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# Mapping of restrictive factors of land in the hydrographic basin of the middle section of the Paraíba River

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## Abstract

This work aimed to identify and map the pedological restrictions of the lands in the middle course of the Paraíba River. For this, GIS SPRING, digital soil map, and the Agricultural Zoning of the State of Paraíba information were used. From these, pedological data were extracted to classify the soils based on salinity/sodicity, effective depth, stoniness, fertility, erosion, drainage, and texture. Data were interpreted and classified according to soil-restricting factors (null, light, moderate, strong, very strong, and extremely strong). It was observed that the most common land use restriction factors in the strong class were texture, effective depth, and stoniness; in the moderate class, erodibility, slope, and fertility; in the light class, slope; and in the null class, salinity and drainage.

**Keywords:** Geotechnologies. Soils. Restriction of Use.

## Introduction

Due to the increasing need for adequate and sustainable planning of human activities, the understanding of ecosystems and especially the provision of environmental services have become imperative (SANCHEZ *et al*., 2009).

Knowledge of natural resources (soils, climate, vegetation, and relief) is part of the essential basis for assessing land use potential. This information, combined with social, economic and cultural contexts, leads to the possibility of analyzing the opportunities, restrictions and impacts linked to land use. Therefore, it is possible to identify areas with greater or lesser aptitude for the most diverse activities, whether agricultural or not, considering aspects of equity, social justice and responsibility in the use of natural resources, aiming to achieve collective benefits (BENEDETTI *et al*., 2008).

Agriculture is an economic activity that largely depends on the physical environment. In a region, there are several sub-regions with different soil and climate conditions, therefore, with different aptitudes to produce different agricultural goods (GLERIANI, 2000). Proper land use is the first step towards sustainable agriculture. For this, soils must be managed according to their carrying capacity and economic productivity (HUDSON, 1971).

The knowledge of land suitability is a factor of great importance to indicate the adequate use of the environmental offer and, above all, to avoid the possible overuse of natural resources (EMBRAPA, 2006). Such interpretations presume the availability of a certain amount of prior information, which has to be provided by appropriate surveys of the area or by pre-existing pedological studies. For the information contained in the soil surveys to be better used, it is necessary that from these data, interpretative thematic maps are composed, based on the criteria of the technical classification system used (RAMALHO FILHO; BEEK, 1995).

Pedological maps at generalized scales, encompassing a significant portion of the territory, allow the visualization of large areas, covering the spatial distribution and the existing variation in soils, represent important documents in the characterization of resources and in the orientation of regional land use planning (ROSSI; OLIVEIRA, 2000). Maps are indispensable supports for planning, not only ordering the effective use of land resources, but also serving as a visual instrument of human perception and a means of recording and analyzing the landscape (LIMA *et al*., 2007).

Technical classifications, also called interpretative, are characterized by using a small number of attributes to separate individuals into classes in order to meet a certain objective. The technical or interpretative classification for land use and management consists of predicting the response of soils, under specific managements and under certain environmental conditions (PEREIRA; LOMBARDI NETO, 2004). It is normally based on interpretation of basic soils studies (taxonomic surveys) (CAMARGO *et al*., 1987; EMBRAPA, 1999).

In Brazil, the most known and used technical classification systems for the purpose of surveying the land use potential are land agricultural suitability (RAMALHO FILHO; BEEK, 1995) and land use capacity, originally developed in the United States and adapted to the Brazilian conditions (LEPSCH *et al*., 1991). In agronomic terms, the interpretative criteria for land groupings are based on agricultural suitability for certain crops; according to erosion risk; the need for liming; irrigation or drainage needs; and depending on the maximum capacity of use. For other purposes, these classifications are also very useful, such as: geotechnics, airport construction, sanitary engineering, taxation, road and railway engineering (RAMALHO FILHO; BEEK, 1995; LEPSCH *et al*., 1991; FREIRE, 1984).

According to Cobra *et al.* (2019), a large number of qualified georeferenced information allows Geographic Information Systems (GIS) to spatialize this data and generate products that support planning and decision making (VALLE JUNIOR *et al*., 2013; ZANELLA *et al*., 2013; CESSA *et al*., 2014; ANGELO; MORAIS, 2017; MACHADO *et al*., 2017). By using GIS it is possible to perform complex analyses, integrate data from different sources, create georeferenced databases and automate map production maps (ELSHEIKH *et al*., 2013; LEITE; FERREIRA, 2013; SILVEIRA *et al*., 2013; NUNES; ROIG, 2015; POELKING *et al*., 2015; SILVA *et al*., 2015; SILVEIRA *et al*., 2015; SOUZA, 2015; SOUZA; SILVA, 2016).

The use of GIS and georeferenced information are essential for land evaluation for agricultural purposes, in which the soil survey becomes the basis for this analysis. In this way, GIS provides a faster and less subjective assessment, enabling the crossing of different information plans to generate valuable maps for land evaluation (ARAÚJO FILHO *et al*., 2013; FRANCISCO *et al*., 2015; SILVA *et al*., 2015; ROCHA FILHO *et al*., 2016; SILVA, 2016).

State that any work of statistical analysis begins with the descriptive analysis of data (ANDRADE; OGLIARI, 2013) which summarize and describe data (KAZMIER, 1998). This analysis consists of a set of methods for organizing and describing data through synthetic or summary indicators (SILVESTRE, 2007). According to Fonseca and Martins (1996), descriptive statistics is a set of techniques used to describe, analyze and interpret the numerical data of a sample. Montgomery and Runger (2013) argue that it serves to organize and summarize data in a way that facilitates their interpretation and subsequent analysis.

This study was developed with the objective of identifying, classifying and mapping some land restrictive factors in the middle course of the Paraíba River, using Geographic Information System.

