Erosion modeling in hydrographic pilot basins in Brasília (Federal District), Brazil

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Abstract: Brasília was inaugurated in 1964 as the new capital of Brazil. Brasília was defined by a restricted area (Federal District) and hence a limited population. This young capital is not yet a megacity, however it already displays characteristics that point to a rapid growth in population. The satellite towns and neighborhood of Brasília have grown up to three million inhabitants within the last three decades. The area shows uncontrolled growth with a deficiency in water supply and illegal extraction of raw materials for construction.

Current data shows that the Federal District consumes large amounts of water. This consumption is the result of the great migratory process and the increase of the agricultural activities. These activities have provoked a series of environmental (or ecological) problems, such as: pollution of the water bodies, deforestation and the consequences of the intensive geodynamic phenomena. The intensification of the anthropic activities causes the loss (or erosion) of the soils and sedimentation of the water bodies, which reduces the capacity of storage and agricultural production.

This GIS –based research makes use of spatial analytical tools. Using the GIS, data can be manipulated quickly and precisely. The estimate of soil loss, which will be further elaborated, has been approached from the perspective of static and dynamic models applied to hydrographic pilot basins in the Federal District. This study supports the socioeconomic and environmental planning in the short and medium period, as well as being able to model future sceneries of the geodynamic phenomena. This study also demonstrates the consolidation of public politics, administration and sustainable development in the Federal District.

Résumé: Brasília a été inauguré en 1964 comme la nouvelle capital de Brésil. Brasília a été défini par une région restreinte (District Fédéral) et, donc, pour une population limitée. Ce jeune capital n'est pas encore un mégalopole, mais il affiche déjà caractéristiques qui pointent à une augmentation rapide de population. Cependant, les villes du satellite et voisinage de Brasília ont grandi trois million d'habitants dans les trois décennies dernières. Cette région montre l'augmentation incontrôlée avec une déficience dans provision de l'eau et extraction illégale de matières premières pour construction.

Données courantes montrent que le District Fédéral consomme grands montants d'eau. Cette consommation est le résultat du grand processus migrateur et le développement des activités agricoles. Ces activités ont provoqué une série de problèmes environnementales (ou écologiques), comme: pollution des corps de l'eau, déboisement et les conséquences des phénomènes géodynamiques intensifs. L'intensification des activités humaines occasionnent la perte (ou l'érosion) des sols et la sédimentation des corps de l'eau et cela réduit la capacité de stockage et production agricole.

Cette recherche avec GIS utilise des outils d'analyse spatiale. Dans le travail avec GIS les données peuvent être manipulées de forme rapide et précise. L'estimation de la perte de sols sera élaborée dans la perspective des modèles statiques et avec modèles dynamiques appliqués aux cuvettes hydrographiques pilote dans le District Fédéral. Cette étude assiste la planification socio-économique et environnemental dans la période courte et moyenne, ainsi que c'est capable de modeler décors futurs des phénomènes géodynamiques. Cette étude démontre aussi la consolidation des politiques publiques, administration et développement soutenable dans le District Fédéral.

Keywords: environmental impact, environmental geology, erosion, geographic information systems, models, sediments

INTRODUCTION

As societies have developed, the uses of the land and its elements have become indispensable for the maintenance of life conditions. Agricultural development has opened space to other activities such as industry, generation of energy, transport and the growth of new towns. These alterations in land-use have modified the natural balance of the elements, which comprise the environment, such as the soil itself, water, wind, vegetation and water bodies (streams, rivers, lakes and seas), thus generating environmental impacts. The encroachment on the natural environment has been justified by Brazil's recently acquired position as a grain exporter. However, it has resulted in the unchaining of environmental imbalance of great proportions. Such imbalance affects engineering works and the water quality of rivers, lakes and reservoirs, as a result of the influx of sediments resulting from the intensification of mechanized agriculture in the Brazilian Savannah area. Erosion constitutes the start of all of the problems resulting from the sediment in the environment. Besides producing harmful sediment, it may also cause serious environmental damage, such as the gradual loss of soil fertility and the reduction of a water reservoir capacity, provoked by the silting up of its riverbed.

Thus, knowledge of the erosive processes in the source basin of a reservoir is a fundamental tool for understanding the generation and movement of sediments in the basin. For the characterization of the erosion phenomena, knowledge of the main attributes of the basin, such as the type and thickness of soil covering, geology, geomorphology, topography, precipitation regimes, wind conditions and the conservation practices adopted is necessary. Such characterization is necessary to plan remedial intervention in the dynamics of such erosive processes. However, the dispersed nature of the necessary information for the characterization of the physical, biotic and anthropogenic environment demands a tool capable of automating manual activities and limiting any subjectivism from different interpretations. The geographical information systems possess these resources, in addition to enabling the quick and precise manipulation of data from several sources.

The use of mathematical models capable of predicting how much material is eroded in a basin, greatly facilitates basin use planning and the verification of the environmental consequences provoked by erosion. Models such as the ones introduced by Meyer & Wischmeier (1969) and Morgan *et al.* (1984), have been used extensively in recent years and have shown excellent results when adapted to specific areas.

