SOILS DISTRIBUTION MODEL BASED ON RELATION BETWEEN GEOLOGY, GEOMORPHOLOGY AND PEDOLOGY, AT THE HIGH PLATEAU OF DISTRITO FEDERAL, BRAZIL

Inara Oliveira BARBOSA[1], Marilusa Pinto Coelho LACERDA[2], Marina Rolim BILICH[2]

[1] Department of Mineral Production -DNPM, Brasília. Email: inara@dnpm.gov.br
[2] Faculty of Agronomy and Veterinary Medicine, University of Brasilia, Brasília. Email: marilusa@unb.br. y maribilich@yahoo.com.br.

ABSTRACT

Studies of the relation between geology and geomorphic surfaces are important for understanding the soil distribution in the landscape. In the Distrito Federal the scale survey does not evidence some pedologic features. This study aimed to generate a pedological distribution model in Distrito Federal High Plateau with more detailed scale, from the relations between geology, geomorphology and soils. The study area is located in the midwest portion of the Distrito Federal. To generate the soil map it was used geoprocessing tools (GIS) supported by field checking. The soil map was obtained from crossing the geoforms (hypsometric and slope) with the geology map. The established pattern of soil distribution in the Distrito Federal High Plateau was shown to be representative. The study allowed establishing the relations between the soil classes with geomorphology and defining altimetry classes, slope and geology on the soil occurrence.

Keywords: *Soil classes, geology, geomorphology, geoprocessing.*

RESUMEN: *Modelo de distribución de suelos basado en la relación entre geología, geomorfología y edafología, en el Altiplano del Distrito Federal, Brasil.* Los estudios de las relaciones entre geología y superficies geomórficas son importantes para entender la distribución de suelo en el paisaje. En el Distrito Federal la escala de levantamiento no evidencia rasgos pedológicos. Este estudio tiene como objeto generar un modelo de distribución pedológico en el Altiplano del Distrito Federal. Para generar el mapa de suelo fueron utilizadas herramientas de reprocesamiento soportadas por GIS para la verificación de campo. El mapa de suelo fue obtenido cruzando las geoformas (hipsométricas y pendiente) con el mapa geológico. Los diseños establecidos de distribución de suelo en el Altiplano del Distrito Federal fueron mostrados como representativos. El estudio permitió establecer las relaciones entre las clases de suelo con la geomorfología y definir clases de altimetría, pendiente y geología en las ocurrencias de suelo.

Palabras clave: *Clases de suelo, geología, geomorfología, geoprocesamiento.*

INTRODUCTION

The soil is the product of interaction between various factors, represented by source material, climate, topography, time and organisms, which are interdependent variables. The soil is an important environmental stratification, it directly influences the ecosystems organization due to their interactions with the bedrock, water, climate and vegetation (Resende *et al.* 2005).

Studies of the relation between soil, geology and geomorphic surfaces are important for understanding the occurrence of soil in the landscape, thus allowing the prediction of the soil distribution, and therefore are important tools to assist the activities of soil mapping and land use planning (Teramoto *et al.* 2001).

There are many factors that help soils classification. The topography and the landscape position are important because generate different influences on the soil properties, even when these suffer strong weathering and have a high homogeneity degree (Curi and Franzmeier 1984).

According to Campos (2004), the substrate presents a remarkable lithological control of the subdivision and geomorphological evolution of the Distrito Federal, Brazil. All the Distrito Federal High Plateaus are controlled by the presence of petrographic types assigned to sandy metarhythmites units and quartzite of the Paranoá Group.

Studies have been developed in Distrito Federal to understand the genesis and soil morphology, however, in a fragmented landscape. The best source of information available comes from the recognition of soil survey conducted by the

