

## English Version

### Geoprossening tools applied in the analysis of land use evolution in the municipality of Rosana, SP, from 1984 and 2007

#### Abstract

This study aimed to evaluate the evolution of land use in the city of Rosana-SP, between the years 1984 and 2007, using geoprocessing techniques. Rosana is located in the extreme west of São Paulo state, bordering the state of Mato Grosso do Sul in North and Parana in South, and, on the border with the state of Mato Grosso do Sul is the Parana River and the border with Parana, the Paranapanema River. The results of the analysis identified the reduction of forest cover in the municipality, the new crop area and a reduction in large areas formerly arable, removed by filling the lakes of the Rosana Hydroelectric and Engineer Sérgio Motta (Porto Primavera).

**Keywords:** Geoprocessing; Land use; Temporal evolution; Municipality of Rosana

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#### Introduction

Until reach the title of municipality, Rosana has undergone many changes over the course of its history. It appeared as an extension of the Estrada de Ferro Sorocabana (Sorocabana Railroad) which passed there, created around 1951. This extension would leave Presidente Prudente, nowadays the regional capital of the region named Oeste Paulista, and would reach the bank of the river Paraná, still in the state of São Paulo. The crossing of the river would be done by ferries to the other margin in the state of Mato Grosso do Sul, where it would follow to Dourados-MS. Due to that, the extension would be called "Ramal de Dourados".

The company Camargo Correia has become the contractor responsible for the building of the São Paulo part of the extension, after the topographic studies had been done and the route of the railroad line has been decided. With that, the speculations about the lands of Pontal do Paranapanema increased.

The contractor Camargo Correia has decided to build a city in the margin of the river Paraná, with 60 kilometers square. This city was named Rosana, after one of the daughters of the proprietor

Sebastião Camargo. Initially, Rosana belonged to the municipality of Presidente Epitácio. The distance between the small Rosana and the headquarters of the municipality was 210 kilometers. Rosana belonged to Presidente Epitácio to 1964, when on February 28<sup>th</sup>, with the Law number 8,092, it was created the district of Rosana, belonging to the municipality of Teodoro Sampaio. It was elevated to the category of municipality with the name of Rosana by the state Law number 6,645, on January 9<sup>th</sup>, 1990. However, it was actually installed on January 1<sup>st</sup>, 1993, with the possession of the first major.

The municipality, despite being young, experiments as the entire planet the exploiting of its natural resources, and has suffered over the years with environmental degradation, deforestation, erosion, silting of water bodies, among other serious problems of degradation of nature.

According to Baseggio et al. (2006), experiments over natural resources and land use are of major importance as contribution to planning, monitoring and control of the process of soil occupation. The same authors say that the orbital remote sensing has proved to be an effective tool to researches of this nature, once it enables

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in a short period of time the obtaining of a wide range of information. They also say that allied to geoprocessing, remote sensing constitutes a technology indispensable to the study and analysis of land environmental changes.

In accordance with Silva (2007), to analyze the geotopology of an environment, i.e., to investigate systematically the positional properties and relations of the events and entities represented in a georeferenced data set, transforming data in information destined to the support of the decision is the main activity of the geoprocessing. It distinguishes it from related fields, such as Remote Sensing, which is intended, mainly, to identify and classify entities and events, distance recorded by detectors, and the Digital Cartography, geared, primarily, to the correct representation of the environmental reality, according to references which enable the reliable identification of the positioning of events and entities, together with measurement of their extensions and spatial directions.

As reported by Nogueira (1997), the Geographic Information System (GIS) is an useful tool to guide the environmental management and to promote the exact location of necessary information, by consulting database, and which include tools to analyze data based on their global positioning.

As for Burrough (1989), Geographic Information Systems are applications which consist of five modules. Each module is a subsystem which enables the operation of data entry and verification, dataset storage and management, data presentation, output and transformation and interaction with the user.

This work aimed to evaluate and quantify the different land uses of the soil of the municipality of Rosana, as well as the evolution of the use between the years of 1984 and 2007, verifying the changes and impact which occurred in this period.

