MONITORING ENVIRONMENTAL IMPACT OF LAND USE: EVALUATING AN AGRICULTURAL AREA OF DISTRITO FEDERAL, BRAZIL

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ABSTRACT:

The formation of the landscape in Distrito Federal (DF) is strongly linked to the densification processes of the urban mesh and of the agricultural occupation growth, which can be considered the main components of the territorial transformations and of the area's reduction occupied by the *Cerrado* biome. The agriculture of the area is represented essentially by the production of grains, vegetables and fruits. In function of this accelerated occupation of the lands, there's need of revaluing the environmental scenery of DF. Associating geoprocessing techniques, as Remote Sensing and GIS it was possible to accomplish this activity from the methodological point of view. The choice of Nucleo Rural do Rio Preto as study area was based in the fact that this area is the biggest producer of grains in Distrito Federal. Using HVR/SPOT 4 and TM/LANDSAT 5 images and information implemented in a digital georeferenced database, it was made the evaluation of the use and occupation of this agricultural area. Through digital classification, it was generated the map of actual use of the lands and its quantities related. With the manipulation of this classified image, the map of environmental risk was elaborated using a GIS and field checkings were made for its refinement. About 44.6% of the area is occupied by arable areas and 31% of bare soil, fields/pastures are 12.5%, *Cerrado* comprehend 4.2%, forests 7.1% and water resources 0.36%. Approximately 8% of the area is under environmental risk and great part of these areas is near forests, pressing the hydrologic resources of the region.

1. INTRODUCTION

An increase on the process of lands' occupation, caused by the urban and agricultural expansion, areas of *Cerrado* are decreasing, causing a reduction of local biodiversity, suppression of the natural resources, more especially soils and water (Felizola et al., 2001).

The lands' occupation by the agricultural activities in Distrito Federal began to have more importance during the 80's, with the introduction of the soybean's culture, irrigated cultures and other extensive cultures. The Distrito Federal's east portion contains the area between the watersheds of Rio Preto and São Bartolomeu, that corresponds the largest concentration of Cultivated Agricultural Areas, and some of these stand out in production values (Felizola et al., 2001).

According to Pereira et al. (1998), the confrontation of the lands' capability with the current lands' use provides the verification of the conflicts' existence of and supplies subsidies to the government entities for the preventive monitoring of the risks associated to the inadequate use of the soils.

For remote areas with heterogeneous land cover it is frequently more efficient to use remotely sensed imagery to identify areas that have been, or are at risk of being, damaged. Image analysis reduces the need for expensive ground-based survey and provides an explicitly spatial data source that may be used as a benchmark for monitoring and management support (Cadell and Matthews, 2002). It is stood out that the challenge of evaluating the agricultural sustainability and the environmental impact of different production systems, associated with several types of use of lands, finds a satisfactory answer in a complementary tool, the Geographical Information Systems (GIS) (Miranda et al., 1996).

The Distrito Federal's city is privileged by the existence of a technological support for the attendance of the evolution of aspects related to the use and occupation of the soil. Besides

images generated by satellite, it can be used, for the aggregation of information, the whole cartographic base produced by the SICAD – Distrito Federal's Cartographic System, scale 1:10,000. The sustainability's scenario should be enhanced, once, the objective of information's systemization to subsidize the planning process, seeks, ultimately, the maintenance of certain environmental aspects of the lands, in the intention of guaranteeing a better quality of life.

The present research aimed to evaluate the Cultivated Agricultural Areas of Distrito Federal, selecting for study the one which has bigger agricultural production for the characterization of the current use of their lands and to correlate these areas with soils' classes and land capability, as well as the establishment of a methodology of lands' use adequacy, based on orbital images and GIS. It was also intended to supply data to subsidize studies of sustainability of the physical environment of Distrito Federal.

2. METHODOLOGY

The area selected for the present study is in Federal District, in the Agricultural Area (ADL) of Rio Preto, inserted in the administrative area of Planaltina, with an area of 376.15 km^2, located in the coordinates UTM, zone 23 S: 224981 and 250981 of latitude S and 8269430 and 8245430 of longitude W.