The applicability of erosion and silting prediction models to Geographical Information Systems (GIS) is not a recent development, but it has increased considerably in recent years. Several studies have emphasized the importance of its application in the development of new support techniques to the planning and administration of environmental resources. There are a great variety of applications using mathematical models integrated with GISs in different parts of the world. The objective of this research was to compare different methods of erosion modeling in the Federal District: Universal Soil Loss Equation (USLE) applied by Baptista (1997) and Morgan, Morgan & Finney (MMF) applied by Francisco *et al.* (2002). In addition to the application of the models to the area of the Federal District, in a future phase, the models will be validated and calibrated in two pilot basins of the area, namely: in the hydrographic basin of the Descoberto river and in the Jardim river basin. Another objective of this research is to model future scenarios in the hydrographic basins of the Federal District, thereby assisting in the environmental planning in the short and long term.

STUDY AREA

Brasilia, the Federal capital, was planned in the centre of the country with the strategic purpose of promoting the development of the interior and national integration. Brasilia, nowadays, has been quickly expanding over the 5,814 km^2 of the Federal District (DF). Intense population migration and growth of agriculture have placed pressure on the environment and they threaten to deform the original city planning (Historic Patrimony of Humanity-UNESCO). The wide scale mechanization of agriculture, particularly since the early 70's, has altered the natural landscape of central Brazil. The scale of agriculture began to have a larger significance during the 80's, with introduction of crops such as soybean, irrigated and extensive cultivation, today concentrating in the eastern part of DF, in the aisle formed between the hydrographic basins of the Rivers Preto and São Bartolomeu. It is estimated that the remaining area with lesser anthropogenic influence represents only 40% of the total area of the Savannah, in other words, 120 million hectares have already been converted to urban and rural activities. With a demographic density of 22 inhabitants per km^2, and an agricultural business policy encouraging rapid substitution of the natural landscape with mechanized monocultures, the area is being characterized by a concentration of population in urban conglomerates. The DF and surrounding areas are migrant attraction poles, predominantly attracting Northeasterners, who have continued to migrate into the area since the foundation of Brasilia. The figured panorama is the conversion of the Savannah into a vastly altered area with significant environment and bio-diversity losses. The hydro, resources, which are characterized by medium and small-sized wide streams and streams, are strongly threatened in this context.

In this perspective, the areas selected for the study within the Federal District, were the basins of the Rivers Descoberto and Jardim (Figure 1), once these areas possess individual geomorphologic characteristics, but have been undergoing a period of increased urbanization, resulting in the construction of impermeable cover over large areas and consequently triggering hydro erosion processes. Besides the urbanization process, the rural areas have been going through intensification processes and agricultural mechanization, resulting in scenarios which favor hydro erosion, thus sterilizing the soil, reducing the capacity of water storage and in addition to the great production of sediments, provoking the silting up of the fluvial channels and reservoirs.

Problem

The mechanisms of the erosive process are very complex, due to a number of contributory factors, such as the geology, geomorphology, climate, precipitation regime, type of soil, position of the water shed and the vegetation, besides the anthropogenic activities. The internal erosion also depends on how these factors intervene in the environment and also on the percolation fluid and the direction and magnitude of the hydraulic gradient. The erosive processes are characterized by two phases. A first phase of disaggregation of the solid particles, which can be analyzed in relation to the plasticity, activity, cohesion, structure, aggregation and the characteristic foundation of the soil. The second phase consists of the transportation of the solid particles, which may be studied knowing the granulometry and the density of these particles.

In the tropical areas, humid conditions and temperature favour the action of physiochemical processes, such as oxidation, reduction, dissolution, rain, temperature variations and the seasonal variation in the temperature and rainfall (the dry and rainy seasons).