## Material and methods

### Material

The material used to the development of this work were: an image of the satellite Landsat 5 - *Thematic Mapper*, 3, 4 and 5 bands, on September 29<sup>th</sup>,

1984; an image of the satellite Landsat 7 - *Enhanced Thematic Mapper*, 3, 4 and 5 bands on August 19<sup>th</sup>, 2001; computer equipment; a GPS navigation device; camera; office and land equipment, text editing and image treating applications as well as Geographic Information System (GIS) *Idrisi Andes*.

### Methods

The work began with the collecting of the basic data with the engineering sector of the city government, to obtain the information, through topographic maps and maps of the municipality.

The different land uses of the municipality area were vectored over the satellite images from 1984 and 2001, in the application *Idrisi for Windows 3.2*. Each area received a different value of identification, to, thus, be possible to analyze them individually, aiming this way at a better comprehension of the studied area and at more concrete results.

In the year 1984 it was found the following land uses and occupations:

- Pasture, Forest, Prepared soil, Urban Area, Streams, Water, Lowlands, Floodplains, Area owned by Cesp, Islands (downstream of the Hydroelectric Plant – UHE Eng. Sergio Motta), Islands in formation (downstream UHE Eng. Sérgio Motta), Island in formation (upstream of the UHE Eng. Sergio Motta), Roads and Others.

In the year 2001 the following information plans were created:

- Pasture, Forest, Prepared Soil, Urban Area, Streams, Water, Settlement Bonanza, Settlement Gleba XV de Novembro, Settlement Nova do Pontal, Settlement Porto Maria, Floodplains, Neighborhood Beira Rio, Area owned by Cesp, Area owned by Duke Energy, Islands (downstream of the UHE Eng. Sergio Motta), Islands in formation (downstream UHE Eng. Sérgio Motta), Subdivision, Annual crops, Roads and Others.

Together with the analysis and vectoring of the land use it was performed field work to confirm covers which presented difficult of interpretation, aiming to reach a good level of accuracy on the

classification.

The field work, performed during the years 2007 and 2008 also served to update the land use of the areas which were modified since the year 2001 (period of the satellite Landsat 7 image - *Enhanced Thematic Mapper*). In this step it was used a navigation GPS to specialize each land use, enabling thus that each use was updated over the satellite image.

Later, with the GIS, it was calculated the area of each information plan and the maps were generated.

## Results and discussion

Considering that the period corresponding to the study comprehend the years between 1984 and 2007 and that the satellite image used as base to the vectoring of the year 2007 is dated August 19<sup>th</sup>, 2001, the performance of this study was only possible due to the complementation with the field work and the knowledge the authors had over the studied area.

It must be considered that the spatial resolution of the satellite images used is 30 meters, i.e., it is only possible to identify in the uses which occupies areas larger then 30 meters. Due to that, some small areas could not be identified. In this case, they were named "others", in both images.

The information plan subdivision, present in the year 2007 is referent to small rural lots located around the district of Primavera.

The vectoring of the islands was performed

separately, on both images. In 1984 it was created the information plans: Islands (downstream of the Hydroelectric Plant – UHE Eng. Sergio Motta), Islands in formation (downstream UHE Eng. Sérgio Motta), Island (upstream of the UHE Eng. Sergio Motta), Island in formation (upstream of the UHE Eng. Sergio Motta).

In 2007 the information plans were named as follows: Islands (downstram UHE Eng. Sérgio Motta) and Islands in formation (downstream UHE Eng. Sérgio Motta). This way it was possible to study the alterations and the impact caused to the islands over the years.

In 2007 it was not found islands on the upstream of the dam UHE Eng. Sérgio Motta, since the filling of the lake caused the dumping of all those which were in this area.

The following table shows the values of each type of soil use found on the municipality of Rosana in 1984.

When analyzing the table and the map referent to the year 1984 it can be observed that the pasture was predominant in all the territory today corresponding to Rosana. In that period the Hydroelectric Plant Engenheiro Sérgio Motta and de Rosana were in construction, as well as the district of Primavera.