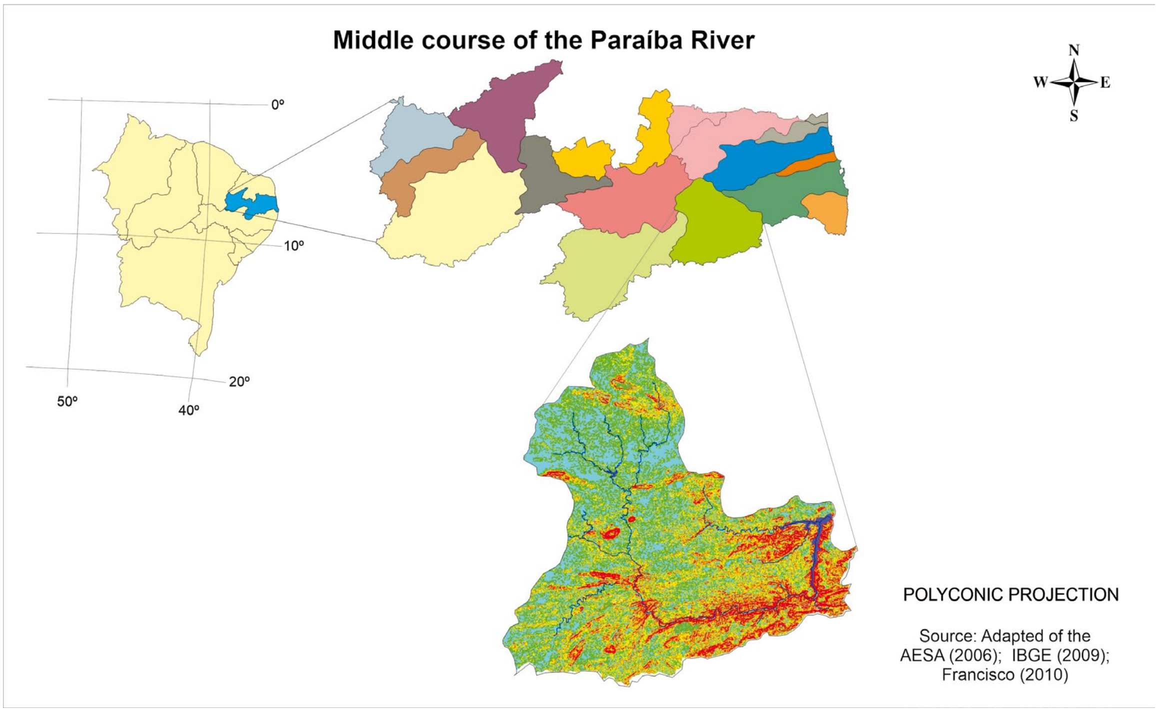
## Material and methods

The study area comprises the region of the middle course of the Paraíba River, with an area of 379,406.37 ha located in the state of Paraíba, comprised by the municipalities of Aroeiras, Alcantil, Barra de Santana, Boa Vista, Boqueirão, Barra of São Miguel, Caturité, Campina Grande, Fagundes, Gado Bravo, Itatuba, Natuba, Pocinhos, Puxinanã, Queimadas, Riacho de Santo Antônio, Santa Cecília and Umbuzeiro (Figure 1).

According to Francisco *et al.* (2012), the study area encompasses the eastern slope of the Borborema Plateau, the eastern portion of the basin, with the type As' – Hot and Humid Tropical climate with autumn-winter rains, according to the Köppen's classification. In this region, the rains are formed by the Atlantic masses brought by the southeast trade winds and the altitude is around 600 m a.s.l. in the highest points of the Plateau foothills. Precipitation decreases from the coast towards the interior of the region (600 mm year$^{-1}$) mainly due to the depression of the relief. In the western portion of the basin, the climate type is BSh– hot semi-arid, with precipitation predominantly below 600 mm year$^{-1}$ and lower temperatures due to the altitude effect (400 to 700 m).

According to Francisco *et al.* (2012), the vegetation representative of the study area is of the hyperxerophilous caatinga type. The predominant soils in the study area, according to Paraíba (1978), are the Non-calcic Bruno and the Eutrophic Litholics, distributed throughout the basin area, as well as the Vertisols, with greater occurrence in the center of the basin, closer to the Epitácio Pessoa Dam and Solonetz Solodized in the Campina Grande region. According to the new Brazilian Soil Classification System, by

**Figure 1.** Study area location and slope.




**Source:** Adapted from Francisco *et al*. (2012); PARAÍBA (2006); IBGE (2009).

Campos and Queiroz (2006), these soil types were reclassified, respectively, as Typical Orthic Chromic Luvisoil, Typical Eutrophic Litholic Neosols, Typical Orthic ChromicVertisol and Typical Orthic Natric Planosol (Figure 2).

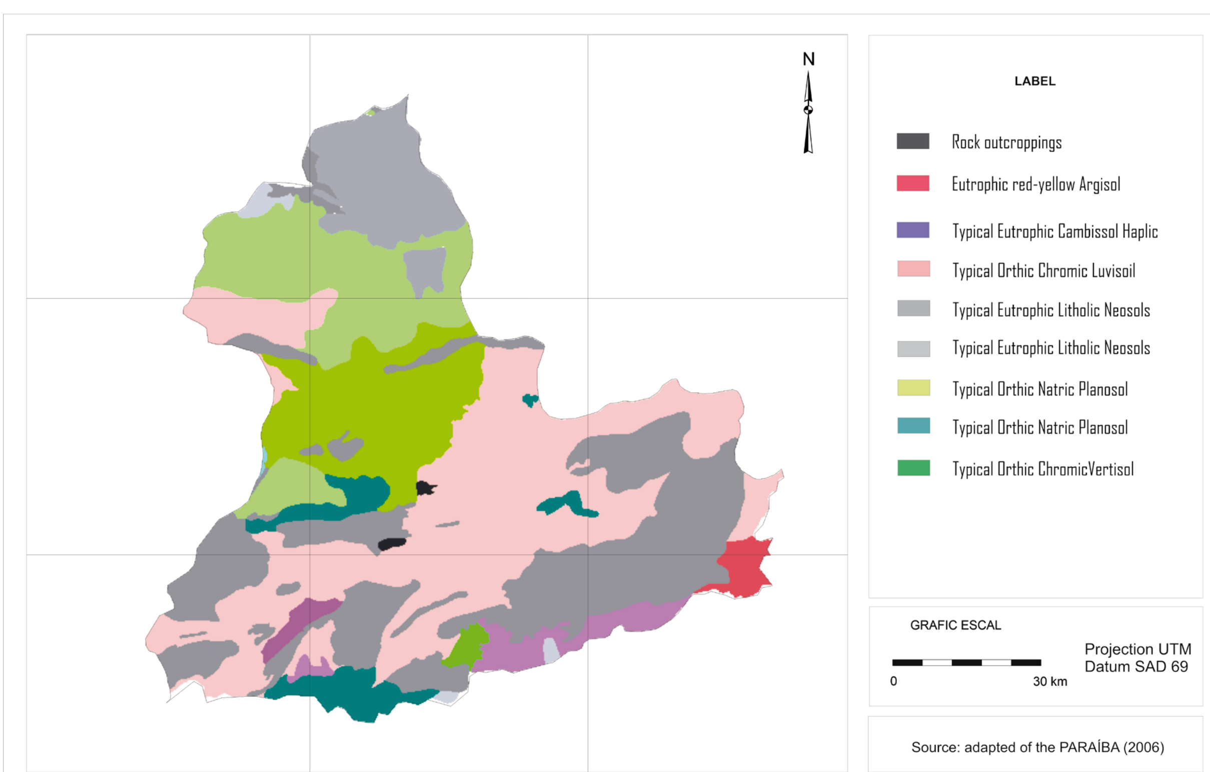
Francisco *et al.* (2015) state that the soil types differ by geological, pedological, and geomorphological diversity, also taking into account a diversity of soil attributes related to morphology, color, texture, structure, slope, stoniness, and other characteristics. The differentiation is justified by the fact that in the semiarid region the type of soil determines the dynamics of water in terms of drainage, retention, or availability, thus conditioning agricultural production systems.

