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USE OF GIS IN ENVIRONMENTAL AND TERRITORIAL MANAGEMENT
OF BOM SUCESSO-MG: PUBLIC DATA AT CHARACTERIZATION OF
LANDSCAPE

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The article reports an application of spatial data analysis procedures for the municipality of Bom Sucesso, located in the state of Minas Gerais, Southeast Brazil. This method is supported by geoprocessing tools and it is an assay applicable to other municipalities. The used spatial and alphanumeric data compose a Geographic Information System (GIS) which have been produced during the Training Program from the Brazilian Ministry of Cities and offered by the Federal University of Minas Gerais (UFMG). The Program's goal is instrumentalize in capture, storage and analysis of a public domain spatial data, which is handled in free software. This specific work for Bom Sucesso shows some results from the Training Program and, in addition, it aims to base the municipal decision making for the land planning and management, in order to ensure a sustainable development.

KEYWORDS: Geoprocessing, Environmental Analysis, Sustainable Development.

INTRODUCTION

A geoprocessing training program for urban planning has been offered to support municipalities throughout Brazil. It has been sponsored by the Brazilian Ministry of Cities and performed by Federal Universities. By the Geoprocessing Training Program, which has been carried out by the Geoprocessing Laboratory from the Federal University of Minas Gerais (UFMG), has been trained 160 municipalities from the state of Minas Gerais. The municipality of Bom Sucesso, located in the state of Minas Gerais, Southeast Brazil, had been chosen as a case study to demonstrate how the database produced by that Program bases an applying of a methodology supported by geoprocessing.

The beginning settlement cluster at Bom Sucesso had been motivated by environmental values related to a confluence of watercourses and by delimitation of a mountain chain. The landscape that received the settlement is a remarkable composition. However, it has been the main reason for conflict in urban growth. The imminent arrival of mining activities will be a growth catalyst and could induce a noticeable change on the landscape, which are of great environmental value and the propeller reason for land occupancy that area on the state.

The geoprocessing according to Moura (2010) *"includes the acquisition, processing and analysis of spatial data"* that can be associated with alphanumeric data and to compose a Geographic Information System (GIS). The GIS had been produced for Bom Sucesso during the Geoprocessing Training Program provides support to recognize the landscape features, with a view to identify environmental preservation areas as well as interesting areas for urban expansion.

Once the environmental and urban interests are identified, they will be combined in order to recognize vocations and conflicts which have been raised by land occupancy. This procedure is done through a spatial analysis models. Despite of them are excerpts from the reality, these models are open for calibration according to the current values. Moreover, the presentation of several variables had been involved in the process contributes to getting in touch with the community, the technicians and the public administrators.

LAND PLANNING SUPPORTED BY GEOPROCESSING

In 2007, the Brazilian Ministry of Cities in partnership with Federal Universities and Technological Institutes created a training program for municipal technicians about geoprocessing and Multipurpose

Registration Land. As stated on the City Statute and in the National Policy for Urban Development perspective, the Support Program for Continuing Education has an objective to disseminate the geoprocessing culture and practice for municipalities. It aims to implement information systems which allow elaborating plans and projects for urban development.

Since the first announcement, the Geoprocessing Laboratory from UFMG has been developed training for municipalities from Minas Gerais. Information materials in the format of digital text, video and manuals have been distributed to self instruction and to stimulate the installation of used free software. During the classes, subjects had been presented such as projections and coordinates, GPS technology, georeferencing and cartographic databases, cartographic data association to alphanumeric, thematic maps elaboration, query and data analysis, images manipulation and spatial analysis.

The above methodology had allowed the composition of a simplified GIS for each municipality. All data had been fed the GISs are of public domain such as topographic maps from the Brazilian Institute of Geography and Statistics (IBGE) ^{1[1]} and Landsat^{2[2]} satellite free images. Both GIS production process as its handling training had been done in free software from National Institute for Space Research (INPE). It had been also used an Online Map Server (GEOSNIC - Brazil in Cities) and the software TerraView and TerraSIG.

