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ORIGINAL ARTICLE

A METHODOLOGY FOR DETERMINING AND ANALYZING PERMANENT PROTECTION AREAS OF PROPERTIES DECLARED IN THE RURAL ENVIRONMENTAL REGISTER- CAR

Uma metodologia para determinar e analisar áreas de proteção permanentes de propriedades declaradas no Cadastro Ambiental Rural-CAR

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Abstract:

The Permanent Protection Areas (PPA) are relevant to ensure vegetation around the drainage network. This paper presents an automated methodology for the extraction of drainage from the river and automated generation of PPA, and analysis of environmental adequacy. The methodology is based on geoprocessing and remote sensing techniques applied to RapidEye satellite images. The analyzed area covers a portion of the Paraíba do Sul river basin, located in the city of São José dos Campos (Southern Brazil). Land use and land cover were determined using a digital classifier and estimated within the APP of four rural properties bordering the river. The digital classification of the RapidEye images was evaluated based on the visual interpretation of high spatial resolution airborne orthophotos, as well as through random points that enabled the generation of the Kappa index and global accuracy, showing high agreement. The analysis shows the inadequate land use practice in some properties analyzed, indicating changes in the areas of PPA over the years analyzed. The results of this research show that the proposed methodology can be used for supervision purposes in properties declared in the Rural Environmental Registry (CAR), thus assisting in the decision-making process.

Keywords: Remote Sensing; Geoprocessing, Permanent Protection Area and CAR.

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1. Introduction

The southeastern region of Brazil has always played an important role in the development of the country, since it has large urban centers and was the first Brazilian region to receive investments in the industrial sector, as well as an important proportion of the production of coffee and sugar cane in earlier times. Recently, with increased water scarcity in the Southeast, the Paraíba do Sul river has assumed greater importance for being the main source of water supply to most of the cities where it runs through (Tedeschi, 2003; Carvalho, 2008; Soriano et al., 2016).

The awareness of the environmental problems caused by the reduction of vegetation around rivers, known as riparian forest, requires an understanding of what it is (Rodrigues and Leitão Filho, 2004). According to these authors, riparian forest is also known as gallery forest, floodplain forest, or river forest, and it is considered by the Brazilian Forest Act (Brasil, 2012) as a Permanent Protection Area (henceforth PPA), which specifies a particular region around water bodies that must be preserved with extension defined according to the width of the river, lake, dam or spring water. In this investigation we consider only rivers and water streams for the PPA determination.

Several researchers have shown the importance of vegetation cover as a natural soil protection agent for the preservation of water sources, and also for understanding how the dynamics of land use and land cover classes interfere in processes related to hydrological flows and water quality (Bertoni and Lombardi Neto, 1985; SAP, 2015; Rodrigues and Leitão Filho, 2004; Sparovek, 2012). The new Brazilian Forest Code, approved in May 25th, 2012, clearly describes the importance of PPA around rivers for the appropriate management of water resources in a region, so that defining and evaluating changes in land use and land cover is considered fundamental to propose actions aimed at planning and restoring vegetation, whenever necessary.

Relevant studies showed a methodology of PPA determination. First, a drainage network is extracted using digital elevation models (DEM) from the Shuttle Radar Topography Mission (SRTM) as input. After, PPA from both springs and rivers can be determined using distance buffers (Mello, et al., 2014; Bonamigo et al., 2017). However, it is noticed from previous mentioned researches that the GIS user is usually responsible for setting-up the buffer distances for each river segment. As a result, this procedure requires time and manual labor. In this sense, the main goal of this work is to present an automated methodology to define and analyze PPA in medium and large river.

environments. The river's layout is defined by image processing techniques that consider color information, such as hue, saturation, and brightness, in multispectral images of the RapidEye satellite constellation, as presented in Namikawa et al. (2016). The PPA are determined automatically through the software developed by Leonardi et al. (2014), for four typical rural properties that have been declared in the Rural Environmental Register (CAR, 2018).

Another significant aspect to be considered for the PPA evaluation is the correct classification of the land use and land cover classes within the rural properties that encompasses the river PPA. According to the Brazilian law, the PPA is a responsibility of the owners of a given rural property. So, the mapping procedure of land use and cover classes was performed using a supervised classification method on a cloud-free RapidEye scene acquired in 2012.

The methodology is an extended version of Paula et al. (2017) which is illustrated with a case study developed for a part of the Paraíba do Sul river (São Paulo State, Brazil). The results of this research demonstrated that the extraction drainage methodology, and its corresponding PPA is a good choice for automatic CAR validation and is encouraged to be replicated in other environments in the country. In addition, this case study resulted in the generation of maps showing a diagnosis for the PPA of each property, based on land use and land cover classifications.

2. Permanent Protection Areas in the Current Brazilian Forest Code

This section refers to the new Brazilian forest code, law number 12.651/2012 (Brazil, 2012) considered as reference for the delimitation of PPA in this work. The new code was approved on May 25th, 2012 and it imposes new rules for the PPA definition. In the previous law from 1965, the PPA for rivers was defined from the upper riverbed, that is, from the highest water level in the flood season. Currently, the limits for the river's PPA are defined from the regular riverbed, and such measures have caused a great reduction in the water sources of PPA. In this paper, the river's PPA was considered in relation to the current law.

The new Forest Code defines the river's PPA in article 4, paragraph I, as the marginal borders of any natural perennial and intermittent watercourse from the edge of the regular riverbed, with a minimum width of: (a) 30 (thirty) meters, for water courses less than 10 (ten) meters wide; (b) 50 (fifty) meters, for water courses ranging from 10 (ten) to 50 (fifty) meters wide; (c) 100 (one hundred) meters, for water courses ranging from 50 (fifty) to 200 (two hundred) meters wide; (d) 200 (two hundred) meters, for water courses ranging from 200 (two hundred) to 600 (six hundred) meters wide; and (e) 500 (five hundred) meters, for water courses with width larger than 600 (six hundred) meters.