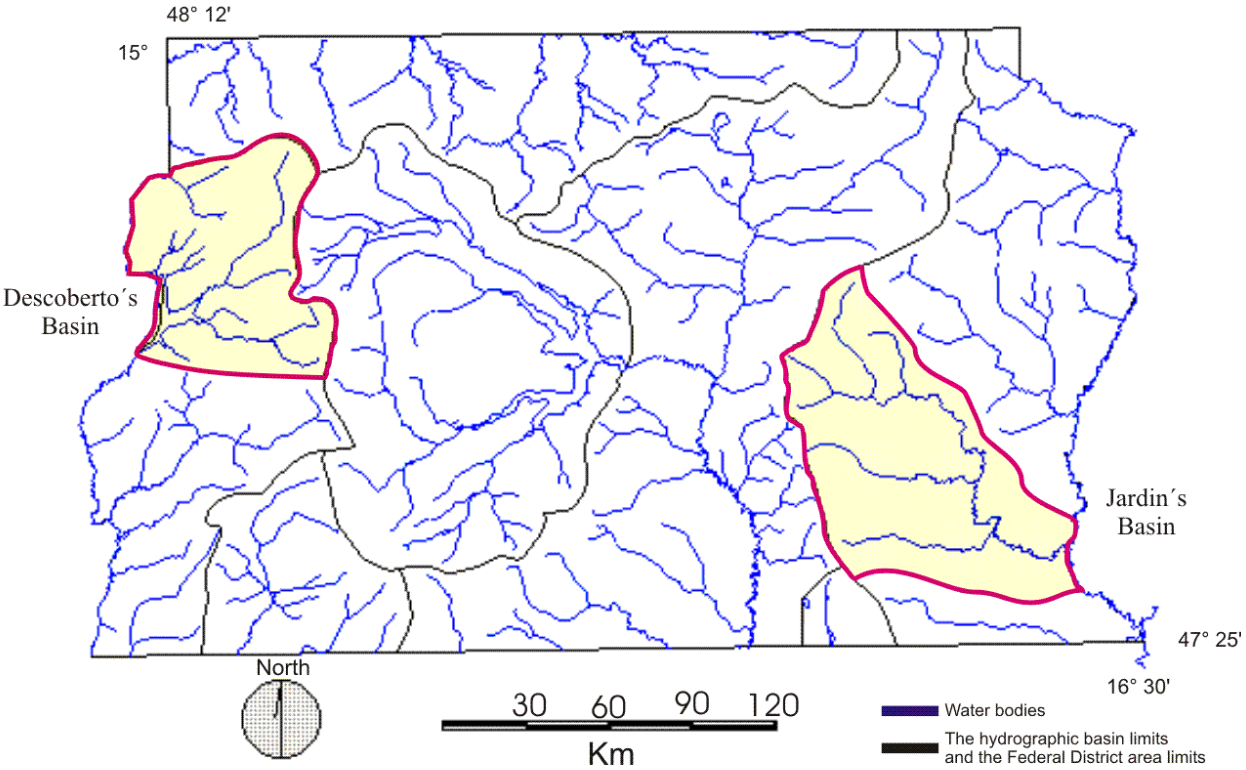


Figure 1. Location of the pilot basins in the Federal District

In the Savannah, erosion appears more intense in the urban areas and its surroundings than in the essentially rural areas. Human activities, along with pluvial erosion and the erosion of underground water, have been fundamental in the intensification of the changes that have occurred in the natural environment. Among the several activities, which accentuate the erosive processes, one can highlight the loss of protection as a consequence of the loss of the soil, the divisions into land parcels, artificial canalization, road construction over steep hillsides, inadequate cultivation in steep-sloping areas and the irrational use of the soil in urban areas (Novaes-Pinto 1990). Analysis of the presence of deep furrows in several hillsides areas of the Savannah, demonstrated that, man's indiscriminate intervention leads to the appearance of linear cave-ins, due to road buildings, deforestation, artificial canalization, etc. The cave-ins partially destroy areas of pasture and cultivation, as well as affecting highways and even reach some housing located in urban and suburban areas. The most serious consequences of erosion in the Savannah are the imbalances provoked in the environment, not only through the silting up in water courses, but also in the water and aquatic fauna quality, in the soil structure and productivity, in the underground water regime, in the hillside stability, in the development of vegetation and the terrestrial fauna, and also in the risk to the populations' lives (Novaes-Pinto 1990).

Physiographical Aspects

The DF is located in the eastern part of the Brasilia Area, underlain by groups of rocks, such as the Canastra, Paranoá, Araxá and Bambuí Groups. The Canastra Group comprises varied phyllites with quartzite, calciphyllites, fine marbles and carbon phyllites. The Bambuí Group, which dominates in the basin of the Jardim River, is characterized by an essentially pelitic sequence with metagrits and clayey metasilts, with a presence of arkose and silt sediments (Freitas-Silva & Campos 1998).

The DF is located in one of the highest areas of the Central Plateau, corresponding to remnants from planation during the Sulamericanas and Velhas erosion cycles, which developed between the Late and Middle Tertiary, and between the Middle and Recent Tertiary, respectively (Braum 1970; Novaes- Pinto 1986; Novaes-Pinto 1987; Novaes-Pinto 1988). The geomorphological features of the Federal District and surrounding areas are characterized by dominant forms of relief, such as remnants from planation, represented by plateaus. They take the form of flat or plane topography to slightly wavy or ramps, covered with vesicular, pisolitic or nodular laterite and latosoils. In inter-plateau areas peripheral lowering resulting from pediplanation processes has resulted in long fluvial valleys, whose hillsides suffer alternate dissection and pedimentation processes (Novaes-Pinto 1993).

Novaes-Pinto (1994) subdivided the landscape of the DF into 13 geomorphologic areas, which have been grouped by morphologic and genetic similarities, into the three great macro units, which were used in this work:

- Plateau Areas: occupy 34% of the DF area, characterized by flat and slightly wavy, but flat topography and low drainage density.
- Intermediate Dissection Areas: occupy 31% of the DF area and are areas of weak dissection, drained by small streams.
- Valley Dissected Region: occupies 35% of the DF area and comprise areas dissected by the main rivers in the region; it presents larger drainage density than the previous areas.

The climate in the DF is considered to be of Tropical Savannah type and dry winter rainy Temperate type, characterized, according to Novaes-Pinto & Neves (1985), by the clear and real existence of two seasons:

- The rainy: which is prolonged from October to March, coinciding with the hot season and with maximum temperature of 32°C. The largest rain concentration is in December and the average precipitation varies from 1,500 to 1,750mm.
- The drought: corresponding to the cold season, with average temperature ranging from 16°C to 18°C between the months of April to September, and strongly accentuated in June and July. The precipitation index can be null.

