English Version

Land use analysis for slope classes in watershed using GIS analysis

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Abstract

The objective of this work was to survey the land use at Limoeiro watershed placed on the Presidente Prudente and Álvares Machado counties in the West of the São Paulo State. The related survey was effected using an image of TM sensor of the satellite Landsat 7 and the Geographic Information System Idrisi. The result of the survey was statistically analyzed through the kappa index. After that, it was digitalized the level curves of the watershed which were interpolated to supply the slope classes of all the studied area. Subsequently, the slope spaces were crossed with the land use with the purpose of verifying the main land uses in each slope class. It was observed that cattle and the urban area are the main ground occupations in the watershed. It was still observed that the predominant slope spaces in the studied area are those between 3 and 12 percent.

Keywords: land use; Limoeiro watershed; geoprocessing.

Introduction

The land use analysis allows the identification of the main soil occupations in an area of interest and provides important information related to the environmental characteristics of the area. On the basis of this information one can evaluate the ambiental conditions on the studied places, and identify areas with a conflict between the current and the ideal use, for instance the presence or not of riparian forest in permanent preservation areas or soil occupation in higher slopes than the technically recommended. In these cases strategies to adequate the conflict areas can be established.

To Venturieri e Santos (1998), monitoring a landscape of a certain region is a prime factor on the rational planning of land use, facing mainly the speed of physical space occupation and the little knowledge of the natural resources.

According to Palavencino et al. (2000), the knowledge of the land use and land cover is one of the first plans of information that can be inserted in a GIS, since they answer the classic questions: which, how much and where are located the resources on a certain political and administrative structure.

By evaluating the different methods of classification available on the Idrisi, Decian et al. (1999) verified that the maximum likelihood method presented the best results for the spectral differentiation of the target.

Stehman e Czaplewski (1998) affirmed that the cover crops maps are used in many applications to describe the space distribution and land cover, and are also useful to estimate wide ranging areas of different cover classes. In these cases, the quantitative evaluation of the map accuracy can help the users to evaluate the use of each map to each application.

To Simões (2001) the last step of a classification usually involves an evaluation of the mapping accuracy. This evaluation can be done through the generation of random points on the map to be verified on the land.

Material and Method

The studied area is located on the West of São Paulo state, on Presidente Prudente and Álvares Machado municipalities, between the coordinates 443,000 to 460,000 east and 7,548,00 to 7,560,000 North, referent to the UTM zone 22, horizontal datum Córrego Alegre, and vertical datum Marégrafo de Imbituba/SC.

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Topographic map and Satellite Imagery georeference

The topographic maps were converted from analog to digital format with a scanner. After that the file was converted to the .rst format, supported by Idrisi for Windows, using the import menu of this software. The next step was to prepare this digital map georeference. According to Eastman (1998) this is a procedure to register spatially an image to its known position on the land. In this study, it was made a conversion to the UTM system (Universal Transverse Mercator).

The georeferencing procedure consisted in a collection of points of control, which were identified on the digital and topographic map. These points were used to create a correspondence file trough the Data Entry/Edit menu, where the coordinate pairs of the points of control were typed. In this file the first line specifies the total number of points of control. The coordinates of the control points are listed below in sequential order. The fists listed are the old coordinates, followed by the coordinates of the new reference system. Based on this dataset, the software generates an equation that describes the relation between the two coordinate systems. From this equation, Idrisi converts the file to the new reference system. This procedure was also executed with the satellite image georeference. The Figure 1 presents the results of the satellite image georeference on the area of the Limoeiro watershed.

Land use classification

The analysis of the land use in the watershed was performed on the image of the Enhanced Thematic Mapper (ETM) sensor installed on Landsat 7 Satellite, path/row 222/075, on August 12th 2001. The 3, 4 and 5 bands were used on this analysis, which correspond to the visible red, near infrared and infrared, respectively. These three bands are commonly used to classify satellite images to agricultural and environmental analysis since they gather the most significant portion of the information of the spectral response captured by the satellite on these areas. The verification of the cover classes was preliminary made trough an unsupervised classification, objecting to obtain an approximate number of the highlighting classes.

Then it was made a supervised classification, when a set of representative pixels of each land use class was digitized. Those polygons were references to the later image classification process. The samples were demarcated on the false RGB 24 bits color composition, which offers good characterization of the existing cover crops.

