Journal of Soil Science and Environmental Management Vol. 3(5), pp. 104-109, May 2012
Available online at http://www.academicjournals.org/JSSEM
DOI: 10.5897/JSSEM11.136
ISSN 2141-2391 ©2012 Academic Journals

Full Length Research Paper

Digital elevation models obtained by contour lines and SRTM/Topodata, for digital soil mapping

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Accepted 27 March, 2012

In the last decade, the quantitative models for digital mapping of soils have experienced rapid development of new methods, more efficient and economic. One reason is due, mainly, to the increase of auxiliary information of physical environment, especially, the images from remote sensing and terrain attributes derived from digital elevation models. Thus, this study aimed to evaluate the quality of digital elevation models obtained by contour lines and from SRTM/Topodata resample to 30 m for digital soil mapping. Both digital elevation models were assessed for vertical quality and the potential to derive terrain attributes which captured the main processes that occurred in the area. To enable comparison, all digital elevation models were generated with a 30 m spatial resolution. The SRTM/Topodata and Digital Elevation Models (DEM) tends to underestimate elevation in peaks and ridges, and at this fine scale, the 1:10,000 cartography contour lines produce a more accurate and more detailed DEM. However, due to the size of Brazil in a lack of soils maps with good scale, the availability and spatial coverage of the SRTM/Topodata make it a desirable option.

Key words: Digital elevation models, digital soil mapping, geographic information system.

INTRODUCTION

The soils distribution in the landscape, according to Birkeland (1984), reflects the influence of various formation factors and is a combination of microclimatic conditions, pedogenesis, relief and geological processes. The relief forms control this distribution, because of their influence on water flow, energy and material redistribution processes on slopes. Also, Gobin et al. (2001) argued that the water movement in landscapes is the main process responsible for soil development. Thus, understanding the relief forms, it allows making inferences and predictions about the soil attributes in different landscape segments. In the last decade, the quantitative modeling on digital soil mapping has experienced a rapid development with new and more economical methods, due mainly to the increase availability of physical environment auxiliary information, especially, those from remote sensing images and elevation attributes, derived from digital elevation models (DEMs) (Dobos et al., 2000; McBratney et al., 2000, 2003; Hengl, 2003).

The use of Digital Elevation Models (DEMs) for understanding the soils distribution, contributes as an important tool to delineate preliminary soils mapping units used to support the soil surveys work in the field phase and also support pedological cartography (Nanni and Rocha, 1997; Hengl, 2003). The digital relief modeling is one of the best quantitative techniques developed for predicting soil classes and attributes (McKenzie and Ryan, 1999). Different attributes can be derived from a DEM (Wilson and Gallant, 2000) and among these attributes, elevation, slope and orientation, have been recognized as the most effective for surveying soil in medium scale (Chagas, 2006; Campling et al., 2002; Debella-Gilo et al., 2007; Bailey et al., 2003; Figueiredo, 2006). Odeh et al. (1991) found that the slope and curvature explained much of the soil variability.