The dominant vegetation covering the area is the Savannah. It is characterized by small to medium sized woody trees with a thick bark and usually developed leaves, appearing isolated or in groups (Silva 2003). Although largely altered by agricultural development, there remain some areas of preserved native vegetation, where Savannah habitats may be identified, often varying according to the humidity and fertility of the soil. Therefore, we have: the Savannah, Savannah field and the thin Savannah, occupying the highest parts of the relief, where these factors are weaker, and forests, along with the great Savannah in the lowest parts, where the soil thickness and humidity is more expressive. In the humid or flooded valleys, there are strips of gallery or ciliar forests.

According to the Technical Bulletin of EMBRAPA (1978), the soils, which are dominant in the DF are: dark red Latossoil, yellow red Latossoil and Cambissoil. According to a more recent study (Silva 2003) in the area, four classes of soils were developed, as described below:

- Latossoils: these include those, in which the main elements responsible for their formation are: the climate and the relief. They are well formed soils, with well developed A, B and C-horizons. They possess a dark-reddish to purple color, clayey texture, and are characterized as being deep and well drained.
- Hydromorphic soils: these occur in very humid areas or in flooded lands, such as meadows and paths. They possess yellowish to dark grey color, and well-defined horizons. They are eutrophic, humic, sometimes organic, well drained, fertile and with an average thickness of 1 to 1.5m.
- Litossoil: recent and lacking horizon. They are shallow, immature with horizons A and C or just A, weakly developed over the main rock. They occur in areas with rough or mountainous relief.
- Concretions: soils, which support the highest content (more than 50%) of rough rocky material in decomposition, quartz fragments of varied sizes and forms, and nodules of rusted concretions. They present variable thickness and occupy extensive areas; often related to the latossoil.

The basins of the Rivers Corumbá, São Bartolomeu, Maranhão, Preto, São Marcos and Verde drain the area. The rivers are important, both in terms of the area that they occupy, as well as the role they have in the regional economy. In general, the rivers demonstrate several characteristics, which are influenced by the geological nature of the land, being therefore, aligned to the structure, lithology and relief forms and presenting strongly aligned valleys.

The hydrography of the area is influenced by perennial rivers, which drain in various directions, including drainage that belongs to the three great hydrographic Brazilian basins. The River Preto belongs to the São Francisco Basin; the Rivers Maranhão and Verde to the Tocantins Basin, while the other water courses occupy the Paranaíba Basin, forming the Paraná River, fed by a drainage network of rivers, including: Corumbá, São Bartolomeu and São Marcos. The Corumbá River Basin is the main hydrographic basin of the area (Silva 2003).

METHODOLOGY

This research considered two erosion models for the calculation of soil loss in Federal District. We used the USLE - Universal Soil Loss Equation (Wischmeier & Smith 1978) and MMF - Morgan, Morgan and Finney (Morgan 1995). The diagram shown in the figure 2 presents the methodology applied in this research.

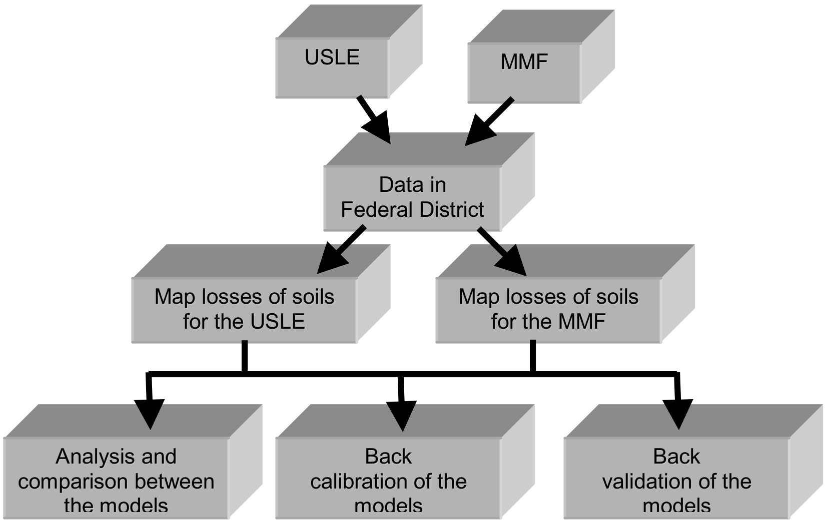


Figure 2. Diagram of the used methodology.

USLE

USLE is one of the more broadly used equations for the calculation of soil losses. It was projected as a method for the prediction of the annual average of soil loss caused by sheet erosion. The equation is defined below:

$A = R.K.LS.CP$

where,

A = Soil Erosion Rate, in t/(ha.annum);
R = Factor-Rainfall Intensity, in MJ.mm/(ha.h.annum);
K = Factor-Soil Erodibility, in t.h/(MJ.mm);
L = Factor-Slope Length, based on the values, in meters, of the slope length;
S = Factor-Slope Percent, based on the values, in percentage, of the slope;
C = Factor-Cover Management; and
P = Factor-Supporting Practices.

