www.ugb.org.br

Revista Brasileira de Geomorfologia - v. 12, nº 1 (2011)

SEMI-AUTOMATIC IDENTIFICATION, GIS-BASED MORPHOMETRY OF GEOMORPHIC FEATURES OF FEDERAL DISTRICT OF BRAZIL

Valdir Adilson Steinke

Prof. Adjunto Depto. de Geografia - Universidade de Brasília - SQN 206 Bloco K Apt 501 - Asa Norte - Brasília, DF - CEP 70844-110 - e-mail: valdirs@unb.br

Edson Eyji Sano

Pesquisador Embrapa Cerrados - Embrapa Cerrados - BR 020 Km 18 - Planaltina, DF - Brasil - CEP 73310-970 - Caixa Postal: 08223 - e-mail: sano@cpac.embrapa.br

Resumo

Para identificar e delimitar padrões de formas semelhantes do relevo no Distrito Federal, localizado na porção central do Brasil, foi conduzida uma análise semi-automática de dados morfométricos com suporte de um Sistema de Informações Geográficas (SIG). A base de dados digitais foi composta de curvas de nível interpoladas para equidistância de 5 metros e de rede de drenagem do Sistema Cartográfico do DF (SICAD). Um modelo digital de elevação (MDE) foi gerado a partir dessas curvas de nível interpoladas. A integração entre o referido modelo e a rede de drenagem permitiu a identificação de 86 unidades morfológicas as quais foram classificadas e agrupadas em quatro padrões de formas semelhantes do relevo: Chapadas, Planícies, Colinas Suaves e Colinas Íngremes. Estes padrões, com base nos indicadores morfométricos de cada unidade, foram detalhados em subclasses. As superfícies de aplainamentos ocorrem predominantemente em relevos residuais e de acumulação fluvial, com declividade inferior a 3%, os residuais situados acima da cota altimétrica de 1.000 metros e as planícies situadas abaixo desta cota. O padrão em colinas suaves pode ser classificado em longas, intermediárias e curtas e as colinas íngremes em abruptas, intermediárias e suaves. Os índices morfométricos centrais para este mapeamento foram a amplitude altimétrica e o índice de rugosidade de cada unidade. A análise semi-automática do MDE e rede de drenagem permitiram a obtenção, de forma operacional, de uma nova proposta de compartimentação geomorfológica do Distrito Federal.

Palavras-chave: geomorfologia, sistema de informações geográficas, feições geomorfológicas, modelo digital de elevação.

Abstract

In order to identify and discriminate similar patterns of relief of Federal District of Brazil, located in the central part of the country, we conducted a semi-automated analysis of morphometric data with support of a Geographical Information System (GIS). The digital database was composed by 5-meter interpolated contour lines and drainage network projected to the local projection system named *Sistema Cartográfico do DF* (SICAD). A digital elevation model (DEM) was generated from the interpolated contour lines. Data integration of DEM and drainage network allowed the identification of 86 morphological units. They were classified and grouped into four major patterns of similar relief: lowland, plateau, gentle hill, and steep hill. These patterns, based on morphometric indicators of each unit, were detailed into subclasses. Planning surfaces occur mainly in residual relieves (elevations higher than 1,000 meters) and regions of accumulation of eluviated materials (elevations lower than 1,000 meters), with slopes smaller than 3%. Gentle hills were subdivided into long, intermediate and short gentle hills while steep hills were subdivided into abrupt, intermediate, and gentle steep hills. The major morphometric indices for this mapping procedure were the elevation amplitude and the roughness indices of each unit. The semi-automatic analysis and the drainage network allowed the operational obtaining of a new proposal of geomorphological classification of the Federal District.

Key words: geomorphology, geographical information system, geomorphological feature, digital elevation model.

Introduction

Landscapes are formed by natural and human-induced complex processes that interact each other over varying spatial and temporal scales. The understandings of geomorphological processes and controls are influenced not only by their real-world variability but also by our ability to observe and measure them (Phillips, 2009). Quantitative approaches in Geomorphology can be realized taking advantage of analytical and data integration capabilities of geographical information system (GIS) software packages.