The main agricultural products of the area are soybean, corn, bean and a diversified horticulture. According to EMATER/DF's data, this rural nucleus occupied in 2002/2003 the first place of Distrito Federal in total production and cultivated area, with respectively, 110,914 tons produced and 25,621 hectares planted.

This area is placed in the Bambui's lithologycal group along the Rio Preto's valley. It is composed by laminated and loamy metassiltites and feldspars-sandstones banks.
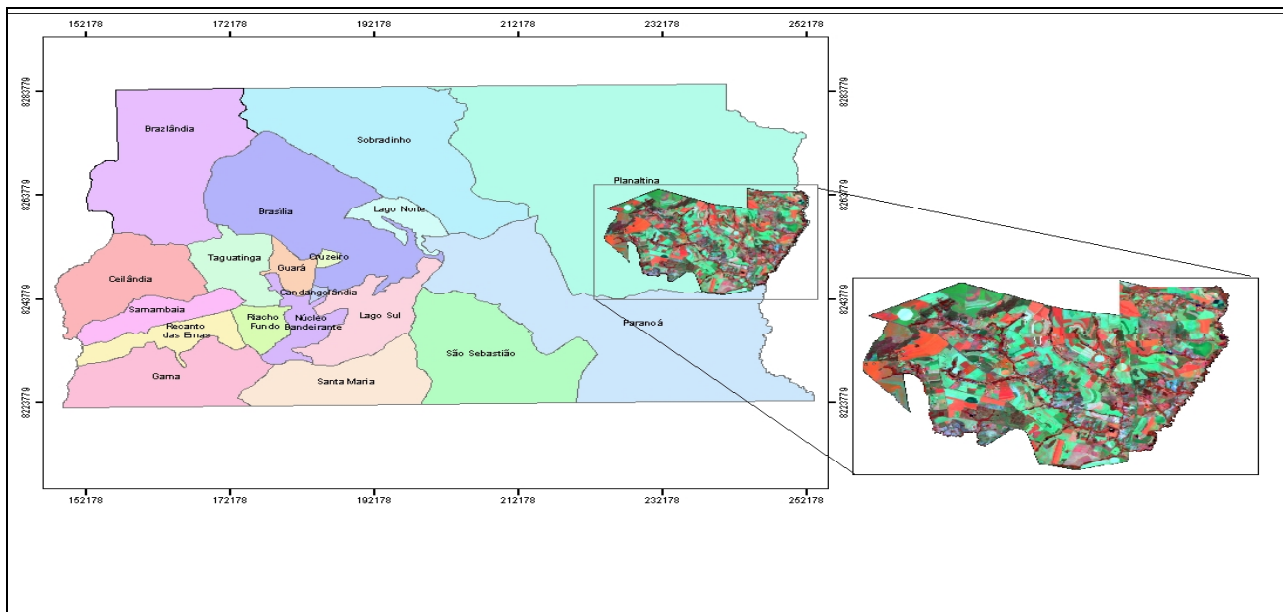
Figure 1. Spatial Localization of Núcleo Rural do Rio Preto - SPOT Image Copyright 2003, CNES

The geomorphology of the region, according to Novaes e Pinto (1994), that recognized three Surfaces, denominated in this work Geomorphologic Surface 1 (1,300 – 1,150 m), 2 (1,150 – 1,000 m) and 3 (1,000-750 m). The study area is localized at the Geomorphologic Surfaces 2 and 3.

In agreement with the Soil's Taxonomy classification, there are, in the study area, the following soils classes: Typic Rhodustox, Typic Plintustox and Typic Haplustox, Typic Haplustept, Typic Tropfluvent, Typic Troppsamment, Tropic Rhodustul, Tropic Haplultult and indiscriminate hidromorfic soils. Preliminary field surveys were done for recognition of the study area, verifying the occupation, soils' management and other relationships between agricultural activities and physical environment.

