

Cientific Paper

Abstract

The Permanent Preservation Areas (PPA) has been the center of debates regarding the proposed changes in the Brazilian Forest Code (Law 4.771/65). These are important for the protection of water bodies and other natural resources. However, its dimensions have been discussed due to possible impacts on the socioeconomics activities. Because of this importance, its determination and representation depends on actual and precise data base. The aim of this study was to assess the representation of the available hydrography on the topographic maps on the scales of 1:50000 and 1:250000, provided by the IBGE, comparing it with the one identified by the images of the PRISM sensor (Panchromatic Remote-sensing for Stereo Mapping), installed in the Japanese satellite ALOS (Advanced Land Observing Satellite). The study was developed from the edition of vectors and generation of buffers from the PPA, using geographic information systems. It was found an important discrepancy between the number of river sources and streams represented on the topographic maps of the studied area and the one identified by using the images of the sensor, which implicates in the PPA dimensions. It was also verified that the images used in the present study allowed adequate identification of the PPA limits, as well as of its usage and occupation.

Keywords: satellite; geoprocessing; riparian forest; ALOS images.

Hydrography update and study of the permanent preservation areas from a remote sensing of high spatial resolution

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Atualização da hidrografia e estudo das áreas de preservação permanente utilizando produtos de sensoriamento remoto de alta resolução espacial

Resumo

As Áreas de Preservação Permanente (APP) tem sido o centro do debate relativo às mudanças propostas no Código Florestal Brasileiro (Lei 4.771/65). Estas são importantes para a proteção dos corpos d'água e demais recursos naturais. No entanto, tem tido suas dimensões discutidas devido a possíveis impactos nas atividades sócio-econômicas. Devido a esta importância, sua determinação e representação, dependem de bases de dados atuais e precisas. O objetivo deste trabalho foi avaliar a representação da hidrografia disponível nas cartas topográficas nas escalas 1:50.000 e 1:250.000, disponibilizadas pelo IBGE, comparando-a com a identificada nas imagens do sensor PRISM (Panchromatic Remote-sensing Instrument for Stereo Mapping) instalado no satélite japonês ALOS (Advanced Land Observing Satellite). O estudo foi desenvolvido a partir da edição de vetores e geração dos buffers das APP, com o uso de sistemas de informações geográficas. Verificou-se importante discrepância entre o número de nascentes e córregos representados nas cartas topográficas da área de estudo e aquele identificado usando as imagens do sensor utilizado, o que implica nas dimensões das APP. Verificou-se ainda que as imagens usadas no presente estudo permitiram identificação adequada dos limites das APP, bem como do seu uso e ocupação.

Palavras-chave: satélite; geoprocessamento; áreas de preservação permanente; imagens ALOS.

Actualización de la hidrografía y estudio de áreas de preservación permanente utilizando teledetección de alta resolución espacial

Resumen

Áreas de Preservación Permanente (APP) han sido el centro del debate sobre los cambios propuestos en el Código Forestal Brasileño (Ley 4.771/65). Estos son importantes para la protección de los cuerpos de agua y otros recursos naturales. Sin

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embargo, se ha tenido sus dimensiones discutidas debido a los posibles impactos en las actividades socio-económicas. Debido a esta importancia, su determinación y representación dependen de bases de datos actuales y precisos. El objetivo de este estudio fue evaluar la representación de la hidrografía disponible en los mapas topográficos en escalas de 1:50.000 y 1:250.000, proporcionados por el IBGE, comparándolo con el identificado en las imágenes del sensor PRISM *Panchromatic Remote-sensing Instrument for Stereo Mapping*) instalado el satélite japonés ALOS (*Advanced Land Observing Satellite*). El estudio se desarrolló a partir de la edición de vectores y la generación de buffers de APP, utilizando sistemas de información geográfica. Hubo discrepancia significativa entre el número de manantiales y arroyos representados en mapas topográficos de la zona de estudio y de aquel identificado utilizando las imágenes del sensor, lo que tiene consecuencias en las dimensiones de la APP. También se encontró que con las imágenes utilizadas en el estudio se permitió la identificación adecuada de los límites de la APP, así como su uso y ocupación.

Palabras clave: satélite; GIS; áreas de preservación permanente; Imágenes ALOS.