For the development of this work, a digital file from the region of the middle course of the Paraíba river was used. It was provided by the Executive Agency for Water Management of the State of Paraíba (AESA), and imported into the SPRING 5.4 program, in a database in the UTM/ SAD69, where maps were prepared and their respective areas were calculated.

In this study, the main database used was the Agricultural Zoning of the State of Paraíba (PARAÍBA, 1978) and the soil map of the State Water Resources Plan (PARAÍBA, 2006), at a scale of 1:200,000, representing the area of study and the occurrence and distribution of the predominant soil classes in the State of Paraíba

Using the Agricultural Zoning of the State of Paraíba (PARAÍBA, 1978), soil pedological information was extracted and a table was created to classify salinity/sodicity, effective depth, stoniness, fertility, erosion, drainage, and texture attributes and generate their maps (Table 1). The data were interpreted and classified according to the soil restrictive factors (null, light, moderate, strong, very strong, and extremely strong) and manually introduced in SPRING, generating thematic maps.

**Figure 2.** Soil map of the study area.




**Source:** adapted from Paraíba (2006).

The classification of soil polygons on the map was based on the key of the basic formula of the land use capacity class contained in the Agricultural Zoning of the State of Paraíba (PARAÍBA, 1978), where the soil units were interpreted.

The slope map used was from Francisco *et al.* (2012) and Francisco *et al*. (2014), generated from the contour map using a modeling process. Then, a refinement of the areas was carried out in order to eliminate those areas smaller than 3 $km^2$, due to the scale of work.

To identify the restricting factors, the areas were calculated using the GIS option "measure of classes", and a spreadsheet was created emphasizing the differences between the territorial extensions.

## Results and discussion

In the salinity/sodicity map (Figure 3a), it is observed that most of the area has 71.58% in the null class overall restriction factor, representing 271,583.37 ha (Table 2). These areas are constituted by the Typical Orthic Chromic Luvisol and the Typical Orthic Hypochromic Luvisol located mostly in the inner zone of the basin, as well as by the Typical Orthic Quartzarenic Neosol, Latosolic Dystrophic Yellow Argisol, and Typical Eutrophic Haplic Cambisol with high-activity clay, distributed in north, southwest and south regions of the basin area.

The moderate class restriction factor, which covers 12,228.00 ha, has 3.22% of the area comprised by the Solodic Eutrophic Haplic Planosol. The area classified in the strong class restriction factor has 95,595.00 ha (25.20% of the whole area), where the Typical Orthic Natric Planosol occurs. Planosols generally have high CEC, high base saturation, and sodium (Na) sorption, with a percentage of exchangeable sodium (ESP) commonly between 8 and 20% in the B or C horizons of Luvisols (EMBRAPA, 2006; CUNHA *et al*., 2008).

The effective depth of soil is the vertical distance into the soil from the surface to a layer that essentially stops the downward growth of plant roots and, in most cases, can indicate better availability of heat, nutrients, air, and water, which are important for growth and development of plants.

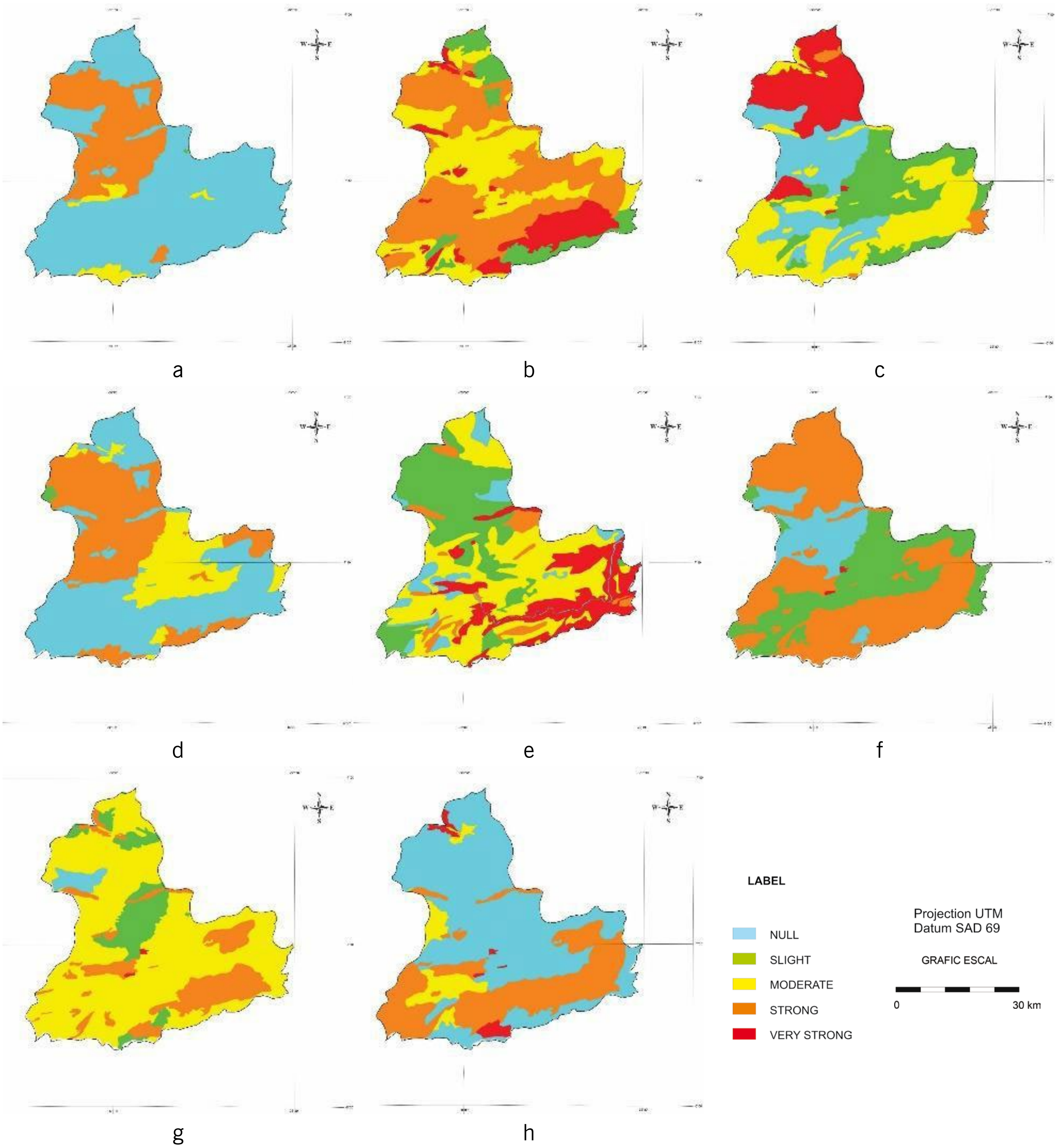
In the effective depth map (Figure 3b), it is observed that the light class represents 10.02% of the restriction factor, summing up