Factor R - Rainfall Intensity

The erosivity of the rain can be understood as a numeric evaluation of the capacity of a storm or of a rainfall to erode the soils of an unprotected area (Wischmeier 1959).

The medium value of the erosivity index was determined through the relationship between the monthly average and the annual average of rainfall. Firstly the simple arithmetic average (historical) was calculated for all the pluviometric stations of CAESB (Company of Environmental Sanitation of Federal District) in Federal District and after the value of R was calculated through of the equations below:

$EI_{30} = 67.355(r^2/P)^{0.85}$

where,

EI30 = monthly average of the erosivity index, in MJ.mm/(ha.h);
r = average of the monthly total of rainfall, in mm;
P = average of the annual total of rainfall, in mm,

and for the determination of R it was necessary to add the 12 monthly values of the erosivity index, in each pluviometric station for the formula:

$$R = \sum_{j=1}^{12} EI30j$$

Factor K - Soil Erodibility

The factor K aims to quantify the “erosion intensity for unit of index of erosion of the rain for a specific soil that it is maintained continually without covering, but suffering normal cultural operations” (Carvalho 1994). It can simply be understood as the susceptibility of the soil to erosives process (Bertoni & Lombardi Neto 1993).

The erodibility of the soils of Federal District was determined through of the Bulletin Technical number 53 (EMBRAPA 1978) which was grouped in 94 profiles of soils.

Fator K's determination was based on the physical-chemical parameters used by the nomogram of Wischmeier *et al.* (1971) by the equation of Roloff & Denardin (1994):

$K = 0.004X_1 + (Mm^{0.5})$

where,

Mm =% lime x (% lime +% very fine sand);
X1 = permeability coded by Wischmeier *et al.* (1971);

for the equation of Denardin (1990):

$$K = 6.08 \text{x} 10^{-3}(PERM)+8.34 \text{x} 10^{-3}(OM)–1.16 \text{x} 10^{-3}(OAL)–3.78 \text{x} 10^{4}(AR)$$

where,

PERM = permeability coded by Wischmeier *et al.* (1971);
OM = percentage of organic matter;
OAL = percentage of oxide of aluminum, extracted by sulfuric acid;
AR = percentage of sand (2 and 0.5 diameter mm).

and for the equation of Chaves (1994):

$$K = 2.47 \text{x} 10^{-3}SIL-5.23 \text{x} 10^{-3}OAL+8.89 \text{x} 10^{-3}(CO)2+1.15 \text{x} 10^{-2}(OFE)^{-1}+1.42 \text{x} 10^{-4}(OSI+OSI2)-1.89 \text{x} 10^{-2} OSI/(OFE+OAL)]^{2}$$

where,

SIL = lime percentage in the soil;
CO = percentage of organic carbon;
OAL = percentage of oxide of aluminum;
OFE = percentage of oxide of iron; and
OSI = percentage of silicon oxide.

Factor LS - Slope Length and Slope Percent

The factor slope length (L) impacts directly on the soil loss since very extensive ramps can generate run-off with high velocities.

The slope percent (S) is understood as the angle or the percentage of the inclination of the land, and it is important in the prediction of soil loss. Sheet erosion is associated to the increase of the speed of overland flow.

The topographical factor (LS) was determined from the digital elevation model (DEM) generated from the topographical map in the scale 1:100 000 of SICAD (Cartographic System of Federal District), interpolated with the kriging method.

For the calculation of the ramp length the index of medium extension of the rainfall was used on the lands by hydrographic basin. This index was obtained by the method of the equivalent rectangle modified by Villela & Mattos (1975) and determined by the following equation:

$$L = A/4l$$

where,

L = factor *s*lope length and/or medium extension of the flow on the lands (m);
A = area of the basin (m^2); and,
l = sum of the length of all the courses of water of the basin (m).

After those procedures, the equation was used below for determination of LS:

$$LS = 0.009841 l^{0.63}.s^{1.18}$$

where,

l = slope length (m);
s = slope percent (%).

Factor CP - Factor Cover Management and Supporting Practices

The factors C and P consider the anthropogenic influences on the process. The value of C is given by the sum of all calculated values of C for periods of the cycle of development of the culture. The variation of C ranges between 0.00004 for the areas covered by native forest and 1 for the areas of exposed soils lacking vegetation.

Bengtson & Sabbagh (1990) defined P as the rate of soil loss among the supporting activities used and the loss occurring in the plantations installed in the sense of the slope.

The factor CP was determined from the use and occupation of the soil of DF using the Stein *et al.* (1987) proposal which integrated the anthropogenic factors of USLE: cover management (factor C) and supporting practices (factor P). After the determination of the values of CP for each use and occupation of the soil they were attributed to the classes of the Map of Use and Occupation of the Soil of Federal District (IEMA/CODEVASF 1994).