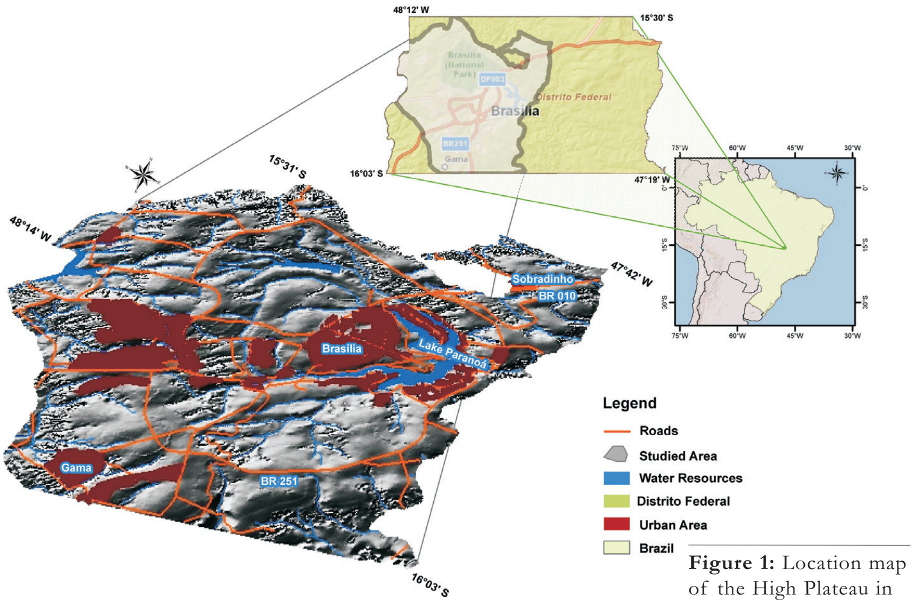

Figure 1: Location map of the High Plateau in Distrito Federal.

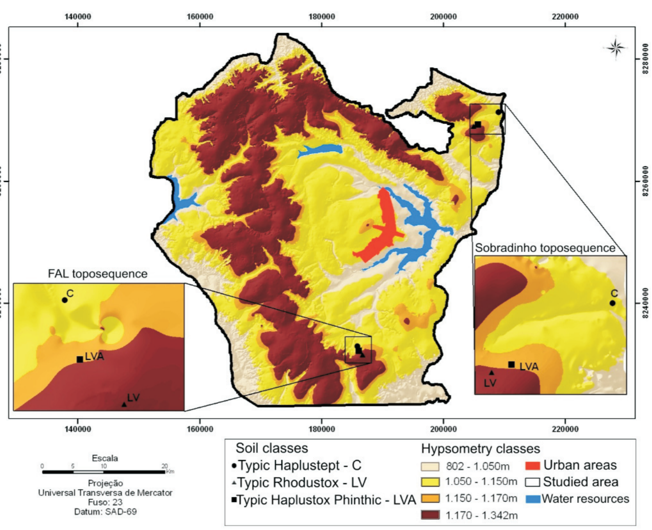

Figure 2: Hypsometry classes map of studied area.

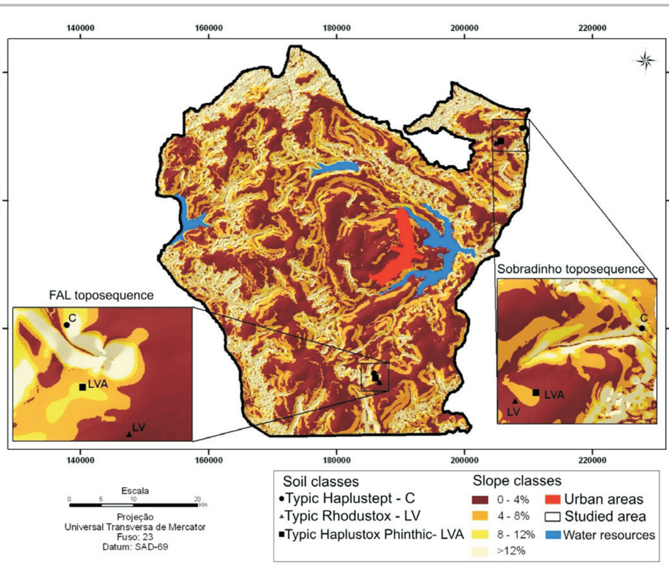

Figure 3: Slope class map of studied area.

Brazilian Enterprise for Agricultural Research (Embrapa 1978), with the generation of pedologic map, scale 1:100,000. This is a pedologic mapping with little detail scale and no evidence of certain features, making necessary, more detailed soils mapping in the DF.