When different geomorphometry-related data such as DEM, stream network, elevation and slope are combined within a GIS framework, we usually obtain a significantly expanded analytical capability. It already passed more than a decade when Vitek et al. (1996) highlighted the rapid increasing of the use of GIS technology in the field of Geomorphology. Now, several consolidated, commercial and public domain GIS software packages with different statistical and data integration possibilities are available for applications in Geomorphology (e.g., Grohmann, 2005; Rowbotham et al., 2005; Lenz and Peters, 2006).

The dominant landscape in the central Brazil is shaped by the vast, flat, residual, Pre-Cambrian plateaus with elevations averaging 1,000 meters. Successional weathering and erosion cycles, mostly in semiarid conditions, generated deep and weathered soils with high silicium and aluminum contents. The Federal District of Brazil (FD) is located in this high plateau, a post-Cretaceous epirogenetic uplift (Ab´Saber, 2000). The headwaters of FD belong to the three largest Brazilian hydrographic basins: the Araguaia-Tocantins basin, the Parana basin and the São Francisco basin.

Geomorphological maps of FD have been proposed by CODEPLAN (1984), Novaes Pinto (1986) and Carneiro and Souza (2001). Depending on the authors, the legends varied from three to four major compartments, composed basically by high plateaus, pediplanes and dissected surfaces (valleys). In the first study, the following geomorphological compartments were identified: "depressões interplanálticas pediplanadas", "planícies dissecadas", "pediplano Brasília", and "pediplano Contagem-Rodeador". The mapping conducted by Novaes Pinto (1986) presented three major compartments – "regiao de Chapada", "area de dissecacao" and "regiao dissecada de vales", with 5, 2 and 6 subunits, respectively. In the last research, the authors also reported three compartments: "regiao das chapadas", "superficies deprimidas" and "superficies dissecadas", with 5, 4 and 3 subunits, respectively. In this study, we propose the use of semi-automated GIS numerical capabilities to generate a new map of relief pattern and more detailed geomorphology compartments in the study area.

The patterns of similar forms of relief is based on group shapes with similar features in the morphology and morphometry (Ross, 1992). In this study the final map shows the subclasses of a same pattern according to the morphometric aspects.

Material and Methods

The test site corresponded to the FD (15^{o}47´30" south latitude; 47^{o}53'23" west longitude) (Figure 1). The precipitation regime in this study area is typically tropical, with the maximum rainfall in summer and minimum in winter. Annual average precipitation is about 1,350 mm. More than 70% of annual rainfall occurs from November to March. Following the Koppen classification system, the climate is classified as tropical savanna (Aw) or humid subtropical (Cwa, dry winter, hot summer).

The FD comprises an area of 5,814 km^2 with dominant gentle topography and elevations ranging approximately from 725 to 1,340 meters. The geological domain consists of low grade, metamorphic rocks. Over the Precambrian rocks, we find lateritic layers with thickness varying from centimeters to up to 30 meters. Oxisols are the dominant soil type in the existing plateaus while Cambisols occur in the transition zones between plateaus and river valleys.

In this study, the most important sources of data were the vector format, contour lines and the hydrology base map (CODEPLAN, 1991; Andrade, 1999). The contour line, digital archives were composed by a set of 1:10,000-scale, 2.5' by 3.75' topographic sheets available in the local cartographic system known as SICAD (Cartographic System of FD; projection system: UTM – Universal Transverse Mercator; datum: SICAD). Five-meter spaced digital elevation models (DEMs, the raster grids of regularly spaced elevation values) were generated from these contour lines using the Triangular Interpolation Network (TIN) method. The TIN technique operates in two steps: first, the scattered point set is triangulated and, second, an interpolation scheme is used for each triangle. It is an efficient method of interpolation, where the size and shape of triangles vary with the complexity of terrain (Weibel and Heller, 1991).

For the entire geomorphological units, we generated morphometric indicators that were used to select categories and classes of patterns of relief. Among these morphometric classes, the most relevants were elevation amplitude (*H*) and roughness index (*Ri*), related to elevation position of units and corresponding slope indices.

Using the *Spatial Analyst* extension available in the ArcGIS 8.2 commercial GIS software package, we created slope and similar morphometric groups from the elevation model. The slope classes were defined by the following intervals: 0-3 %; 4-12 %; and >12%.