As it can be seen in Figure 1, the pasture was predominant as the land use of the municipality of Rosana. It is also noteworthy in the landscape the floodplains, in the margins of the river Paranapanema

**Table 1.** Area of each soil use in 1984 in the municipality of Rosana – SP, elaborated by the authors.

TYPE OF USE	AREA(ha)
Pasture	47,309.25
Forest	6,218.0006
Prepared Soil	1,566.70
Urban Area	530.00
Water	5,240.00
Wetlands	7,116.12
Area owned by Cesp	896.90
Islands (downstream of UHE Eng. Sergio Motta)	1,147.60
Islands in formation (downstream UHE Eng. Sérgio Motta)	77.10
Islands (upstream of the UHE Eng. Sergio Motta)	541.70
Island in formation (upstream of the UHE Eng. Sergio Motta)	24.40
Others	72.30

and the forests, located mainly on the West of the municipality, although already reduced if we consider that all the area was covered by forest originally.

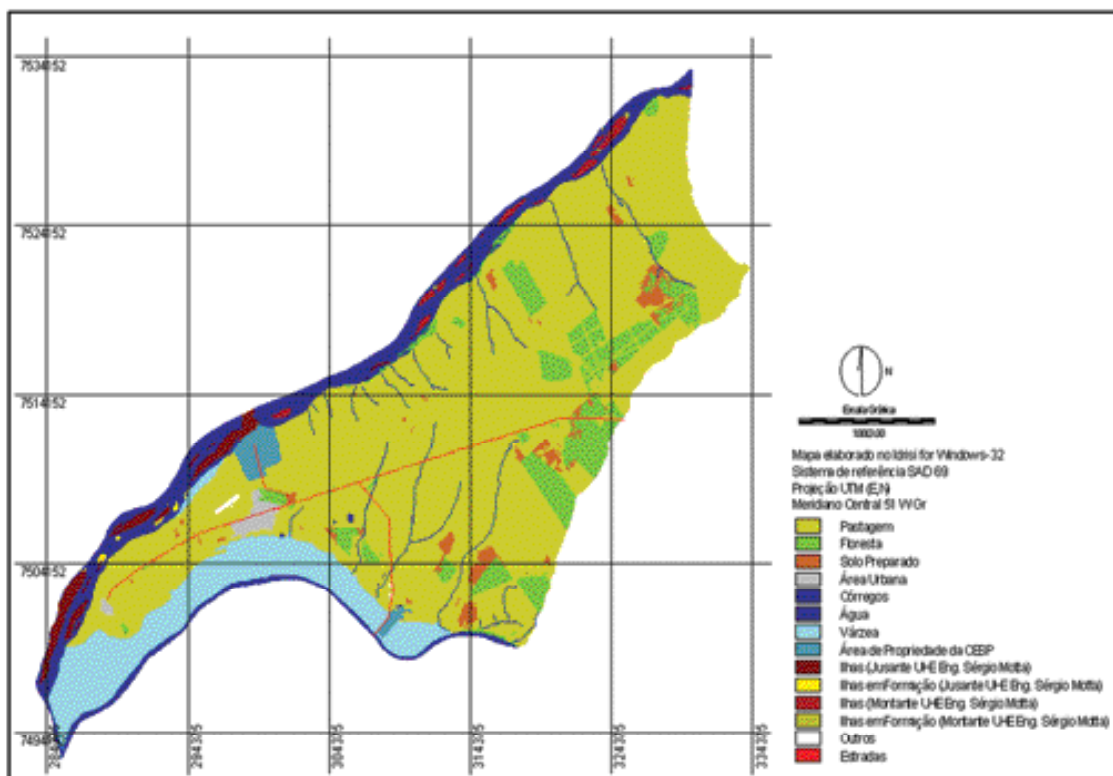
According to Valadares-Pádua (apud RODRIGUES et al, 2004), the large amount of areas occupied by forests in the region of Pontal do Paranapanema, let the governor of the State of São Paulo, Fernando Costa, to create, in 1942, a large reservation of fauna and flora, named “Grande Reserva do Pontal”. However, the governor Ademar de Barros, in 1950, distributed the lands of the Grande Reserva, initiating an uncontrolled process of soil occupation, reducing the plant cover to approximately 1.85% of what it was originally, with the major part of the remaining forest centered in the Parque Estadual Morro do Diabo, municipality of Teodoro Sampaio, located near to Rosana.

