THE USE OF GEOPROCESSING TECHNOLOGIES FOR THE MANAGEMENT OF WATER RESOURCES

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ABSTRACT

The Geographical Information System – SIG understood as a set of technologies used in collecting and treating, handling an producing information has enabled the improvement in the management of data concerning river basins in the northeastern part of the State of Santa Catarina, Brazil. The areas of knowledge using geo-processing technologies are connected through their common interest in the spatialization, of information, its location or distribution. Presently, in Brazil, the River Basin Authorities are drawing up their water resources plans, in which the use of SIG tools is by now absolutely necessary in order to create a structure of geo-referenced databases, contributing to the drawing up of spatial diagnoses, analyses and planning, plus offering a basis for future decision making. These studies and analyses allow environmental projects to be drawn up, evaluated and monitored using spatial information pertaining to mapping in general (such as the use of soil, surveying natural resources and water user registry) and environmental planning involving environmental diagnosis and inventory, yielding immediate results. In this sense, the granting of water user status will be based on information contained in these databases, solving conflicts and ensuring the quality and quantity of water resources in the region.

KEY WORDS

Environmental analyses in river basins, geoprocessing and geographical information system.

INTRODUCTION

The management of river basins has become of ever increasing importance in Brazil in the light of increased water degradation and its effects on the environment. The National Policy for Water Resources, Federal Law N° 9433, published on January 8th, 1997, establishes new procedures to be followed in managing water in Brazil. Central to this law are the following concepts: Water management must be by river basin and water has an economic value. The implementation of water resource management programs, which, through this law considers river basins spatial units for the development of projects and actions related to the preservation and conservation of the existing natural resources, seek to promote water protection and the protection of other natural resources which are responsible for environmental, economical and social sustainability.

The North Cubatão Water Basin Management Commission - CCJ created by State Decree N° 3.391, of November 23 1998 is collegiate organization of a consulting and deliberating nature, which seeks to promote the management of the water resources in the Cubatão river basin, in which it has, at this moment, the support of Universidade da Região de Joinville - UNIVILLE, which has been supplying the technical support required to set up an Information System of The North Cubatão River Basin – BHRC.

The available information and data on the BHRC water resources were dispersed and mostly inconclusive. In view of this it became essential that greater knowledge on the natural physical aspects of BHRC be acquired, as well as the location and quantification of the problems and the supporting capacity of the water system under study.

The essence of the structure of SIG – Cubatão will be presented in this article, in an effort to cooperate with the handling and conservation of the water basin, benefiting the regional planning

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and management organs, the society and the scientific community, establishing a basis from which guidance can be obtained for decision making on the sustainable conservation and use of the region’s water resources.

**STUDY AREA**

BHRC is in the Northeastern part of the State of Santa Catarina, 75% within Joinville county and 25% in Garuva county (figure 1), within the following coordinates: Between 26° and 26° 5’ South latitude and 48 45’ and 49° 10’ West longitude. According to the Brazilian hydrographical regions defined by ANA – The National Water Agency (2002) this basin is in the Southern Coastal Area. Within the state, according to the regions determined by the Secretariat for Urban Development and the Environment – SDM (2000) it is with Hydrographic Region 06 of the Northern Lowlands.

The total area of the basin is 492 km², the main canal being 88 km long, its source being in the Serra Queimada (mountains) at 1100m altitude, draining towards a plateau consisting of softly rolling hill country, with hills alternating with shallow valleys. Next comes the Serra do Mar scarp with steep reliefs and 500m valleys. This stretch includes Falls 1 and 2 with respectively 360 and 40 m through the steep Serra do Mar descent until it reaches its flood plain, characterized by flatlands with isolated hills, where the main canal becomes more sinuous until it runs into the estuary of Babitonga Bay, which is held to be the largest estuary complex on the Southern coastline of Brazil. It also must be remembered that the BHRC is the main source of water for Joinville County, the largest in the state, which makes its conservation extremely important.

**METHODS**

This job has followed a methodological procedure divided into three distinct stages: data collection, data storage and structuring, and information generation.

**Data collection**

Initially the available Instituto Brasileiro de Geografia e Estatística - IBGE and Serviço Geográfico do Exército - SGE (Table 1) charts covering São Miguel, Garuva, São Francisco do Sul, Jaraguá do Sul, Joinville, Araquari and São Francisco do Sul were entered on a 1:50.000 scale. The charts were scanned and geo-referenced using the Idrisi 32 program. Then cartographical elements such as contour lines every 20m, hydrographical networks and road system, county limits and state lines were entered on-screen.
The basin and the subbasin limits evolved into digital data through the contour lines and hydrographical network and their areas could be calculated.

<table>
<thead>
<tr>
<th>Table 1. Basin and the subbasin limits</th>
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<tr>
<td>São Miguel</td>
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<td>MI-2869/2</td>
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<tr>
<td>Jaraguá do Sul</td>
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<td>MI-2869/4</td>
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Landsat TM 5 and ETM 7 supplied satellite images with 30m resolution, scene 220_078 bands 1, 2, 3, 4, 5, 6 and 7 of March 27, 1988 and May 07, 2000, respectively. The images first were filtered through a Stretch module since they were rough and without adequate resolution. This resulted in images with heightened contrasts and highlights for a better visualization. As to geo-referencing, the IBGE pages, which already had been geo-referenced were used as a basis for the collection of control points which were obtained from fixed spatial elements such as crossroads, highways and bridges, adding up to a total of 800 points, which contributed to a good image precision. After obtaining control points the images were corrected for the UTM projection system, using datum UTM22 SAD.