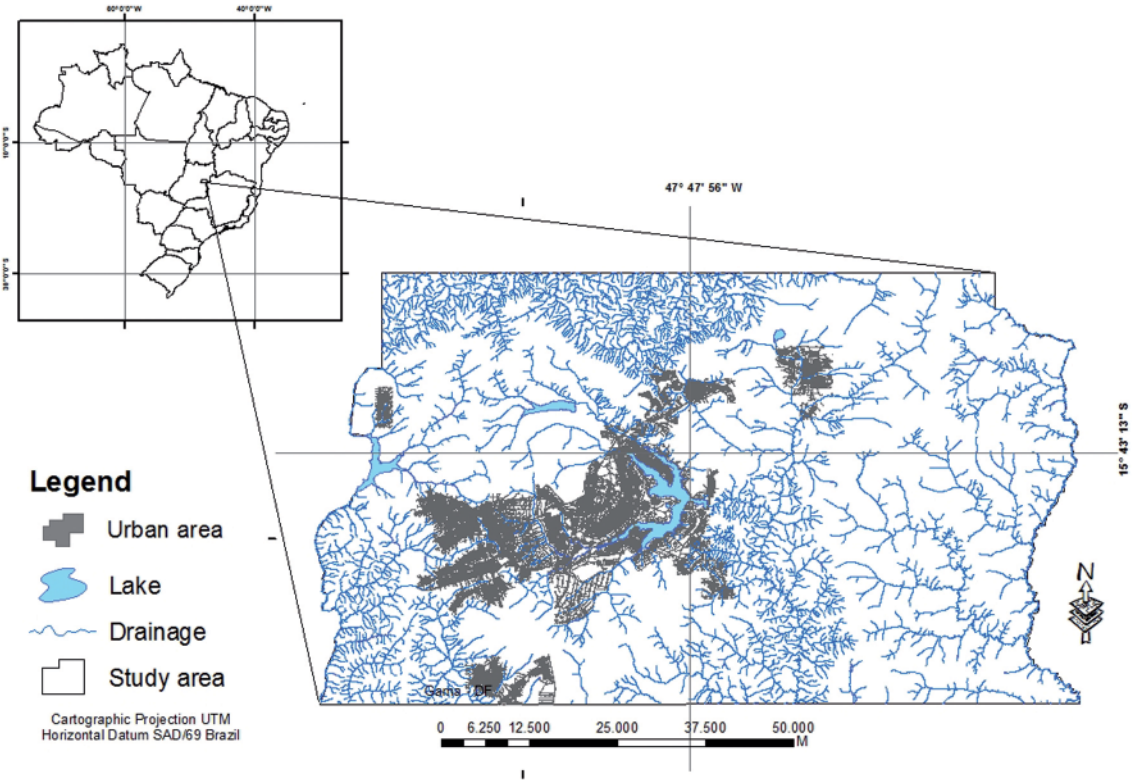

Figure 1 - Location of the study area.

Drainage density (*Dd*) data, the measure of the total stream length per unit area of study site, were derived from the hydrology base map of the test site. Measurements of *Dd* is important for geomorphical, geological and hidrological applications (Vogt et al., 2003; Reddy et al., 2004; Wechsler et al., 2009).

The slope, amplitude altimétrica (*H*) and drainage density (*Dd*) layers were integrated in the *ArcMap* function of ArcGIS 8.2 to produce geomorphic units of FD. Roughness index (R_i) and relation of relief (R_r) (Strahler, 1952; Christofoletti, 1973, 1980, 1981, 2000) were computed for each unit by the following equations:

$$R_i = H \cdot D_d \tag{1}$$

where *H* = elevation amplitude, the difference between the minimum and maxim elevation.

$$R_r = \frac{H_m}{A^{0.5}} \tag{2}$$

where H_m = maximum elevation amplitude; *A* = area.

For R_i and R_r calculations, the stream segments were classified according to the Strahler ordering classification system. In this system, channel segments are ordered numerically from a stream's headwaters to a point somewhere down stream. The R_i and R_r values were used to generate major geomorphic groups of FD through the multivariate cluster analysis (Dillon and Goldstein, 1984). The euclidean distance was selected to measure similarity among samples. Soil maps of FD (EMBRAPA, 1978) and 50 topographic profiles derived from the digital elevation model and located along major roads to garantee field validation and documentation were used to better characterize the proposed geomorphological compartments.