The PPA located on private rural properties is considered the owner's responsibility. The current version of the Forest Code is also applied to small properties, which are defined as being those exploited through the personal work of the owner's family and rural family entrepreneur, including settlements and agrarian reform projects. Therefore, these properties should also be inspected regarding the removal of native vegetation, according to the law parameters.

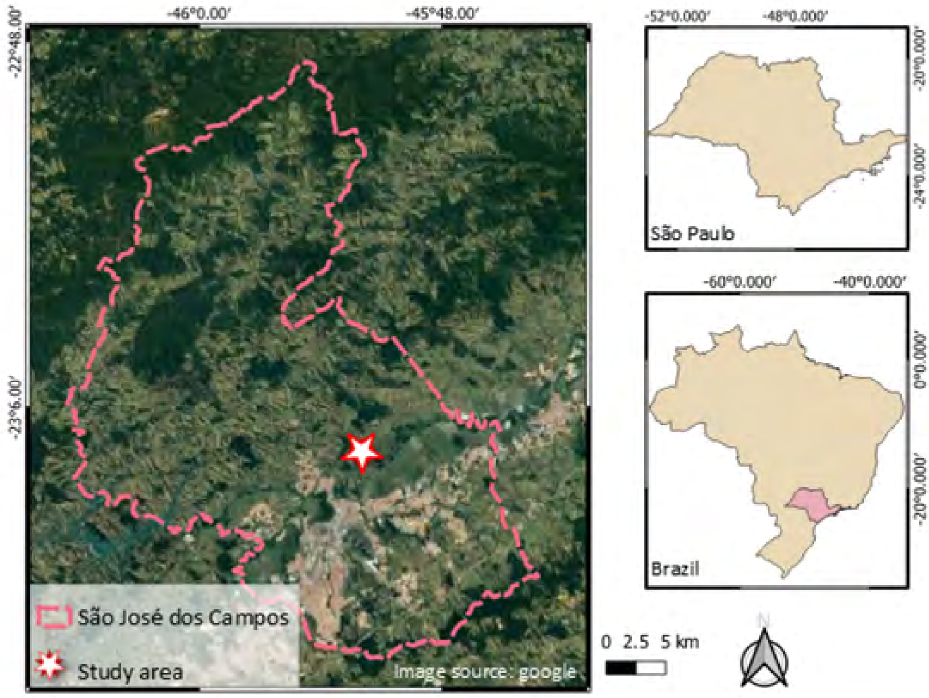
In this context, the Rural Environmental Register - CAR was created through law 12.651/2012, article 29, in order to compose a database with all rural properties to control, supervise and combat deforestation in rural properties and possessions. The CAR is an instrument for mapping both PPA and Legal Reserve (LR), and for applying the Native Vegetation Protection Law. In this paper, the acronym CAR is used instead of its translation given that CAR is well known in the environmental community. It is important to note that, according to the National Institute of Colonization and Agrarian Reform (INCRA,2020), the fiscal module considered in the study area corresponds to 12 ha.

3. Material and Methods

3.1 Case study: experimental areas

The study area encompasses part of the Paraíba do Sul river due to its importance for the water supply of many cities in the Paraíba Valley region (Sao Paulo State). The study area is located in the east part of the Sao Paulo state and passes through the municipality of the São Jose dos Campos city (Figure 1).

It is characterized by a moderate topography ranging from 660 to 975 meters above sea level. According to the Köppen climatic classification, the area is classified as having a dry-winter humid subtropical climate (Cwa type) (Köppen and Geiger, 1928).



Source: The authors (2021).

Figure 1: Study Area.

To test the automated determination of the PPA, four typical rural properties on the riverbank were chosen in the National System of Rural Environmental (SiCAR), the CAR database. The choice was made by visual analysis of the properties that were bordered the chosen river. In figure 2, the red lines represent the property limits.

Source: The authors (2021).

Figure 2: CAR properties chosen for Analysis.

3.2 Data description

A cloud-free RapidEye scene (ID2328411) acquired on 3rd July 2012 was selected. It contains a spatial resolution of 5m, and five spectral bands (e.g. blue, green, red and red-edge). The Environmental Ministry acquired annual coverages from 2010 to 2014 of the RapidEye constellation for CAR purposes. Therefore, the scenes are available for free for governmental agencies at federal, state, and municipal levels. The scenes can be accessed under the catalog (https://geocatalogo.mma.gov.br).

Complementarily, Landsat-5/TM scenes from January 1, 1993 and January 1, 2005, with a spatial resolution of 30 meters, and for red, near-infrared, and shortwave infrared spectral bands were classified individually into different land use and land cover classes. The two dates allowed change detection analysis. The Orthophotos with a spatial resolution of 1 m, were provided by the infrastructure and environment secretary of São Paulo (SICAR, 2012), and were used for validating the digital classification.

