GEOPROCESSING TECHNIQUES APPLIED TO THE STUDY OF THE DYNAMICS OF LAND USE AND LAND COVER AT SMALL WATERSHEDS

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Abstract. This study compares the land use support capacity of an agricultural region in Northern Paraná State (Brazil) for the year 1993 with that of 1980, using a GIS and an Image Analysis System. The methodology consists of three steps, namely: 1. A land use and land cover map was obtained using digital image processing techniques applied to images from 1993 and by visual interpretation of the resulting product. An available survey for 1980 was also used. 2. An agricultural land suitability map was obtained by cross-checking soil limiting factors. Given the importance of the slope factor, a more detailed analysis was performed. 3. The land use/land cover and agricultural land suitability maps were integrated in order to generate land use adequacy maps for 1980 and 1993, followed by an analysis of the adequacy for this period. This analysis proved to be very useful for rural activities, because it allows the detection of areas with high erosion risks, and therefore reduces the efforts for conservation control.

INTRODUCTION

The intensive soil occupation for agricultural use, without considering its support capacity, is highly responsible for the soil erosion and degradation processes and its negative results for water resources. The support capacity of soils can be obtained by the determination of the Agricultural Land Suitability, that allows a technical and economical evaluation for the adequate agricultural use of soils. The availability of information concerning the Agricultural Land Suitability allows the monitoring of agricultural areas, referring to its use, and specially to the discrepancies related to its bad use. This allows agricultural planning at regional level and even at small watersheds. In order to perform this analysis, the land use/land cover, its survey is necessary and remote sensing techniques have proved to be useful tools for this work, as it was shown, by several authors, among others, by [7], [5], [6], and [3].

To obtain information on Agricultural Land Suitability the integration of environmental variables (such as edaphic conditions, relief, climate) is needed, and presently GIS allows the manipulation of different databases, and to cross data. An example of this, is the evaluation of Agricultural Land Suitability, that consists in the comparison of land use maps with the recommendations for its proper use. These data manipulation operations are possible by the use of joint remote sensing and GIS techniques, as presented by [8], [1], [2]. In this frame, the objective of our study is to present a methodology using both remote sensing and GIS techniques for the analysis of adequateness of land use/land cover, as well as the of its dynamics.

AREA UNDER STUDY

The area under study is located in Paraná State (Brazil) and has the following coordinates: S 23° 16' 30" to 23° 22' 30" and W 51° 11' 40" to 51° 23' 30". The relief is made up of hills with flat tops and long slopes in almost the entire area. The original vegetation was a Subperennial Forest now covering only 4% of the area.

MATERIALS AND METHODS

In order to perform this study the following materials were used: TM/Landsat images, Topographic maps at 1:50,000 scale, the image analysis system SITIM/INPE and SGI/INPE. The TM-Landsat data were submitted to image processing techniques (geometric correction and digital enhancement) and color composites were obtained. The visual analysis of these products allowed the elaboration of land use/land cover map for 1993. The 1980 map was already available, only the legend was adapted to fit with the 1993 map. To obtain the map on Agricultural Land Suitability, initially we made a map of the slopes, using an analogical abacus, applied manually to the cartographic base (the topographic maps used have a contour interval of 20 m). In parallel to that, a slope map was obtained using the software available at SGI/INPE. As a second step, the map of Agricultural Land Suitability was obtained by the integration of environmental parameters such as: soil type, slope, climate and limiting factors like deficiency of fertility, water deficit, oxygen deficit (water stress), erosion risk and impediment to mechanization. For each one of these parameters an Information Plane (IP) was created, that were

afterwards integrated by SGI/INPE to obtain the map of Agricultural Land Suitability. This map was crossed with the land use/land cover maps to evaluate those areas of discrepancies (where land use is not compatible with the technical recommendations of the Agricultural Land Suitability map) and its quantification for the timeframe analyzed. All these data manipulation operations were made at the SGI/INPE environment.

RESULTS AND DISCUSSION

The analysis and interpretation of TM/Landsat products as color composites TM 5/ Red, TM/ Green, TM3/ Blue and TM 4R 3G 5B, as well as information obtained during field work, allowed the elaboration of the land use/land cover map. We observed that, during the interpretation of the color composites, that the TM 4R 3G 5B composite was most informative, agreeing with [7]. Table 1 presents the quantitative results of land use/land cover classes for the period under study, showing mainly the decrease of areas with perennial cultures and pastures and the increase of annual cultures. The class "bare soil" that shows up only in 1993, is essentially associated with those areas to be used for summer crops.