**Table 1.** Restrictive soil factors.

| Classes | Restrictive Factor | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Slope (%) | Stoniness (%) | Effective depth (m) | Texture | Drainability | Fertility | Salinity/ Sodicity | Erosion |
| Null | 0-3 | 0 | >2 | Sandy | Excessive / Strong/ Accentuated | Very high | Non-saline/ Non-sodic | Not apparent |
| Slight | 3-6 | <1 | 1 to 2 | Average/ Silty | Good | High | Low/Slightly | Slight |
| Moderate | 6-12 | <10 | 0,5 to 1 | Clayey | Moderate | Average | Moderately/ Moderately | Moderate |
| Strong | 12-20 | <30 | 0,25 to 0,5 | Very Clay/ Indiscriminate | Low | Low | High/High | Severe |
| Very strong | >20 | >30 | <0,25 | | Very low | Very low | Very high /Very high | Very Severe/ Extremely Severe |

**Source:** Adapted from PARAÍBA (1978); Francisco *et al*. (2014).

**Figure 3.** Restriction map regarding (a) salinity/sodicity, (b) effective depth, (c) fertility, (d) drainability, (e) slope, (f) texture, (g) erosion, and (h) stoniness.




**Source:** Adapted from Paraíba (1978; 2006); Francisco *et al*. (2014); AESA (2020).

to 38,006.00 ha (Table 2). It is also observed that 115,386.00 ha (30.41% of the area) are classified in the moderate class in the restrictive factor of effective depth, with the occurrence of the Typical Orthic Chromic Vertisol.

For the strong class, regarding the restrictive factor of the effective depth of the soils, it is observed that 180,376.37 ha, which represents 47.54% of the area, are composed of the Typical Orthic Natric Planosol.

**Table 2.** Distribution of restriction classes.

| Classe | Null | | Slight | | Moderate | | Strong | | Very Strong | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ha | % | ha | % | ha | % | ha | % | ha | % |
| Slope | 31,063.00 | 8.19 | 108,487.37 | 28.59 | 150,412.00 | 39.64 | 23,216.00 | 6.12 | 66,228.00 | 17.46 |
| Drainability | 178,400.37 | 47.02 | 1,735.00 | 0.46 | 65,198.00 | 17.18 | 134,073.00 | 35.34 | - | - |
| Erosion | 8,718.00 | 2.30 | 39,766.00 | 10.48 | 264,387.37 | 69.68 | 65,827.00 | 17.35 | 708.00 | 0.19 |
| Fertility | 84,917.00 | 22.38 | 86,777.00 | 22.87 | 124,346.37 | 32.77 | 7,496.00 | 1.98 | 75,870.00 | 20.00 |
| Stoniness | 224,756.00 | 59.24 | - | - | 26,753.00 | 7.05 | 120,071.37 | 31.65 | 7,826.00 | 2.06 |
| Depth | - | - | 38,006.00 | 10.02 | 115,386.00 | 30.41 | 180,376.37 | 47.54 | 4,5638.00 | 12.03 |
| Salinity | 271,583.37 | 71.58 | - | - | 12,228.00 | 3.22 | 9,5595.00 | 25.20 | - | - |
| Texture | 53,352.00 | 14.06 | 105,083.00 | 27.70 | - | - | 220,256.37 | 58.05 | 715.00 | 0.19 |

The very strong restriction class, with 45,638.00 ha (12.03% of the total area), is where Typical Eutrophic Litholic Neosols occur. These soils are in complex associations with rock outcrops and are usually found in terrains of strong, undulating, and mountainous relief (Francisco *et al.*, 2012). Litholic Neosols have few alternatives for use because they are shallow or very shallow and, usually, rocky and stony. They are located in rugged areas of mountain ranges and steep slopes, usually with problems of rill and severe or very severe laminar erosion (CUNHA *et al*., 2010).

Fertility is considered a broad concept, which represents the productive capacity of the soil involving its chemical and physical properties. In the fertility map (Figure 3c), it is observed that 22.38% of the area is covered by the null class restriction factor, with 84,917.00 ha. In this class, the Typical Orthic Chromic Luvisol, the typical Ortic Hypochromic Luvisol, and the Vertisols classes occur, located in the center and south portions of the basin.

Vertisols, due to the high values of base summation and cation exchange capacity, associated with the frequent presence of very significant amounts of easily weathered minerals, have the high nutritional potential for plants (CUNHA *et al*., 2010).