The DEMs can be obtained in several ways: as a

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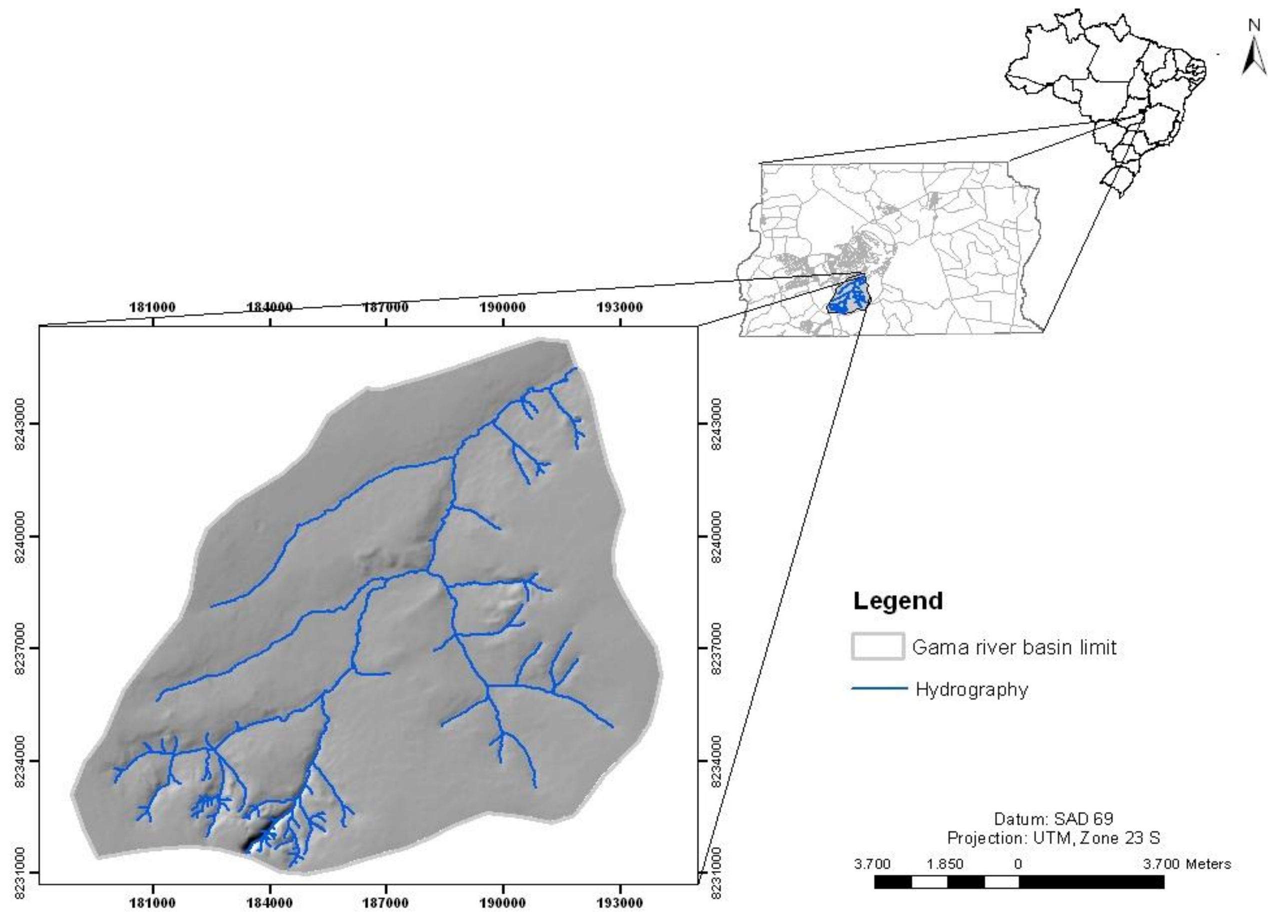

Figure 1. Location map of the Gama river basin.

restorer devices from digital video plotter (DVP) that can extract data directly from the three-dimensional aerial photos, optical sensors, image sensors such as ERS and RADARSAT radar, laser altimetry by using airborne sensors (LIDAR) and interpolation of topographic information (Valeriano, 2004).

The SRTM project (shuttle radar topographic mission) provided three-dimensional models with two quality and spatial resolution of 1 arc-s (~30 m) and 3 arc-s (~ 90 m) with horizontal datum WGS84 and vertical datum WGS84/EGM96 with relative vertical accuracy on the order of 5 m (Smith and Sandwell, 2003). The Topodata products offers free access to Brazilian local geomorphometric variables derived from SRTM (shuttle radar topographic mission) for the entire national territory. These data were refined from the original spatial resolution of 3 arc-s (~ 90 m) to 1 arc-s (~ 30 m) by kriging. Then, geomorphometric algorithms analyses were applied on the refined data to calculate the variables as slope, orientation of slopes, horizontal curvature and vertical curvature (Valeriano, 2008).