Floodplains, which are areas protected by the law 4,711/65 – Forest Code – and by the resolution CONAMA 303/02, are areas considered as part of the stream bed (seasonal flooding) and by this it

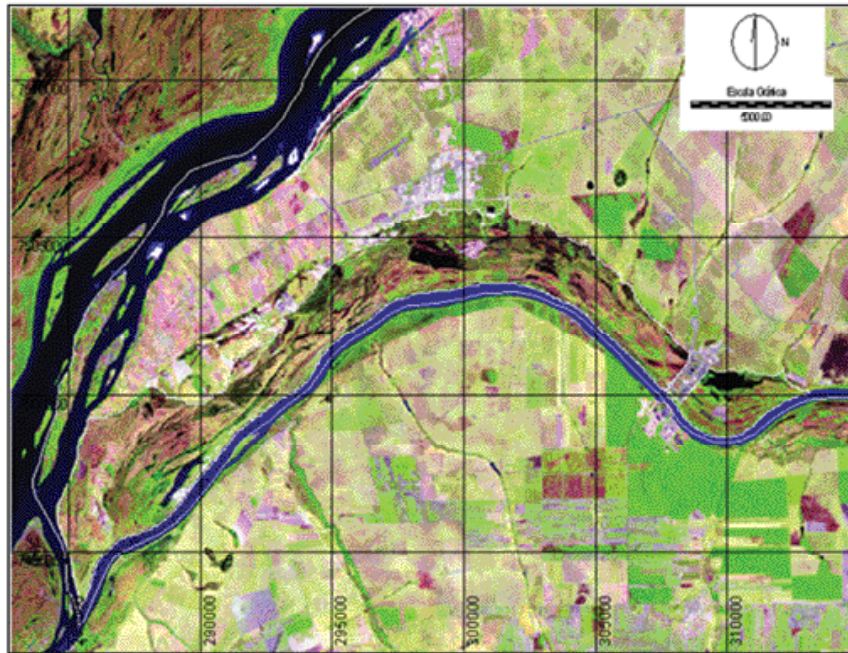
cannot be occupied or suffer human intervention. However, it must be noted that the floodplains of the river Paranapanema, in the municipality of Rosana, in 1984 were filled by rice crop and cattle grazing. Nowadays the rice crop is not found in those areas, but the cattle grazing remains in all the extension of the floodplains in the municipality, and still presents entire farms included in this plain. Figures 2 and 3 are highlighted in the satellite images in the years 1984 and 2001, respectively.

In the image from 1984 (Figure 2), it is possible to observe more presence of the water (dark areas) in the floodplains of Paranapanema, which indicates that on the period the impacts caused by agriculture, cattle and mainly by the construction of the Usina Hidrelétrica de Rosana, which changed the hydrometric river regime, where not that evident yet.

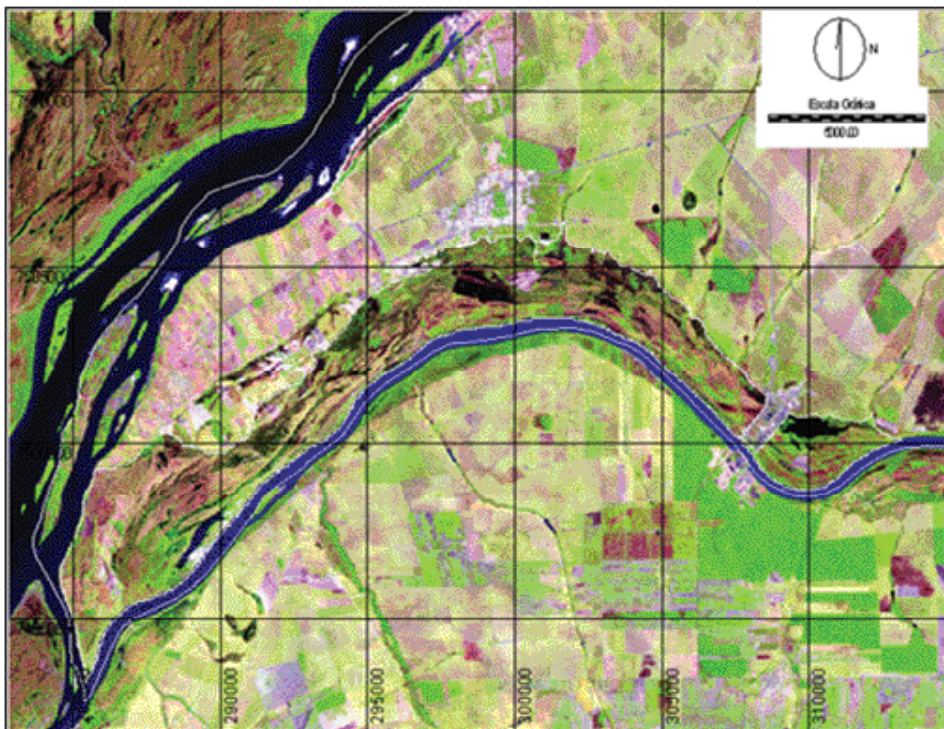
By contrast, in the image from 2001 (Figure 3), it can be noted that the quantity of water decreased comparing to 1984, due to chance on the regime of the river floods and also because many drains