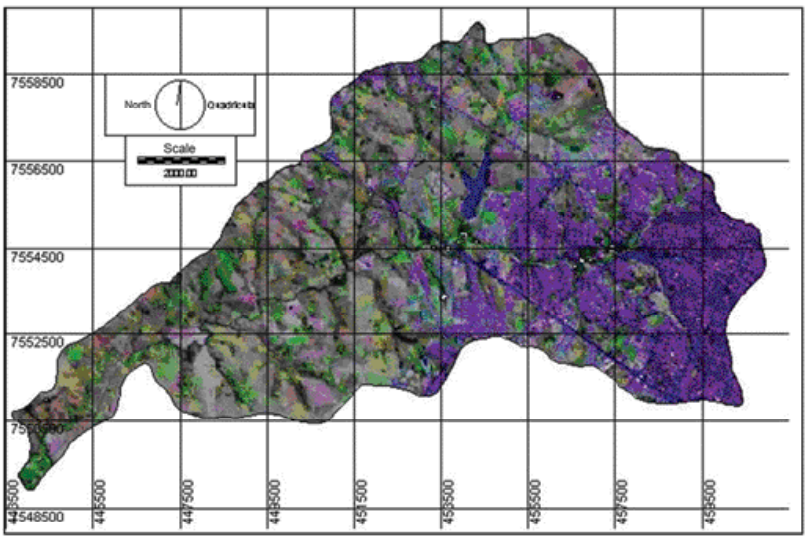

Figure 1. Satellite image of the Limoeiro watershed with georeferencing

The classification was made in an area slightly larger than the watershed with the goal of having more options of samples. The use of each reference polygon was defined according to the recognition of the predominant classes in the 24-bit image.

This work uses the classification method of Maxver (maximum likelihood). In this method, the values of the reflectance on a training area are described by a probability density function, based on Bayesian statistics. This classificator verifies the probability that a pixel has to belong to a determined class and classifies it on the most likely category. The classification was made trough the image processing, signature development e hard classifiers modules.

Results and Discussion

Figure 2 shows the results of the digital classification of the land use on the watershed and Table 1 presents the results related to the area occupied by each category of land use.

As it can be seen on Figure 2 and Table 1, the predominant land occupation on the watershed is pasture, that occupies 49.89% of the total area. This confirms what was expected, since Presidente Prudente is located on a region whose economy is based on cattle.

The urban area with 24.07% of the total area is the second occupation of the watershed, taking