Results and Discussion

The GIS-based data integration of slope, hillshade and drainage density layers resulted in an identification of 86 morphological units in the study area. Due to the journal´s space limitation, the geomorphical characteristics (*Ri* and *Rr*) of these units are not presented here, but they can be found in Steinke (2003) and Steinke et al. (2007). The cluster analysis generated four major geomorphological groups, as shown in the dendrogram of Figure 2: lowland; plateau; gentle hill and steep hill.

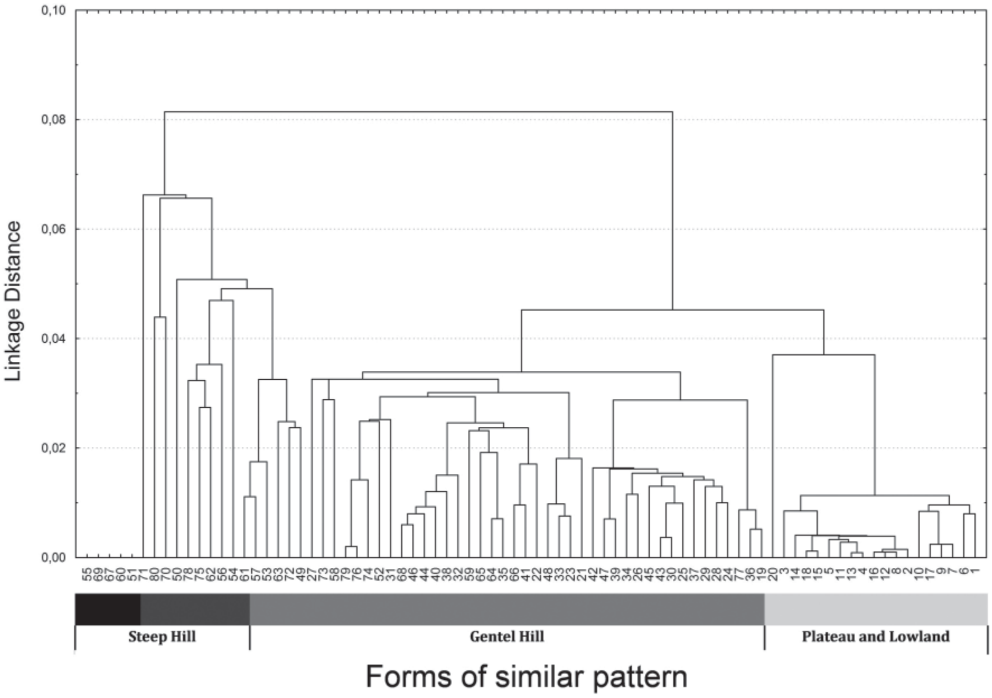

Figure 2 - Dendrogram obtained by the cluster analysis considering, as variables, roughness index, relation of relief, elevation and drainage density.

The lowland and plateau (Figure 3) are the most extensive groups of FD, occupy 40 % of the FD and is characterized by flat topography, with a maximum of 3 % of slope (Table 1). This group often occurs in areas with elevations higher than 830 meters.

Table 1 - Morphometric parameters for the major geomorphological units in the Federal District of Brazil.

Process	Types of Forms of Relief		Roughness index (R_i)	Altimetric range of occurrance	Form	Slope
Aggradation	**Lowland**		0 – 0.036	< 1.000m	Plain	< 3%
Denudation	**Plateau**		0 – 0.021	> 1.000m	Plain	< 3%
	Gentle Hill	Long	0.072 – 0.150	variable 810 – 1240m	Concave Convex Complex Rectilinear	4 - 12%
		Intermediate	0.160 – 0.299			
		Short	0.300 – 0.456			
	Steep Hill	Gentle	0.476 – 0.678	variable 730 – 1320m	Concave Convex Complex Rectilinear	>12%
		Intermediate	0.680 – 1.700			
		Abrupt	2.142 – 3.068			