**Figure 1.** Map of Soil Use in 1984 in the municipality of Rosana – SP, elaborated by the authors



**Figure 2.** False color 543 composition of the image of the satellite Landsat 5, from 1984, highlighting the river Paranapanema (South) before the lake flooding, and the floodplains. Elaborated by the authors.



**Figure 3.** False color 543 composition of the image of the satellite Landsat 7 ETM, from 2001, highlighting the dam of the UHE Rosana, upstream and floodplains of the river Paranapanema, downstream. Elaborated by the authors.

were built to remove the exceeding water, aiming to increase the area available for pasture. This area suffered, thus, great environmental impact over the years of this study.

Regarding to the coverage of the floodplain area, in the year 1984 this achieved 7,116.12 hectares, while in 2007 it was reduced to 6,525.50 hectares.

The Forest Code also defines that the areas located on the margin of the water bodies must be protected. They are called the areas of permanent preservation (APPs).

This areas must be completely preserved and may not suffer any type of human intervention, but those protected by the current law, due to the characteristic of water body protection. It can be seen, by the analysis of the satellite image and the studies *in loco*, that they are in advanced process of degradation, making it clear that the legislation is not being complied.

In the year 1984 pasture represented a total of 47,309.25 hectares. In 2007 they had been reduced to 35,509.6 hectares. Various events motivated this reduction. Among the major ones, it can be cited: the deployment of rural settlement, with consequent change on the agricultural activities developed; the

filling of the dams of the two hydroelectric plants and still their substitution for agricultural crops in some large properties. Although, it is important to emphasize that part of the forest areas which were deleted between the years of the analysis were transformed in pasture nowadays, which indicates a wider range in relation to the percentage of cover of this activity.

The following table shows the areas of each use of land type in Rosana in the year 2007.

Figure 4 presents the distribution of the land use in the municipality of Rosana in the year 2007.