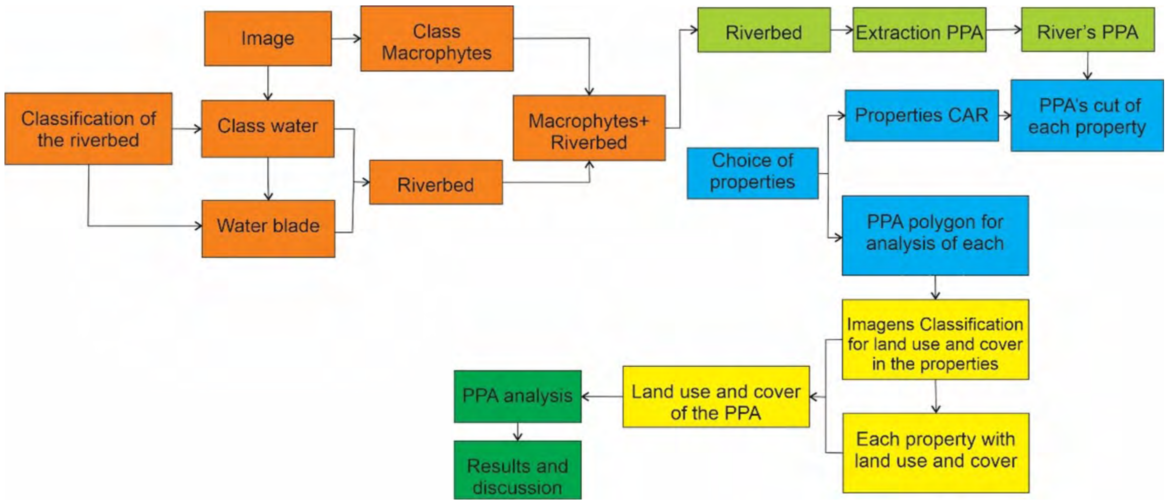
It is important to note that the images used in this work had no atmospheric correction, as related by Ponzoni et al. (2015); Abreu and Coutinho (2014), according to them, such operation is not necessary when vegetation indices will not be used in the analyses.

3.2.1 Properties from CAR database

The CAR is an electronic national public registry that is mandatory for all rural properties with the purpose of integrating the environmental information of the rural properties related to PPA, restricted use, Legal Reserve, remnants of forests and other forms of native vegetation, and consolidated areas. The CAR comprises a database to control, monitor, make environmental and economic plans, and combat deforestation. The online platform of the SiCAR makes it possible to carry out data downloads of any municipality in which the register has already been made. For each property selected for this work, the PPA was automatically delimited.

3.3 Methodology

The main processing steps applied to assessment data can be summarized as follow in Figure 3. The methodology proposed in this work is composed by: the delimitation of the water body, including the areas covered by macrophytes identified in the RapidEye scene, as published in Paula et al. (2017), and are represented by the orange color in Figure 3; the river's PPA extraction, are shown in light green; the clipping of PPA for each 4 selected properties in the CAR database, are represented in blue color; the classification of land use and soil cover for the PPAs are presented in yellow and the analysis and discussion of results, are shown in dark green.



Source: The authors (2021).

Figure 3: Flowchart of the applied methodology.

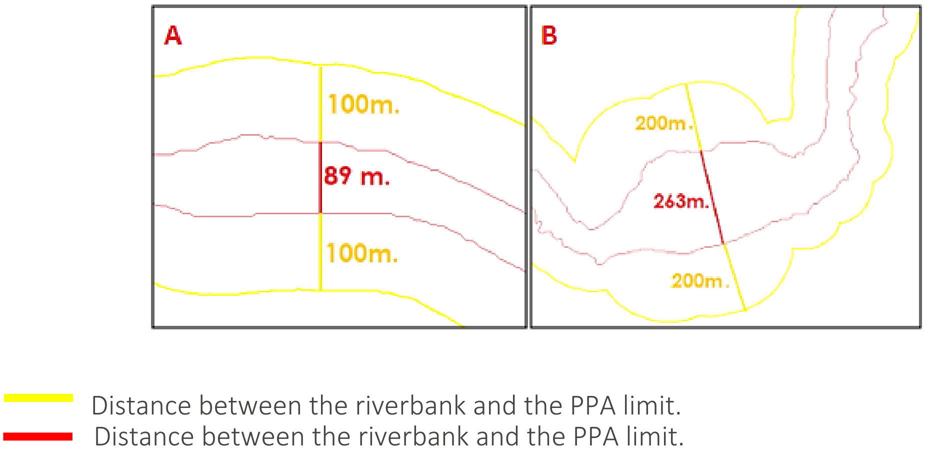
3.3.1 Definition of riverbed outline and determination of PPA

The first part of figure 3, in orange, describes the delimitation of the riverbed by digital image classification. From the RapidEye scene of 2012, the riverbed, which crosses the whole scene, was automatically extracted by the method developed by Namikawa et al. (2016). The method uses color information, such as the Hue component, which is less influenced by mixed pixels. This component results from the RGB color space (red, green, and blue) transformation to the HSI model (hue, saturation and intensity or brightness).

It is important to define which color compositions are most suitable for extracting the Hue component. The minimum radiance value from the five RapidEye bands is used to support the water bodies classification into a seven-class ranking for the "water" target.

After the river extraction, a manual edition was carried out in order to keep only the polygon of interest. From this step, it was possible to identify that the river polygon has some areas with the accumulation of sediments and vegetation of the macrophytes type that interfered in the water reflectance. For this reason, in some parts of the river, it was necessary to manually edit the macrophyte areas to correctly define the river's layout. This step is presented in Paula et al. (2017), who demonstrated the importance of considering the macrophytes for the correct river delimitation and consequently in the definition of PPA.PPA were extracted automatically by a dedicated software developed by Leonardi et al. (2014), executed by TerraHidro system (Rosim, 2008), and which takes into account the properties registered in the Rural Environmental Register (CAR, 2018) and the rules defined by the current Brazilian Forest Code (Brazil, 2012).

PPA extraction is based on polygons classified as river, and also on the definition of each property, according to the CAR database. Figure 4 exhibits two examples of PPA according to this methodology. Example A has a width of 89 m and consequently, according to the law, a 100 m. PPA. Example B presents a bed width of 263 m and then 200 m of PPA.