For the light restriction class, an area of 86,777.0 ha (22.87%) is observed, represented by the Typical Orthic Chromic Luvisol, Typical Orthic Hypochromic Luvisol, Solodic Eutrophic Haplic Planosol and Typical Eutrophic Haplic Cambisol with high-activity clay.

Planosols in the region have high values of base summation and base saturation, in addition to large amounts of easily weathered primary minerals, which gives them a great capacity to provide nutrients to plants (CUNHA *et al*., 2010).

In the moderate restriction class, in terms of fertility, a portion of 124,346.37 ha (32.77%) is observed, with a higher occurrence of Typical Eutrophic Litholic Neosols located in the south region of the basin. These soils are shallower, stony, and rocky, predominant in an area of strong, undulating, and mountainous relief to the south, following the channel of the Paraíba River (FRANCISCO *et al.*, 2012).

For the strong restriction class, considering soil fertility, it has 7,496.00 ha of area (1.98%) related to the Latosolic Dystrophic Yellow Argisol, located to the southeast of the basin. According to Cunha *et al.* (2020), the low natural fertility of Ultisols is a factor that limits their use for agriculture. Dystrophic soils have naturally low nutritional potential in the B horizon.

The very strong class restriction, which corresponds to an area of 75,870.00 ha (20.0%), has the Typical Orthic Quartzarenic Neosol. Cavalcante *et al.* (2005) emphasize that the main limitations of its agricultural use are the low natural fertility and low water and nutrient retention capacity, determined by its sandy texture. Despite the low natural fertility and low water retention and availability, the high infiltration rates and the gentle relief where they occur make these soils less susceptible to erosion.

Drainage is a property related to the hydrodynamic conditions of soils, crucial for the development of plants. It can be understood as the removal of excess water from the soil profile. This property is related to porosity, which in turn depends on the texture, soil structure, nature, and content of soil organic matter and clay (FRANCISCO *et al*., 2012).

In the drainability map (Figure 3d), it is observed that 178,400.37 ha (47.02% of the area) falls under the null class restriction factor. These areas are distributed throughout the basin, with the occurrence of Typical Orthic Quartzarenic Neosols and Typical Eutrophic Litholic Neosols.

The moderate restriction class, in terms of drainage, covers 65,198.00 ha (17.18% of the area) and occurs in the southeastern region of the basin, represented by the Typical Orthic Hypochromic Luvisol with planosolic character. There is also an area of Vertisols in the center of the basin. Vertisols are poorly permeable, which restricts their drainage. Infiltration, although slow, is generally better in soils with a granular surface structure, which can be maintained and even improved by means of crop rotation, use of crop residues, and use under pasture (OLIVEIRA *et al*., 1992).

For the strong restriction class, in terms of drainability, the occurrence of the Typical Orthic Natric Planosol and the Solodic Eutrophic Haplic Planosol is observed in 134,073.00 ha (35.34%), distributed in the central-north of the basin. There is also the occurrence of Typical Haplic Eutrophic Cambisol with high-activity clay in smaller areas to the southern border with the neighboring State of Pernambuco. At the outflow of the basin, near the Acauã reservoir, where the Typical Orthic Hypochromic Luvisol with planosolic character occurs, the strong restriction class is also present.

The physical properties of Planosols are the greatest obstacles to agricultural use. The planic B horizon, when occurring in shallow soil, is extremely hard, firm, and often plastic and sticky, which makes soil preparation a difficult operation. The densification can limit the internal drainage of water, creating conditions of reduction in the environment during most times of the year due to the elevation of the groundwater level. In addition, it can limit the development of the root system of crops, making it difficult for roots to penetrate the soil (JACOMINE, 1996).

In Figure 3e, regarding the slope, 31,063.00 ha can be classified in the null class restriction factor, representing 8.19% of the area. The light class, with 108,487.37 ha, represents 36.78% of the area. The slope is a striking feature of the landscape, as it defines levels of stability of its physical-chemical and biodynamic components, and can serve as a reference to separate environments (FRANCISCO *et al.*, 2012). It is observed that 63.22% of the area is distributed among the highest restriction classes. These soils do not show the best conditions for rational agricultural use, in view of the strong restrictions that exist, caused by the strong wavy relief (CAVALCANTE *et al*., 2005).

Francisco *et al.* (2012) state that the lands of Paraíba State are predominantly flat to gently undulating, with slopes of less than 6% in more than 56% of its territory. It can be seen in the texture map (Figure 3f) that 220,256.37 ha fit the strong class restriction factor, representing 58.05% of the area. Another 105,083.00 $km^2$ (27.70%) and 53,352.00 $km^2$ (14.06%) of the territory fall, respectively, into the light and null classes. In the strong class occur the Typical Ortic Natric Planosol, Solodic Eutrophic Haplic

Planosol, and Eutrophic Haplic Cambisol with high-activity clay. In the light class, the Typical Orthic Chromic Luvisol and the Typical Orthic Hypochromic Luvisol. The null class comprises the Typical Orthic Chromic Vertisol.

Planosols typically occur in low-lying, flat to gently undulating areas. They are generally shallow, with a light-colored surface horizon and a sandy or medium (light) texture, followed by a planic B horizon, of medium texture, clayey or very clayey, dense, poorly permeable, with reduced colors, resulting from imperfect drainage and responsible for the formation of temporarily suspended groundwater level (EMBRAPA, 2006).

During the period in which there are good conditions of soil moisture, the preparation of Vertisols is difficult due to their very clayey texture. The high stickiness when wet along with the high hardness when dry, might demand a great tractive effort, limiting the use of these soils for farming (CUNHA *et al*., 2010).

Erosion is caused by active forces such as rainfall, slope steepness, slope length, and the soil's ability to absorb water. It can also be caused by passive forces, such as the resistance that the soil exerts against the erosive action of water and the density of the vegetation cover (BERTONI; LOMBARDI NETO, 1999). In Figure 3g, for the erosion restriction factor map, it is observed that the null class comprises an area of 8,718.00 ha (2.30%), composed of the Typical Orthic Hypochromic Luvisol.

The light class, regarding the restrictive factor of erosion, distributed in 39,766.00 ha (10.48%), is composed of the Typical Orthic Chromic Vertisol and the Typical Orthic Quartzarenic Neosol, located to the north, center, and south portions of the basin. As a result of the smooth undulating relief, erosion problems are considered to be less intense for these soils (CAVALCANTE *et al*., 2005).