Introduction

According to MARQUES and BARBOSA (2006), the Brazilian occupation was characterized by the lack of planning and subsequent destruction of natural resources, due to the false idea that those were inexhaustible goods. This factor stimulated the so called disordered "development", without future commitments. The process of forest fragmentation and elimination, which is stronger in more developed regions, resulted in a set of environmental problems, such as the extinction of several fauna and flora species, local climatic changes, soil erosion and silting of watercourses. The riparian forests, although protected by law, did not escape from degradation. On the contrary, they were target of all sorts of aggression, resulting in several environmental problems that currently require corrective actions of multidisciplinary character.

BIGARELLA and SUGUIO (1990) inform that the riparian forest helps the rainwater infiltration in the soils, disseminating the flow and blocking, through the physical and stabilizing protection of roots and through the interception of raindrops by the leaves, the direct impact of the rainwater over it. This cushioning of raindrops regulates the surface runoff of the water, contributing on the reduction of soil erosion, siltation, pollution of water sources, controlling the floods (MOTA, 1995). Besides, the stabilizing of river margins by the riparian forests elevates the water infiltration rate in the forest soil (BOIN, 2005).

Although the legislation determines the preservation need of these areas, defining the rules for suppression in exceptional cases, the occupations in Permanent Preservation Areas are common, occurring in many cases in function of the search for food, clean water, wood and fuel (BOIN, 2005).

The same author also affirms that by the easiness of water access, the PPA becomes an attraction for the agricultural and livestock expansion, occupying even the interior of water bodies on floodplain areas.

At the same line, RIBEIRO et al. (2005) affirms that the agricultural productivity decline, along with shortsighted view of the natural resources abundance, forces continuously the conversion of more and more lands to the agriculture, leaving a trail of degraded areas, including the PPA.

BARBOSA (2001) states that the drastic reduction of riparian forests and the fragmentation of forests in general, verified in the last years in Brazil, have been causing significant increase of the soil erosion processes, with damages to the regional hydrology, evident reduction of biodiversity and degradation of huge areas.

In spite of the importance of the PPA, it has been verified a continuous advance of human activity over these fragile ecosystems. At the sight of this situation, in the last decades, several complementary laws have been created to the Forest Code (1965), aiming the protection of natural resources. One of the main laws was the number 9433/1997, which created the National Policy for Water Resources and instituted the hydrographic basin as the basic unity for the managing of water resources, recommending it as the adequate space for the management of the other natural resources.

This recommendation is due to the fact that the basin can be defined as being an area with pation to the information representation due to the outdated, how to develop planning activities with reliability and safety?

Considering this difficulty, we sought support on the remote sensing, which, according to JENSEN (2009), treats the information collecting over an object or geographic area from a privileged distant point.

In function of the need for images with spatial resolution capable to offer adequate data to the study of small areas, we opted to use in this research products of the Japanese satellite ALOS (*Advanced Land Observing Satellite*), which was launched on January 24th of 2006 by the Japan Aerospace Exploration Agency (JAXA). Its orbit is solar-synchronous with average height of 691 km. It carries onboard three sensing instruments: (1) the *Panchromatic Remote-sensing Instrument for Stereo Mapping* (PRISM), a sensor with a panchromatic band with spatial resolution of 2.5 meters, used in this study; (2) the *Visible and Near Infrared Radiometer type 2* (AVNIR-2), a multispectral sensor that has 4 spectral bands in the visible, and near infrared with spatial resolution of 10 meters; and (3) the *Phased Array type L-band Synthetic Aperture Radar* (PALSAR), a radar sensor whose products were not used in this study. The ALOS satellite images used in this research were acquired along with the IBGE (Brazilian Institute of Geography and Statistics) by a reduced price, due to an established agreement by the latter with the Japan Aerospace Exploration Agency (JAXA).

This study aimed to assess and quantify the differences between the representations of the hydrography in the topographic maps on scales of 1:50000 and 1:250000 and the hydrography generated from satellite images of high spatial resolution, using techniques of geoprocessing and field verifications. It was also assessed the changes that different representations have over the Permanent Preservation Areas.

