136%, and a 22% increase if we compare 2015 with 2018.

In order to analyze the evolution of PPAs' vegetation, we selected some parts of the upper course, middle course and river mouth (Figures 9, 10, 11 and 12)

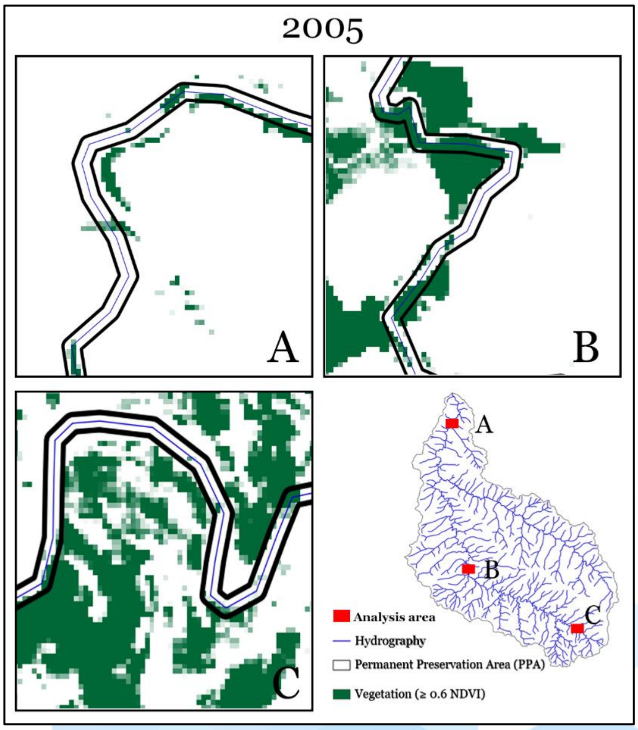


Figure 9 – Parts of the basin, Permanent Preservation Areas in 2005
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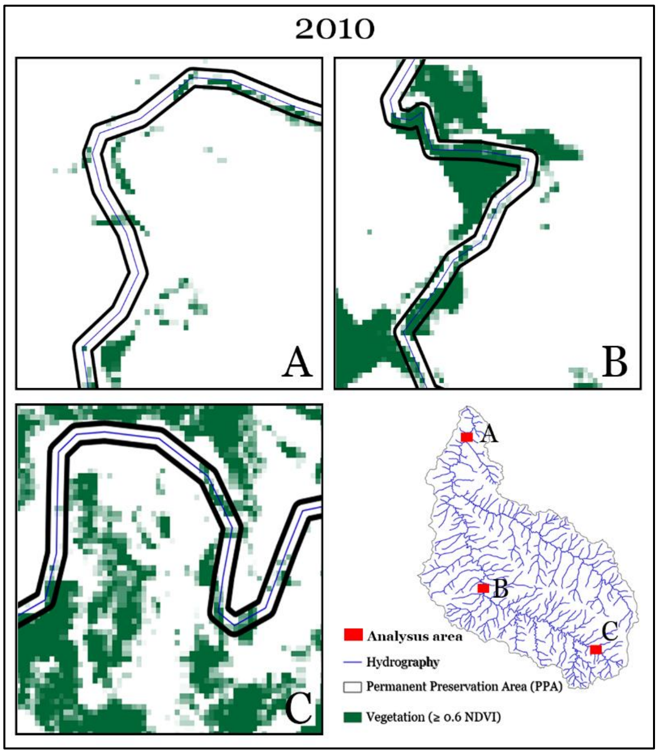

Figure 10 – Parts of the basin, Permanent Preservation Areas in 2010

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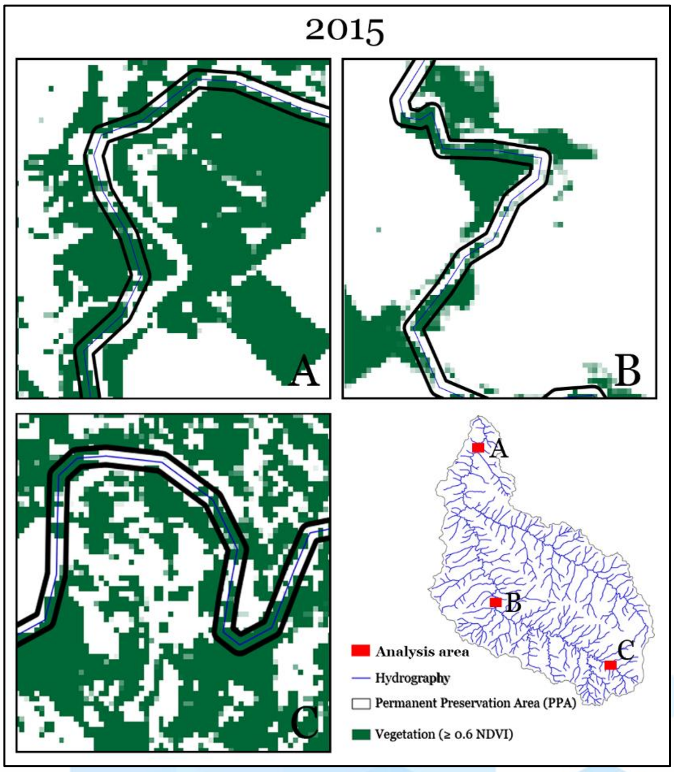