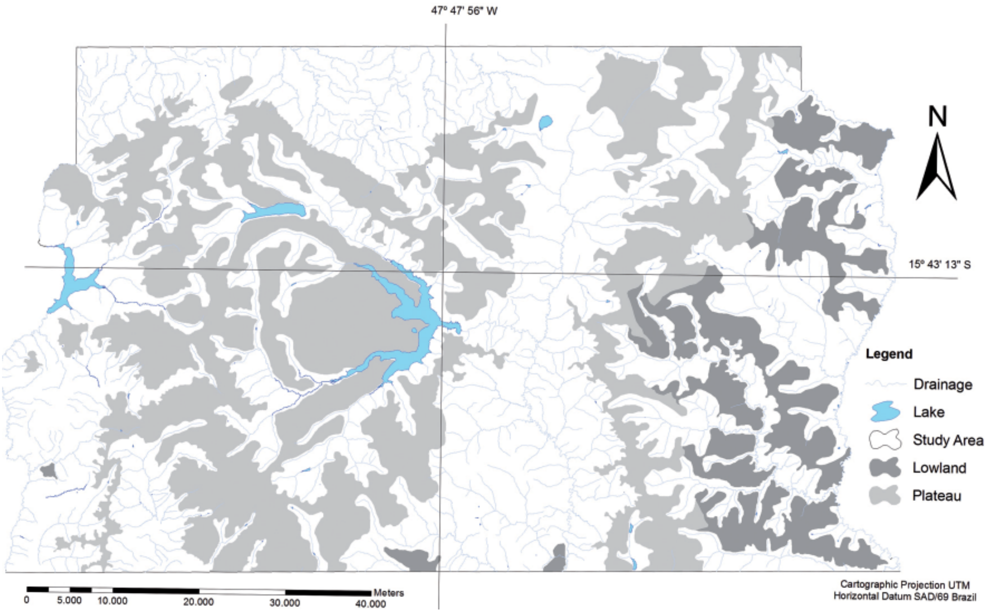

Figure 3 - Spatial distribution of lowlands and plateaus in the study area.

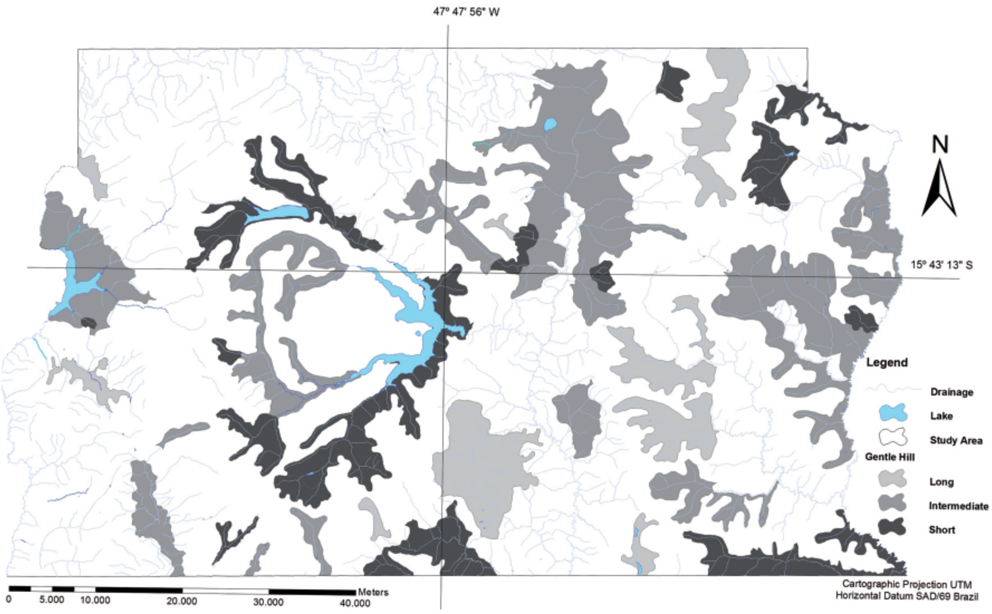

Figure 4 - Spatial distribution of gentle hills in the study area.