Material and Methods

The application area of this study was the basin of the high river Pardo, which is located on the region of the main river sources of Pardo River, on the cities of Pardinho, Botucatu, Itatinga and Avaré, on the state of São Paulo, among the coordinates UTM (Universal Transverse Mercator), band 22, South, 690000 and 770000 (E) and 7440000 and 7480000 (N). Figure 1 shows the location of the Managing Unit of Water Resources 17 (UGRHI - 17), corresponding to the CBH-MP area of operation and the area of this study (Figure 1).

For the development of this research, it was used a digital file containing the hydrography of the study area provided by the CBH-MP on the scale of 1:250000, and the topographic maps on the

scale of 1:50000 of Bofete (SF-22-Z-D-III-1) and of Botucatu (SF-22-Z-R-IV-3), provided by the IBGE. For comparison, we used the images from PRISM sensor, of ALOS satellite.

The obtained data of these bases, the interpretation of the satellite images and the insertion of the gathered information in the field surveys were processed in the Geographic Information Systems (SIG) ArcGIS 9.3.1 and Idrisi Taiga.

Initially, we assessed the PPA location, analyzing the river sources and streams of the studied area, using the digital cartographic base from the IBGE, provided by the CBH-MP on the scale of 1:250000. Then, the river sources and streams of Pardo River were vectorized using the topographic maps on the scale of 1:50000. At this stage, each river source was represented by a dot and each stream was represented by a line.

Subsequently, the hydrography was vectorized over images of the PRISM sensor, from ALOS satellite. In this process, we opted to represent each river source as being a single dot and each stream as being a single line, since their average width are inferior to the spatial resolution of the images' pixels from PRISM, which is 2.5 meters.

The topographic maps and the PRISM-ALOS images were geographically referenced on the SIG, applying the UTM coordinates system, Datum SAD 69 (*South American Datum*, 1969).

After, the generated vectors were compared among them, observing the (non)representation of each river source and stream on the topographic maps and in the images from PRISM-ALOS.

Based on the vectors, buffers of 50 meters were generated around the river sources and of 30 meters of each side of the streams. In order to confirm the collected information from the satellite images, field works were conducted, in which, in addition to the location of river sources and streams, we also assessed the characteristics of the riparian forests and the way they are represented on the images.

Results and Discussion

At the first stage of the research, we compared the hydrography adopted by the CBH-MP on the scale of 1:250000 (provided by the IBGE, to be downloaded from the website in vector format) with the hydrography identified on the satellite images. For this comparison, the hydrography identified in