Table 1 - Quantitative assessment of land use and land cover classes in 1980 and 1993.

Land Use Classes	1980		1993	
	Area (ha)	Area (%)	Area (ha)	Area (%)
Urban areas	209.5	1.7	316.5	2.6
Lots	38.6	0.3	324.3	2.7
Summer crops	5464.4	46.2	6835.0	57.6
Perennial crops	2184.4	18.4	714.6	6.2
Pasture	2894.7	24.4	1678.3	14.2
Floodplain vegetation	292.6	2.4	129.8	1.1
Reforestation	163.3	1.3	127.8	1.0
Natural vegetation	557.3	4.7	448.4	3.7
Water bodies	15.4	0.1	27.2	0.2
Bare soil			1218.2	10.3
Total	11820.4	100.0	11820.4	100.0

The slope map obtained by the SGI/INPE software did not show much coherence with the topographic changes, if compared quantitatively with the map obtained by the analogical abacus. These results confirm the findings from [4], who states that those areas with a homogeneous and flat

relief are less sampled due to a larger distance among contour lines. The integration of environmental parameters, as presented before, allowed to obtain the map of Agricultural Land Suitability. Therefore we created a file of rules that includes all possible combinations of the parameters considered. As a result of this integration, we came up with three groups of Agricultural Land Suitability: Group I - areas suitable for summer and perennial crops; Group II - areas regularly suitable for summer and perennial crops; Group III - inappropriate areas for summer/perennial crops, but suitable for pasture and reforestation The other groups (II, IV and VI), that normally occur on the Agricultural Land Suitability maps did not show up in the area under study.

After crossing the Agricultural Land Suitability map and the land use/land cover maps, it was possible to characterize those areas of discrepancy in the area under study, for both dates. Table 2 presents the results obtained from those areas showing land use patterns that are compatible with the Agricultural Land Suitability map and those that are under or over-used in 1980.(When lands are used below its support capacity, these areas are considered as "under use", while for those lands that are used for activities beyond its support capacity, they are named as "over use") One can observe that, for this date, 81.16% of the area was used within the limits of its support capacity and just 16.61% incompatible, that were partially responsible for soil degradation processes.

Table 2 - Quantitative assessment of land use class adequacy in 1980.

Adequacy Classes	Area (ha)	Area (%)
Urban Areas	209.56	1.77
Lots	038.62	0.33
Water bodies	015.41	0.13
Under use	5483.56	46.39
Compatible use	4110.12	34.77
Over use	1963.19	16.61
Total	11820.46	100.00

At Table 3 the results for 1993 are shown. For this date, 68.07% of the area is being adequately used and 26.28% is incompatible with the land support capacity. This indicates an increase of discrepant land use areas by about 10% for the timeframe under study.

In a feasibility analysis for this timeframe, (Table 4) we concluded that 7.23% of the area changed activities to other less intensive ones, while for 29.78% of the area, activities were intensified. On the other hand, 44.14% were stable, in a good state of conservation. This figure should be added by 16.53% that changed from "under use" to "compatible use". Being so, 60.67% of this region are used within the tolerance limits. Special attention should be paid to those areas of "stable over use" (13.20%) and those of "implanted over use" (13.25%), because these are critical areas where the

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agricultural activities increase the soil degradation processes and consequently increase the sediment load in the drainage of this small watershed

Table 3 - Quantitative assessment of land use class adequacy in 1993.

Adequacy Classes	Area (ha)	Area (%)
Urban Areas	315.55	02.68
Lots	324.76	02.75
Water bodies	027.20	00.22
Under use	2891.38	24.46
Compatible use	5155.35	43.61
Over use	3105.22	26.28
Total	11820.46	100.00

Table 4 - Quantitative assessment of land use adequacy in the time frame.

Classes	Area (ha)	Area (%)
Stable under use	2093.33	17.71
Stable compatible use	3124.19	26.43
Stable over use	1560.62	13.20
Compatible use to under use	480.96	4.07
Under use to compatible use	1953.94	16.53
Removed over use	373.25	3.16
Implanted over use	1565.64	13.25
Urban area	316.55	2.68
Lots	324.76	2.75
Water bodies	27.20	0.22
Total	11820.46	100.00

CONCLUSIONS

The methodology proposed in this study, using both remote sensing and GIS techniques, is an important tool for the survey, analysis and integration of environmental parameters and for the quantification of areas of discrepancy, referring to land use/land cover at small watersheds. This analysis is of high interest for those activities in the rural areas, because it allows to detect areas of erosion risks and therefore reduces the efforts for environmental control.

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