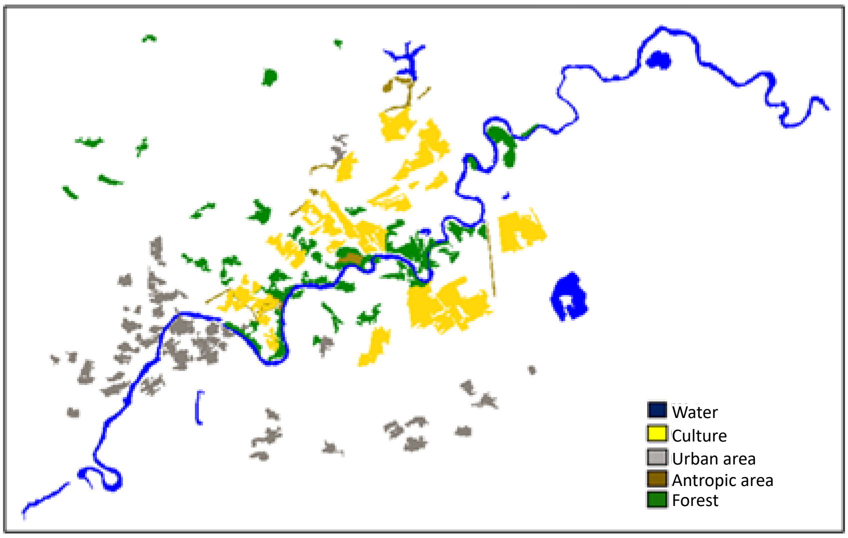
Source: The authors (2021).

Figure 4: Examples of the Permanent Protection Area.

3.3.2 Land use and cover classification

To evaluate the land use and land cover classes within the PPAs, the RapidEye scene was classified using the region-based Bhattacharya classifier (Bhattacharya, 1967), available in the SPRING (Camara et al., 1996). Two hundred and thirty four segment samples were acquired, totalizing 472.014 pixels. Figure 5 shows the selected regions used in this supervised classification.

Afterward, we used the manual classification from orthophotos, considered as test samples. It is possible to derive from a confusion matrix some measures of classification accuracy, such as: overall accuracy and Kappa index (Foody, 2002).



Source: The authors (2021).

Figure 5: Distribution of the segment samples used to train the classifier.

In order to observe the land use and land cover changes over the years, TM/Landsat-5 images from the years 1993 and 2005 were classified. For this, it was used 109 and 68 acquisitions (samples), with 46.880 and 199.713 pixels, respectively. All samples were obtained within the study area and close to the rural properties (Figure 5). In order to validate these results, orthophotos of the year 2011 were visually interpreted and were used as a reference map to obtain a measure of agreement of the land use classification, in relation to the year 2012 classification. The orthophoto was manually classified and cross-tabulation was performed between the reference map (ortophotos) and the RapidEye scene. With the cross-tabulation results, the Kappa index was calculated, and the values summarized the quantitative evaluation of the classification.

Kappa concordance analysis was used to evaluate the classification performance in this study. The Kappa coefficient (K), according to Congalton (1991), is satisfactory in the evaluation of the precision of a thematic classification, because it takes into account the whole confusion matrix in its calculation, including elements outside the main diagonal, which represent the disagreements in the classification, unlike the global accuracy, for example, which uses only the diagonal elements (real agreement).

Although the selected rural properties are still under analysis by the CAR, the owners have not been notified yet. We aim with this approach to deliver results of the reference map (orthophoto) and the other years to determine where irregular occupation within the PPAs exist and that is characterized as a commissive error. In summary, this type of analysis can be performed in any period where images are available and can assist decision makers in diagnosing irregular areas.

4. Results and discussions

4.1 Determination PPA

In order to compare the PPA result obtained in this work, an overlap was made with the PPAs of the properties declared in the CAR, showing a satisfactory result. Figure 6 shows the result of determining the PPA for the northwest of the study area. Automatic PPA tracking is done considering the rules of the current Brazilian Forest Act which considers a riverbed width throughout its course and therefore defines PPAs of different sizes along the river. Using image processing and geoprocessing techniques, it is extremely easy to identify riverbed width variations, whether anthropogenic or natural, and to accurately map the PPA.

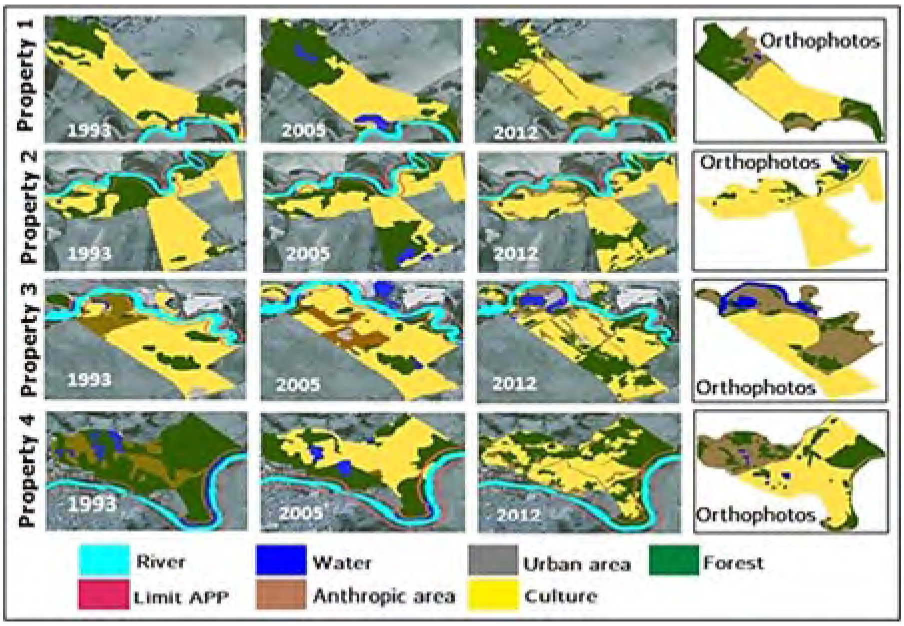
In the case of the manual determination of the PPAs considering a long river such as Paraiba do Sul and with varying widths, the technician has to evaluate the sections of the same width path and partition the river into smaller segments to facilitate this work. With the automatic tracing of PPAs there is a gain in accuracy and time on the processing part and consequently the delimitation of PPAs.