GEOSNIC^{3[3]} Online Map Server is part of National System of Cities Information (SNIC) and it had been created by the Brazilian Ministry

1[1] Available for view and download in <http://www.ibge.gov.br/home/geociencias/cartografia/default.shtm> or in FTP server.

2[2] Available for free download in the NASA website (<http://landsat.gsfc.nasa.gov/>), INPE website (<http://www.dgi.inpe.br/CDSR/>) and Maryland University website (<http://glcfapp.glcf.umd.edu:8080/esdi/index.jsp>)

3[3] <http://www.brasilemcidades.gov.br/src/html/home.html>

of Cities to ensure public access to georeferenced indicators both political and administrative as socioeconomic. The TerraView software is for visualization and data analysis. Through it, it is possible to develop spatial queries and by attribute, density evaluations by Kernel method and associations with external alphanumeric tables. The TerraSIG software is for production and data edition.

It is possible to achieve a simplified analysis of municipality conditions by means of only knowledge and data had been produced during the Training Program. Despite of simplified, that analysis is effective because it allows visualizing spatial and socioeconomic data, in the format of themed maps, and the correlations between them.

For an improved diagnosis, the Analysis System Geo-Environmental (SAGA) 4[4] is free software which allows an application of spatial analysis models. It was used analysis models of multi-criteria and combinatorial of basis matrix for the Bom Sucesso database analysis.

Spatial Analysis: Multi-criteria and Decision Tree

Moura (2007, 2900) explains that Multi-criteria analysis methodology is quite appropriated for the use of geotechnology for creating variables syntheses, which purpose is to identify priority areas for some phenomena or geographical arrangement:

"The Multi-criteria analysis procedure is often used in geoprocessing, precisely because it is based on a basic logic of GIS producing: selection of main variables that characterize a phenomenon, already doing a methodological approach for simplifying spatial complexity, representation from reality according to different variables, organized into information layers; discretization of analysis plans in spatial resolutions suitable for both data sources as to the objectives to be achieved, promoting the variables layers combination, as an integrated system, which reflects the reality complexity, and finally,

4[4] Free Software produced by LAGEOP – UFRJ. Available for download in <http://www.lageop.ufrj.br/downloads.php>

possibility of the system validation and calibration by identifying and correcting the relations between the mapped variables. "

With the aim of realizing Multi-criteria analysis, different variables were selected based on the cartographic and alphanumeric database performed in the TerraView and TerraSIG software. The variables were prepared in the beginning as ordinary themed maps and, then, converted from vector into matrix format (*raster*). The topological relation within the matrix process justifies this conversion, as it optimizes the data combination and is a *sine qua non* condition for the used model. Considering the land analysis dimension and LandSat image resolution, it was adopted pixel value 25 by 25 meters for the data land unit integration as the answer per area unit, of 25 by 25 meters, is sufficient for this specific work in Bom Sucesso.

The used algebra was Pondered average, by giving weights for combined variables and grades for their legend components. The allocated weights demonstrate the relative importance of each variable to the analyses. Grades, in turn, were attributed to each legend component, within themed maps, according to their relevance degree/occurrence for each analysis' goal. Moura (2007, 2902) explains the logic within variables combination:

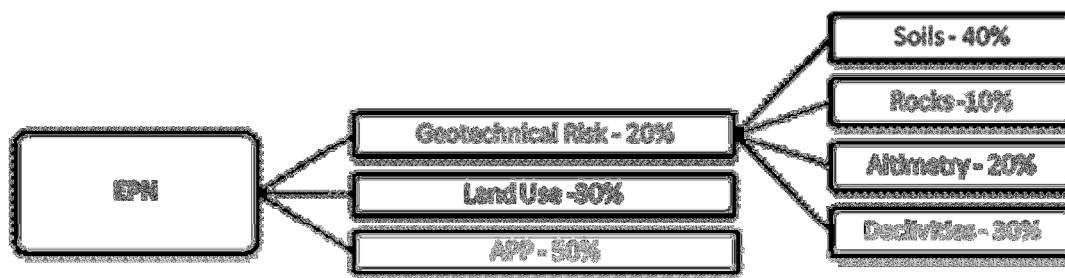
"The application of Pondered average creates a classificatory space, ordinal, which may also be understood as an interval scale. This process may also be used in a nominal scale, since events are inserted into a hierarchy according to a value criterion. Pondering must be used by 'knowledge driven evaluation', meaning, inclusion of opinions expressed by informed people on phenomena and variables, or by 'data-driven evaluation', which refers to previous knowledge of similar situations. In this process, the possibility of pondering a situation inadequately is the reverse of the number of attributed pondering."