Among the soils that occur in the Distrito Federal predominates the Typic Rhodustox, Typic Haplustox and Typic Haplustept. According to Lacerda *et al.* (2006), in the Haplustox predominates goethite that occur to the mineral stability in deficient internal drainage conditions over the soils profiles, due to presence of layers formed by the petroplinthite.

Currently, the use of geoprocessing (GIS, geostatistics and remote sensing) has been highlighted as a new method of mapping that aid to the traditional method. This method has the ability to display and interact with several layers that can be superimposed on each other, such as geology, geomorphology, soil, topography, and others.

The Geographic Information Systems (GISs) provide efficient organization of the earth's surface, according to a predefined morphological model and show potential to improve the prediction of soil types occurrence, also like the position in the landscape influence and the pedological formation (Ippoliti *et al.* 2005).

The approach of three-dimensional landscapes with Digital Terrain Models (DTM) has provided the interpretation of the relation between the relief and pedogenetic evolution (Campos *et al.* 2006).

Therefore, to understand the soil distribution in the Distrito Federal landscape, to assist activities of detailed mapping, using GIS, is necessary to understand the mechanisms of pedogenetical evolution of these soils in the region.

The objective of this study is to assess the relation between soils, geology and geomorphology and create a pedological distribution model in High Plateau of Distrito Federal, through geoprocessing.

REGIONAL GEOLOGY

The Distrito Federal is inserted into the eastern portion of the Tocantins Province, specifically in the central portion of the Brasilia belt, in transition with its internal portions (higher degree of metamorphic rocks) (Campos 2004). Litho-structural changes occurred in five deformation phases ranked within a single deformational event related to Brasiliano orogenic event (end of Neoproterozoic, some 570 Ma) (Campos 2004). This cycle, characterized by compressive tectonics toward the San Francisco craton, presents the first of four stages with folds and ductile-brittle faults and were responsible for the dome formation (the Brasilia, the Pipiripau and Sobradinho domes) and structural basins (Freitas-Silva and Campos 1998).

The Paranoá and Canastra Groups have Meso/ Neoproterozoic age (1300 to 1100 Ma) and the Araxa and Bambuí Groups, Neoproterozoic age (950 to 750 Ma). The litho-structural evolution resulted in a reverse stratigraphy produced by thrust faults, positioning older lithostratigraphic units on younger ones (Freitas-Silva and Campos 1998).

The Distrito Federal geology was recently revised and updated from the new geological map at 1: 100,000 scale, without the land coverage, developed by Freitas-Silva and Campos (1998). Four distinct lithological boundaries set up the regional geological context of which include the Paranoá (metasedimentary rocks), Canastra (phyllites), Araxá (schists) and Bambuí (clayed metasiltites rolled, clay and metasiltites banks) Groups and soil or waste colluvial coverage (pedimentary type).

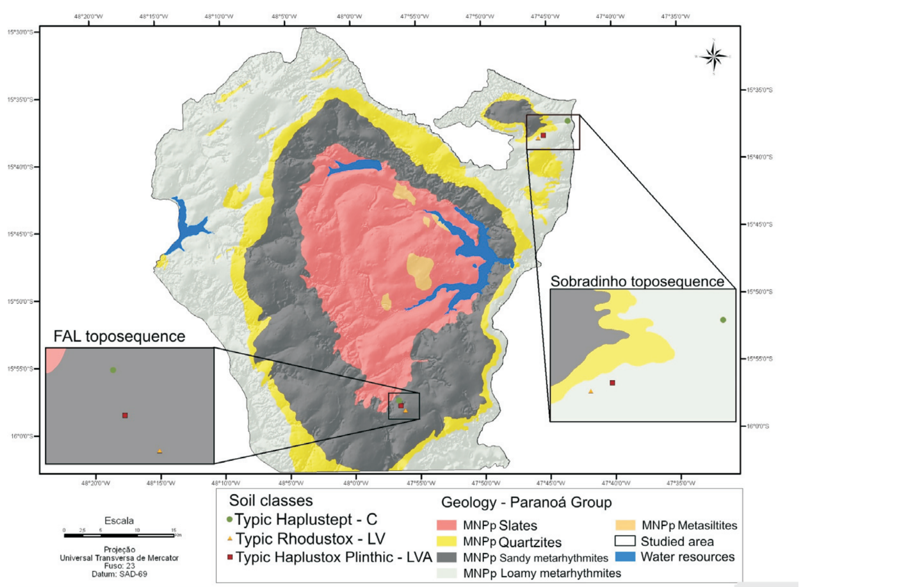

Figure 4: Geologic map of studied area.