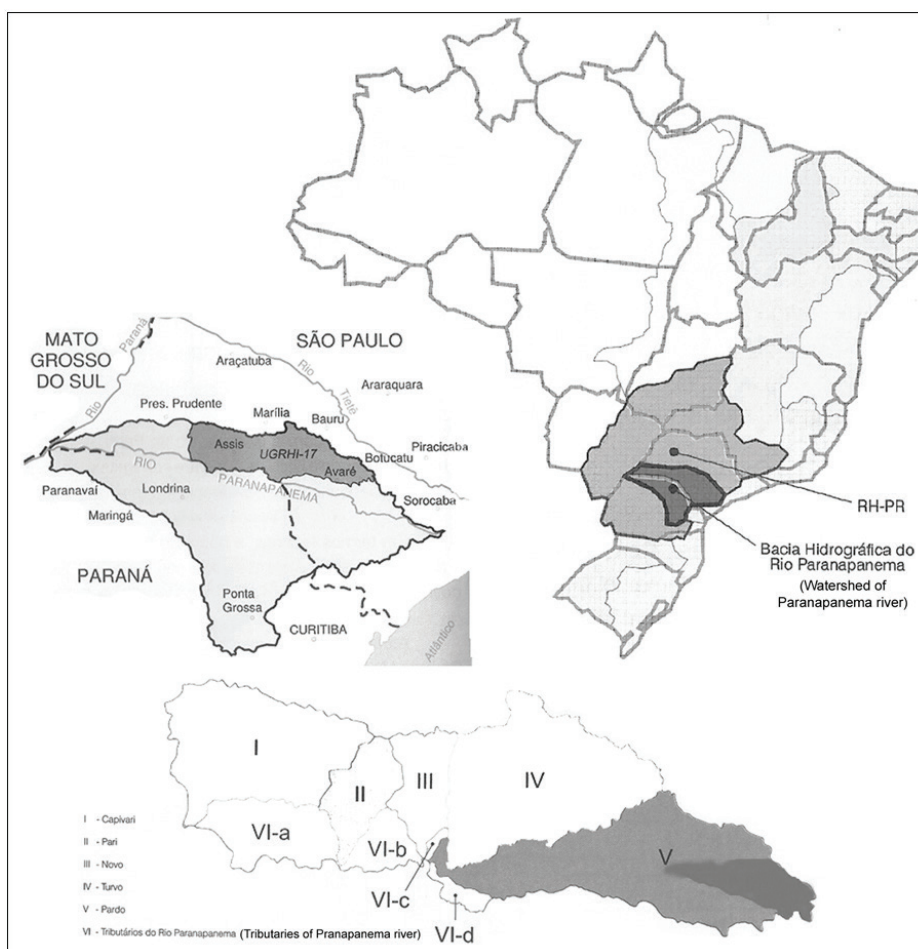


Figure 1. Location of the study area, highlighted in dark gray. Source: Basin Plan UGRHI 17 Organization of the authors.

the PRISM-ALOS image was superimposed to the IBGE one.

According to MARTINS et al. (2007), the study of the drainage network and of hydrographic basins have an important role, for it leads to the comprehension of several active processes on the sculpturing of landscape, making this kind of study useful to analyses' studies, based on the drainage behavior, usage of water resources, among others. In the present research, as it can be observed in Figure 2, the majority of small streams and its sources are not shown in the official available hydrography. Besides, those represented by the gray color generalize excessively the information, since they don't match to the real tracing of the water bodies. We observed in the analysis of the hydrography set that part of

this situation occurs due to the low-detailed scale and part because of problems in generating data, since streams with many kilometers long and with several tributaries are not represented.

Based on this observation, and considering that the importance of this cartographic base is crucial to the information representation relating to the PPA, a concern arises about how the activities of the basin committees, of city halls and state departments are being conducted, and, more importantly, how they are planned out of inaccurate and inadequate data bases, in terms of scale. It must be considered that if the scale of representation is not adequate, the generated products from that data base won't be, as well, having, among other, problems of location. Moreover, the lack of representation of river sources