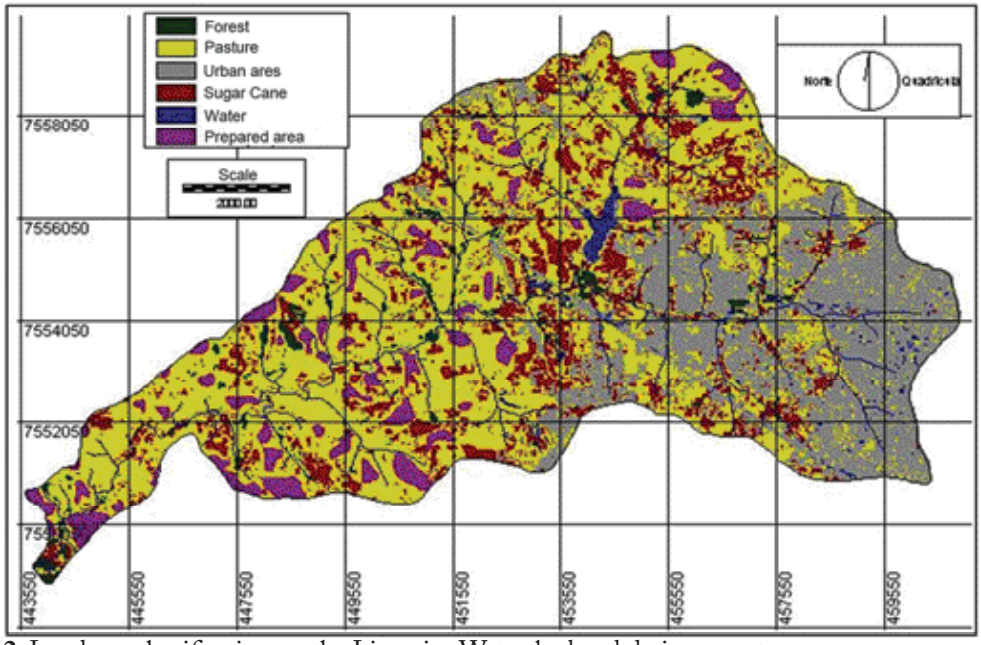

Figure 2. Land use classification on the Limoeiro Watershed and drainage system

Table 1. Category of land use, occupied area and cover percentage on Limoeiro watershed

Category of land use	Total area (ha)	Percentage on total area (%)
1 – Forest	222.12	2.53
2 – Pasture	4378.06	49.89
3 – Urban ares	2112.69	24.07
4 – Sugar cane	1389.63	15.84
5 – Water	102.50	1.17
6 – Prepared area	570.12	6.50
Total	8,775.12	100

into account that some of the springs that form the stream are located on the urban area.

The sugar cane covering 15.84% of the area is the third main occupation. The prepared area can be added to this number considering that most of it will be used to this crop.

The forest area with only 2.53% indicates that the environment on the watershed is in an advanced state of degradation. According to the Brazilian Forestry Code each property must have at least 20% of forest recovery, called legal reserve, without taking account on the permanent preservation areas. In this case, even discounting the urban area, the percentage of forests should be higher.

The watershed area occupied by prepared land is only 6.5%, and it is almost always used to develop the sugar cane culture, which is one of the main agricultural cultures on the region of Presidente Prudente.

The watershed area covered by water reaches 1.17%. The main part of this area constitutes the Baneário da Amizade dam, located on the west of Presidente Prudente, on the border with Alvares Machado.

After the land use classification it was made en evaluation of the classification accuracy by using Kappa index (Table 2), according to the descriptions made by Ippoliti-Ramilo (1999), Simões (2001) and Piroli(2002).

The interpretation of the Kappa index shows that the land use classes number 1 (forest), 5 (water), and 6 (prepared land) have all their pixels sampled inside their own class on the ground truth map to the error of inclusion, i.e. they showed no classification errors on the evaluated pixels.

Class number 4 (sugar cane) showed the higher errors due to the fact that this crop has diverse interactions with the soil, presents different percentage of covering and different heights by the time the image was obtained, which made the classifier even confuse it with high grasses.

With regard to the omission error, classes 2 and 6 had no problem, and the highest error occurred on class 5.

The obtained Kappa index was 0.87, which evaluates the classification accuracy as excellent, according to the table proposed by Landis e Koch (1977).

Slope class map

The slope class map was elaborated based on the topographic maps in the scale 1:50.000, in which the level curves were digitized from 20 to 20 meters.

The first step towards the implementation of this work was the conversion of the topographic maps from the analogical format to digital, trough a scanner. Then it was georeferenced. In a next step, the level curves of the entire watershed including the exterior area were digitized, aiming to have no influence on the watershed borders. This interpolation was effected through the surface interpolation module of Idrisi, which utilizes the most used irregular triangle grid construction method (TIN), i.e., the Delaunay triangulation.

Figure 3 shows the vectorized contour in the watershed area.

Figure 4 presents the results of the interpolation of the watershed contours, that were then reclassified to the soil conservation rages, as suggested by Lepsch et al. (1991).

As it can be seen in Table 3, slope class 6-12% represents 46.64% of the watershed total area,

Table 2. Results obtained with the Kappa index to evaluate the classification accuracy on the land use on Limoeiro Watershed

Classificated land use	Ground truth						Error of inclusion
	1	2	3	4	5	6	
1	4	0	0	0	0	0	0
2	0	39	2	1	0	0	0.093
3	0	0	18	0	1	0	0.0526
4	1	0	0	9	0	0	0.1818
5	0	0	0	0	2	0	0
6	0	0	0	0	0	2	0
Omission error	0.2	0	0.1	0.1	0.33	0	