Source: The authors (2021).

Figure 6: Zoom of the PPA determination in the northwest part of the study area.

4.2 Rural Properties classification

Figure 7 shows an overview of the selected rural properties taking into account the time series. The assessment of land use and land cover will focus only what is inside PPA.



Source: The authors (2021).

Figure 7: Land use and land cover in the analyzed properties.

From the above classifications, one can observe that in all rural properties there have been changes in land use and land cover between 1993 and 2005. In the first rural property it is evident that the native vegetation reduzed significantly in area. In the second property, the amount of existing vegetation, mainly near the riverbed, significantly decreased between 1993 and 2005, and in 2012 a large part of its forest area has been converted into agriculture. In the third property, forest fragments (either secondary forest) has their size and location changed. It is also possible to observe that there are small fragments where the vegetation was regenerated, forming small portions of grasslands, shrublands and in some cases even emergent trees, constituting more dense vegetation, being characterized in the classification scheme as forest.

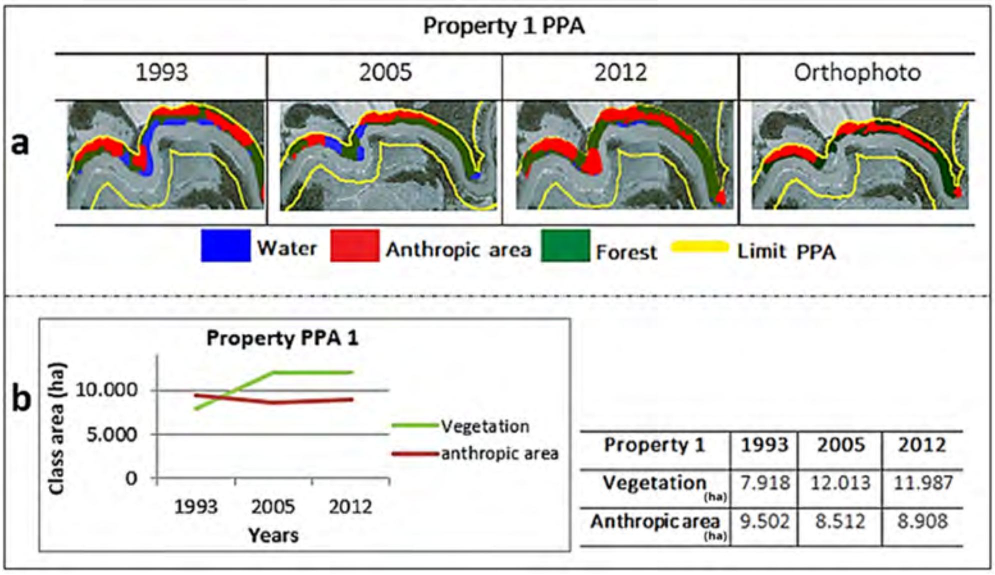
In addition, the classification in 2012 showed a water surface that flooded a considerable portion of the PPA, emphasizing the importance of preserving these areas, which serve as a protection to the river's edges to guarantee a place of escape for the watercourse in the rainy season. In the fourth rural property, it is clear that a great modification of the vegetation occurred, and this scenario was gradually fragmented until 2012. One can also observe that this property is close to the urban area, therefore there are some constructions that were considered as urban areas in the final classification.

4.3 Land use analysis in the PPA

In order to analyze land use and land cover changes, one must understand the dynamics that exists between the human interactions that modify the environment according to its needs. Thus, it is necessary to understand urbanization as a growing phenomenon that demands new challenges from governments requiring plans for concentrated actions. Such actions must be able to meet the needs of the populations to deal with the consequences of this process, which can be economic, social, cultural, and environmental, and that transform the patterns of land use and land cover.

The phenomena of urban expansion have been taking place in the Paraíba river valley region, and the PPA is inserted in this context. The PPA is directly linked to environmental functions, through the provision of basic goods and services for the entire population, from soil conservation and groundwater recharge to ecotourism.

In order to analyze the dynamics within the PPA, all classifications were clipped to follow the PPA limit in each property. Figures 8, 9, 10, 11 and 12 show these results by separating spatially, and by their respective charts and tables, all in hectare units.



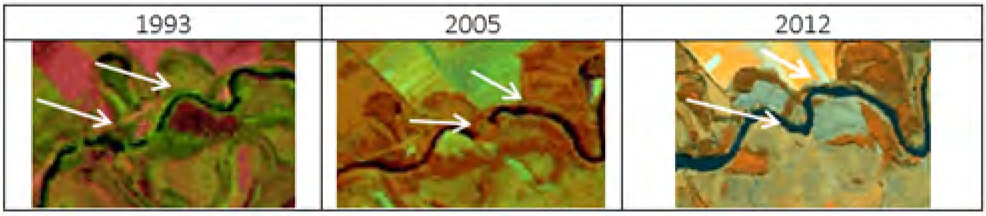
Property 1	1993	2005	2012
Vegetation (ha)	7.918	12.013	11.987
Anthropic area (ha)	9.502	8.512	8.908

Source: The authors (2021).

Figure 8: (a) Land use map and (b) trend graph and results of land use areas in first rural property.