MORGAN, MORGAN & FINNEY (MMF)

The model Morgan, Morgan and Finney was originally developed to predict the annual loss of soils due to sheet erosion and in gullies in small agricultural areas. However in a generalized attempt to model larger areas the MMF was later applied, using resources of remote sensing and geoprocessing, to a larger area of Indonesia (Jong & Riezebos 1992 in Morgan 1995).

The model separates the erosive processes into an aqueous phase and sediment production phase (Figure 3). The sedimentary phase considers the erosion of the soil as a result of the detachment of particles of the soil due to the impact of the raindrop (rain splash) and the subsequent transport of the released particles by superficial flow (overland flow). The sedimentary phase is represented by two equations: one to evaluate the detachment rate, the effect of the raindrops (splash) and another to evaluate the transport capacity for overland flow. In these equations, the input of the energy of the fall of the raindrops and the volume of superficial flow are obtained from the aqueous phase.

The model uses six operational functions that require the calculation of fifteen physical parameters. As final result the model compares the detachment prediction for raindrop (F) and the transport capacity for superficial flow (G), utilizing the lower of the two values in the calculation of the annual rate of soil loss.

Phase Water

$$E = R(11.9+8.7\log_{10}^{I})$$

$$Q = R\exp(-R_c/R_0)$$

where

$$Rc = 1000MS.BD.RD(E_t/E_0)^{0.5}$$
$$R_0 = R/R_n$$

Phase Sediment

$$F = K(E_0^{-aA})^b.10^{-3}$$

$$G = C.Q^d.\sin S.10^{-3}$$

where,

E = kinetic energy of rainfall (J/m2)
Q = volume of overland flow (mm)
F = rate of soil detachment by raindrop impact(Kg/m2)
G = transport capacity of overland flow (Kg/m2)
Values of exponents: a=0.05; b=1.0; d=2.0

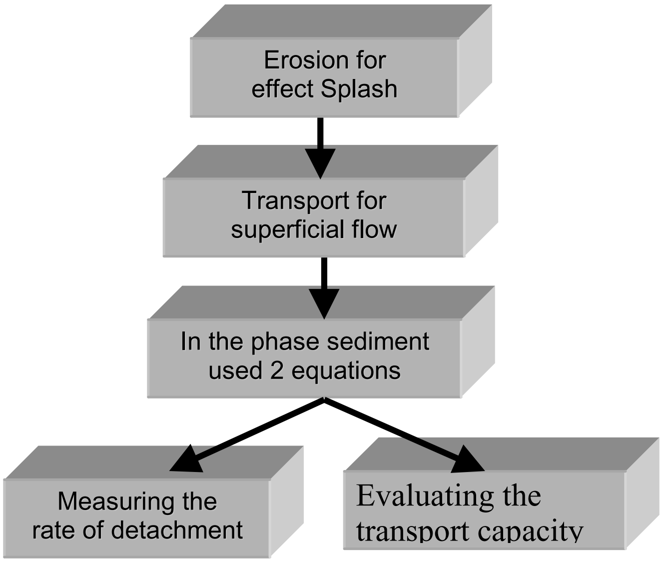


Figure 3. Illustrating the diagram of the model of MMF.

- Ms = Field capacity (% w/w);
- BD = Bulk density (Mg/m^3) ;
- RD = Top soil rooting depth (m);
- SD = Soil depth (m);
- K = Detachability (g/J);
- W = Rate of increase in soil depth by weathering at the rock-soil interface (mm/y);
- V = Rate of increase in the top soil rooting layer (mm/y) and the natural breakdown of vegetative matter into humus;
- S = Slope angle;
- R = Annual rainfall (mm);
- Rn = Number of rain days in the year;
- I = Value for intensity of erosive rain (mm/h);
- A = Percentage rainfall contributing to permanent interception and stemflow;

- E_t/E_o = Ratio of actual to potential evaporation;
- C = Crop cover management factor;
- N = Number of year for which the model is to operate.

RESULTS AND DISCUSSION

The application of the models USLE and MMF in Federal District showed coherence. The USLE model presented a soil loss of approximately 7,725.74 t/ha.year while the model of MMF presented 5,444.40 t/ha.year. Figures 4 and 5 are the results of the application of the models USLE and MMF respectively. Figure 4 confirms that of the input factors to the USLE model the LS factor (slope length and slope percent) contributed most significantly to the overestimate of the total loss of soils modeled in relation to the results obtained using MMF. This is observed in the class 0-1, since in field in spite of corresponding to the highlands these area also possess the susceptibility to the erosion processes by virtue of the wide agricultural use. For example, for the soil loss of approximately 7,725.74 t/ha.year it would be necessary that at least a point of the land would possess the characteristics more critical soil loss. This is not seen in the Federal District, indeed a pixel placed in the edge of Contagem plateau in the direction of the dissected valley of Maranhão presented the value of 3,454 t/ha.year, which was the largest value found. However as the calculated absolute values were not calibrated by field experiments they cannot be compared with the reality. On the other hand, in Figure 5 it can be seen that in the areas with intensive land-use higher values of soil loss comprise scenarios with a tendency for soil loss to be dominated by sheet erosion. It has been verified that the agricultural practices adopted in field increase the potential of the erosive processes, which confirm in a qualitative way the modeled losses of soils.

