VEREDAS IN THE BOM JARDIM RIVER BASIN: ORIGIN, TYPOLOGIES AND TOPOGRAPHIC AND MORPHOLOGICAL CHARACTERIZATION

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ABSTRACT

In the central plateau region, interior of Brazil, veredas are subsystems typical of landscapes of the Cerrado domain. They are wetlands, occurring in large quantities in the Bom Jardim river basin, Triângulo Mineiro-MG, an area responsible for production of water for public supply in the city of Uberlândia. In this basin there are some vereda typologies that can be grouped and classified by their correlations between relief, lithology and soils. In order to perform such grouping, fieldworks were carried out to identify the physical characteristics, typology and interpretation of their origin in the landscape. A topographic and morphological profile was also developed to characterize a cross-section in the valley-floor, complementing this analysis. Results of the correlations were identified as follows: In the higher areas of the basin with flat relief, soils of clayey texture and occurrence of Cenozoic Coverage is where the floodplain and on level surface veredas occur. In areas of flat/undulating relief, sandstones of the Bauru Group and soils of medium texture appear other types, including terrace and hillside veredas.

Keywords: Cerrado; Springs; Wetlands; Geomorphology.

AS VEREDAS NA BACIA HIDROGRÁFICA DO RIBEIRÃO BOM JARDIM: GÊNESE, TIPOLOGIAS E CARACTERIZAÇÃO TOPOMORFOLÓGICA

RESUMO

No interior do Brasil, região do planalto central, as veredas são subsistemas típicos das paisagens do domínio dos Cerrados, configuram-se como áreas úmidas, ocorrendo em grande quantidade na bacia hidrográfica do Ribeirão Bom Jardim, Triângulo Mineiro-MG, área responsável pela produção de águas para abastecimento público da cidade de Uberlândia. Nesta bacia ocorrem algumas tipologias de veredas que podem ser agrupadas e classificadas por suas correlações entre relevo, litologia e solos. Para executar tal agrupamento, foram realizados trabalhos de campo para identificação de suas características físicas, tipologia e interpretação de sua gênese na paisagem. Também foi realizado perfil topomorfológico para caracterizar um transecto em fundo de vale complementando tal análise. Como resultados foram identificadas as seguintes correlações: Em áreas mais elevadas da bacia possuindo relevo com topo plano, solos de textura argilosa e ocorrência de Coberturas Cenozoicas, ocorrem as tipologias de veredas várzea e superfície aplainada. Em áreas de relevo plano/ondulado, arenitos do Grupo Bauru e solos de textura média, surgem outras tipologias, veredas terraço e de encosta.

Palavras-chave: Cerrado. Nascentes. Áreas úmidas. Geomorfologia.

INTRODUCTION

Veredas consist of subsystems in the Brazilian Cerrado that can be characterized by their biological and physical attributes including: flora, fauna, soils, relief and hydrological dynamics. However, highlighted here is its important role as a source of perennial water, which maintains the flow of rivers and streams during the rainy and dry periods, being a point of contact between surface and subsurface waters.

In general, veredas can be characterized as an outcropping, i.e., upwelling of the groundwater in concave valleys with flat bottom, filled by Gleysols that have a high concentration of organic matter. The buriti plant (*Mauritia Flexuosa*) is a characteristic plant species of this subsystem because it adapts to the constant hydromorphy in the core environment of the vereda, standing out in the landscape in the form of rows or dispersed throughout the entire vereda (BOAVENTURA, 2007).

In the Bom Jardim river basin, *veredas* occur at the springs, starting the first-order water courses or in the valley-floor along the river channel of either first or higher order water course, fulfilling an important role in the maintenance of water systems and ensuring the water production of this important basin. Therefore, understanding the distribution, origin and environmental conditions for maintenance of the veredas is of paramount importance for environmental planning and their conservation.

Based on the above, this work sought to identify the vereda typologies found in the Bom Jardim river basin, according to the classification of Boaventura (1974,2007), correlating them with regards to relief, lithology and soils. Extending the scale of this approach, the objective is to construct/analyze the topographic and morphological profile of one of the veredas studied, showing in detail the physical surface, subsurface and vegetation aspects.