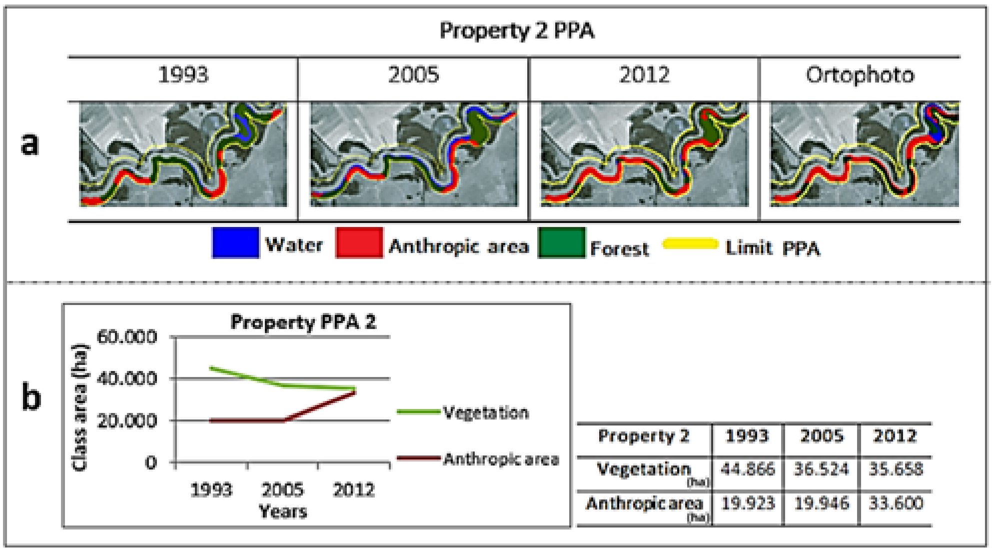
In Figure 8 it can be observed that a decrease in the anthropic area occurred, from 9.502 ha to 8.512 ha. At the same time, the forest area increased between the years 1993 to 2005, going from 7,918 to 12,013 ha.

Another fact to consider is that a small change occurred in the riverbed morphology. This type of alteration can occur by human intervention, when native vegetation is removed, or by natural factors, as noticed in this study after visual analysis (Figure 9).



Source: The authors (2021).

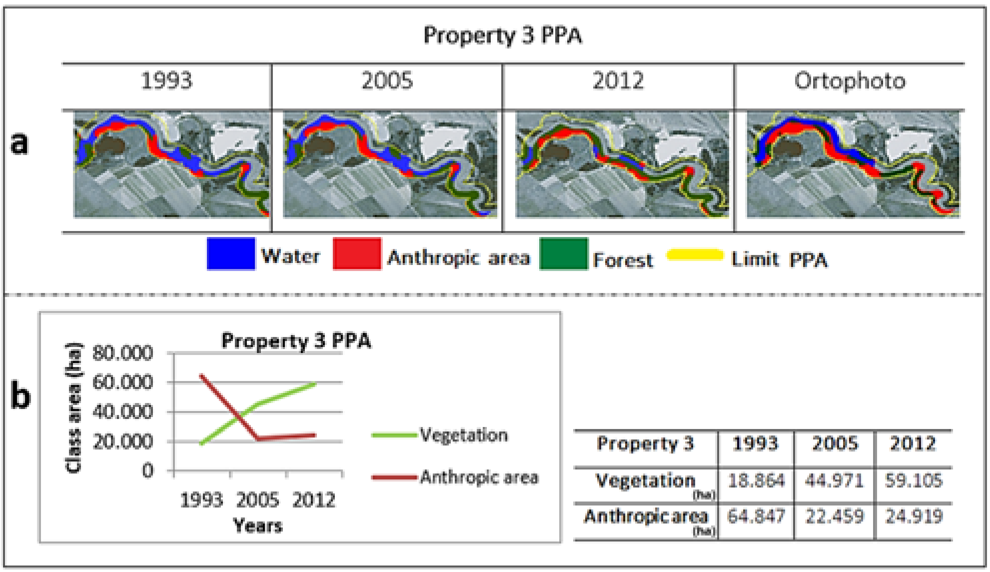
Figure 9: A subset of the study area showing changes in the morphology of the river. Two arrows are fixed in the same places to highlight the changes.



Source: The authors (2021).

Figure 10: (a) Land use map and (b) trend graph and results of land use areas in second rural property.

One notices that in property 2 the vegetation decreased by 8.342 ha, although between 2005 and 2012 by only 0.866 ha. However, the anthropic area increased between 2005 and 2012, from 19.946 ha to 33.600 ha, due to the same factor mentioned above, the river dynamics, which again changed its morphology (Figure 9). The figure 10 shows that the vegetation change increased over the years, and that the anthropic area showed a significant increase in the period from 2005 to 2012.

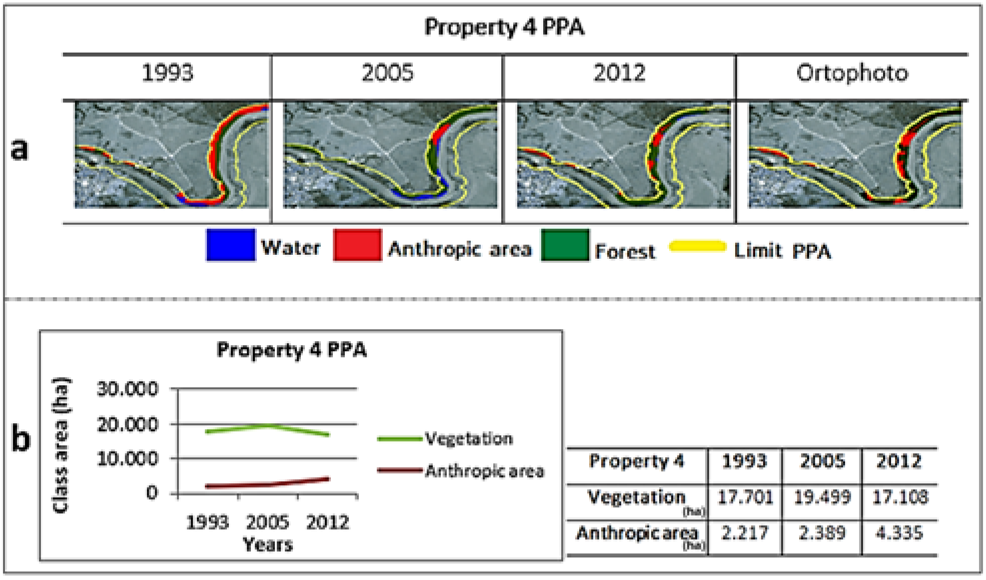


Property 3	1993	2005	2012
Vegetation (ha)	18.864	44.971	59.105
Anthropic area (ha)	64.847	22.459	24.919

Source: The authors (2021).