Several field jobs were also undertaken specifically to register such information as: classes of land use, potential polluters and water catchments. This data was collected through the use of GPS indicated coordinates. Data on ground and surface water quality were obtained from several collection points besides obtaining historical data series on flow and rainfall at the various river flow and rain meter stations, whether deactivated or still in use.

Data Storage and Structuring
The database was structured in the Linx Chart program through the basic digitalized cartographic elements, where the various information fields were created. The contour lines were given a z dimension for altitude, in order to generate a Numeric Terrain Model – NTM. The hydrographic network was graded as to hierarchy according to Strahler (1957) in which the channels were given toponimies and subbasins. The road system was classified according to type by surface material and toponimy. The registry of water collection was represented by articulated points with a set of data referring to collection as consumption in m$^3$ day/month/year. Pollution sources were classified as to industrial process and name of the element. Surface and ground water collection are frequently updated according to surveys that are conducted and their qualities are linked to the analyzed parameters.

Information Generation
The database being structured, several 1:50,000 scale charts were produced such as: The Hydrographic Chart, Hypsometrical Chart; Clinographical Chart (declivities); Multiperiod Land Use Charts for 1988 and 2000; Permanent Preservation Area Chart; Geological Chart. Geomorphic Chart; Pedological Chart; Vegetation Cover Chart; Landslide Risk Chart; Flood Risk Chart; Land use Incompatibility with Permanent Preservation Area Chart. These Charts are in Figure 2.
RESULTS AND DISCUSSIONS
Based on the above and in order to achieve more precise results, it is understood that adopting a SIG both for final result presentation and as a supporting agent for the analyses undertaken, fosters significantly enhanced product generation, besides enabling easier information storage and update. The use of SIG has proved to be a powerful tool as an aid in simulating various processes, since most of the results depend on a good simulation of the physical means. Therefore, the deployment of SIG allows not only more precise results but also speedier and more efficient model applications, enabling a systematic survey of river basins. The results allow rapid comparison studies of the potential impact of natural and anthropical physical characteristics in the basin, such as the land use incompatibility chart with the environmental legislation, which presents the spatial distribution of conflicting uses (Figure 3).
According to the data obtained, BHRC has 206 km$^2$, that, according to the Forestry Code are considered Permanent Preservation Areas – PPA’s, and these represent 42% of the basin area, and the remaining 58% may be used without conflict. But when the Land Use Charts are checked against the legal limitations, the fact that the 42% PPA is not being fully complied with, since there are about 12% irregular use or coverage areas, with only 88% of the area free of incompatibilities.

The non-complying areas encompass about 26 km$^2$, which are represented by several different soils and cover usage such as: banana plantations, pastureland, various types of plantation, reforestation with *Pinus Elliottii*, exposed soil and urbanization. The areas comprising exposed soil add up to 51% representing the largest area of land use non-compliance with the legislation (1294 ha). This class is distributed throughout the BHRC area, particularly in the Urban *mucuia* and recent allotment developments, in the seasonal planting areas along the rivers, especially the lower reaches, as well as in the upper reaches of the Cubatão River where exotic tree reforestation is being undertaken.

The date of the satellite image used to produce the land use chart of 2000 coincides with the suppression of the exotic vegetation suppression of the reforestation projects, representing a 7% area, covering hilltops, hillsides with gradients above 45% as well as the riversides on the upper Cubatão course.

Pastureland represents 27% of the incompatibility area, mainly in the lower reaches of the Cubatão River, especially after the BR 101 highway. This category is close to the riverbanks, on hillsides and hilltops. The channel banks in this area of the BHRC are short of ciliar vegetation, increasing the problems related to surface water quality and the silting of the riverbeds.

Banana cultivation represents 8% of the non-compliance area, covering parts of river banks and specially steep inclines such as in the valleys of the Prata, Issak, Quiriri and Seco rivers, to name only a few.

The urban areas represent 7% of the non-compliant areas and always occur by river channels, the highest density being in the lower reaches. The BHRC is a lightly degraded area with *focci* of incompatibility, in which the most critical areas are in the lower reaches, which suffer urban encroachment, and the upper reaches where part of the area is used for exotic species reforestation. Therefore, as far as managing the BHRC degraded area recuperation programs is concerned, the designated decision makers will know where to apply the scarce available financial resources.

Finally, it should be stressed that in order to structure a SIG in a hydrographical basin, a specific program should be chosen and mainly the people that will be working on it will have to be taught the required skills. Data must be organized in such a way as to ease data search within the system. What tends to happen is that people are supplied with the program, data, information but the system is not organized in a practical way, a fact that goes totally against the SIG objectives.

In the case of the BHRC, the present 1:50.000 scale has already been completely overtaken and the future CCJ objective is to increase it in order to improve the information.

**CONCLUSION**

The present paper has enabled the production of various kinds of data that can be processed in a river basin and which, if used in a holistic way with the aid of SIG techniques, enable an analysis which will supply decision making support on management strategies and the evaluation of areas for urban, agricultural, industrial and other activity development, in a conservationist mode, always bearing in mind the natural resource limitations and potentials. Another application is to supply
guidelines for the Committee for the Management of the North Cubatão River Basin, in order to establish investment priorities for the recovery and maintenance of the water resources.

The results herein are not definitive and do not seek to offer an outlook that implies in the reduction of the large number and complexity of the factors related with the planning and management of river basins, however, they stress the existence of tools for data integration that make the construction of different aspect evaluations of the same area more flexible and dynamic. The great merit of this technology lies in the possibility of reducing diagnoses, evaluations and projections of the many areas comprising environmental studies, which makes SIG a fundamental element in any environmental project, not to mention the speed and low cost of obtaining these analyses.

REFERENCES