The results from the combinations were the partial Environmental Preservation Need and Potential Urban Expansion Syntheses. Both of them had their interests combined, in a way to exhaust the combination possibilities producing as result the Conflicting Interests Matrix from which are identified conflicts of interest, potential transformations and new land use possibilities.

Environmental Preservation Need Synthesis

The variables which are most decisive on environmental interest were identified and, then, a Decision Tree (Figure 1) with variables weights was organized in order to create the partial Environmental Preservation Need Synthesis.

Figure 1: Decision Tree – Environmental Preservation Need



The Geotechnical Risk synthesis is composed by the variables Soils, Rocks, Altimetry and Declivities which were weighted by the need to protect some areas due to risks posed to settlement. The soil typologies and rocks that have high preservation need received higher grades.

The Declivities and Altimetry variables were classified as follows: areas on elevated altimetric quotas and with high declivities, according to the susceptibility to erosion and landslide; areas located in lower altitudes and with low declivities, according to the sedimentation susceptibility and, consequently, flood. Where there

are higher susceptibilities the assigned grades are higher. Thus, the higher weight factors and grades were assigned, respectively, to the variables and its legend components considered restrictions to settlement and, therefore, shall be preserved.

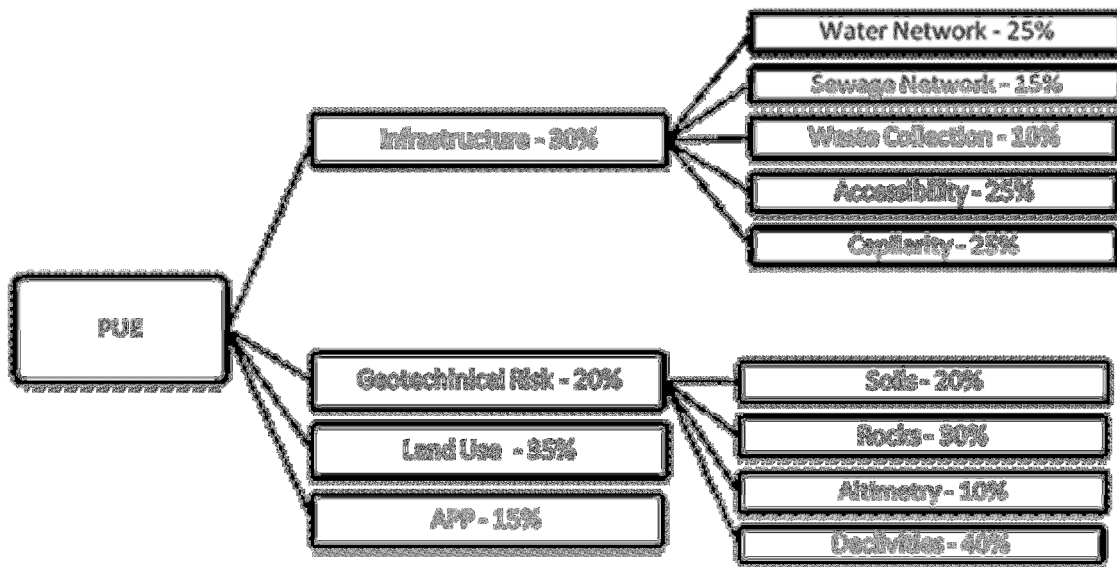
Within the Land Use variable, high grades were assigned to the legend components such as watercourses and vegetation cover due to their high environmental preservation interest.