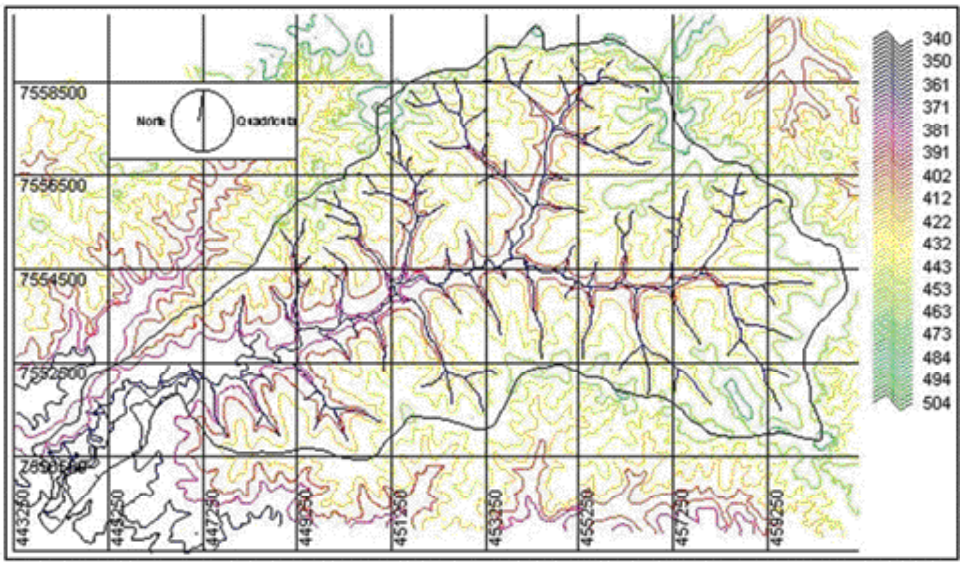

Figure 3. Vetorized contour and Drainage system on the Limoeiro Waterhed

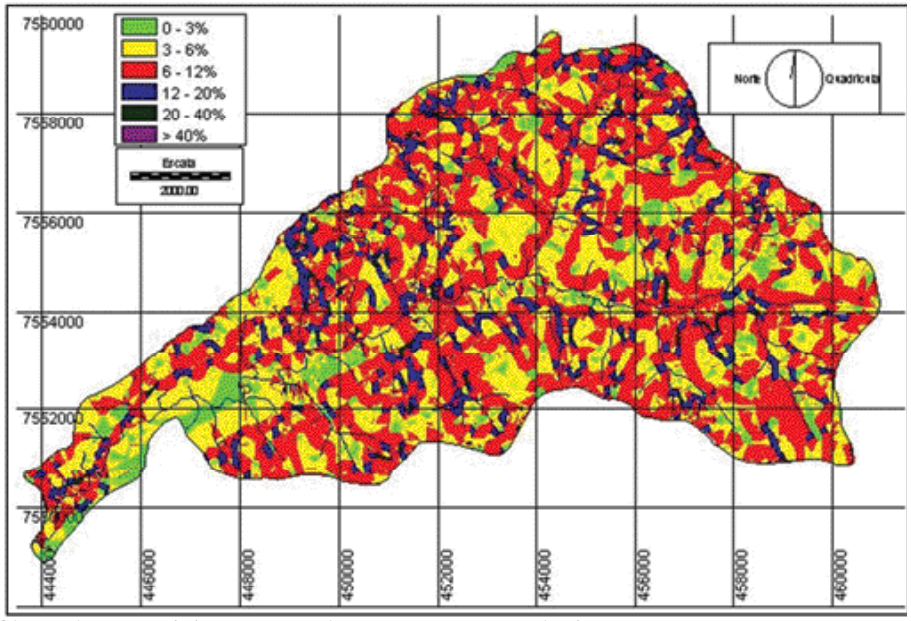

Figure 4. Slope classes and drainage on the Limoeiro Watershed

occupying the larger area. The second slope class in the occupied area is 3-6%, representing 33.42% of the total area. Slope class 12-20% occupies 10.76% of the area, and is the third larger slope. Slope class 0-3% represents 7.97% of the total area, what makes it the fourth larger class. Slope class 20-40% represents 1.17% of the watershed total area and the class with slopes higher then 40% represents 0.04% of the total area. This data set shows that the topography of the area is gently undulated, with few areas with high slopes.