The available secondary data on natural resources and production system characteristics of the region was reviewed. To complement these informations field surveys were carried out in order to verify the soil's occupation, agricultural activities and the environment. A georreferenced digital database was implemented on the ArcGIS 8.3. Thematic layers such as soils and land capability (EMBRAPA, 1978), drainage, contours and spot height informations were obtained from the topographic maps by digitizing. With the drainage, contours and spot height data (IBGE 1984, scale 1:25,000) it was generated a TIN (Triangular Irregular Network) of the study area. Through this TIN, it was elaborated a DTM (Digital Terrain Model), reclassified into 2 classes, corresponding to the Geomorphologic Surfaces 2 and 3. It was also generated through the DTM a relief map, reclassified into 5 classes (0-3%, 3-10%, 10-24%, 24-45% and >45%).

Digital images from the HVR/SPOT 4 (September of 2003, orbit/point 221/71, 10m spatial resolution, false colour composite 2R3G1B) and TM/LANDSAT 5 (July of 2004 orbit/point 221/71, 30m spatial resolution, false colour composite 4R5G3B) sensors were treated in ENVI 3.6.

The ISODATA algorithm was used for the unsupervised classification of the image. This type of classification was chosen due to the fact of the land use homogeneity of the region. The thematic map *Actual Land Use* generated from the classified image identified the following land cover classes: **Arable Areas** (fields with different degrees of crop development); **Bare Soils** (comprehending areas prepared for cultivation and soils in degradation's process); **Forest** (correspondent to vegetation that surrounds water resources and *cerradão* – Brazilian savannah woodlands); *Cerrado* (comprehends typical, dense and thin *cerrados*); **Fields/Pastures** (comprehend human or natural formations with herbaceous predominance) and **Water Resources** (lakes, ponds and dams).

With the purpose of improving the result of the classification, pos classification techniques like clump and sieve classes of ENVI 3.6 were used. Field surveys were carried out to check the classification's reliability. The maps generated were crossed using ArcGIS 8.3. The thematic layers *Actual Land Use* x *Soils Classes*, *Actual Land Use* x *Slope Classes* and *Actual Land Use* x *Land Capability* were overlaid and the quantitative relations were evaluated. The thematic map *Land's Use Adequacy* resulted of the *Actual Land Use* and *Land Capability* overlay. This layer detected areas that weren't in agreement with the established in the agricultural aptitude of the lands. The study area was divided in 2 classes: **Satisfactory Use** (areas that are used correctly, according to the land capability); **Incompatible Use** (areas that are used differently than it's recommended by the land capability).