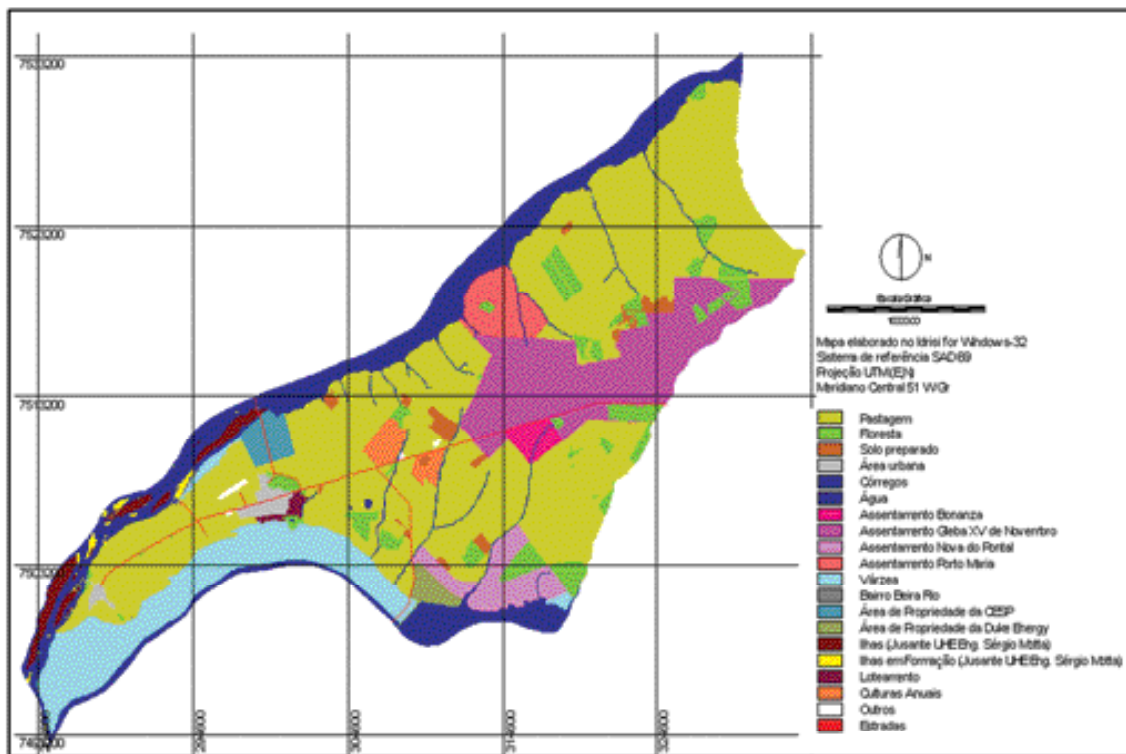
Through the analysis of the land use in 2007, it may be observed that pasture is still predominant in the landscape of the municipality.

Over the years, during the occupation of the interior of São Paulo, as well as all the Brazilian territory, wide areas of native vegetation gave place to pasture and plantations. During a long period, forests were depleted without any concern regarding to the important role they have in the environmental and regional balance of the planet.

In 1984 there was 6,218.06 hectares of forest in the municipality of Rosana. It was reduced to 3,888.3 hectares in 2007. The data showed that there

**Table 2.** Area of each type of Land Use in 2007 in the municipality of Rosana – SP. Elaborated by the authors

TYPE OF USE	AREA(ha)
Pasture	35,509.60
Forests	3,888.30
Prepared Soil	846.00
Urban Area	610.50
Water	8,580.00
Settlement Bonanza	585.00
Settlement Gleba XV de Novembro	8,000.00
Settlement Nova do Pontal	1,840.00
Settlement Porto Maria	1,600.00
Floodplain	6,525.50
Neighborhood Beira Rio	29.70
Area Owned by Cesp	787.40
Area Owned by Duke Energy	480.20
Islands (Downstream UHE Eng. Sérgio Motta)	959.20
Islands in formation (Downstream UHE Eng. Sérgio Motta)	254.10
Subdivision	192.70
Annual Crops	777.90
Others	113.40



**Figure 4.** Map of the land use in 2007 in the municipality of Rosana – SP. Elaborated by the authors.

was a reduction of 37.5% of the forest reservation of the municipality. Most of those areas are nowadays occupied by pasture. Figure 6 presents an example of this alteration between the two periods evaluated.

As it can be seen in Figure 5 (left), most of the area was covered by forest in 1984. In 2001 (right), much of the area had been modified. In the left image it can be noted a consistent vegetation, but already suffering deforestation. The point of deforestation occurred in the places where the soil reflected the most reddish tones, indicating exposed soil. In the right image it is possible to observe only part of the Forest. The rest of the area had already been cleared. The red point indicated the Settlement Gleba XV de Novembro.

This settlement is the largest of the four settlements implanted in the municipality nowadays (covers approximately 8,000.00 hectares). The area of the four settlements reaches approximately 12,000 hectares.