The Permanent Preservation Areas (APPs - CONAMA 303/2002; Lei 4.771/1965) and areas considered *non aedificandi* (Lei 6.766/79) integrate the APP variable, which is more decisive in this analysis, which interest is environmental. Therefore, it received the highest weight. The legend components are hilltops; watercourses marginal bands and areas around their head; and declivities above 47%. All of them are considered as of environmental protection and, thus, received the higher grade.

Potential Urban Expansion Synthesis

The variables which are most decisive on urban settlement interest were identified and, then, a Decision Tree (Figure 2) with variables weights was organized in order to create the partial Potential Urban Expansion Synthesis.

Figure 2: Decision Tree – Potential Urban Expansion



The Geotechnical Risk synthesis has the objective to control areas not suitable for building. Considering risks to occupancy, this synthesis was developed based on the potential of use from each area. Therefore, the grades were assigned to the legend components in order of potential. Soils and rocks with higher potential of use received higher grades. Lower grades were attributed to altitude and declivity bands that represent risks to settlement. Besides the risks, Altimetry and Declivities variables were evaluated regarding difficulties to implement rainwater drainage system and sanitary sewage. The variables were assigned according to the degree of importance each variable represents to settlement.

For the Infrastructure synthesis, it was used 2000 Census Data from the IBGE. This synthesis was elaborated for knowledge of the current situation and patterns distribution along the urban area. The Accessibility, Capillarity and Water Network variables received same and higher weights, because they are considered most decisive on urban settlement interest when compared to the Sewage Network and Waste collection services. The provided infrastructure is an indicator of life quality at an area. Thus, the basic sanitation variables

were classified according to their legend components which are already classificatory. The highest grades indicate areas with sanitation satisfactory conditions and the lowest indicate where are considered precarious conditions.

The Accessibility and Capillarity variables had grades assigned to their legend components according to, respectively, capacity qualitative and quantitative of reaching a certain place. According to Moura (2011), accessibility is responsible for the presence of fast and easy pathways throughout the area, and capillarity responds to the presence of more pathways, favoring displacement alternatives.

The highest capacity received the highest grade. Those variables were produced through the *Kernel's* density model based on the road system provided by IBGE. It was used for the Accessibility the pondered procedure, since the analysis is qualitative, and for the Capillarity the simple procedure, since it is a quantitative analysis.

For the legend components from Land Use variable were assigned high grades to land uses are not understood and classified as an impediment factor to urban interest. These uses are urban settlement, exposed soil and rarefied vegetation cover.

Within the APP variable, the components which received higher grades, according to the regulated legislations, are not considered either Permanent Preservation or *non aedificandi* areas. The declivity band between 30 - 47% received an intermediate grade, since settlement is only regulated reporting geotechnical valuation.

As this analysis' goal is diagnosis interesting areas for urban expansion, the most important variables are Land Use and Infrastructure that received higher weights. The Geotechnical Risk and APP received lower values since they represent impediment factors to the analyzed interest.

Identification of potentials and conflicts of interest

Once elaborated, the environmental and urban expansion interests' syntheses (Figure 3) were combined in order to promote the identification of areas where settlement potential is clearly defined, where there are conflicts of interest, potentials for specific conditions and restrictions. The Conflicting Interests Matrix is the result of all possible combinations of interests (Figure 4).