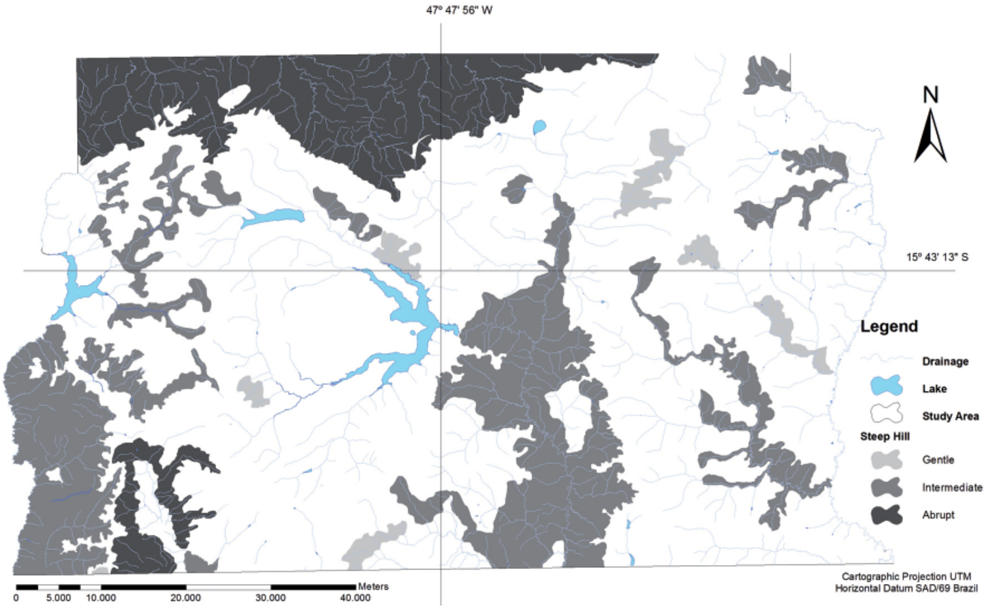

Figure 5 - Spatial distribution of steep hills in the study area.

The surfaces related to zones of erosion are concentrated in two regions with different average elevations. Residual surfaces are mainly located in terrains with elevation higher than 1,000 meters while surfaces corresponding to zones of deposition are located mainly in elevations lower than 1,000 meters, especially in the right margin of Preto river. Long, intermediate and short gentle hills are distributed throughout the study area, with the exception of Maranhao river basin (Figure 4). Steep hills were classified in gentle, intermediate and abrupt and are also found throughtout the study area (Figure 5).

Conclusions

The statistical analysis of morphometric parameters derived from the digital elevation model and drainage at 1:10,000 scale contributed for identifying 86 relief patterns in the Federal District of Brazil. Besides, this approach allowed the identification of small-scale morphological units in the study area that were not mapped in the previous studies.

The results of this work are particularly important for new studies that integrate social, environmental, biological and physical aspects for best practices of land resources management in the Federal District of Brazil.

Acknowledgments

The authors acknowledge the Brazilian Environmental Agency (IBAMA) and the University of Brasilia (UnB) for the opportunity to develop first author´s M.S. program. The Brazilian National Research Council (CNPq) has provided individual research grant for the second author. Special thanks to Mr. Flávio Simas de Andrade from IBAMA who kindly provided the shapefiles from FD. Suggestions from Dr. Archimedes Perez Filho were greatly appreciated. References to commercial products do not represent endorsements or recommendations for use by the authors.

References

AB´SABER, A.N. Summit surfaces in Brazil. **Revista Brasileira de Geociências**, 30(1): 515-516. 2000.

ANDRADE, F.S. Uso de sistemas de informação geográfica na identificação de áreas potenciais para a instalação de aterros sanitários no Distrito Federal. Brasília: **Universidade de Brasília, Instituto de Geociências.** 131 p. (Dissertação de Mestrado). 1999.

CARNEIRO, P.J.R.; SOUZA, N.M. Compartimentos geomorfológicos do Distrito Federal. **Revista Universa**, 9(2):339-348. 2001.

CHRISTOFOLETTI, A. Geomorfologia: definição e classificação. **Boletim de Geografia Teorética**, 3(5):39-45. 1973.