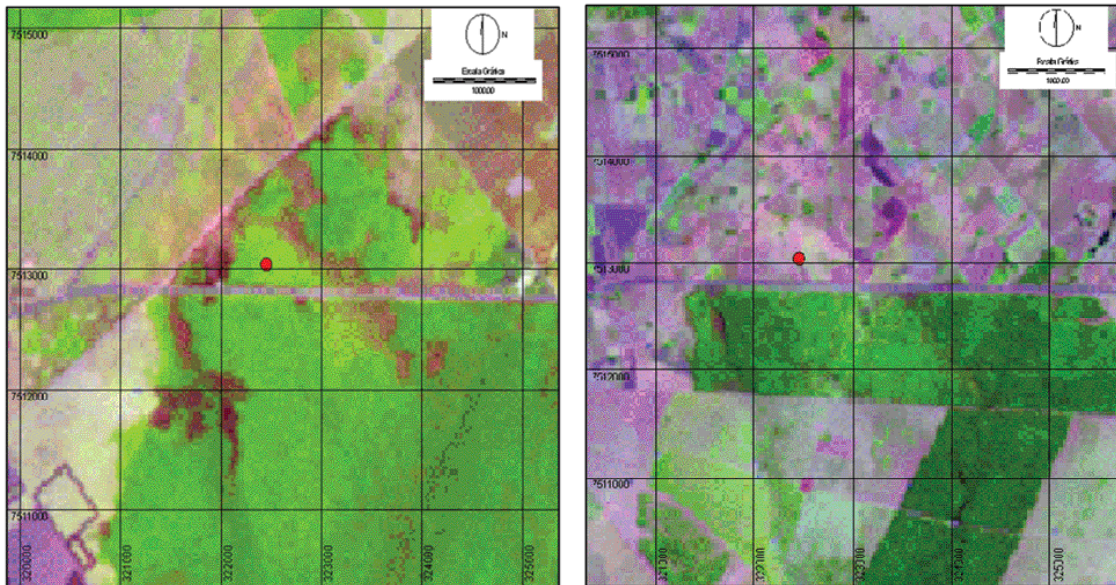
The other settlements existent in the municipality are the Settlement Bonanza, with

approximately 585 hectares, Settlement Nova do Pontal with approximately 1,840 hectares and Settlement Porto Maria, the most recent, with approximately 1,600 hectares.

In this study, the rural settlements were analyzed together, without taking in consideration the type of exploitation which occurs in each lot. In a general way, the activities performed in them are predominantly dairy and beef cattle and the subsistence farming.

The area of prepared soil was 1,566.70 hectares in 1984 and of 846 in 2007. These areas are normally used to agricultural crops and in some cases, to reform grazing. It was observed in the land work that in the last decade there was an insertion of the soybean plantation. These crops occupied an area of approximately 780 hectares.

Nowadays, in the margins of the river Paraná it can be seen the Neighborhood Beira Rio, which didn't exist in the year 1984. In the field works it was found that in this place professional angler, who derive their livelihood from fishing, live. It can also be



**Figure 5.** Modification in the Forest cover in an area of the municipality between 1984 and 2007. Elaborated by the authors.

found many ranches, most of them whose owners live in other municipalities, hotels, restaurants and even a harbor for small vessels. All those buildings are in an appropriated and prohibited place, according to the Law 4,711/65, since in this place, as well as it occurs in the river Paranapanema there is a system of floodplains and, therefore, are built inside the river (seasonal flooding). This buildings should be at least 500 meters after the slope, once this water body, measured by the highest level, in horizontal projection, as it is referenced on the CONAMA Resolution number 303/02, exceeds 600 meters.

In the municipality there are still two plants which generate electric energy built by CESP (Companhia Energética de São Paulo – São Paulo Energy Company). Although, with the privatizations which occurred in Brazil in the end of the decade 1990, the Hydroelectric Plant de Rosana, located on the river Paranapanema, started to be administrated by the North American company Duke Energy. The Hydroelectric Plant Engenheiro Sérgio Motta (Figure 7), located on the river Paraná, is still managed by CESP.

Due to the filling of the reservoir of the two hydroelectric plants built in the municipality, the area

occupied with water increased significantly between the two periods analyzed. In 1984, year in which the two generating centers were under construction, summing the rivers Paraná and Paranapanema and the largest lagoons visible in the satellite image, water occupied an area of approximately 5,240 hectares. In 2007, this value increased to approximately 8,580 hectares.