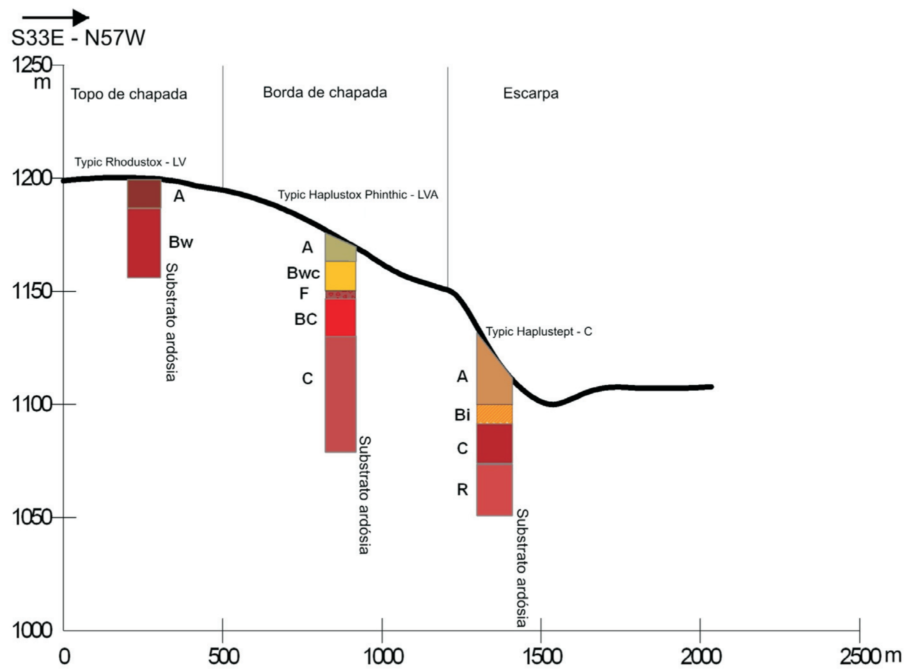

Figure 5: Geomorphological distribution profiles of studied soils.

Local geology

The geology of the study area consists predominantly of metasedimentary rocks of Paranoá Group correlated from the base to the top as follows: A (slate gray color or green, to purple tones when amended, homogeneous and folded), R3 (sandy metarhythmites), Q3 (middle quartzite, quartzite represented by fine to medium, often coarse texture) and R4 (loamy metarhythmites). According to Martins (2000) the geomorphological compartment of the High Plateau is composed of rock sheets at the top of the unit R3 (sandy metarhythmite). Near the edges of the sheets are thick levels of quartzite unit's Q3, with the presence of Haplustept soils.

The location of sampling points was called FAL and Sobradinho toposequences. In the available geological map, the bedrock in these points is sandy metarhythmites units and loamy metarhythmites, respectively. However, field studies verified that the geology of these sampling points did not match with the geological map available. In the FAL

Figure 6: Detail of the Typic Rhodustox – LV soil profile studied.

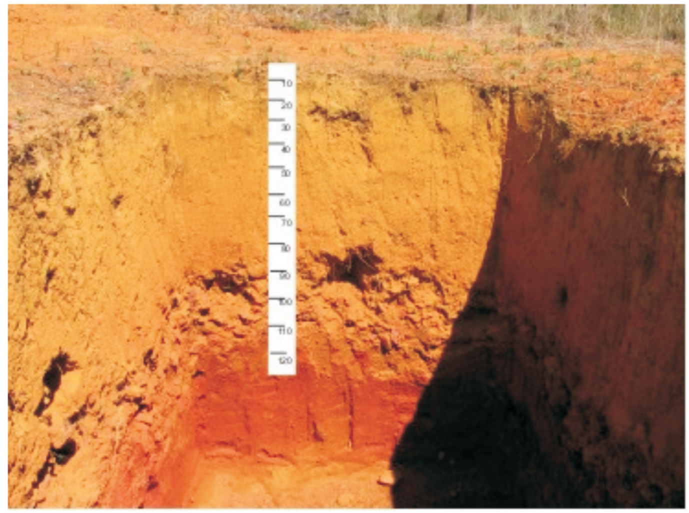

Figure 7: Detail of the Typic Haplustox Plinthic – LVA soil profile studied.