Due to their characteristics, Vertisols are very susceptible to erosion and require careful management, by using soil conservation practices. It is important to consider that if these soils are used intensively, problems of laminar erosion will arise (CUNHA *et al*., 2010).

The erosion constraining factor of the moderate class with 264,387.37 ha (69.68%) is composed of the Typical Orthic Natric Planosol, Solodic Eutrophic Haplic Planosol, and Eutrophic Haplic Cambisol with high-activity clay; Typical Orthic Chromic Luvisol, Typical Orthic Hypochromic Luvisol; and Typical Orthic Chromic Vertisol.

According to Cunha *et al.* (2010), Planosols are soils, from a morphological point of view, very prone to erosive processes, particularly by interrill erosion.

Luvisols are shallow to shallow soils, with a brightly colored textural B horizon and high activity clay, with a weak (ochric) A horizon, light in color, not very thick, massive, or with a poorly developed structure. They are moderately acidic to neutral, with high base saturation. They often have a stony coating (desert pavement surface) or in the soil mass and usually have a surface crust 5 to 10 mm thick, in addition to high levels of silt. They are highly susceptible to erosive processes due to the significant textural difference between the A and the Bt horizons (EMBRAPA, 2006; RIBEIRO *et al.,* 2009), high clay activity, high erodibility, even when located in smooth undulating relief, as a consequence of the cohesion and consistency of the surface horizon and the expressive textural change to the Bt horizon (OLIVEIRA *et al*., 1992).

In the strong erosion restriction class, 65,827.00 ha (17.35%) were observed, composed of the Typical Eutrophic Litholic Neosols mainly in rocky areas with greater slope and the Typical Orthic Quartzarenic Neosols near the Paraíba river channel. These areas represented by units of Litholic Neosols are soils with high levels of silt and fine sand – fractions that, together, are associated with 93% of the variations in soil susceptibility to erosion (FRANCISCO *et al.,* 2012). The susceptibility to erosion of these soils is very high, basically determined by the occurrence of the rocky substrate at a small depth, especially when the original vegetation is removed (CUNHA *et al.*, 2010).

The stoniness and rockiness are limiting factors to the mechanization of great importance, as they restrict agricultural activities. These factors, together with the relief, provide the main subsidies for establishing the degrees of limitations on the use of agricultural implements (BRASIL, 1972).

As shown in the map of stoniness (Figure 3h), it can be observed that the area under study includes 59.24% in the null class restriction factor with values from 0 to 1% of stones in the volume of soil mass, representing 2,24756.00 ha. It is composed of Typical Orthic Natric Planosol, Solodic Eutrophic Haplic Planosol, Eutrophic Haplic Cambisol with high-activity clay, Typical Orthic Chromic Luvisol, Typical Orthic Hypochromic Luvisol, and Typical Orthic Chromic Vertisol.

For Luvisols, the limitations are due to the frequent presence of pebbles and even boulders spread not only on the soil surface but also in the top layer; very hard to extremely hard consistency, which makes it difficult for the crop root systems to develop (OLIVEIRA *et al*., 1992).

The moderate class of restriction due to stoniness covers an area of 26,753.00 ha, which corresponds to 7.05%. The areas of strong restriction class with 120,071.37 ha (31.65%) are represented by the Eutrophic Litholic Neosols, which occur in the eastern foothills of the Borborema Plateau, spreading to the south, following the Paraíba river channel.

The areas with a very strong class of restriction due to stoniness with 7,826.00 ha (2.06%) are composed of rocky outcrops, which, according to Paraíba (1978) and Brasil (1972), this mapping unit constitutes a type of terrain and not properly a class of soils. According to Carmo *et al.* (2008), soil and water conservation practices should be applied in all aptitude classes, with lower or higher intensity and cost, according to the natural attributes of each area.

Efficient management is a basic and fundamental practice for the planning and rational use of natural resources. The administration of this resource will guarantee the preservation, environmental conservation and, as a result, sustainable development, creating more effective means for decision-making by managers (FRANCISCO *et al*., 2012).

## Conclusions

The most common land use restriction factors were texture, effective depth, and stoniness in the strong class, followed by erodibility, slope, and fertility in the moderate class. The most common land use restriction in the light class was the slope, followed by the null class for salinity and drainage factors.

## References

AESA. Agência Executiva de Gestão das Águas do Estado da Paraíba. 2011. Disponível em: http://geo.aesa.pb.gov.br. Acesso on: 9 July 2020.

ANDRADE, D. F.; OGLIARI, P. J. **Estatística para as ciências agrárias e biológicas:** com noções de experimentação. 3. ed. Florianópolis: Editora da UFSC, 2013. 475 p.

ANGELO, A. R.; MORAIS, J. L. Geoprocessamento aplicado à determinação da aptidão agrícola de terras: localidade de Serrinha, Paiçandu, Estado do Paraná, Brasil. **Ambiência**, v.13, edição especial, p.158-175, 2017.

ARAÚJO FILHO, J. C.; BARBOSA NETO, M. V.; SILVA, C. B.; ARAÚJO, M. S. B.; MENEZES, J. B. Levantamento semi-detalhado dos solos da bacia hidrográfica do Rio Natuba, Pernambuco. **Revista Brasileira de Geografia Física**, v.6, n.3, p.384-397, 2013.

BENEDETTI, M. M.; SPAROVEK, G.; COOPER, M.; CURI, N.; CARVALHO FILHO, A. DE. Representatividade e potencial de utilização de um banco de dados de solos do Brasil. **Revista Brasileira de Ciência do Solo**, v.32, n.06, p.2591-2600, 2008.

BERTONI, J.; LOMBARDI NETO, F. **Conservação do solo**. 4. ed. São Paulo: Ícone, 1999. 355 p.

BRASIL. Ministério da Agricultura. **Levantamento exploratório e de reconhecimento dos solos do Estado da Paraíba**. Rio de Janeiro. Convênio MA/CONTA/USAID/BRASIL, 1972. (Boletins DPFS-EPE-MA, 15 - Pedologia, 8).

CAMPOS, M. C. C.; QUEIROZ, S. B. Reclassificação dos perfis descritos no Levantamento Exploratório - Reconhecimento de solos do estado da Paraíba. **Revista de Biologia e Ciências da Terra**, v.6, n.1, p.45-50, 2006.