With the analysis of these values, it can be seen the environmental impacts caused by the construction of large hydroelectric plants. The loss of potentially arable land within the territorial limits in the municipality studied was approximately 2,760 hectares. The flooded areas were part of the APPs of both rivers, which before the filling of the lakes were 500 meters and after the filling was 100 meters (according to the CONAMA resolution 303/02), which were also not being recovered.

Other environmental degradation that has been occurred is the accelerated process of silting, mainly in the river Paraná, as a result of the building of the UHE Eng. Sérgio Motta and the modification of the islands, with disappearance of others, mainly those located next to the spillway and appearance of others downstream, more distant to the dam, as it





**Figure 6.** Aerial view of the Plant Usina de Primavera – SP – Municipal City Hall of Rosana.

was verified by Piroli et al. (2008). In the map 2007 it is possible to observe many islands in formation, process which occurred on a smaller scale in 1984.

This accelerated process of silting occurs due to the fluvial erosion which acts over the borders of the river Paraná upstream of the dam. With the filling of the lake, the small riparian forests (which have fundamental importance for conservation of soil, water bodies, gene flow, etc) that existed over the river were submerged. The riparian vegetation also “holds” the soil so that the fluvial erosion does not break down and take sediments to the bed of the river, causing silting. In this case, since the margin of the reservoir was changed its place, they do not have riparian protection, and therefore they have bounds exposed to the action of waves formed by the large reservoir. Thus, the landslide of the bounds is intense, bringing many suspended sediments. After that, the non-existence of riparian forests (which filter the water runoff by preserving the water bodies) enables the water from the surface runoff, which can contain fertilizers and agrochemicals, reach the water bodies and may cause contamination (by agrochemicals) and eutrophication (by fertilizers) which bring negative effects to the aquatic life.

The creation of the lake of the Usina Hidrelétrica Engenheiro Sérgio Motta also provided microclimatic chances in the region and changes in all the tributaries of the river Paraná which empties into the big dam.

As it can be seen in the maps, in the municipality of Rosana there are two urban centers, the city of Rosana and the district of Primavera. Rosana is the headquarter of the municipality, where

the mayor and the city council is located.

The housing project of Primavera is distant 13 kilometers from Rosana, and it is a planned city, built by CESP to house the workers during the construction of the two hydroelectric plants. Most of the infrastructure of the municipality is concentrated in Primavera, as hospital, university, fire department, military police and even an airport, which is private, property of CESP. The total area of the two urban centers is approximately 610.50 hectares in 2007 against approximately 530.00 hectares in 1984. According to the Brazilian Institute of Geography and Statistics (IBGE), the population of the municipality totaled 19,943 inhabitants in the year 2007.

Around the district of Primavera, it was found small rural properties originated from allotments, occupying an area of approximately 190.00 hectares.

As it could be observed over the analysis, in the municipality of Rosana, as well as in the other municipalities of the Pontal do Paranapanema, is the cattle which predominate as the main soil occupation. Against a regional trend, Rosana is one of the few municipalities from that region in which it still did not have the insertion of the sugarcane cultivation, for the production of sugar and alcohol.

In the last ten years it appeared plantations of annual crops, basically soybean and maize, which do not represent large numbers in the total area of the territory of the municipality.

One of the most significant changes which occurred between the studied periods was the formation of the lakes of the Usinas Engenheiro Sérgio Motta and de Rosana which flooded large

productive and permanent preservation areas, mainly the lake of the Usina de Porto Primavera due to the magnificence of the work. Other important aspect to be emphasized is the reduction of forests in the municipality, which could be observed in the preliminary analysis of the satellite images, even before it was used the techniques of geoprocessing.

### Final considerations

With the data presented, it could be verified that the land use in the municipality of Rosana changed over the years, passing from a use closely related to pasture to a most diversified use.

The small insertion of the annual crops will

enrich the agricultural activities of the municipality, enabling greater variability in the land use.

The forests which were deleted over the years must be preserved and recovered, at least in those areas required by the Brazilian legislation, mainly in the areas of permanent preservation and in the legal reservation of the properties, since they are of main importance to maintain the balance of the regional micro-climate, which ultimately generates global reflexes.

Finally, it was verified that the geoprocessing tools, allied to field work were appropriated to perform this study, enabling an accurate analysis of the studied area.

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