Table 3. Slope classes and respective areas on Limoeiro watershed

Slope (%)	Total area (ha)	Total area percentage (%)
0 – 3	699.75	7.97
3 – 6	2933.00	33.42
6 – 12	4092.62	46.64
12 – 20	943.88	10.76
20 – 40	102.50	1.17
> 40	3.37	0.04
Total	8775.12	100

Land occupation and land use in each slope class

Land use classes on slope class 0-3%

As it can be seen on Figures 5 and Table 4, the area occupied with pasture reaches 48.91%, which makes it the largest land occupation on this slope class. The urban area corresponds to 23.45% of the total area, making it the second major occupation of this slope class.

The areas occupied by sugar cane (15.17%), forest (2.27%), water (0.89%) and prepared land (8.81%) complete the land occupation on the studied slope class.

Land use classes on slope class 3-6%

The largest occupation of soil on this slope class is still pasture, which corresponds to 49.28% of the total area. Urban area is the second larger use, with 24.70% of the total area. Sugar cane occupies 16.44% of this slope class total varea, water occupies 0.91%, forest covers 2.70%, and the prepared land area is 5.97% of the total slope class area that was analyzed.

Figure 6 presents the results of this analysis and Table 5 the occupied areas for each land use on this slope class.

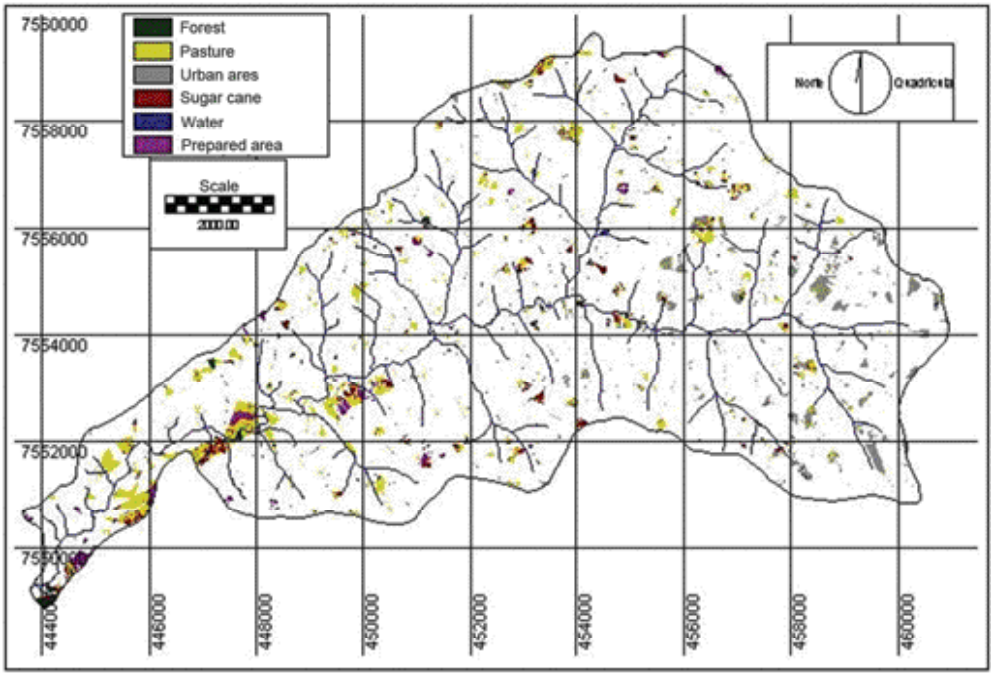

Figure 5. Land use classes on the slope class 0-3% and drainage system

Table 4. Land use classes, occupied area and percentage of cover on the slope class 0 – 3%

Land use class	Total area (ha)	Percentage of the total slope class area (%)
Forest	19.37	2.77
Pasture	342.25	48.91
Urban area	164.06	23.45
Sugar cane	106.12	15.17
Water	6.25	0.89
Prepared land	61.68	8.81
Total	699.73	100