In this sense, this work aimed to analyze the quality of digital elevation models obtained by contour lines and the SRTM/Topodata, in order to make possible its use as an auxiliary tool in soil surveys.

MATERIALS AND METHODS

Description of the study area

The Gama river basin has an area of 141.20 km^2 located between coordinates UTM Zone 23 S, 191664 m and 179621 m South and 8245203 m and 8231473 m West, inserted in the Cerrado Biome (Figure 1). The climate in the study area, according to Köppen classification, fits between "tropical savanna" and "mild rainy winter dry", with a concentration of rainfall in summer (Martins and Baptista, 1998). The geology of the Gama river basin comprises the Paranoá group with age Meso/Neoproterozoic (1300 to 1100 million years), and is characterized by slate and sandy metarrythmites (Freitas-Silva and Campos, 1998).

The geomorphology of the study specific area has been studied for several years and there is a significant body of studies such as Codeplan (1984), Novaes (1986, 1987, 1994a, 1994b), Novaes and Carneiro (1984) and Martins and Baptista (1998). In the basin under study, according to Codeplan (1984) proposed geomorphological compartmentation to two smoothing residual surface in higher altitudes, depressions and plains. The main source of soil information for study area is the soil survey conducted by Embrapa (1978), with development of pedological map scale 1:100,000.

Table 1. Descriptive statistics of DEM obtained by contours lines and DEM SRTM/Topodata.

DEM	Contours lines		SRTM/Topodata	
	Altitude (m)	Slope (degree)	Altitude (m)	Slope (degree)
Minimun	1002.22	0.01	1003.00	0.00
Maximum	1248.12	31.97	1248.00	43.00
Average	1097.25	5.18	1099.70	5.54
Standard deviation	48.23	5.64	47.33	4.08

Gama river basin is present mainly in the following classes: Red Oxisols (Latosols), Yellow-Red Oxisols, Cambisol, and Indiscriminate Hydromorfic soils and Plinthosols.

Assessment of digital elevation models

This study evaluated a DEM generated from contour lines and a DEM obtained from SRTM/Topodata project (Valeriano, 2008) that provides free access to Brazilian local geomorphometric variables. The SRTM/Topodata was refined from the original spatial resolution to 1 arc-s (~30 m) through the kriging interpolation process. Both DEMs were assessed for vertical quality and the potential to derive terrain attributes that capture the main processes that occur in the area, like pedogenetic processes as hydromorphism, which occurs in places with water accumulation, in places where mineral transformation occurs and where there is an accumulation of organic matter, due to water presence. To enable comparison, all DEMs were generated with a 30 m spatial resolution. The DEM derived from contour lines was prepared using data such as elevation points, contours line, sand and hydrography from topographic maps (Codeplan, 1984) generated from aerial photographs restitution on a scale of 1: 10,000 with equidistance of 10 m between the contour lines. It used a method based on surface adjustment Topo to Raster module® from ArcGIS 9.2®, which is an interpolation method specifically designed for the creation of hydrologically correct digital elevation models. It is based on the ANUDEM program developed by Hutchinson (1989).

The SRTM/Topodata used in this study was obtained from the Topodata Project that aimed at the construction of a national database with elevation and geomorphometric variables calculated from the available SRTM data for Brazil. Data processing was designed to perform interpolation of the original SRTM-90m data by kriging (to 1” or nearly 30 m resolution), followed by geomorphometric analyses of the produced digital elevation model, through GIS-based algorithms (Landim, 2003). This database included digital maps (images) of the basic local variables as height and slope angle. This development was based on two research components concerning DEM processing, namely; resampling and derivation. In the first component, the selection of a geostatistical set for a uniform interpolation to perform kriging on diverse topographic conditions was conducted among regionally pre-selected sets. Derivation procedures were adapted from previously developed algorithms designed to perform the basic derivations of DEM through geometrical approach, digitally simulating the measurement of the topographic variables according to their theoretical concepts (Shary et al., 2002).