Figure 11 – Parts of the basin, Permanent Preservation Areas in 2015

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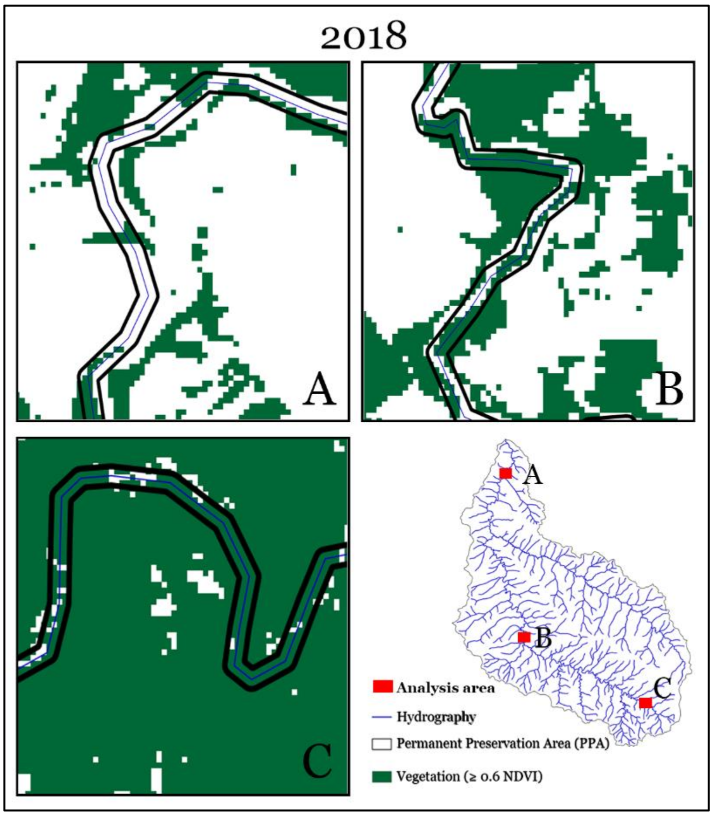

Figure 12 – Parts of the basin, Permanent Preservation Areas in 2018

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Part (A) is in the mouth of Pirapó river, part (B) is the in middle course area and, finally, part (C) is in the river upper course area.

Based on part (A), we can notice that the area corresponding to the mouth of Pirapó River had almost no vegetation in 2005 and 2010 considering the NDVI. On the other hand, in 2015 the area had an increase in vegetation. In 2018, there was a decrease in vegetation coverage taking into account the NDVI.

Part (B) shows that in 2005, 2010 and 2015 the area had the same proportion of vegetation. In 2018, considering the NDVI data, there was a boost regarding vegetation coverage.

All in all, part (B) was the area that had the smallest amount of vegetation, which can be explained by the fact that it is a region over which agribusiness has great influence because of its declivity, climate and fertile soil. Therefore, crop cultivation, especially soya and corn, changes the landscape, even near the river, which is evidenced by the absence of riparian forest in field observations.

Finally, part (C) allows us to notice a raise in vegetation coverage in a way that even during the first analysis periods the area already showed greater vegetation density. However, it was not part of the PPAs. In 2015, the increase in vegetation was already considerable, especially in the PPAs. Yet, in 2018, we had the most significant increase, in which almost the whole area was vegetated.

Analysis of the PPAs – field observations

Figure 13 shows some aspects related to this analysis through field observation. The main cultivation of the basin is soybean, followed by corn and sugarcane. Only a few areas have pasture. On the one hand, this is influenced by the economic dynamics of the region, that is, the agribusiness, and, on the other hand, by the characteristics of the relief, soil and climate of the region.