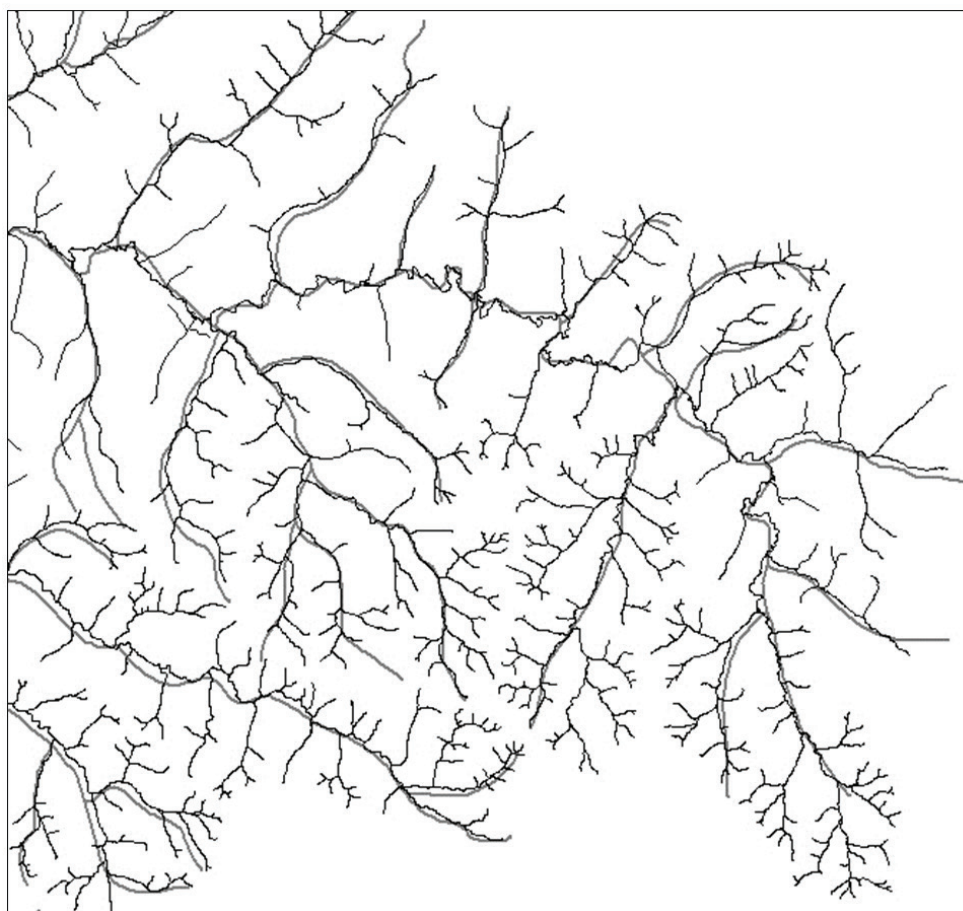


Figure 2. Hydrography on the scale of 1:250000 in gray and identified and vectorized hydrography over the ALOS images (PRISM sensor) in this research in black color.

and tributaries influence directly the activities of surveillance, handling, and protection of these and of the PPA, as recommended by the CBH-MP (2007).

Subsequently, we proceeded with the analysis of the information relating the hydrography present on the topographic maps on the scale of 1:50000. The generated vectors from that data base were inserted over the ALOS satellite images for verification. It was identified that part of the existent river sources and streams are not represented on the topographic map, even on this scale, which presents higher detailing.

We observed that in some regions of the studied area the number of river sources and streams that are not represented on the topographic maps overcomes those that are represented, as it is seen on the region next to the urban area of the city of Pardinho, shown in Figures 3 and 4. The Figure 3

shows the official hydrography represented on the topographic map and the Figure 4 presents the official hydrography overlaid by the vectorized hydrography, from the images of the PRISM sensor of ALOS satellite.

As observed in Figures 3 and 4, only in that little area there's a representation difference of thirty nine river sources and its respective streams, since we have in the left figure four springs and tributaries of the high river Pardo, and in the figure on the right forty three springs and streams formers of the high river Pardo.

In Figure 4, it is possible to observe that at Northeast and East from the urban area of Pardinho there is an entire micro basin with nine river sources, with its respective streams, that is not represented on the topographic map.

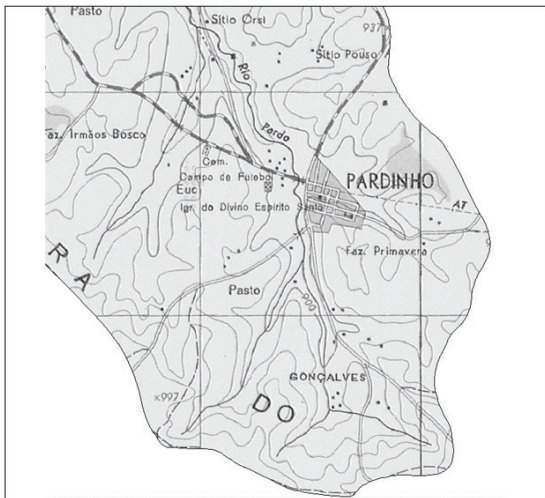


Figure 3. Streams represented in the topographic map.



Figure 4. Vectorized streams in the image of ALOS satellite, inserted over the topographic map.

Apart from this issue, we found that there's an important outdated of the topographic maps, since these were generated from aerial photogram obtained more than four decades ago. Presently, the city of Pardinho has grown and occupied much larger areas than those occupied in the late 1960s (as seen in Figures 3 and 4), common situation on all cities of the region. In Figures 5 and 6 it is shown the image from the ALOS satellite (PRISM sensor) of the area

next to Pardinho, on March of 2007, with emphasis to the hydrography on Figure 6.

Apart from the problems related to the location, the non representation of various water bodies and the outdated, we also observed problems related to the quality of the information presented on the topographic maps. As an example, we describe the case of the stream Janeirinho (first tributary of the right margin of Pardo river) that, according to the information on the topographic map, moves



Figure 5. Presently occupied area by the urban center of Pardinho.



Figure 6. Emphasis on the hydrography identified by the satellite image, marked with white lines.

its water towards the flux, ascending the hills for approximately 160 (one hundred and sixty) meters, as it is seen in Figure 7.

These observations show the necessity of information updating contained on the topographic maps. VIADANA (1999) says that, for the development of those activities, it can be used several methodologies, and reassures that over the past few years the usage of orbital images has had a spotlight on works that treat this subject.