CARMO, L. F. Z. DO; MORAES, R. N. DE S.; SILVA, S. S. DA. **Aptidão dos solos para mecanização agrícola nas áreas desmatadas do município de Rio Branco-AC**. Programa de Zoneamento Econômico, Ambiental, Social e Cultural de Rio Branco-AC. ZEAS. Boletim Técnico, 4. Rio Branco: PMRB, 2008. 50 p.

CAVALCANTE, F. DE S.; DANTAS, J. S.; SANTOS, D.; CAMPOS, M. C. C. Considerações sobre a utilização dos principais solos no Estado da Paraíba. **Revista Científica Eletrônica de Agronomia**, v.4, n.8, p.1-10, 2005.

CESSA, R. M. A.; FARIA, G. S. M.; RIBEIRO, A. F. D. N. Uso da terra em uma porção da microbacia do Rio Dourados. **Revista Agrogeoambiental**, v.6, n.1, p.51-58, 2014.

COBRA, R. L.; SILVA, R. DE C. DA; OLIVEIRA, G. F. A. D. DE; MIRANDA, D. L. DE; LEONARDI, F. A.; SILVA, M. L. DA. Geoprocessamento aplicado ao levantamento e avaliação de solos: Proposta de avaliação de terras para fins agrícolas no município de Inconfidentes-MG. **Revista Brasileira de Geografia Física**, v.12, n.2, p.397-411, 2019.

CUNHA, T. J. F.; PETRERE, V. G.; SILVA, D. J.; MONTEIRO, A.; MENDES, S.; MELO, R. F. DE; OLIVEIRA NETO, M. B. DE; SILVA, M. S. L. DA; ALVAREZ, I. A. Principais solos do Semiárido tropical brasileiro: caracterização, potencialidades, limitações, fertilidade e manejo. In: SÁ, I. B.; SILVA, P. C. G. DA. (Ed.). **Semiárido Brasileiro**: pesquisa, desenvolvimento e inovação. Petrolina: Embrapa Semiárido, 2010. p.49-88.

CUNHA, T. J. F.; SILVA, F. H. B. B. DA; SILVA, M. S. L. DA; PETRERE, V. G.; SÁ, I. B.; OLIVEIRA NETO, M. B. DE; CAVALCANTI, A. C. **Solos do Submédio do Vale do São Francisco:** potencialidades e limitações para uso agrícola. Petrolina: Embrapa Semiárido, 2008. 60p. (Embrapa SemiÁrido. Documentos, 211).

ELSHEIKH, R.; MOHAMED SHARIFF, A. R. B.; AMIRI, F.; AHMAD, N. B.; BALASUNDRAM, S. K.; SOOM, M. A. M. Agriculture land suitability evaluator (ALSE): A decision and planning support tool for tropical and subtropical crops. **Computers and Electronics in Agriculture**, v.93, p.98-110, 2013.

EMBRAPA. Empresa Brasileira de Pesquisa Agropecuária. **Plintossolos. Definição e características gerais.** ZARONI, M. J.; SANTOS, H. G. DOS (Ed.). Brasília: Agência Embrapa de Informação e Tecnologia, 2006. Available in: https://www.agencia.cnptia.embrapa.br/

gestor/solos_tropicais/arvore/CONTAG01_15_2212200611542.html . Acess on: 7 November 2021.

FONSECA, J. S.; MARTINS, G. A. **Curso de estatística**. 6.ed. São Paulo: Editora Atlas, 1996. 320 p.

FRANCISCO, P. R. M.; CHAVES, I. DE B.; LIMA, E. R. V. DE. Mapeamento das terras para mecanização agrícola - Estado da Paraíba. **Revista Brasileira de Geografia Física**, v.5, n.2, p.233-249, 2012.

FRANCISCO, P. R. M.; CHAVES, I. DE B.; LIMA, E. R. V. DE; SANTOS, D. Tecnologia da geoinformação aplicada no mapeamento das terras à mecanização agrícola. **Revista Educação Agrícola Superior**, v.29, n.1, p.45-51, 2014.

FRANCISCO, P. R. M.; PEREIRA, F. C.; BRANDÃO, Z. N. Mapeamento da aptidão edáfica para fruticultura segundo o zoneamento agropecuário do Estado da Paraíba. **Revista Brasileira de Geografia Física**, v.8, n.02, p.377-390, 2015.

FREIRE, O. **Apontamentos de edafologia**. 2. ed. Piracicaba, 1984. 317 p.

GLERIANI, J. M. **Concordância da aptidão agrícola das terras do Estado de São Paulo elaborada nos anos setenta com os dados do Censo Agropecuário do IBGE ano 95/96**. INPE. São José dos Campos. 2000.

HUDSON, N. **Soil Conservation**. New York, Cornell University Press, 1971. 302 p.

IBGE. Instituto Brasileiro de Geografia e Estatística. 2009. Available in: http://www.ibge.gov.br. Access on: 12 March 2011.

JACOMINE, P. K. T. Solos sob Caatinga: características e uso agrícola. In: ALVAREZ, V. H.; FONTES, L. E. F.; FONTES, M. P. F. (Ed.). **O solo nos grandes domínios morfoclimáticos do Brasil e o desenvolvimento sustentado**. Viçosa: SBCS; UFV, DPS, 1996. p. 95-133.

KAZMIER, L. J. **Estadística aplicada a la administración y la economia**. 3. ed. Mexico: Mc Graw Hill, 1998. 416 p.

LEITE, M. E.; FERREIRA, M. F. F. Análise espaço-temporal do uso da terra na Bacia Hidrográfica do Rio Tabuas, Norte de Minas Gerais, com aplicação das geotecnologias. **Revista Brasileira de Geografia Física**, v.6, n.02, p.184-194, 2013.

LEPSCH, I. F.; BELLINAZZI JR., R.; BERTOLINI, D.; ESPÍNDOLA, C. R. **Manual para levantamento utilitário do meio físico e classificação de terras no sistema de capacidade de uso**. Campinas: SBCS, 1991. 175 p.

LIMA, D. F. B. DE; REMPEL, C.; ECKHARDT, R. R. Análise ambiental da bacia hidrográfica do rio Taquari - proposta de zoneamento ambiental. **Revista Geografia**, v.16, n.1, p.51-78, 2007.