Using the MMF model a total loss of about 5,444.40 t/ha.year was calculated, however empirical models like the USLE and MMF models present problems related to wide-scale application, because they were created for small areas with strong empirical controls on the acquisition of data and ideally they should not be extrapolated beyond the sampled area. Similarly, these models rarely supply satisfactory results when applied in other areas (Morgan 1995). Therefore, it is necessary to compare and calibrate the results of each of the models to improve the reliability of the results. This component of the work is on-going. Thus the attributes that contribute to the problem are being investigated and the models are being tested to assess the parameter sensitivity by defining the boundary of natural variation of each of the attributes and consequently the boundaries of variation in the model outputs. Based on this information, modifications to the structure of the mathematical models can be proposed in order to more accurately represent the actual observed conditions. Modification to the weighting of the attributes will be necessary and, in extreme cases, the incorporation of new attributes that better represent the conditions will be incorporated in the models. Having made the proposed modifications to the mathematical models of erosion it will be possible to model future scenarios that achieve an understanding of the evolution of the phenomena, as well as the provision of an understanding of the future behavior of the processes of the sedimentation in the basins.

The results obtained from the calibrated models will provide an estimation of the amount of sediments being deposited in the reservoir of the basin of the Descoberto River. These results will be compared with actual reservoir sedimentation data, which takes the form of bathymetry data. The comparative process will give a direct comparison of the calculations from the models of the basins with relation to the initial conditions of the problem.

A back calibration process and final adjustment of the models of soil loss and sedimentation will be accomplished for the two hydrographic basins of the Federal District. The final models will have as input information fixed attributes, such as geology, geomorphology, soil types and variable attributes, such as uses of the soil and hydrology.