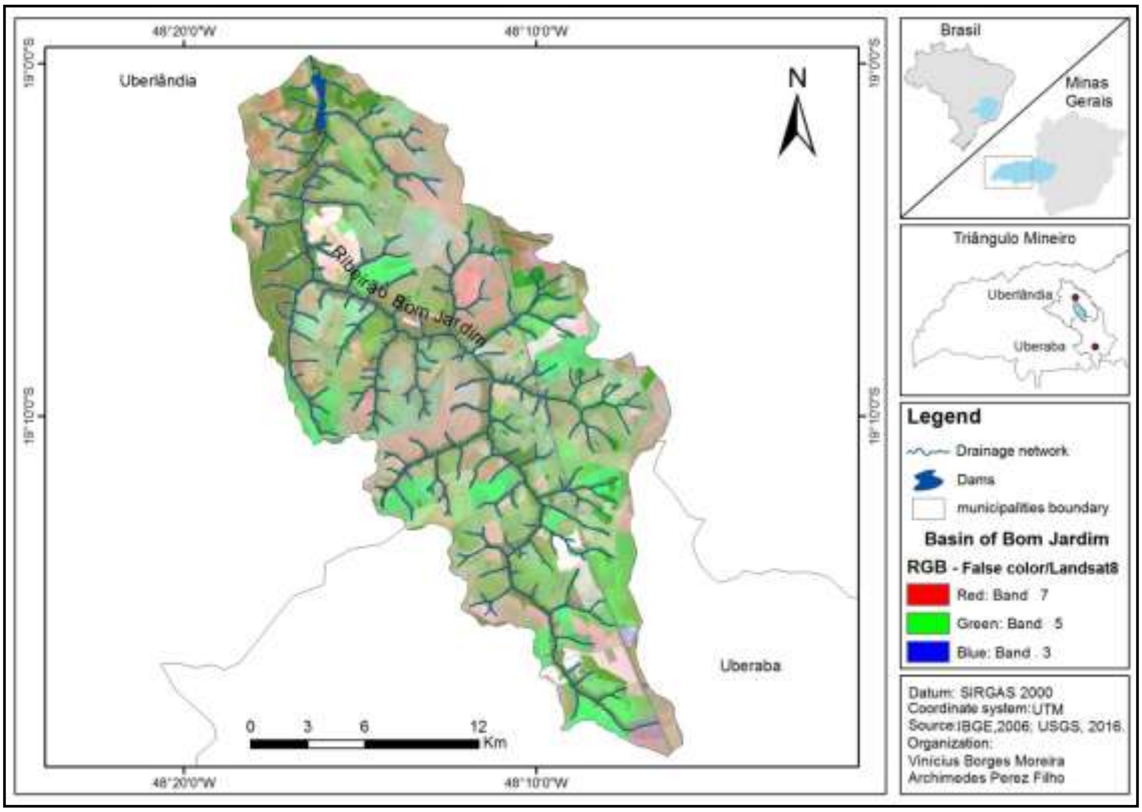
The results of this work seek to collaborate with basic information on the subsystem of veredas, with the purpose of divulging the importance of conserving these fragile environments of the Cerrado, contributing to future elaboration and formulation of public policies applied to environmental planning, seeking to preserve and conserve these strategic areas for public water supply.

CHARACTERIZATION OF THE AREA OF STUDY

Located between the municipalities of Uberlândia and Uberaba in the Triângulo Mineiro - MG, Brazil, the Bom Jardim River basin (Figure 1) is characterized as an important water source, partially supplying water to the city of Uberlândia-MG. According to Brito (2002), the area drained by the river basin is 398.54 km² and its perimeter corresponds to 108.848 km. The source of the Bom Jardim river is located near the highway (BR-050), in the municipality of Uberaba, and runs approximately 40 km to its confluence with the Uberabinha river in the urban center of Uberlândia, where a water catchment dam of the Municipal Department of Water and Sewage (Departamento Municipal de Água e Esgoto - DMAE) is located near its mouth.

The climatic characteristics can be considered one of the main variables that favor the emergence and maintenance of veredas in the Cerrado, decisive in the establishment of two well defined seasons during the year. Corroborating with this premise, the climate in the Triângulo Mineiro region and consequently in the Bom Jardim river basin is classified as Tropical Savannah (AW) according to the classification of Köppen, with summer rains and winter droughts, as described by Rosa et al. (1991).

Figure 1. Location of the Bom Jardim river basin



Configuration of the regional relief is also extremely important to understand the processes and characteristics of the Bom Jardim river basin. Baccaro (1991) proposed four geomorphological units for the Triângulo Mineiro region, taking into account geological aspects, Landforms and relief dissection, in which two are located in the area of study as described below.