MACHADO, T. C. E.; CAMPOS, M. C. C.; PAGANINI, C. H. P.; MAURÍCIO, J. C.; SOARES, M. D. R. Avaliação do uso e ocupação das áreas de preservação permanente nos anos de 2008 e 2013 na zona urbana de Humaitá, Amazonas. **Revista Universidade Vale do Rio Verde**, v.15, n.02, p.744-750, 2017.

MONTEGOMERY, D. C.; RUNGER, G. C. **Estatística aplicada e probabilidade para engenheiros**. Rio de Janeiro: Editora LTC, 2013. 319 p.

NUNES, J. F.; ROIG, H. L. Análise do uso e ocupação do solo da bacia do Alto do Descoberto DF/GO através de uma classificação automática baseada em lógica nebulosa. **Revista Árvore**, v.39, n.1, p.25-36, 2015.

OLIVEIRA, J. B.; JACOMINE, P. K. T.; CAMARGO, M. N. **Classes gerais de solos do Brasil:** guia auxiliar para seu reconhecimento. Jaboticabal: FUNEP, 1992. 201 p.

PARAÍBA. Governo do Estado. Secretaria de Agricultura e Abastecimento. CEPA-PB. **Zoneamento Agropecuário do Estado da Paraíba**. Relatório ZAP-B-D-2146/1. UFPB-Eletro Consult Ltda. 1978. 448 p.

PARAÍBA. Secretaria de Estado da Ciência e Tecnologia e do Meio Ambiente. Agência Executiva de Gestão de Águas do Estado da Paraíba, AESA. **PERH-PB - Plano Estadual de Recursos Hídricos - Resumo Executivo e Atlas**. Brasília, 2006. 112 p.

POELKING, E. L.; DALMOLIN, R. S. D.; PEDRON, F. A.; FINK, J. R. Sistemas de Informação Geográfica aplicado ao levantamento de solos e aptidão agrícola das terras como subsídios para o planejamento ambiental do Município de Itaara, RS. **Revista Árvore**, v.39, n.02, p.215-223, 2015.

RAMALHO FILHO, A.; BEEK, K. J. **Sistema de avaliação da aptidão agrícola das terras.** 3. ed. Rio de Janeiro: EMBRAPA-CNPS, 1995. 65 p.

RIBEIRO, M. R.; SAMPAIO, E. V. S. B.; GALINDO, I. C. L. Os solos e o processo de desertificação no Semiárido brasileiro. **Tópicos em Ciência do Solo**, eds. Viçosa, MG, Sociedade Brasileira de Ciência do Solo, 2009. v.6. p.413-459.

ROCHA FILHO, G. B.; ARAÚJO, FILHO, J. C.; CARVALHO, R. M. C. M. O.; ARAÚJO, M. S. B.; FRUTUOSO, M. N. M. A.; BRANDÃO, S. S. F. Potencial agroecológico do município de Itacuruba, Pernambuco, Brasil. **Revista Brasileira de Geografia Física**, v.9, n.01, p.172-184, 2016.

ROSSI, M.; OLIVEIRA, J. B. DE. O mapa pedológico do Estado de São Paulo. **O Agronômico**, v.52, n.1, p.21-23, 2000.

SANCHEZ, P. A.; AHAMED, S.; CARRE, F.; HARTEMINK, A. E.; HEMPEL, J.; HUISING, J.; LAGACHERIE, P.; MCBRATNEY, A. B.; MCKENZIE, N. J.; MENDONCA-SANTOS, M. D.; MINASNY, B.; MONTANARELLA, L.; OKOTH, P.; PALM, C. A.; SACHS, J. D.; SHEPHERD, K. D.; VAGEN, T. G.; VANLAUWE, B.; WALSH, M. G.; WINOWIECKI, L. A.; ZHANG, G. L. Digital soil map of the world. **Science**, v.325, n.5941, p.680-681, 2009.

SILVA, D. A. N.; SILVA, M. L.; LEONARDI, F. A. Geoprocessamento aplicado ao planejamento urbano: proposta preliminar de expansão urbano no município de Inconfidentes - MG. **Revista Brasileira de Geografia Física**, v.8, n.04, p.1187-1201, 2015.

SILVA, M. L. Mapeamento de superfícies aplainadas no norte de Minas Gerais. **Revista Brasileira de Geografia Física**, v.9, n.02, p.526-545, 2016.

SILVEIRA, G. R. P.; CAMPOS, S.; GARCIA, Y. M.; SILVA, H. A. S.; CAMPOS, M.; NARDINI, R. C.; FELIPE, A. C. Geoprocessamento aplicado na determinação das subclasses de capacidade de uso do solo para o planejamento conservacionista. **Revista Comunicata Scientiae**, v.4, n. 04, p.330-336, 2013.

SILVEIRA, G. R. P.; CAMPOS, S.; GONÇALVES, A. K.; BARROS, Z. X.; POLLO, R. A. Geoprocessamento aplicado na espacialização da capacidade de uso do solo em uma área de importância agrícola. **Energia na Agricultura**, v.30, n.04, p.363-371, 2015.

SILVESTRE, A. L. **Análise de dados e estatística descritiva**. Curitiba: Escolar Editora, 2007. 352 p.

SOUZA, A. C. C.; SILVA, M. L. Geoprocessamento aplicado ao levantamento de solos no município de Inconfidentes - MG. **Revista Brasileira de Geografia Física**, v.9, n.01, p.200-214, 2016.

SOUZA, S. O. Geotecnologias aplicadas à análise espaço-temporal do uso e da ocupação da terra na planície costeira de Caravelas (BA). **Boletim Goiano de Geografia**, v.35, n.01, p.71-79, 2015.

VALLE JUNIOR, R. F. DO; GALBIATTI, J. A.; PISSARRA, T. C. T.; FILHO, M. V. M. Diagnóstico do conflito de uso e ocupação do solo na Bacia do Rio Uberaba. **Global Science and Technology**, v.6, n.01, p.40-52, 2013.

ZANELLA, M. E., OLÍMPIO, J. L. S.; COSTA, M. C. L.; DANTAS, E. W. C. Vulnerabilidade socioambiental do baixo curso da Bacia Hidrográfica do Rio Cocó, Fortaleza-CE. **Revista Sociedade e Natureza**, v.25, n.2, p.317-332, 2013.