Figure 11: (a) Land use map and (b) trend graph and results of land use areas in the third rural property.

It can be observed in the figure 11 that a growth of the class corresponding to vegetation occurred, mainly between the years of 1993 and 2005 and an increase of 14.134 ha between the period of 2005 and 2012. The corresponding classes to anthropized area showed a decrease of 42.388 ha between 1993 and 2005, and between 2005 and 2012 there was a small increase. It can be considered that the vegetation class increased significantly while the anthropic area decreased.



Property 4	1993	2005	2012
Vegetation (ha)	17.701	19.499	17.108
Anthropic area (ha)	2.217	2.389	4.335

Source: The authors (2021).

Figure 12: (a) Land use map and (b) trend graph and results of land use areas in the fourth rural property.

The PPA of the property 4 showed growth of vegetation class between 1993 and 2005, and a decrease in 2012, reaching the same area that it had in the year of 1993. The anthropic area presented small increase between 1993 and 2005, and in 2012 an increase of 1.946 ha.

It is important to highlight that the evaluation of land use in the study areas showed the long period that they were undergone irregular interventions regarding to the conservation of the rivers. That result makes possible to identify the places where restoration actions of the riparian forest are necessary. It was possible to evaluate if the areas present demographic and economic growth, directly affecting the demand for food and construction, consequently presenting a strong propensity to irregular occupation within the PPAS for agricultural production or, in some cases, urban expansion, such as the northern part of the city of São José dos Campos, where property 4 is located. We understand that to guarantee the preservation of the water resources we must pay attention to possible future scenarios, where the demand for supplies will be even greater.

4.4 Evaluation of the classification

The digital classification generated from RapidEye image was compared with the visual classification from orthophotos that was used as reference. Table 1 summarizes the concordance index and global accuracy obtained in the classification for each property, based on orthophotos. It is possible to observe that the classifications have presented different kappa values and overall accuracy. This difference is due to the fact that there is confusion between classes that correspond to anthropized and cultural areas in properties 3 and 4. In addition, the variance of all classifications presented values close to zero, indicating that the classification variability in relation to the truth was close to the average.

Table 1: Kappa Index and overall accuracy for each property.

Property 2012	**1**	**2**	**3**	**4**
Global accuracy	100%	72.3%	53.4%	58.5%
KAPPA	0.999	0.625	0.543	0.588

In addition to manual classification, 5 sample points from each class were also randomly acquired for each property that were later used to generate another confusion matrix (Table 2).

Table 2: Kappa index and overall accuracy for each property using sample points.

Property 2012	**1**	**2**	**3**	**4**
Global accuracy	70%	62.2%	54.1%	50.0%
KAPPA	0.600	0.536	0.405	0.294

The result of the confusion matrix 2 showed a greater difference in property 1 compared to the other evaluation method used, since when using manual classification as field truth, the global accuracy of 100% was obtained. And when validation by random points was performed, the overall accuracy was 70%.

5. Conclusions

This study showed a methodology to determine automatically PPA for medium and large rivers and to analyze the land use and cover inside that. The proposed approach is based on the combination of: image processing techniques to define the riverbed taking account color information, such as hue, saturation and intensity from multispectral satellite image; geoprocessing techniques to determine automatically the PPA considering the rules of the new Brazilian forest code and digital image classification.

The results from the automatic PPA determination for medium and large rivers show optimization and accuracy when considering the varying widths of the riverbed and hence the PPAs that will vary as well. Similar cases, in general, make use of altimetry from digital elevation models, as for example SRTM data, and the PPA is delimited by fixed width buffers. In addition, the implementation to delimit the river PPA allows you to consider the properties declared in the CAR when those ones are bordering with the PPA. In that case, the forest code requires different rules that have already been provided by the software used in this work.

When considering the impossibility of carrying out a validation with fieldwork, which would be the ideal situation, regarding to the land use maps generated by digital supervised classification from the RapidEye scene, the accuracy assessment was based on confusion matrix, kappa coefficient and overall accuracy. The results showed the overall accuracy (Table 1), for properties 1, 2, 3 and 4, over the classifications with the following performances: 100%, 72.3%, 53.4% and 58.5%, that indicates the map reliability, for each property, respectively. The kappa statistic indicated very good and excellent performance levels as 0.999, 0.625, 0.543 and 0.588, respectively for each property.

The results of the validation by random points (Table 2) showed the accuracy of 70%, 62.2%, 54.1% and 50%, for properties 1, 2, 3 and 4 respectively and 0.600, 0.536, 0.405 and 0.294 for Kappa performance levels.

Rural properties that are registered in the CAR have become instruments of environmental management and the results of this study indicate the potential of the proposition as an alternative to supervise the declared properties in the CAR and, as much as possible, and avoiding the laborious field surveys, thus assisting decision-makers in surveillance activities.

AUTHOR'S CONTRIBUTION

Danielle Silva de Paula: carried out the bibliographic survey, developed the methodology and analyzed the results; Jussara de Oliveira Ortiz, Sergio Rosim and Laércio Massaru Namikawa: supervised and guided the entire process.