CHRISTOFOLETTI, A. **Geomorfologia**. 2ª ed. São Paulo: Edgard Blücher, 188p. 1980.

CHRISTOFOLETTI, A. **A Geomorfologia Fluvial**. 1ª ed. São Paulo: Edgard Blücher, 313p. 1981.

CHRISTOFOLETTI, A. **Modelagem de Sistemas Ambientais**. 2ª ed. São Paulo: Edgard Blücher, 236p. 2000.

CODEPLAN. Companhia de Planejamento do Distrito Federal. **Atlas do Distrito Federal**. Brasília: 1984.

CODEPLAN. Companhia de Planejamento do Distrito Federal, **Atlas do Distrito Federal**. Brasília: 1991.

DILLON, W.R.; GOLDSTEIN, M. **Multivariate analysis. Methods and Applications**. John Wiley & Sons, 208p. 1984.

EMBRAPA. Empresa Brasileira de Pesquisa Agropecuária. **Mapa de Reconhecimento dos Solos do Distrito Federal**. 1ª ed., Brasília, 1 mapa: color.: .1,20 x 80 cm. Escala 1:100.000. 1978.

GROHMANN, C.H. Trend-surface analysis of morphometric parameters: a case study in southeastern Brazil. **Computer & Geosciences**, 31(8):1007-1014. 2005.

LENZ, R.; PETERS, D. From data to decisions: steps to an application-oriented landscape research. **Ecological Indicators**, 6(1):250-263. 2006.

NOVAES PINTO, M. Unidades geomorfológicas do Distrito Federal. **Geografia**, 11(21):97-109. 1986.

PHILLIPS, J.D. Landscape evolution space and the relative importance of geomorphic processes and controls. **Geomorphology**, 109:79-85. 2009.

REDDY, G.P.O.; MAJI, A.K.; GAJBHIYE, K.S. Drainage morphometry and its influence on landform characteristics in a basaltic terrain, Central India – a remote sensing and GIS approach. **International Journal of Applied Earth Observation and Geoinformation**, 6:1-16. 2004.

ROSS, J.L.S. O registro cartográfico dos fatos geomórficos e a questão da taxonomia do relevo. **Revista do Departamento de Geografia**, 6, FFCCH/USP. Pgs 17-29. 1992.

ROWBOTHAM, D.; SCALLY, F.D.; LOUIS, J. The identification of debris torrent basins using morphometric measures derived within a GIS. **Geografiska Annaler**, 87(A):527-537. 2005.

STEINKE, V. A. Uso integrado de dados digitais morfométricos (altimetria e sistema de drenagem) na definição de unidades geomorfológicas no Distrito Federal. Brasília: **Universidade de Brasília, Instituto de Geociências**, 104 p. (Dissertação de Mestrado). 2003.

STEINKE, V. A.; SANO, E.E.; STEINKE, E.T.; NASCIMENTO, R.O. O desenvolvimento dos estudos geomorfológicos no Distrito Federal. **Geografia**, Rio Claro, 32(1):107-120. 2007.

STRAHLER, A.N. Hypsometric (area-altitude) analysis of erosional topography. **Geological Society of America Bulletin**, 63:1117-1142. 1952.

VITEK, J.D.; GIARDINO, T.R.; FITZGERALD, J.W. Mapping geomorphology: a jorney from paper maps, through computer mapping to GIS and virtual reality. **Geomorphology**, 16(3):233-249. 1996.

VOGT, J.V.; COLOMBO, R.; BERTOLO, F. Deriving drainage networks and catchment boundaries: a new methodology combining digital elevation model data and environmental characteristics. **Geomorphology**, 53:281-298. 2003.

WECHSLER, N.; ROCKWELL, T.; BEN-ZION, Y. Application of high-resolution DEM data to detect rock damage from geomorphic signals along the central San Jacinto Fault. **Geomorphology**, 113(1-2):82-96. 2009.

WEIBEL, R.; HELLER, M. Digital terrain modelling. In: MAGUIRE, D.J.; GOODCHILD, M.F.; RHIND, D.W. (eds). **Geographical Information Systems**. Ed. Longman Scientific Technical, London: 269-297. 1991.