Figure 8: Detail of the Typic Haplustept –C soil profile studied.

toposequence, was found the slate unit and in the Sobradinho toposequence, the sandy metarhythmite unit. This problem probably is related to the map scale.

REGIONAL GEOMORPHOLOGY

The Distrito Federal is located in the Central Plateau, according Novaes Pinto (1994) and has three geomorphologic surfaces. The first surface correspond to the ancient peneplane developed by the South American erosion cycle (Braun 1971), whose plateau is the remaining area from this cycle and its edges are covered by thick layer of ferruginous concretions (Motta *et al.* 2002). The second surface extends as inclined plane from the edges of the first surface toward to the main water courses, corresponding to the Pleistocene pediplane due to dissection of oldest surface, of the first erosion cycle (Motta *et al.* 2002). The third surface is characterized by more mountainous relief, with undulating to steep sloping and corresponds to areas of more recent dissection (Motta *et al.* 2002).

Local geomorphology

The study area is located in the first geomorphological surface called High Plateau. The subdivision has large collection of studies focusing on geomorphologic, such as Penteado (1976), CODEPLAN (Central Plateaux Development Company) (1984), Novaes Pinto (1987, 1994) and Baptista and Martins (1998). Penteado (1976) established a subdivision involving the geomorphological ferruginous concretions present on surfaces. The first area, formed in the Tertiary, with elevations between 1050 to 1.300m (Contagem High Plateau) developed on a more sandy material showing ferruginous concretions of two types: ferruginous concretions and massive and pedogenetic lateritic.

PEDOLOGY

According to Distrito Federal soil survey conducted by Embrapa, (1978) it was noted the occurrence of four major classes of soils in the study area: Typic Rhodustox, Typic Haplustox, Typic Haplustept and occasionally the Troppsamments. Some soils are found in fields such as: the Haplustox in the two toposequence studied, but the Rhodustox soil in the FAL toposequence did not match with the Embrapa soils map of 1978, probably because of the map scale.

The formation of Typic Rhodustox and Typic Haplustox is associated with an intense weathering process in the minerals in all mineral fractions. On clay fraction, predominates mineralogical association of kaolinite, gibbsite, hematite and goethite (Breemen and Buurman 1998).

The Rhodustox class occurs, especially in the tops of the plateau in flat relief and smooth sloping. These soils are rich in sesquioxides of Fe (hematite) and Al (gibbsite).

The Haplustox class occurs, mostly in the edges of plateau and always adjacent to the class of Rhodustox. Another feature of these soils is the presence of iron concretions, which may constitute Plintustox. The presence of these concretions is due to changes in groundwater regime, layers that can make the soil poorly drained, acting in the hydration of iron oxides (hematite) and turning to goethite (Martins 2000).

The Haplustept class occurs preferentially on regions with more pronounced slope. The class Troppsamments occurs, especially on the edges of the plateau in smooth undulating relief where the origin material is quartzite.

MATERIALS AND METHODS

It was created a database with secondary georeferenced information of natural resources: geology (Freita-Silva and Campos 1998, scale 1:100,000), soils (Embrapa 1978), level curves, level dimensional points and hydrography of CODEPLAN-Sicad (1991).

In order to choose the two representative toposequences, field studies were made. The choice of the toposequences profiles were based on the organization of natural landscapes, taking into consideration the geology, geomorphology and the soil distribution, as well as native vegetation. The representative toposequences include the Rhodustox, Typic Haplustox and Typic Haplustept.

The study area is located in the Midwest portion of the Distrito Federal, between the geographical coordinates 15°31' and 16°03' of south latitude and 47°42' and 48°14' of west latitude(horizontal datum South American 69) (Fig. 1). The toposequence called "Sobradinho" is located in the Sobradinho Plateau in northeast area of the Distrito Federal, along the BR 010 highway between Sobradinho and Planaltina. The toposequence called FAL is located in the Brasília Plateau situated in south-southeast of Distrito Federal.