Figure 3: Synthesis of environmental and urban interests

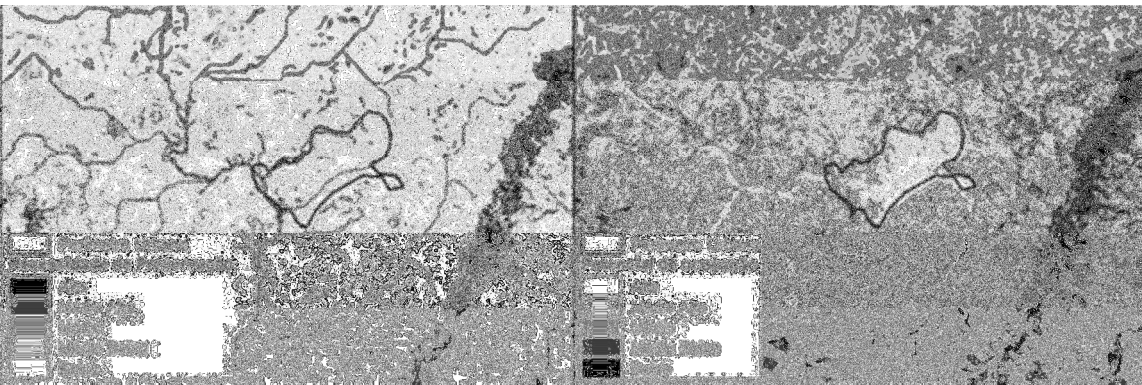


Figure 4: Conflicting Interests Matrix

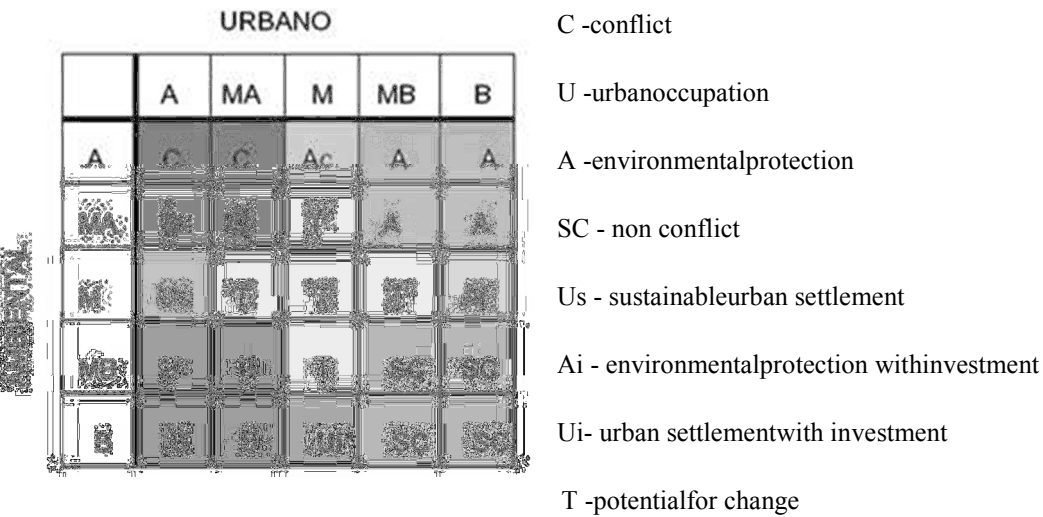


Figura 5: Matriz de interesses conflitantes

The combination of areas which present high or medium to high urban interest and high or medium to high environmental interest causes a Conflict (C) relation because, while these areas are favorable to the occupation, they are also areas that shall be preserved.

On the other hand, areas of low or medium to low urban interest and low or medium to low environmental interest, when combined, result in areas Without Conflict (SC), where there is neither settlement nor preservation interest. These areas are indicated for the necessary land uses such as sanitary landfills, recycling plants, industrial parks that, if located in other areas, could generate conflicts.

In areas of high or medium to high urban interest and low or medium to low environmental interest, there is the urban predominance. On opposed conditions, there is predominance of the environmental interest.

Areas of medium urban interest and low environmental interest have potential to urban expansion but still with the need for investments to make them properly attractive (Ui). The opposite conditions, defines them as of environmental interest (Ai), but with the need for recovery investments.

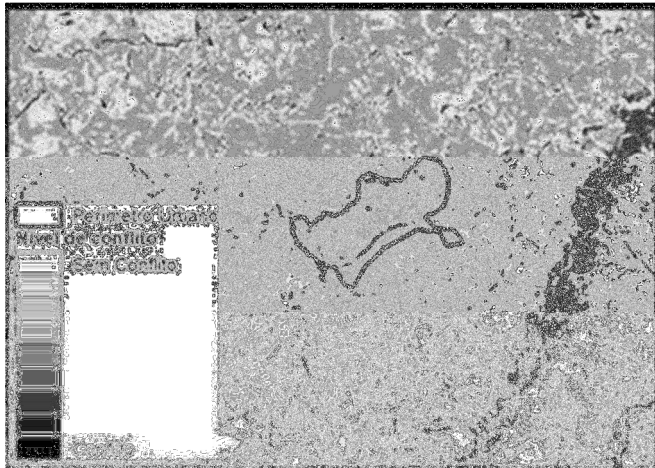
Areas of high environmental interest and medium urban interest result in environmental interest areas (Ac), but monitoring and maintenance are needed, since there is some degree of urban interest, and consequent pressure.