With the data obtained in the last stage, field campaigns were accomplished to validate the *Lands' Use Adequacy Map*. In the areas identified as incompatible, soil samples were collected, with three repetitions, in the interval of 0-10 cm, for physical (Soil's Density) and chemical analyses (Organic Carbon) for evaluation of the quality of the soils, according to methodologies described in EMBRAPA (1979). For the deviation's evaluation of the soils' quality, the analyses data were compared with the respective parameters in virgin soils. The sampling points were georeferenced and their analytical data implemented in ArcGIS 8.3.
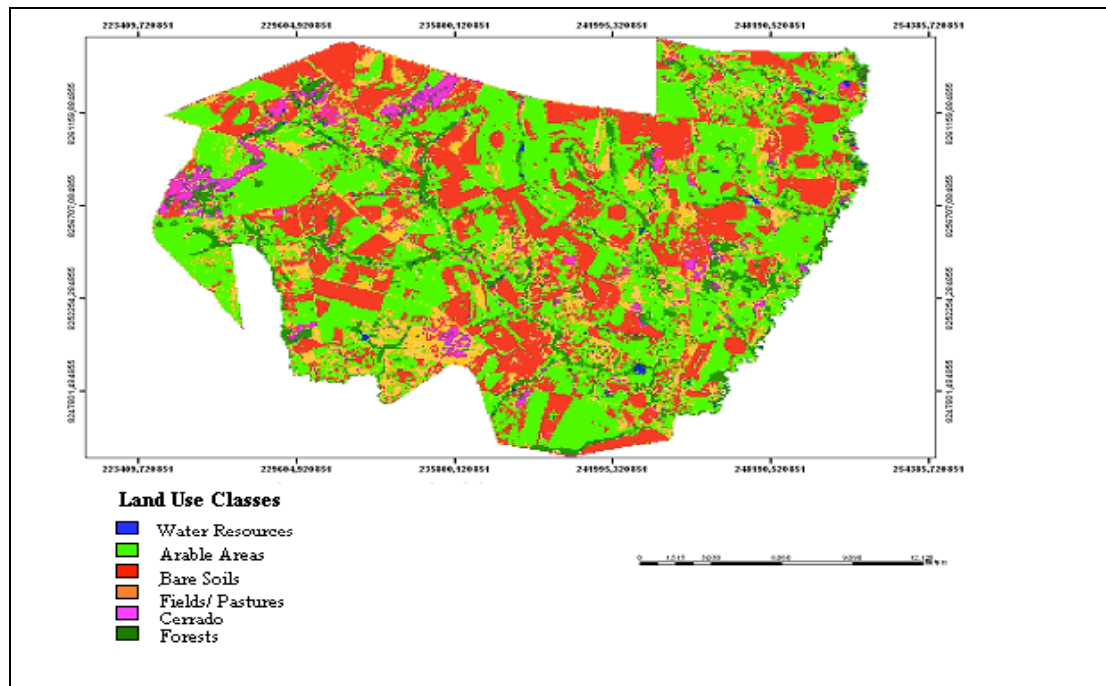
Figure 2. Actual Land Use Map of Núcleo Rural do Rio Preto

3. RESULTS AND DISCUSSION

The *Actual Land Use Map* of Rio Preto's Agricultural Area (Figure 2), generated by the unsupervised classification ISODATA of the image HVR/SPOT4 showed that the arable areas occupy 167.76 km^2 (44.6%), the bare soils are 116.86 km^2 (31.07%), the forests are 26.96 km^2 (7.17%), fields/pastures and *Cerrado* occupy 47.20 km^2 respectively (12.55%) and 15.91 km^2 (4.23%) and the water resources constitute 1.37 km^2 (0.36%). These results were confronted with the terrestrial reality, showing a good degree of reliability.

Tables 1, 2 and 3 show the results of the cross tabulation between *Actual Land Use* x *Soils Classes*, *Actual Land Use* x *Slope Classes* and *Actual Land Use* x *Land Capability*. The cross tabulation Actual Land Use x Soils Classes showed that 73.7% of the area are in Oxic Rhodustox dystrofic, and 34.5% of this total is in arable areas, 24% in bare soil areas. About 5.7% of the arable area is placed in Typica Haplustept, what brings concern, due to this soil type is susceptible to erosion process. The cross tabulation Actual Land Use x Land Capability showed that 87.16% of the lands are in the group of

aptitude 2 of Brazilian Land Capability Classification (Ramalho Filho e Beek, 1995), and 40% of this total are in arable areas and 30% in bare soils. The cross tabulation *Actual Land Use* x *Slope Classes* showed that 29% of the arable area and 20.4% of the bare soils are in plain relief. About 0.04% of the arable area is localized at a relief higher than 24%, what is not recommended by the Land Capability Classification.

About 1.41% of the arable area is distributed at the aptitude V, what is a degradating factor of the environment, given that the group of aptitude V indicates that the lands cannot hold annual cultures.

The Lands' Use Adequacy Map (Figure 3) showed that the water resources, especially the Extrema's river, are pressed with the progress of the agricultural activities, like pastures and horticulture. About 80% of the farmers aren't respecting the environmental legislation that considers untouchable 30 meters of vegetation along water resources of 10 meters width, as it's the Extrema's River case.