The DEMs were evaluated and comparisons between the DEM generated by contour lines and obtained by the SRTM/Topodata were made by analyzing qualitatively the overall shape of the elevation profiles, like the differences between peaks and valley sand also, comparing some descriptive data obtained from the DEMs. This analysis is important for the study area, because the soil distribution depends highly of the landscape shape.

According to Hutchinson and Gallant (2000), the contour lines derived from a MDE provides a sensitive assessment on the soil structure, which is quite useful, because of its high sensitivity to errors in source data. Thus, took a visual comparison between level curves derived from the DEMs with the original contour lines to detect the presence of artifacts in the first. Moreover, as suggested by Wise (1998) and Hutchinson and Gallant (2000), a visual comparison between the drainage network mapped and derived drainage network was carried out by the different DEMs as well as a comparison between the original contours lines and the derived contours lines.

The stream network derived from DEMs represents the pattern of flow accumulation and the potential location of river networks, which are important for identifying places that have higher probability of the occurrence of hydromorphism pedogenetics processes. Through trial and error, the accumulated flow value was obtained, using the Spatial Analyst® tool from ArcGis 9.2® necessary to generate the numerical drainage network with approximately the same level of detail of the drainage network mapped.

RESULTS AND DISCUSSION

The results obtained in Table 1 showed similarity between the values produced by DEM obtained by contours lines of the DEM SRTM/Topodata. Chagas et al. (2010) also observed similar values. The results obtained for the SRTM DEM can be influenced by the characteristics of the terrain. Results obtained by Kocak et al. (2004) showed that the accuracy of DEMs derived from remote sensing images is very dependent on the slope, and the lower quality occurs in hilly areas that are in the plain areas. Figure 2 shows the elevation profiles of the evaluated DEMs. In the SRTM/Topodata profile, near the stream, it is not clear that the valley breakdown is probably due to the sensor type, which registers the tree tops, and in these areas is usually large.

Jarvis et al. (2004) observed a similar trend in the elevation data influenced by the slope orientation when assessing an SRTM DEM to Honduras, but in this study, the positive differences in relation to DEM from topographic maps, were present on the North, Northeast or East slopes, while the negative slopes were observed in the South, East or West. These results, according to the authors were attributed to the effect of viewing angle.

The creation of a DEM seeks to obtain a model that contains topographical details, always preserving the land characteristics. In this study, the best agreement

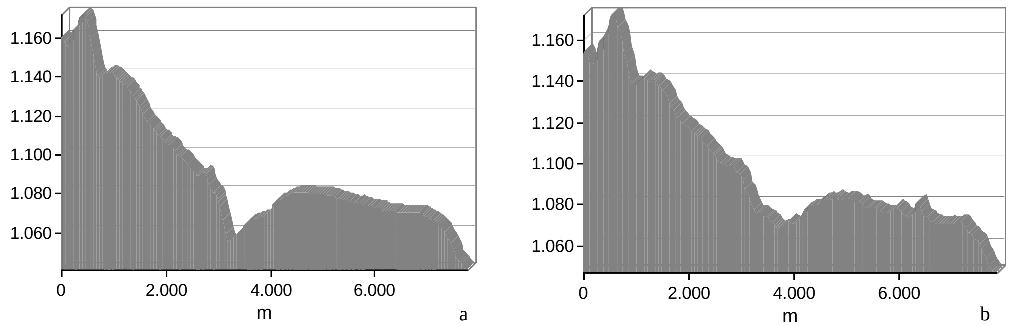

Figure 2. Elevation profile from digital elevation model generated from contour lines (a) and SRTM/Topodata (b) in the Gama river basin.