It was established a soil distribution model in the High Plateau of Distrito Federal, based on the relations between geomorphology (represented hypsometric and by the slope class), geological units and soil classes of the study area.

To generate the preliminary soil map was used the ArcGis 9.1 software (ESRI 2007)

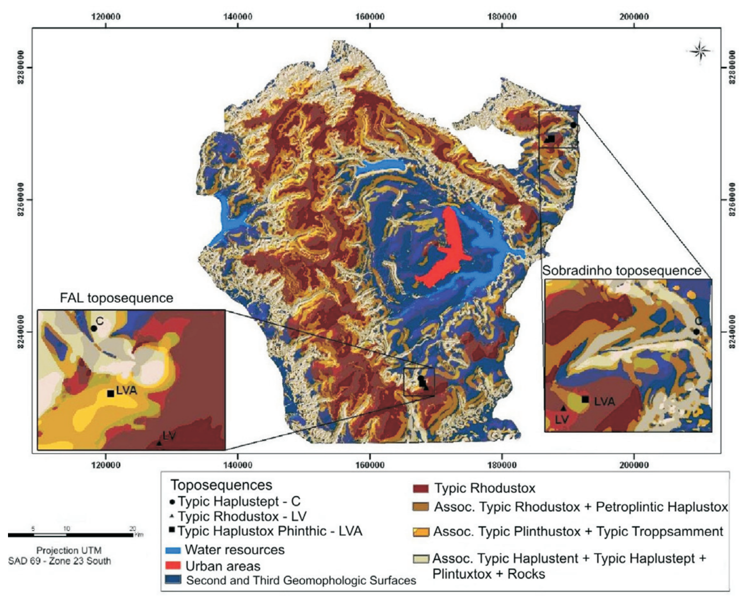

Figure 9: Soil map in the High Plateau of the Distrito Federal.

and its Spatial Analyst extension module. Using the georeferenced database (CODEPLAN-Sicad, 1991) was generated the digital terrain model (DTM).

To generate the digital terrain model of the study area it were used level-dimensional points, hydrography and level curves (1:25,000 scale, of CODEPLAN Sicad-1991) modules of the 3D Analyst, in ArcGIS 9.1. The option of 3D Analyst extension was the interpolator TopoGrid, which is based on the ANUDEM program developed by Hutchinson (1989). The choice of this method for the MDT creation was based in Guimarães (2000) which considers that this tool and the methodologies for the modeling of terrain is more efficiency when compared with the real topography.

The digital terrain model was reclassified to generate the hypsometric map of the study area with the following altitude classes: 1345 - 1170m (plateau top), 1170-1150m (edges of the plateau), 1150-1050m (steep, in edge of plateau) and 1050 - 816m (second and third geomorphological surface) (Fig. 2). From the DTM was generated the slope map of the study area, which was reclassified, according to the following classes: 0-4% (plateau top), 4-8% (transition between the top and the edge of the High Plateau) 8-12% (near the edge of the plateau) and> 12% slope (edge of the plateau) (Fig. 3).

The geoforms map was made crossing the hypsometric and slope classes maps, using the Raster Calculator of Spatial Analyst extension. After that, was made a reclassification developing the geoforms map of the study area, according to the conducted study.

The soil map was then generated from the crossing of geoforms map with the geology map (Fig. 4). This map was then checked and validated with field activities.

RESULTS AND DISCUSSIONS

The soil distribution model was determined by geo-pedological rules and correlations established on the pedogenesis, supported with literature and verification in the field, respecting the slope and hypsometric classes and geology.

The most important feature in the study area was the Brasilia structural dome, comprising the Paranoá Group rocks. The structure dome has been affected by planation processes, forming a plane surface whose nucleus has been eroded, causing the process of inversion of relief. The High Plateau of the Distrito Federal is developed on the flanks of

TABLE 1: Distribution Model for Soil in High Plateau of Distrito Federal.