Land Use Classes	Soil Classes (%)							
	Typic Rhodustox	Typic Haplustox	Tropic Rhodustul	Hidromorfic soils	Typic Haplustept	Tropic Haplustox	Typic Tropfluvent	Total
Water resources	0.19	0.02	0.00	0.03	0.10	0.00	0.02	**0.36**
Bare Soil	24.24	0.51	0.41	0.15	0.96	0.04	0.06	**26.37**
Fields/ Pastures	8.60	0.55	0.11	0.42	2.74	0.12	0.02	**12.56**
Arable Area	34.49	2.25	0.08	1.43	5.68	0.50	0.15	**44.58**
Cerrado	4.08	0.53	0.07	0.64	1.40	0.20	0.23	**7.15**
Forest	2.10	1.30	0.15	1.11	4.11	0.14	0.04	**8.95**
Total	**73.7**	**5.16**	**0.82**	**3.78**	**14.99**	**1.00**	**0.52**	**100**

Table 1. Results of the cross tabulation between Soil Classes and Land Use Classes

Land Use Classes	Land Capability Classes (%)						
	1	**2**	**3**	**4**	**5**	**6**	**Total**
Water resources	0.06	0.27	0.00	0.00	0.00	0.02	**0.36**
Bare Soil	0.76	28.01	0.10	0.29	1.56	0.37	**31.09**
Fields/ Pastures	0.57	10.84	0.06	0.12	0.71	0.25	**31.45**
Arable Area	2.42	40.35	0.12	0.09	1.41	0.19	**44.59**
Cerrado	1.78	4.89	0.08	0.01	0.18	0.24	**7.17**
Forest	0.26	2.8	0.27	0.28	0.23	0.39	**51.75**
Total	**5.85**	**87.16**	**0.63**	**0.80**	**4.09**	**1.46**	**100.00**

Table 2. Results of the cross tabulation between Land Capability Groups and Land Use Classes

Land Use Classes	Slope Classes (%)					
	Plain	**Gently Undulated**	**Undulated**	**Strongly Undulated**	**Mountainous**	**Total**
Water resources	0.27	0.09	0.01	0.00	0.00	**0.37**
Bare Soil	20.38	9.82	0.49	0.04	0.00	**30.73**
Fields/ Pastures	8.09	4.10	0.32	0.03	0.00	**12.54**
Arable Area	29.32	15.11	0.38	0.03	0.01	**44.85**
Cerrado	1.89	1.86	0.49	0.03	0.00	**4.27**
Forest	5.03	1.81	0.35	0.05	0.01	**7.25**
Total	**64.98**	**32.79**	**2.04**	**0.18**	**0.02**	**100**

Table 3. Results of the cross tabulation between Slope Classes and Land Use Classes

The adequacy's classes areas were quantified and 8% was considered of incompatible use.

In the areas identified as incompatible, laboratorial analyses of soils' quality were accomplished. Typica Haplustept samples in pasture areas and Oxic Rhodustox dystrofic with the no-tillage production system, in areas that had to be destined to the environmental preservation.

In relation to the quantification of the Soil's Organic Matter, the following results were obtained: in the pasture areas, the smallest percentages were observed, that in the repetitions' average was of 2.9%, what is considered a medium level. According to Guimarães et al. (1980), when the soil contains up to 1.5% of organic matter, it is classified as low level; from 1.6 to 3.0%, medium level; and above 3.0%, high level.

The Organic Matter's levels found in the area of Typic Rhodustox dystrofic with no-tillage system were, on average of the repetitions, of 3.9% and in the area of Typic Haplustox dystrogic were, on average of the repetitions, 3.5%. For the two Rhodustox areas, the levels of Organic Matter are considered medium, because the literature recognizes as high values those whose are larger than 45 g kg^{-1} (4.5%).

The soils' density of the Typica Haplustept and Oxic Rhodustox dystrophic are, on global average of 1.47Mg.m^{-3}, above the normal indicated of 1.00 M g.m^{-3} in virgin soils. Compacting process is very evolved in the pastures areas.

All the results of the chemical and physical analyses reflect the effects of the inadequate use in soil's quality.