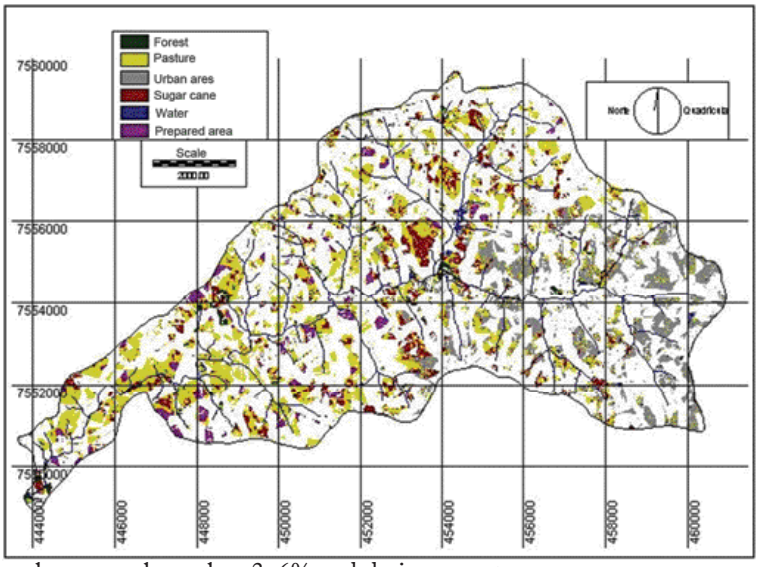

Figure 6. Land use classes on slope class 3–6% and drainage system

Land use classes on slope class 6-12%

In this slope class pasture occupies 49.38% of the watershed total area, urban area corresponds to 24.59% of the total area, sugar cane area corresponds to 16.04%, water corresponds to 1.48% and prepared land corresponds to 6.13% of the total class area verified. Figure 7 presents the result of this crossing and Table 6 the areas and the percentage occupied by each land use class on this slope class.

Land use class on slope class 12-20%

In slope class 12-20% the land occupied by pasture is 53.82%, the urban area occupies 20.85%, forest covers 2.48%, sugar cane area is 14.16%, water

Table 5. Land use classes, occupied area and percentage of cover on the slope class 3 – 6%

Land use class	Total area (ha)	Percentage of the total slope class area (%)
Forest	79.25	2.70
Pasture	1445.31	49.28
Urban area	724.43	24.70
Sugar cane	482.06	16.44
Water	26.69	0.91
Prepared land	175.25	5.97
Total	2932.99	100

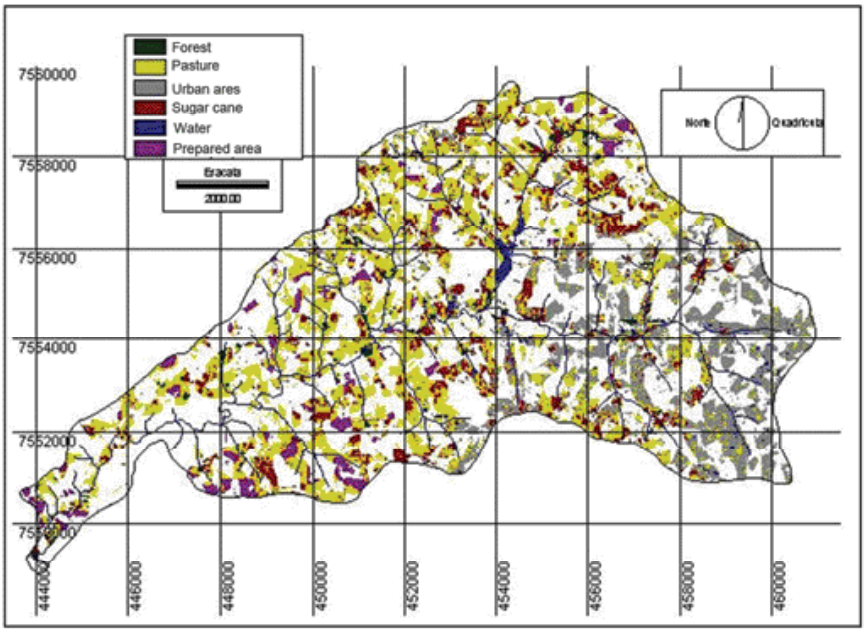

Figure 7. Land use classes on the slope class 6-12% and drainage system.

