DEMHC generation from IBGE topographic maps using ArcGis software

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Abstract

The hydrographically conditioned digital elevation models (DEMHCs) is a grid of regular valueted cells that allowed the representation of the water main way trough relief, been indicated in hydrologic studies for showing consistence between relief and superficial drainage. This paper has, as objective, presents the initial steps to generate the HCDEM from data supplied by IBGE, subsidizing it uses in hydrologic studies. In this sense, were selected three topographic vectorial maps, from the systematic mapping, scale 1:50.0000, supplied by IBGE (Instituto Brasileiro de Geografia e Estatística) on the website www.ibge.gov.br , which includes the Formoso river extension, a trybutary of Pomba river, named: Santos Dumont (26454), Paiva (26463) and Pomba river (26464). Were adopted projected coordinate system UTM (Universal Transversal de Mercator), using "Córrego Alegre" datum on 23 south zone. The HCDEM was generated using ArcGIS 10® software, having as databases vectorial level curves, spaced in 20 meters distance between one and another, higher elevation points e hydrograph already digitized. To process data on ArcMap mode, a shape file for each data was generated on ArcCatalog, corresponding to the level curves and hydrograph in polyline.dgn shape. IBGE had distributed, for free, those files already vectorized and georreferencized, and also, the hydrograph with flow direction, making easier to carrying out the work. The preparation of level curves was based on merge the disconnected lines, with "merge" command, in "Editor", and to insert its elevation values on the attribute table. A similar procedure was done with the valuated points. The available hydrograph had presented a few imperfections, such as double river borders, discontinuity of the rivers between the maps and others nonconformities that changes the congruency relation of the generated model with reality. Therefore, it was necessary their adjustment from available tools on Spatial Adjustment interface. The prepared files (level curves, valuated points, and hydrograph of each map) were merged by "Merge" command, of ArcToolbox, and interpolated by "Topo to Raster" command, generating DEM, which it was treated, to remove undesirable characteristics, and after that, the HCDEM was generated. Finally, the model was validated comparing the generated numerical drainage with the drainage mapped by IBGE and the watershed automatic delimitation, been observed a superposition between numerical drainage and drainage mapped by

IBGE, considered as a Brazilian standard, and that the drainage area delimitation was consistent. The appropriate processing of data from IBGE on ArcGis software had allowed generate solids and reliable results in a fast way, compared with manual methods.

Keywords: Geographic information system, watershed, digital elevation model, topology.

1. Introduction

The population increase in the last decades, had required a large exploration of natural resources to supply the new demand. The wrong use of these resources, brought us to alarming situations, considering our reality, due to the damage caused in natural environment. On these circumstances, appears environmental analysis tools as a way to control and prevention of natural conflicts or disasters. Destacase the geographic information system (SIG), which make possible different information match and its interaction analysis, obtaining trustable results in different presentation forms to attend as good as possible users needs (Lana, 2007). Another great advantage of SIGs is it connection and reproduction simplicity with other data sources, besides make easy the access of these information to all users.

In this context we try to found models which simulates as good as possible the earth surface reality. The relief, with watershed, forms an excellent management unit of natural and social elements, once they allowed the anthropic changes monitoring and the respective nature response (Cardoso, 2006). One method of topographic representation and resultant watershed delimitation is the digital elevation model hydrographically consisted (DEMHC), being defined as a grid of regular valuated cells that allows a representation of water preferential way along the relief.

The topographic and hydrological data from DEMHC are obtained in a faster and less subjective way than manual or traditional methods applied in topographic maps, besides it also provides a bigger information number due to its facility to cross entry data and the acquisition of them (Saito, 2011). The DEMHC is obtained after digital elevation model hydrological validation, to assure the right surface flow convergence to and along the mapped drainage.

According to Lana (2007), the DEM can be obtained from remote sensors like ASTER, EROS-A, IKONOS II, QuickBird, SPOT-5 and SRTM, being its images usually utilized for representing a big part of the globe and for having low acquisition costs. Another modeling method is trough hydrographic and hypsometric data interpolation obtained by aerophotogrammetric surveys or those available for free by Brazilian Geography and Statistic Institute (IBGE) on website www.ibge.gov.br, being these only available in Brazil.

The generated DEM must inquire a faithful relief representation de forma a reproduce, as good as possible, the water surface flow preferential way to the drainage channel of the real world (ESRI, 2011). It is important to rebound that the final product quality depends on a precautious processing by the analyst and also depends on trustable entry data. According to Saito (2011), from a rigorous relief characterization, it is possible to keep and spread morphometric information that will subside planning and management of water resources, hydrological surface studies or any other item that uses watershed shape and relief. Therefore, from only

one data source, we have multiples information, avoiding onerous resources replication and procedures that occurs on a traditional way.

This paper has as an objective to present the basic methodology about DEM generation from data available by IBGE on ArcGis software, intending to subside its use in hydrological studies.