The high urban interest and medium environmental interest define areas of urban interest (Us), however, with sustainable use. They are favorable to Environmental Protection Areas (APAs - Lei 9.985/2000).

In cases areas present medium interests for both urban settlement and environmental preservation, they are classified as transitional or

as having transformation potential (T). These areas are significantly interesting for land planning since there are no predominant interests. They have vocation to develop according to both, following the city occupancy dynamics, through making public or private investments.

Figura 6: Mapa de conflitos



THE IMPACTS OF URBAN DEVELOPMENT

The development process, which causes disturbance in the urban forms, is responsible for changes in microclimate conditions - "Urban Heat Island Effect" - altering the urban thermal comfort. Molion (2007) thus explains:

"On average, the available energy is part used to evapotranspiration (latent heat) and the remainder to heat the air (sensitive heat). On surfaces with vegetation, most of the available energy is used in the form of latent heat, which cools the surface. With the change of superficial cover, from vegetation fields into asphalt and concrete, the relation is reversed, and more heat in the form of sensitive heat enters the atmosphere, warming the air. This is named heat island effect."

In addition to affecting the urban thermal comfort, the vegetation cover removal implicates disastrous effects for cities. If soil has vegetation cover, rainwater permeates, but, with the waterproofing, water cannot permeate. And also, under the effect of the raindrops, the exposed soil, which has lower resistance to water erosive action, has disaggregated their particles. The water rushing stream, then, accelerates the erosion and landslide processes, and thus, causes the rivers siltation which, in turn, alters water quality and aquatic life and, above all, is the cause of flood.

In the face of those processes, the population vulnerability that dwells in risk areas has a considerable increase. Therefore, policies are required from the municipal administration in order to reduce possible damages by means of establishing settlement conditions respectful to environmental values.

Thus, the data handling by municipal technicians becomes indispensable to behold dynamics of occupancy of the landscape and ecological relations among them. Since, the scale of environmental impacts does not depend only on natural phenomena, but also aspects of land uses. In this way, the settlement negative effects could be managed with a purpose to guarantee good thermal comfort and security settlement conditions.

Conclusions

It is concluded that making investments towards geotechnologies is extremely important to the land planning and management. Inasmuch as an urban planner requires combining several variables, the geotechnology offers tools to aid, in an effective way, an understanding of the variables relevance and their crossings. Furthermore, since the analyses have been presented, they improve the communication among community, technicians and public

administrators that are fundamental agents in the production of their own urban space.

The Geoprocessing Training Program from the Brazilian Ministry of Cities and all databases, satellite images of public domain and free software have an important role, because, through analysis tools, it is possible to make a detailed municipal diagnosis. This, in turn, enables to prepare alert systems capable to inform where there are urban areas with problems arising from disrespectful of landscape ecological relations.

The recognition of Bom Sucesso landscape, by means of the GIS has been produced during the Training Program, as well as the syntheses from the spatial analysis models created urban planning subsidies towards an environmental preservation. Once the potentialities, restrictions and conflicts of interest are identified, they stimulate policies with the aim of a development through a sustainable manner in order to ensure future generations have the natural resources we have nowadays.

A similar analysis, such as that has been undertaken for Bom Sucesso, could be made for at least 160 municipalities which have gone through the Training in GIS from Federal University of Minas Gerais. It has already been produced a Geographic Information Systems for each of them as the Program activity. Moreover, this analysis could be applied to any other municipality, provided that is made investments in structuring Geographic Information System.

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