Table 6. Land use classes, occupied area and percentage of cover on the slope class 6 – 12%

Land use class	Total area (ha)	Percentage of the total slope class area (%)
Forest	97.81	2.39
Pasture	2019.31	49.38
Urban area	1006.19	24.59
Sugar Cane	656.19	16.03
Water	60.69	1.48
Prepared Land	250.94	6.13
Total	4091.13	100

occupies 0.85% and prepared land covers 7.84% of the watershed area. It is necessary to be attentive with the results on this slope class since according to Lepsch et al. (1991) and Zimback and Rodrigues (1993) this is the limit to agricultural occupation. Special care with the soil is recommended when it is occupied with agricultural activities.

Figure 8 represents the results of the comparison between land use classes data and the slope class data. Table 7 presents the area and percentage occupied by each land use class on the slope class 12-20%.

Land use class on slope class 20-40%

As it can be seen on Figure 9, the area covered by pasture reaches 57.51% of the total area of this slope. Urban area corresponds to 20.18% of the total area. The third larger land occupation on this slope class is sugar cane, which corresponds to 11.40%. The area covered by water on this slope class corresponds to 0.85%, the forest covers 2.14% and the prepared land reaches 7.92% of the total Limoeiro watershed area. It is important to observe that the slope classes 20 - 40% are considered high according to Lepsch et al. (1991) and, therefore, must be occupied by activities that are less aggressive to the soil, for instance, reforesting.

Table 8 presents the area and percentage of each land use on this slope class.

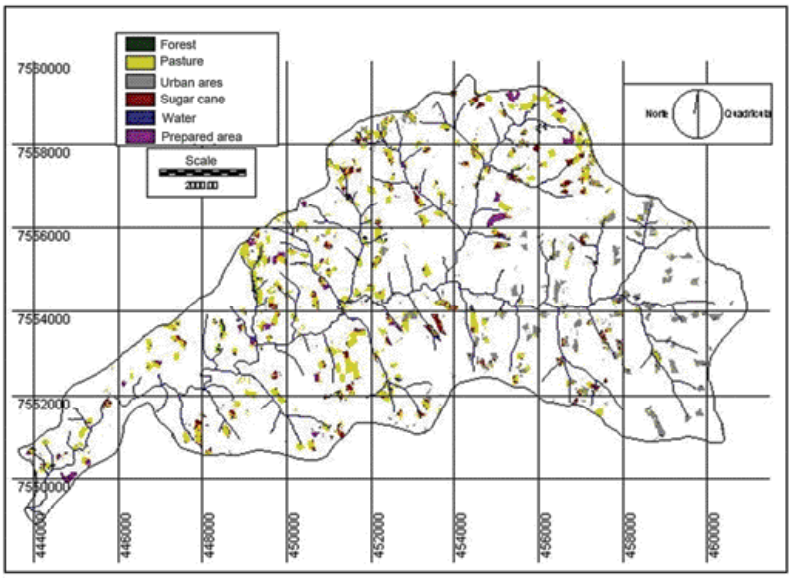

Figure 8. Land use classes on slope class 12–20% and drainage system

Table 7. Land use classes, occupied area and percentage of cover on the slope class 12 – 20%

Land use classes	Total area (ha)	Percentage of the total slope class area (%)
Forest	23.5	2.48
Pasture	508.8	53.82
Urban area	197.1	20.85
Sugar cane	133.9	14.16
Water	8.0	0.85
Prepared land	74.1	7.84
Total	945.40	100