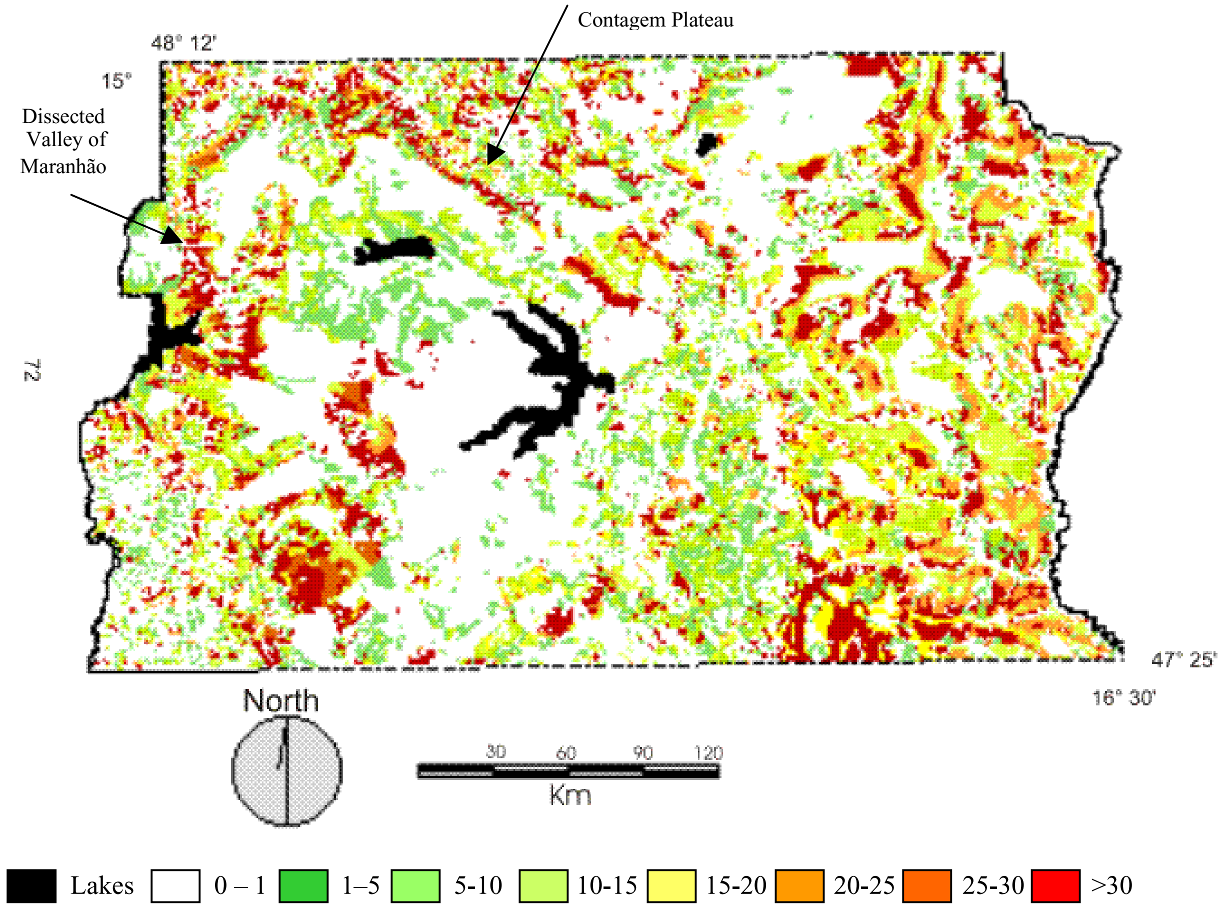


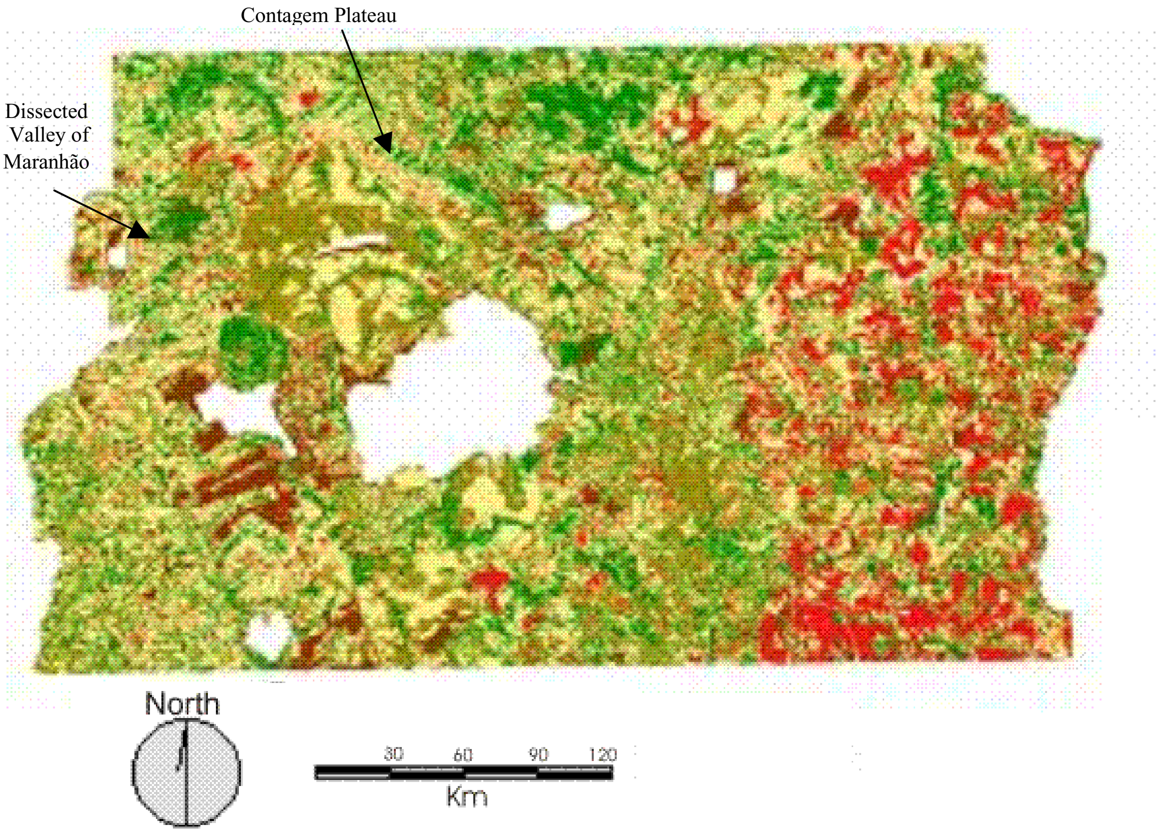
Figure 4. Application of the model USLE for the Federal District (Baptista 1997).

CONCLUSIONS

In spite of their limitations in the quantitative aspect when used in large areas the application of the USLE and MMF models enable the identification of the soil losses that are caused by the present occupation. They also enable simulations of future sceneries. The parameters have to pass through several stages of refinement to improve the precision of the estimate of soil erosion in countries of tropical climate.

It was verified in the Figures 4 and 5 that the modeling highlighted the potential areas susceptible to sheet erosion. Modeling carried out using the USLE overestimated soil losses in the areas with high dissection of the relief and that in the areas with low slope angles values were underestimated. At the same time, modeling using MMF verified that areas with larger erosion values are in the areas dominated by agricultural land-use. It is also noticed that although the values are high (detachment values) they were below the values found by USLE.

In addition, it has been identified that there is no possibility of using of the quantitative data without field validation. For this reason the analysis was based on qualitative aspects, then in the case of Federal District it was necessary both to carry out field studies and to calibrate the model. This work will allow a better adjustment of each of the parameters of the USLE and MMF models, aligning the model with the tropical soils and the larger areas, thus enabling quantitative determination of the soil loss. Nevertheless it was not developed in the ambit of this article so the results obtained cannot yet be aligned with actual erosional losses.



🟥 35-48 🟧 20-35 🟨 10-20 🟩 5-10 🟫 2-5 ⬜ Urbanized areas and bodies of water.

Figure 5. Application of the model MMF for the Federal District (Francisco *et al.* 2002).

Return visits to the study place will allow further validation of the results, as well as to enabling final fittings to improve the precision of the models. It is important to note that rarely does the calibration of the models allow applicability to other practical cases, for instance the applicability may be limited to the reservoir for which the data was measured.

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