REFERENCES

Abreu, K. D. and Coutinho, L. M. 2014. Sensoriamento remoto aplicado ao estudo da vegetação_com ênfase em índice de vegetação e métricas da paisagem. *Vértices,* 16 (1), PP.173-198.

Bhattacharya, C. G. 1967. A simple method of resolution of a distribution into Gaussian components. *Biometrics,* p. 115-135.

Brasil. 2012. Lei n 12.651, de 25 de maio de 2012. Brasília, *Diário Oficial da União*. Available at: <http://www. planalto. gov. br/ccivil_03/_ato2011-2014/2012/lei/l12651. htm>. [Accessed 16 February 2018].

Bertoni, J. and Lombardi Neto, F. 1985. *Conservação do solo*. Piracicaba: Livroceres.

Bonamigo, et al. 2017. Changes in permanent preservation areas in rural properties of the Santa Catarina state southern plateau according to the laws No. 4,771 and 12,651. *Ciência Rural*, *47*(2), e20160489.

CAR - Cadastro Ambiental Rural. 2018. Available at: <http://www.car.gov.br/#/>. [Accessed 02 May 2018].

Camara, G. et al. 1996. SPRING: Integrating Remote Sensing and GIS with Object Oriented Data Modelling. *Computers e Graphics*, 15 (6), p. 13-22.

Carvalho, E. C. de A. and Santos, E. D. 2008. *O impacto econômico na bacia hidrográfica do Rio Paraíba do Sul, na região do estado de São Paulo sustentabilidade ou crise*. Dissertação (Mestrado em Planejamento Urbano) - Universidade do Vale do Paraíba, Instituto de Pesquisa e Desenvolvimento, São José dos Campos.

Congalton, R. G. 1991. A review of assessing the accuracy of classifications of remotely sensed data. *Remote Sensing of Environment*, 49 (12), p. 1671-1678.

Mello, Kaline et al. 2014. Cenários ambientais para o ordenamento territorial de áreas de preservação permanente no município de Sorocaba, SP. *Revista* Árvore, 38(2), pp. 309-317.

Foody, G. M. 2002. Status of land cover classification accuracy assessment. *Remote Sensing of Environment*, 80 (1), p. 185– 201.

Instituto Nacional de Colonização e Reforma Agrária (INCRA). 2020. *Módulos fiscais*. Available at :< https://www.embrapa.br/codigo-florestal/area-de-reserva-legal-arl/modulo-fiscal>. [Accessed 18 Jan 2020].

Köppen, W. and Geiger, R. 1928. *Klimate der Erde*. Gotha: Verlag Justus Perthes. Wall-map 150cmx200cm.

Leonardi, S. S. and Namikawa, L. M. and Oliveira, J. R. F. and Rosim, S. 2014. Delimitation of permanent protected areas of rivers in Brazil. In *Remote Sensing for Agriculture, Ecosystems, and Hydrology XVI* (Vol. 9239, p. 92391C). International Society for Optics and Photonics, Amsterdam, Netherlands.

Namikawa, L. M. and Körting, T. S. and Castejon, E. F. 2016. Water body extraction from Rapideye images: An automated methodology based on hue component of color transformation from RGB to HSV model. *Revista Brasileira de Cartografia*, 68 (6), pp.1097-1111.

Paula, D. S. and Ortiz, J. O. and Rosim, S. and Namikawa, L. M. 2017. Determinação e Análise de Áreas de Proteção Permanente Para Rios de Médio e Grande Porte Utilizando Imagens RapidEye, Segundo Novo Código Florestal Brasileiro. In: *Simpósio Brasileiro De Sensoriamento Remoto, 18. (SBSR)*, Santos. São José dos Campos: INPE, p.3806-3813.Available at: <http://urlib.net/8JMKD3MGP6W34M/3PSLTLH>. [Acessed 15 October 2018].

Ponzoni, F. J., Shimabukuro, Y. E., and Kuplich, T. M. 2015. *Sensoriamento remoto da vegetação*. São Paulo: Oficina de Textos. 164 p.

Rodrigues, R.R. and Leitão Filho, H.F. 2004. *Matas Ciliares: Conservação e Recuperação*. 3. ed. São Paulo: EDUSP/FAPESP, v. 2500. 320p.

Rosim, S. and Monteiro, A. M. V. and Rennó, C. D. and Oliveira, J. R. F. 2008. Uma ferramenta open source que unifica representações de fluxo local para apoio à gestão de recursos hídricos no Brasil. IP. *Informática Pública*, 10, pp. 29-49.

SAP- Sistema Ambiental Paulista, 2015. Available at: <http://www.ambiente.sp.gov.br/2015/08/pesquisas-comprovam-a-importancia-da-vegetacao-na-producao-de-agua-com-qualidade/>. [Accessed 05 October 2018].

SICAR - Secretaria de Infraestrutura e Meio Ambiente de São Paulo, 2012. Available at: < https://www.infraestruturameioambiente.sp.gov.br/>. [Acesses 05 February 2018].

Soriano, É. et al. 2016. Water crisis in São Paulo evaluated under the disaster's point of view. *Ambiente & Sociedade,* 19 (1), p. 21-42.

Sparovek et al. 2012. *The revision of the Brazilian Forest act: increased deforestation or a historic step towards balancing agricultural development and nature conservation?* Environ. Sci. Pol., 16, p 65 – 72.

Tedeschi, W. 2003. *Gestão intergovernamental da política de recursos hídricos: estudo de caso da dinâmica do comitê para integração da Bacia Hidrográfica do Rio Paraíba do Sul-CEIVAP.* 217 f. *Dissertação (*Mestrado em Administração) – FACE/CEPEAD/UFMG, Minas Gerais.