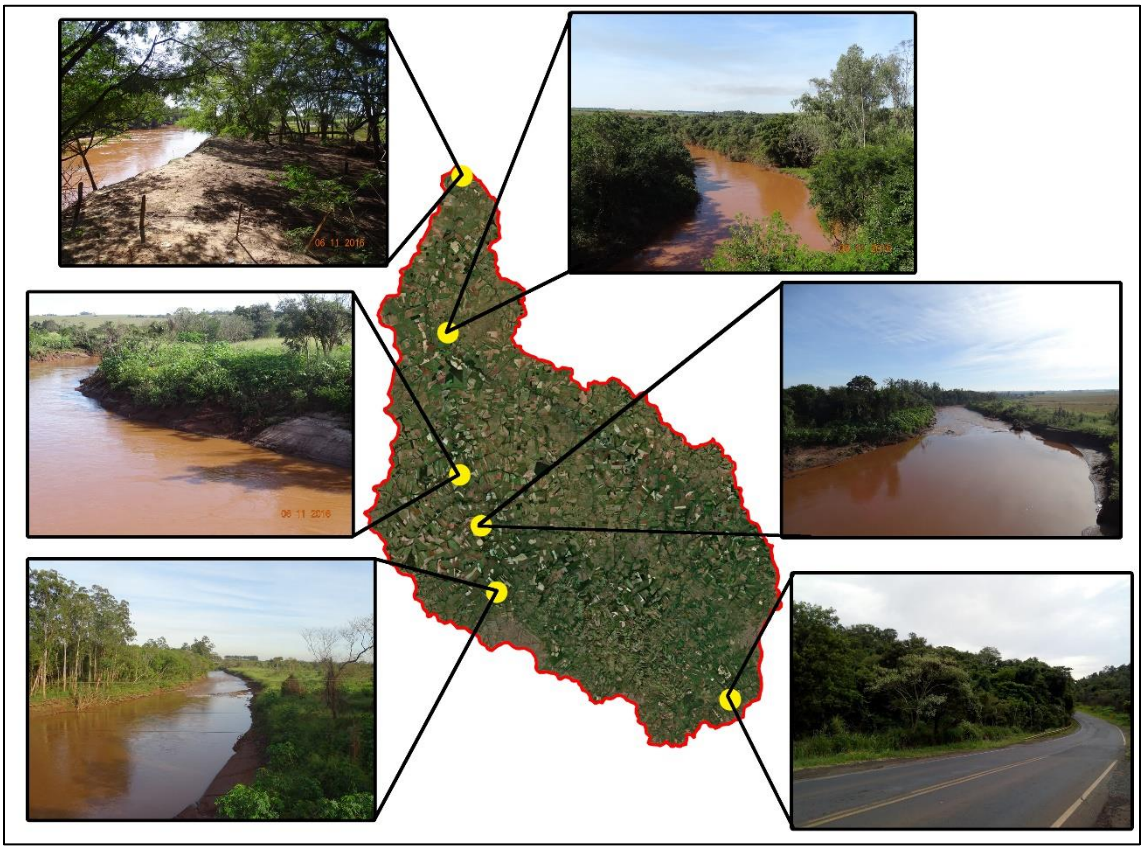

Figure 13 - Field observations carried out on 11th June, 2016.
Font - Elaborated by the writers

In the first point, in Figure 13, land use is marked by corn and soybean cultivation, in addition to pasture. In the second point, with respect to the river banks, it was seen that only the left margin had a small area of degraded vegetation and there was proximity of the corn plantation to the river, a factor that may contribute to the siltation process.

In the third point, the area is marked by the presence of pasture and soybean/corn cultivation. A strip of arboreal vegetation was seen on the banks of the river, but it did not include what was required by law. In some areas the presence of sugar cane cultivation was perceived within the range that should be of environmental preservation.

In the fourth point, some changes of the types of culture were seen; in this case, the sugarcane predominated in the landscape. This is due to the influence of alcohol and sugar mills in this region associated with the soil type. In the fifth point, the absence of a bridge was highlighted; such a bridge had fallen down with the water force of Pirapó River due to a rainy period in January 2016. Another aspect to be emphasized is that the whole area of the right bank had flooded due to the same event. It was seen that the right bank did not have any vegetation, with the predominance of sugar cane cultivation in the vicinities.

Conclusions

Based on both, the analysis carried out and the mapping, it is possible to reflect on the conditions of the APPs in Pirapó River, considering the importance of the Forest Code, 2012.

During the 4 years of analysis, the area of the basin upper course was the one that showed the highest presence of vegetation, possibly due to its slope, thus hindering both, the access to mechanization and the concern with this area preservation. In general, there was an increase in vegetation in the basin, principalmente em relação ao ano de 2010 e 2015, especially in the PPAs, even though it does not fully meet the Forest Code norms, However, the most significant increase was in 2018.

The changes that occurred in the Forest Code in the last years (enforced in 2012) may deepen the environmental impacts, since they indicate several detrimental factors for the conservation and maintenance of the preservation areas. An example of this is the non-obligatory maintenance of the APPs in properties smaller than 4 hectares, in addition to the delimitation of the preservation area, which is now considered the seasonal margin of the river. The accounting of Legal Reserves together with the APPs is another negative factor incorporated in the Forest Code.

It should be emphasized that not only the presence of vegetation in the PPAs is enough, but its quality as well, which was not the purpose of the present study. However, the presence of exotic and local species was seen in the field where the vegetation had been degraded.

Another factor worth mentioning is that most of the tributaries of Pirapó River are silted and have no vegetation on their banks; a major factor mainly in the vicinity of the river mouth.

Finally, the techniques of remote sensing and multitemporal analyzes are important tools for monitoring and understanding the dynamics of the landscape, since they will directly reflect on the environmental quality of these areas. The use of Google Earth Engine – Code editor, ensures a faster processing with greater amount of data, which enables more effective analyses.

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