Thus, based on the vectorized data of the images, we proceeded with the analysis of the location and the number of river sources and streams of the studied area. We identified, on the studied basin, 785 (seven hundred and eighty-five) springs represented on the topographic maps on the scale of 1:50000, and 1221 (one thousand, two hundred and twenty-one) springs presented in the images of ALOS satellite, PRISM sensor. In this calculus, we considered only the springs that do not originate any other superficial water course, not being considered springs on the margins of rivers and neither those

which might be located on regions of swamps.

Analyzing this information, it is found that there's an omission error of 35.7% (thirty five point seven percent) over the hydrography representation of the topographic maps on the scale of 1:50000. This data has direct influence on the size of the permanent preservation area of the basin, since the legislation (BRAZIL, 2012) defines that these have a 50 meters radius around each river source, which generates an area to be preserved per spring of 7853.98 m², considering that the water flow occurs in a single point.

Then, we calculated the PPA difference of the river sources between the information obtained from the topographic maps and those extracted from the satellite images of high resolution. The permanent preservation areas of the 785 springs represented on the topographic maps reach 616.54 acres. The PPA of the 1221 springs identified in the satellite images reaches 958.97 acres. It is found, then, that there's a 342.43 acres difference between the two representations.

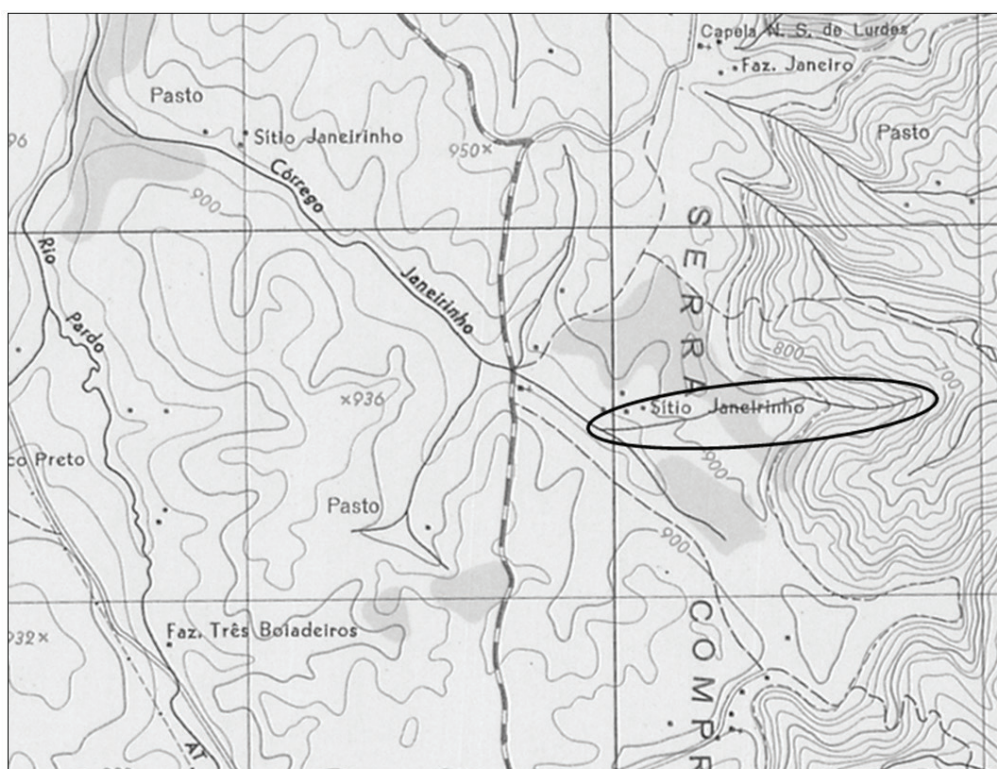


Figure 7. Part of topographical map of Bofete, showing a tributary of Janeirinho stream "ascending" the Sierra (highlighted by the ellipse).