The “Peak areas with broad and wide flat tops” occur in the basin between the highest elevations of approximately 900 and 1000 meters. They are characterized by hills with low slopes, drainage network with low density and little branching, and flat surfaces covered by Cenozoic sediments. On both margins of all fluvial channels are Gleysols, sometimes populated with “murundus” that are abundant in this unit. Almost all the valleys are wide with wetland bottoms. Ravines and deep gullies are not common in this region which has a very clayey soil texture.

With larger dimensions in the analyzed basin, the “Areas with Moderately Dissected Relief” shows leveled tops between 750 and 900 meters, with convex forms and slopes with greater slope than the previous unit. The Adamantina and Marília Formations are more representative in this unit. The instability of the slopes is more pronounced than the previous unit, and isolated erosion processes may occur. The presence of ferruginous concretions associated with Gleysols is common and *veredas* subsystems are abundant.

When studying western Minas Gerais, Feltran Filho (1997) constructed a geomorphological sketch to compartmentalize the several plains of the region according to their physical characteristics and relief features. In this grouping the author classified the Bom Jardim river basin as a singular unit, behaving as a transition area between the upper course of the Uberabinha river/Claro river and the middle course of the Uberabinha river.

According to Feltran Filho (1997), the geomorphological characteristics of the Bom Jardim river basin are: hilly relief with presence of terraces, alluvial plains and alluvial soils accompanying almost all of the main river course and absence of depressions in the interfluvial regions. The slope was characterized as: Moderately dissected, with broad, long and convex valleys, moderately embedded streams and traces of mass slippage processes.

In relation to lithology according to Barcelos (1984) and Nishiyama (1989), the basin is composed of Cenozoic Coverage, identified in the high and flat portions. In most of the ramps and slopes of the flat/wavy relief of the basin, sandstones of the Marilia and Adamantina Formations belonging to the Bauru Group predominate. Basaltic spills of the Serra Geral Formation appear near the exuberance of Bom Jardim river at its confluence with the Uberabinha river, forming sloped lands that present Waterfalls. They cover almost all the Holocene deposits that give rise to forms of terraces and plains.

According to Brito (2002) there are six soil types in the area: Red-yellow Latosols (RYLw) and Acric Red Latosols (RLw) both of clayey texture, occurring in the highest tops and basin plains correlated with Cenozoic Coverage. Dystrophic Red-yellow Latosols (RYLd) and Dystrophic Red Latosols (RLd) are located on ramps and slopes of flat/wavy relief in the middle and lower portion of the basin. Restricted to the valley-floor in areas of great hydromorphic activity and fluvial deposition are the Quartzarenic Neosols (QNo) and Fluvic Neosols (GXbd).

The natural vegetation of the hydrographic basin in question, Cerrado phytophysiognomies, has been largely replaced by mechanized annual crops and silviculture, due to the aptitude of relief, climate and water availability. According to Schneider (1996), this process began in the 1960's, were the Triângulo Mineiro region was the stage of the "green revolution".

Based on the historical studies of land use in the Bom Jardim river basin by Schneider (1996) and Brito (2001), using historical series from 1964 to 2010, Resende (2010) concluded that the native Cerrado area (including areas occupied by veredas), which represented 2/3 of the Bom Jardim river basin was replaced by agriculture, demonstrating the lack of public policy for the conservation of natural areas in the basin. However, Resende (2010) showed that between 1999 and 2010 the wetlands/riparian forests were maintained and even expanded, increasing from 20.3% of the total area in the basin to 20.6%.

MATERIALS AND METHODS

In order to perform this work several field studies were carried out in the Bom Jardim river basin, with the purpose of observing, recognizing, documenting and analyzing the physical characteristics of the veredas, identifying their typologies according to their geographical location, lithology, relief and soils, thus correlating them with the consulted literature.

After analyzing several veredas, a transect model was selected, which clearly represented the formation processes of these environments, in order to generate a topographic and morphological profile to be illustrated on a detailed scale. The location selected corresponds to the right bank of the Bom Jardim river, near a bridge in the low course between the coordinates 19°6'12.92"S - 48°15'39.90"W and 19°6'24.86"S - 48°15'40.65"W, as shown in Figure 2.

The traced topographic and morphological profile consists of 2190 meters and was obtained with the aid of the geodetic GPS TRIMBLE, model GEOEXPLORER XH 2008, using control points at every 10 meters. During the measurements some soil samples were obtained to identify the material of the surface cover. The GPS device used has a high resolution with precision of less than 30 centimeters in the field, with further reduction of the error to less than 10 centimeters with the use of an external antenna and post-processing in the office. The post-processing procedure was performed using a specific software with the support of data from the Brazilian Network for Continuous Monitoring of GNSS Systems, made available by the IBGE, using a reference station located in Uberlândia-MG for triangulation of the data.