Features	Hypsometry (m)	Relief	Slope	Geology	Soils
Plateau Top	1.342 and 1.170	flat	0 to 4%	Slates, Quartzites, Sandy Metarhythmites and Loamy Metarhythmites	Typic Rhodustox
Transition Area	1.340 and 1.050	Plan to soft undulated	4 to 8%	Slates, Quartzites, Sandy Metarhythmites and Loamy Metarhythmites	Association of Typic Rhodustox with Typic Haplustox Plinthic
Plate Edge	1.170 and 1.150	soft undulated	8 to 12%	Slates, Quartzites, Sandy Metarhythmites, Quartzites and Loamy Metarhythmites	Association of Typic Haplustox Plinthic and petroplinthic with Troppsamments
Slope	1.150 to 1.050	Undulated to fort undulated	>12%	Slates, Quartzites, and Sandy Metarhythmites	Typic Haplustept and Typic Haplustent and Rocks (quartzites) and Plintustox

structural Domes organized according to the lithology as reported by Martins (2000).

These High Plateau is controlled by the presence of a quartzite layer that separate the geomorphological edge of the sheets on the metarhythmites and slates. The ferruginous concretions are important agents of stratifications of the landscape, limiting the edges of the sheets in the form of scarps, observed by Martins (2000). Therefore, the edges of plateau are conditioned by the presence of quartz and iron concretions by taking the task of sustaining them.

The distribution of soil classes in High Plateau of Distrito Federal is conditioned by the shape of the topography and geology. The maximum altitude observed in High Plateau enabled the analysis of this fragment of the landscape with altitudes ranging from 1342 to 1050m, as described by Penteado (1976).

The geology was a conditioning factor to a more precise delimitation of the soil classes. It was crossed the geology map and geoform map, even with incompatibility between the maps scales. However, this process was possible because of field study on the distribution of the geological units in the area.

The Typic Rhodustox is developed in areas with flat relief, correlated to the top of the High Plateau on psamo-pelitic rocks of the Paranoá Group.

The association of Typic Rhodustox with Typic Haplustox Plinthic occurs in smooth sloping in the transition between the top and the edge of the High Plateau.

The Typic Haplustox Plinthic or Plintustox occur in undulating sloping, if located in geomorphological called edges of the High Plateau, on units of the Paranoá Group.

The Troppsamments are developed in undulating sloping, located in the edges of the High Plateau, according to the occurrence of more surficial quartzites (Q3 unit) of the Paranoá Group.

The Typic Haplustept occurs in mountainous relief, in the field of geomorphological escarpment, on the quartzite's units, and sandy metarhythmites of Paranoá Group (Figs. 5, 6, 7 and 8).

The establishment of transition areas between the Typic Rhodustox and Typic Haplustox was done considering that soil formation does not have a fixed limit, in agree with Valerian and Prado (2001), who believe that the representation of an environmental phenomenon landscape is often inappropriate, because the changes don't occur in local with defined abrupt limits.

Thus the soil distribution model of in High Plateau of Distrito Federal was established from the table 1.

The generated soil map of the study area can be seen in (Fig. 9).

The soil distribution model of the sheets of the Distrito Federal High Plateau was representative to the classes of soils found in the field. Comparing the soil map of the Distrito Federal conducted by Embrapa (1978), the proposed model showed a better distribution in the variation in the soil classes, as also observed by Lacerda *et al.* (2006).

The evolutionary process of the soil in High Plateau showed that the slope is a very important factor, because the variation of soil in the study area was determined mainly by the slope. Since the chemical analysis, mineralogical and geochemical soil toposequences studied have very similar characteristics (Barbosa 2007), it was originated from different source material, slates (toposequence FAL) and sandy metarhythmite (toposequence Sobradinho).

It is important to emphasize that when changes occurs in chemical, mineralogical and geochemical features of original material with the presence of the quartzite, the geology becomes a factor as important as the slope.

The use of the digital terrain model has demonstrated the ability to relate the hypsometric classes with the slope of the landscapes for generation of landscape forms of a region, and enable the association to the soil classes, thereby assisting in the activities of soil surveys. (Campos *et al.* 2006).

CONCLUSIONS

- The generation of hypsometric and slope classes maps in addition to digital terrain models of a region, through geoprocessing techniques, to shape geomorphology of the landscape and soils distribution associated.
- The soil distribution model of the Distrito Federal High Plateau was representative to the classes of soils found in the field.
- The study showed that establishing relationships between the soils classes with geomorphological and geological features, allows obtaining a soil map of an area, compatible to current needs.

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