2. Material and methods

The study area consists in *Formoso* river sub-watershed, *Pomba* river right border tributary, *Paraíba do Sul* river watershed component. This stream presents a exextension next to 64 km and drainage area next to 398 km^2 running through the city councils *Oliveira Fontes, Aracitaba, Tabuleiro* and *Santos Dummond*. On Figure 1 it is presented the study area localization referent to the state where it belongs.
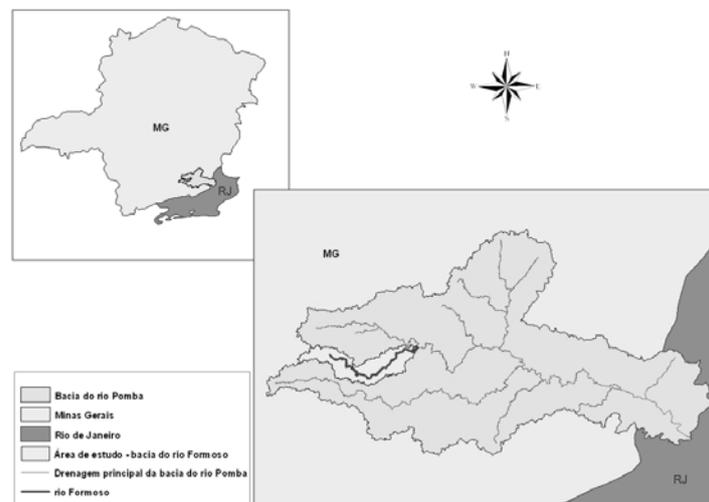
Fonte: Gomes, 2011.
Fig. 1: Study area visualization in relation with watershed and the state that it belongs

To DEMHC generation it was necessary obtaining digitalized entry data, getting from vectorial topographic maps, available at IBGE website, http://www.ibge.gov.br . Thus were selected three maps that comprehend *Formoso* river extension, correspondent to Santos Dumont (26454), Paiva (26463) and *Pomba* river (26464) at 1:50.000 scale. Those already possess individual georreferenced digital hydrographic data oriented on surface flow direction, altimetry data discriminated in level curves spaced 20 meters and valuated points, both required on modeling.

Was adopted projected coordinates system UTM (Universal Transverse of Mercator) using *Córrego Alegre* Datum, on 23 south zone. the software used on generation of DEMHC was ArcGis®, version 10, from Environmental System Research Institute,Inc. (ESRI), and it includes ArcMap, ArcCatalog and ArcToolBox extensions.

Besides the available free of charge IBGE's data already been vectorized and georreferencized, facilitating the work, those presented a few inaccuracies and

required a preparation to guarantee it quality. To process data on ArcMap extension, was generated shapefile data on polyline.dgn format on ArcCatalog, correspondent to hydrography and level curves of each map. The preparation of level curves was based on unite the unconnected lines from "merge" command located on Editor and also on filling out elevation values, based on the reference IBGE map, on it attribute table, both manually. To valuate higher elevation points, it was realized a similar procedure.

In the case of hydrography, the consistence validation of the vectorial data was a little more complex, once that we must considerer the flow direction and the right river connectivity through topological analysis and geometric networks. The confluence, riverheads and outfall, must be represented by points and the hydrographic networks must be represented by lines, such that each segment begins in a point directing to another, building a one filament network, topological conditioned, as to connectivity in graph format aspects and without double confluences (ANA, 2006). A way to prepare linear feature data to the network structure generation it is by "Planarize Lines" function, ArcGis exclusive, ensuring that all node are connected to the arrows and those cannot overlaps or represent duplicity. Subsequently, is created a geometric network for each map, to inquire the river connectivity. To the three hydrography maps union, it is necessary adjust the borders between them using "Editor", "Advanced Editing" and "Spatial Adjustment" tools. To finish, we create a geometric network to ensuring the consistence of the new hydrographical base.

The prepared data (level curves, valuated points and hydrography of each map) was united by "Merge" tool, from ArcToolBox, and were interpolated by "Topo to Raster" tool, obtaining the DEM. Still, before DEMHC generation, it was necessary a previews treatment of DEM so it could have hydrological consistence, as the drainage fit verification generated by the model with consisted vectorial drainage from cartographical base. To do so, we have made the channel river along the numerical drainage deepening to ensuring the flow continuity to the outfall. With a deepest hydrography on DEM, it was identify all spurious depression, originated from vectorial data interpolation, that act as "drains" on numerical drainage, being filling on sequence. These corrections ware done by "Sink and "Fill" command, respectively, from Spatial Analysis extension, and later, the new flow direction it was defined through "Flow Direction" function and its accumulation through "Flow Accumulation" function. Therefore, it was obtained a hydrographical network, with preferential way defined and a guarantee of continuity on it, having as a result a digital elevation model hydrographically consisted.

Finally, it was validated the model generated from two aspects: the comparison of numerical drainage with hydrography from IBGE maps and also the automatic Formoso river watershed delimitation from a point inserted in his outfall.

3. Results and Discussion

The entry data preparation stage had a big importance, for determinate the final product quality, requiring time and effort.