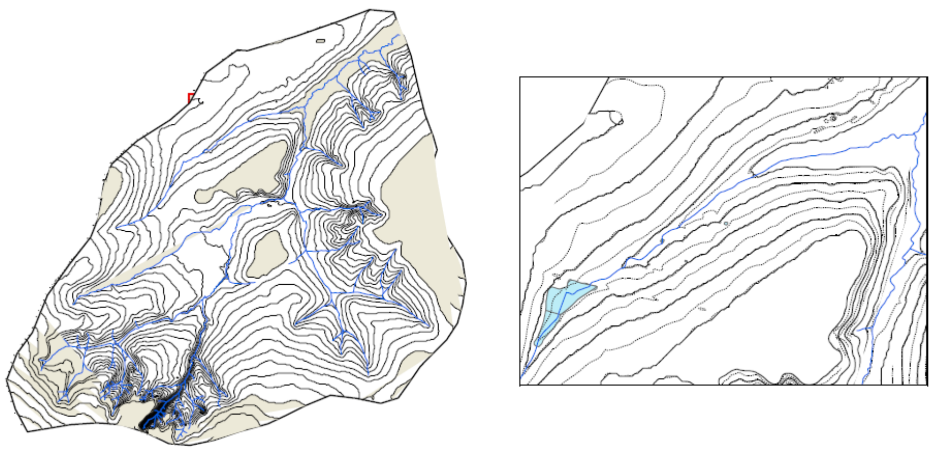

Figure 3. Contours lines restored from the DEM obtained by contours lines.

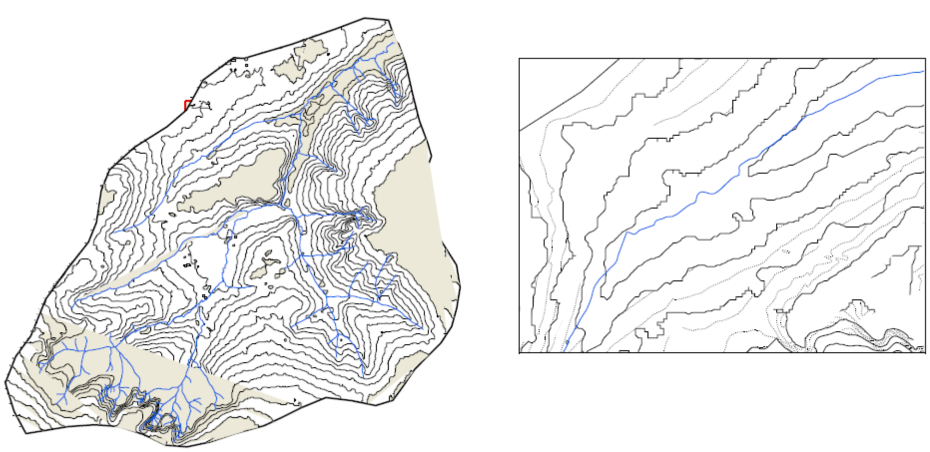

Figure 4. Contours lines restored from the DEM SRTM/Topodata.

with the digitalized contour lines was restored by DEM created by contour lines as shown in Figure 3. The peaks were maintained and only minor variations were noted when compared to the original lines and the DEM obtained by the contour lines presented the best results to this criterion. The DEM SRTM/Topodata showed little agreement with the original contour lines (Figure 4); however, contour lines that intersect have not been verified.