This way, considering that one of the priorities of the plans of management goals of the CBH-MP (2007) is to recompose the riparian forest of the PPA, and taking in account that those areas must have their vegetation recomposed to attend the Brazilian legislation, we've reached the situation where if the CBH-MP were to recompose only the PPA of the springs of high river Pardo, with seedlings of native forest species, considering that it has to be done in the whole area, and considering the spacing between plants to be 2 x 3 meters, totaling 1667 seedlings per acre, they would have to produce or purchase 1027772 (one million, twenty seven thousand, seven hundred and seventy-two) seedlings, if they would use as reference the topographic maps or 1598603 (one million, five hundred and ninety eight thousand, six hundred and three) seedlings, if they would use as reference the extracted data from the satellite images. There is, therefore, a 570832 (five hundred and seventy thousand, eight hundred and thirty-two) difference of seedlings.

If it is considered that each one of those seedlings has a cost of production or acquisition of 1 (one) Real (average price practiced on the region, by the time of the elaboration of this study), we have, then, a difference of values correspondent to 570832 Reais.

With this assessment it is verified the importance of data accuracy on the moment of decision making. This precision, though, cannot be reached if there isn't a trustworthy cartographic base and on the adequate scale (PIROLI, 2013).

Based on this evaluation, it is possible to affirm that the topographic maps on the scale of 1:50000, currently available to the studied area, apart from the outdated and the appointed errors, do not attend to this precision, since on that scale there's a big generalization of the represented information.

This generalization can be demonstrated from the analysis of the areas represented on each scale. On the scale of 1:50000, one centimeter corresponds to five hundred meters on the land, and one millimeter represents fifty meters on the land. The Brazilian legislation requires the maintenance or recomposing of the vegetation of PPA, in marginal ranges, for streams with the dimensions of the area of this study of 30 meters in each side (the width of these ranges can be lower, in case the properties have smaller sizes than four fiscal modules and need to do the recomposing - Law 12651/12 and Interim Measure 571/12). The legislation requires yet native vegetation

around the springs in a 50 meters radius.

It arises, then, the question of how to assess, represent and develop activities of planning, relying on data bases that show the conditions of the PPA on the space of one millimeter for the river sources, and on 0.6 millimeter for stream margins up to 10 meters width.

Even with the support of sophisticated equipment, the human visual system does not allow the precise identification of details on that space, which compromises the analysis and planning processes.

The results of this study show that the solving of such issues is on the updating of the hydrography representation by the basin committees, governmental departments, or even universities, using satellite images of high resolution, agreeing with VERGARA et al. (2002) who emphasized that the remote sensing images have potential to cartographic updating, for they are more economic than aerial photographs, have better temporal and spectral resolution and provide a synoptic vision of the studied area when it comes to smaller scales.

Based on the mapping made by using the ALOS satellite images, PRISM sensor, and on the field evaluations, we observed that these reach safe scales of interpretation up to 1:5000, where a centimeter represents 50 meters on land and a millimeter represents 5 meters on land. This scale allows to clearly identify the different usages of land in a determined PPA, mainly if these are forestal or (according to legislation requirement) agricultural. The Figure 8 shows part of the studied area, where it is possible to identify the usage of land of the PPA, being able to emphasize a small forest area on the river source located west (left). The other usages are predominantly related to pasturage for cattle breeding.

After the data analysis rose in this research it is suggested that the basin committees, the city halls and the states invest on the updating of the cartographic bases on higher scales, compatible with the precision needed for its various activities, mainly for those related to the environmental planning and the PPA management.

It is suggested, for such matter, the use of products from remote sensing of high spatial resolution, since these allow precise identifications, as presented in this article, and also the monitoring of changes that occur throughout time.



Figure 8. Permanent Preservation Areas bounded by buffers over the image of ALOS-PRISM satellite, allowing the identification of the land use.

Conclusion

In view of the results of the activities conducted and the elaborated studies over the data, it is possible to affirm that the cartographic base related to the hydrography of the studied area finds itself outdated and contain representation errors, both in inclusion and omission, and even location. This condition compromises the development of projects related to the surveillance of the land use in the PPA and to the preservation and recovering of riparian forests, with consequential damage to the natural resources of those areas, which also impacts the society and the economy of the region due to the erosion on the river margins, siltation of water bodies, with consequential decrease of the quality of water

and the riparian ecosystem as a whole.

As a consequence from the inadequacy of the current available cartography, every management activity of water resources and planning of the usage of hydrographic basins, mostly those regarding the PPA gets compromised, since the inconsistent data base leads to errors that can bring environmental, social and economic damages.

Acknowledgments

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