From a level curve virtual analysis were identified the discontinuities and unnecessary information, that could endanger the interpolation process, the necessary

corrections were done on a easy and fast way with the presented methodology. The entry of each high value on the level curves attribute table for each map based on the digitalized IBGE reference map had expended more time than the other process. The same methodology it was used to the higher elevation points at IBGE map, also called valuated points. It is important to rebound that this information is the MDE generation base. At Figure 2 is exemplified one of the corrections.
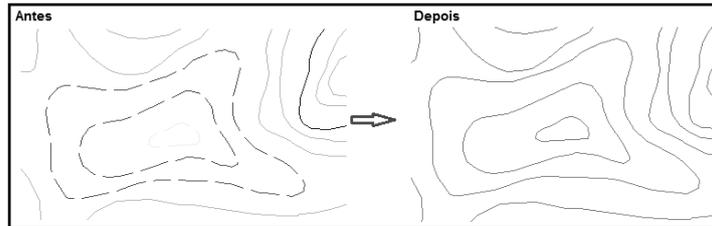

Fig. 2: Discontinuity correction on level curves

The already vectorized and georreferencized IBGE data base access, have brought a enormous agility to the work. If the maps were only digitalized and in raster format, it would be necessary include stages of georreferencing and vectoring, which in this context it would result in a large number of inconsistence and residue, making difficult and delaying the model generation.

In relation to the drainage, besides all the mentioned benefits, the hydrography available by IBGE had presented the right flow direction, checking visually on the maps, facilitating even more the data processing. However, it was necessary to simplify the hydrographical network end converge all arrows to the outfall section, ensuring the generated DEM quality (Saito, 2011). Those were realized through topological analysis of the linear data and the geometric network generation to hydrography , relative easy procedures, but that requires time and caution on the inconsistence characterization. Some adjusts made on drainage can be visualized on Figure 3.

Fig. 3:. a) Convergence arrows to the outfall section guarantee; b) One filament hydrographical network guarantee

To DEM obtaining it was used the "Topo to Raster" interpolator, based on comparative studies of interpolators (Guedes et al., 2011; Saito, 2011).

According to Cuartero et al. (2001), the cross validation must be done from the comparison between the level curves generated from the DEM and of IBGE (Figure 4)
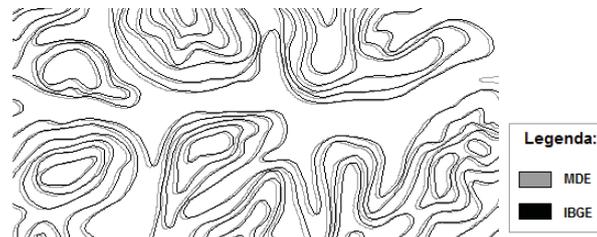
Fig. 4: Cross validation between level curves generated from DEM and the ones supplied by
IBGE

We can see at Figure 4 a satisfactory concordance between the both level curves, on an attempt to preserve the maximum of topographic details on construction of a DEM (Chagas et al. , 2010). The small noted incoherencies can occur due to errors on the entry data or during the interpolation process.

In possess of the DEM, it was realized the after treatment of hydrological consistence. This phase consists in a number of procedure replicates, with the objective of guarantee the right surface water flow. The generated model validation, it was based on the comparison of the generated numerical drainage with the one available by IBGE. At Figure 5 it is presented the DEMHC generated fur the *Formoso* river sub-watershed.
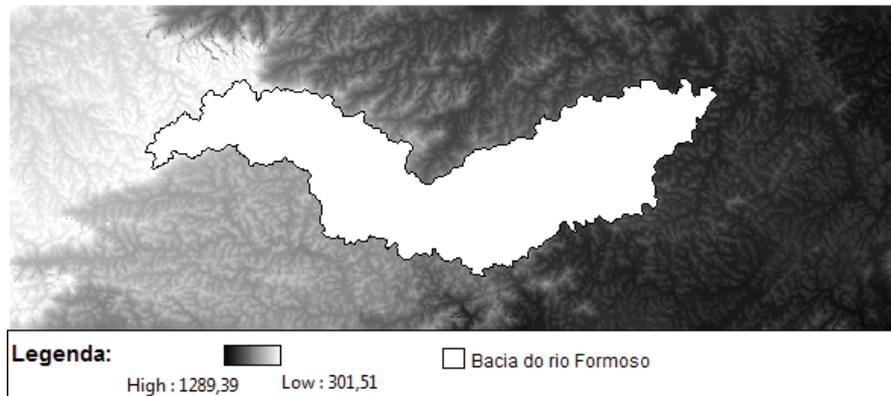

Fig. 5: DEMHC generated and the Formoso river sub-watershed delimitation.

4. Conclusion

This paper shows how accessible it is a important tool to our current reality, that it has showing great application in environmental issues. The generated DEMHC, from data free of charge available, it can be applied in different science areas such as engineering, geography and geology.

The results quality depends on the entry data quantity and quality, besides the correct modeling stages processing.

Despite of handling difficulties with ArcGis software, and the time expended to vectorial entry data edition, all process it became simplified when compared to a manual process. Finally, we have the guarantee of a solid and trustable result when you realize an appropriate IBGE data processing on the software in question.

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