4. CONCLUSIONS

The *Actual Land Use* Map of Rio Preto kept good reliability to the field reality, allowing to identify and quantify the several types of occupation of the soil, particularly agricultural activities, besides allowing the accomplishment of correlations of use type and occupation with soil classes and lands capability.

The *Land's Use Adequacy* Map of Rio Preto had great importance for the evaluation of areas with degradation risk and allows to locate where the conditions are more critical.

Planners and policymakers, as well as members of the public, need to know about the effects of landscape change. The Lands' Use Adequacy Map produced can subsidize the decision making for the several agents that act in the administration territorial, urban and environmental.

The evaluation of the areas of environmental protection in relation to the use and occupation of the soil, demonstrates inadequate use of this natural resource, committing the sustainability of the lands of Distrito Federal.

The integration of the Remote Sensing techniques (using TM/LANDSAT 5 and HVR/SPOT 4 images) and Geographical Information Systems (GIS) demonstrated efficiency in the evaluation of the processes of lands' occupation and in the determination of the discrepancies between the potential use and the current land use of the Núcleo Rural do Rio Preto.

The Distrito Federal's environmental management needs to evolve from a curative approach, today predominant in the legislation and administrative apparel, for a preventive posture, that contemplates the use and the conservation of the natural resources in a long period, based in its potentialities and observing its vulnerabilities.
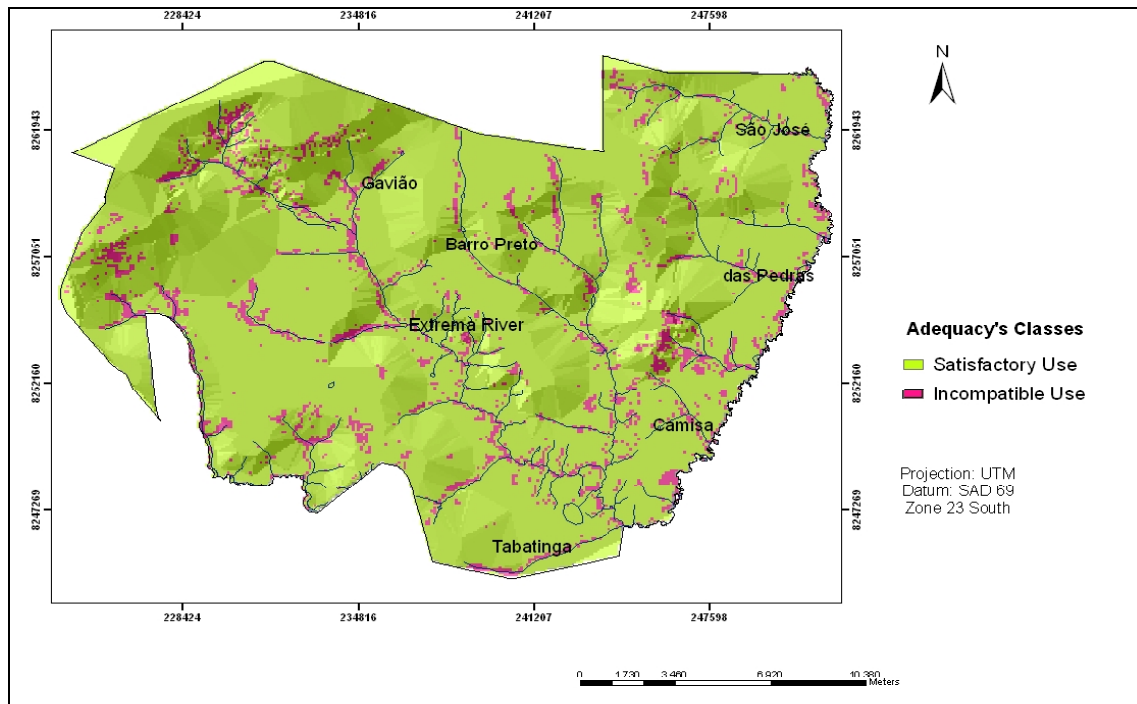
Figure 3. Lands' Use Adequacy Map of Núcleo Rural do Rio Preto

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