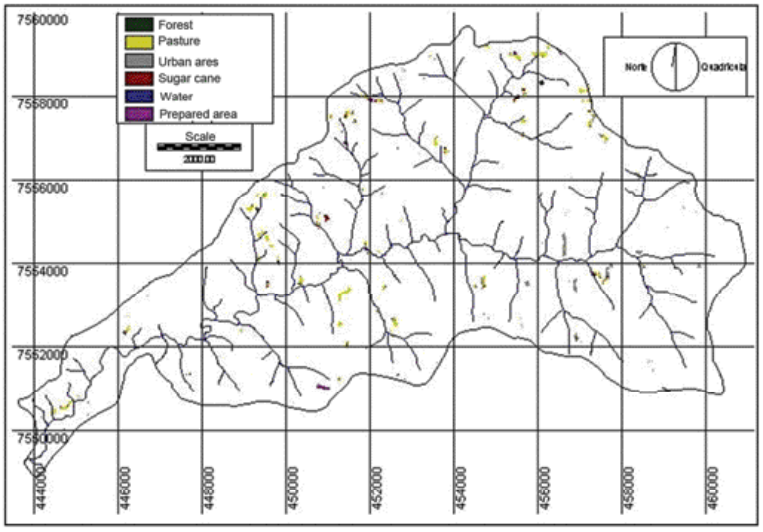

Figure 9. Land use classes on slope class 20–40% and drainage system

Land use class on slope class higher than 40%

On this slope class there is only pasture, with 75.96%, urban area with 5.64% and sugar cane with 18.40%. These are locals with high slopes, where the only recommended use, according to Lepsch et al. (1991) is the protection of wild flora and fauna, recreation or water storage. These should be places covered mainly by forests, which is different from the actual current use. Figure 10 shows the location of

Table 8. Land use classes, occupied area and percentage of cover on the slope class 20 – 40%

Land use classes	Total area (ha)	Percentage of the total slope class area (%)
Forest	2.19	2.14
Pasture	58.94	57.51
Urban area	20.69	20.18
Sugar cane	11.69	11.40
Water	0.87	0.85
Prepared land	8.12	7.92
Total	102.50	100

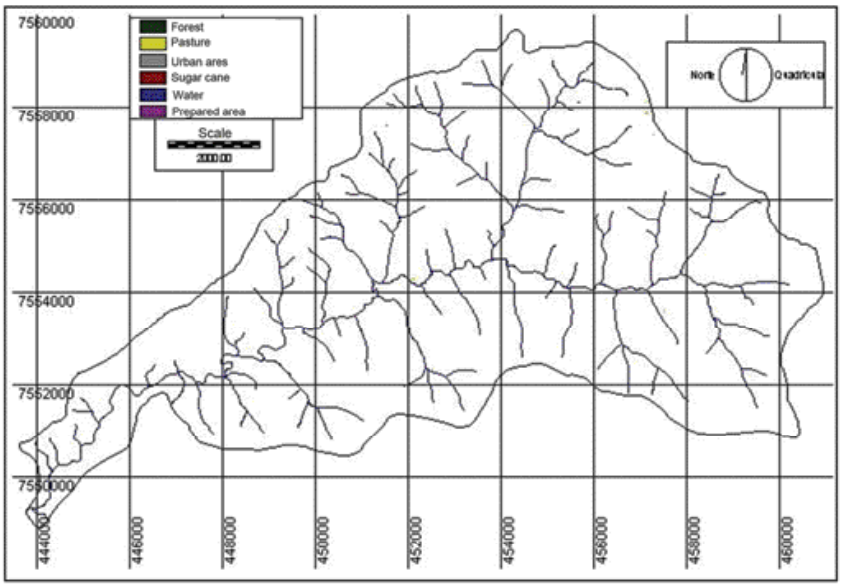

Figure 10. Land use classes on slope class higher than 40% and drainage system

Table 9. Land use classes, occupied area and percentage of cover on the slope class higher than 40%

Land use classes	**Total area (ha)**	**Percentage of the total slope class area (%)**
Forest	0	0
Pasture	2.56	75.96
Urban area	0.19	5.64
Sugar cane	0.62	18.40
Water	0	0
Prepared land	0	0
Total	3.37	100

these areas and Table 9 presents the use of land area on the watershed.

Conclusions

After the completion of the different analysis required for the performance of this work, it was concluded that:

The integration of the Geoprocessing tools allowed agility in data collection, data manipulation and in the different analysis required;

The Geographic Information System used was essential for scanning data, interpolations, algebra, storage and generation of the final maps;

Landsat 7 satellite image was a good database for evaluate the land use on the watershed;

The methodology used to obtain the land use classes and slope classes was suitable for the work, reducing time and financial resources;

The major land occupation on Limoeiro watershed is the pasture reaching almost half of the area. The second main occupation is urban area occupying almost a quarter of the hole county area;

Urban area is the class with the greater tendency of increase, since Presidente Prudente city is expanding towards West;

It is necessary to adopt urgent measures to protect Limoeiro watershed, mainly with the reforesting of its banks and with soil conservation programs.

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