Flow networks are critical for modeling run-off

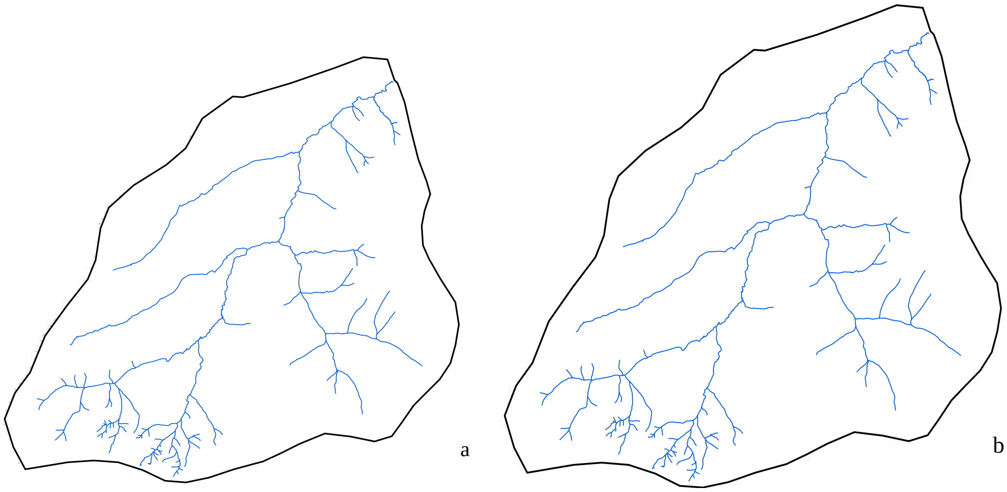

Figure 5. Flow direction generated from DEM obtained by contours lines and DEM SRTM/Topodata.

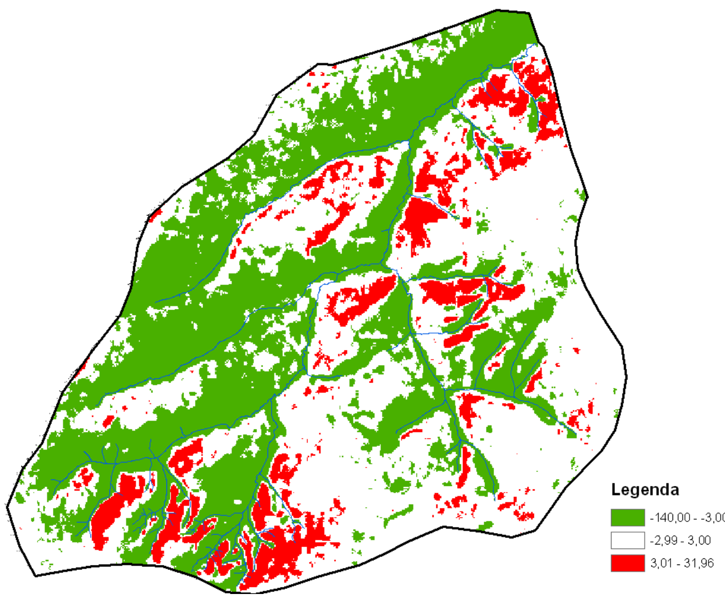

Figure 6. Difference between altitudes derived from DEM obtained by contours lines and DEM SRTM/Topodata.

accumulation, stream flow, and flood response, and are derived using a neighborhood operator over a DEM represented as raster grids (O'Callaghan and Mark, 1984). The drainage network derived from DEM SRTM/Topodata showed poor agreement with the original map (Figure 5). The drainage network is important for identifying places that have a higher probability of the occurrence of hydromorphism pedogenetics process.

According to Figure 6, it is possible that the DEM SRTM/Topodata overestimated the altitude range especially, at urbanized area (West portion) of Gama river basin. In areas with native vegetation preserved (East portion) this difference was about 3 m for more or less. This differences were also observed by Jarvis et al. (2004), a similar trend in the elevation data influenced by the slope orientation, when assessing an SRTM DEM to Honduras, but in this study, the positive differences in relation to DEM from topographic maps were present on the North, North-east or East slopes, while the negative slopes were observed in the South, East or West; these results, according to the authors were attributed to the effect of the viewing angle. After examining the quality of the DEMs, it was observed that the DEM obtained from contour lines presented better quality as compared to the DEM SRTM/Topodata.

This study showed that the SRTM DEM tends to underestimate elevation in peaks and ridges, and at this fine scale, the 1:10,000 cartography contour lines produced a more accurate and more detailed DEM. However, due to the size of Brazil and the lack of soil maps with good scale, it should be considered that the current availability of digital elevation models like the SRTM/Topodata, which is now freely accessible, covers the entire national territory, which can assist in soil mapping in other regions of Brazil.

Conclusion

This study showed that the SRTM DEM tends to underestimate elevation in peaks and ridges, and at this fine scale, the 1:10,000 cartography contour lines produced a more accurate and more detailed DEM. However, due to the size of Brazil in a lack of soils maps with good scale, the availability and spatial coverage of the SRTM/Topodata makes it a desirable option.

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