Figure 2. Topographic and morphological profile in the valley-floor of the Bom Jardim river

Source: Google Earth, 2017.

Accuracy of the GPS device was of great importance for the success of this study, because only with this precision was it possible to identify the landforms in such a small cliff areal, aiding to interpret the physical characteristics of the location and monitoring variations of only a few centimeters.

Later the profile was illustrated with the help of the Corel Draw software, where the vegetation, subsurface material (surface cover and rocks) according to field measurements and model proposed by Boaventura (2007) were inserted. Also inserted were the forms of relief and topography according to the methodology of Perez Filho et al. (1980).

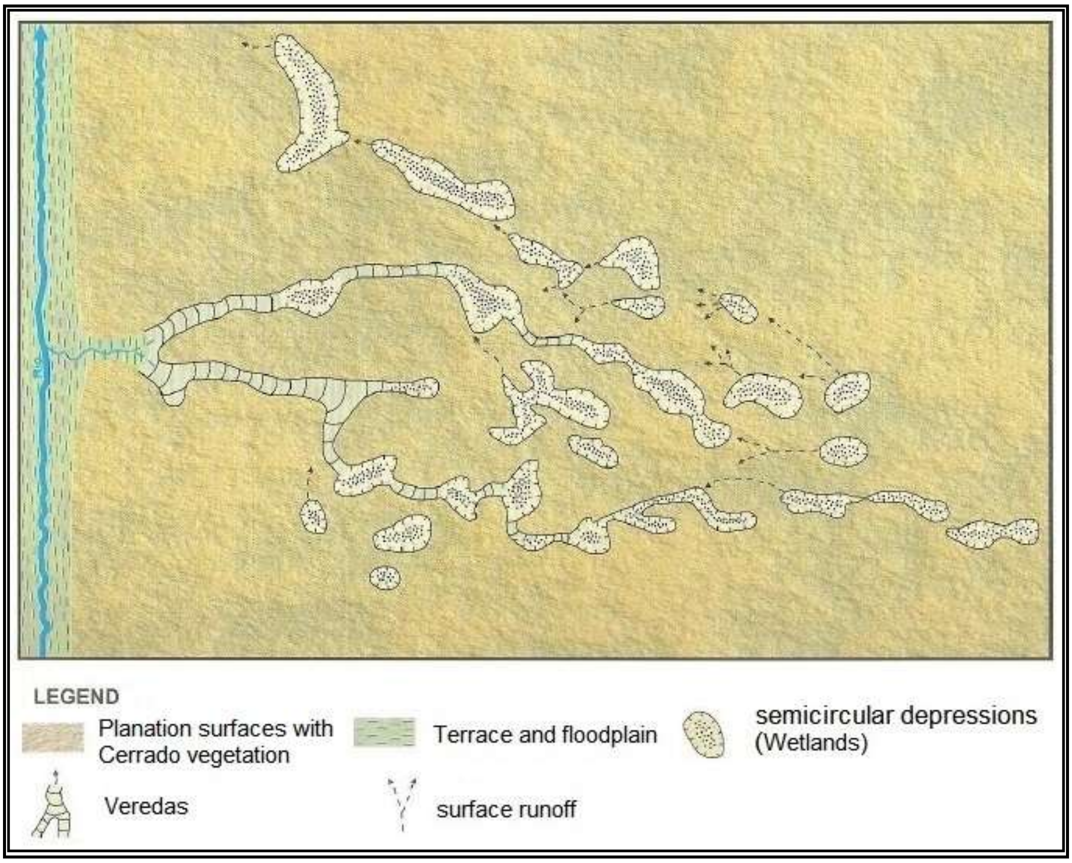
VEREDAS AND THEIR ORIGIN IN THE LANDSCAPE

The veredas were extensively studied not only in geographic science, but in several areas of science with extensive published literature, typically treated as a subsystem or ecosystem of the Cerrado domain. However, this work will only address geographic works, for a review of their physical characteristics with geomorphological emphasis.

Studies with geomorphological and evolutionary focus stand out in the works produced by Barbosa (1967), Boaventura (1978, 1981, 2007), Lima (1996), Ferreira (2003) and others. The cited authors performed studies in different areas of the Brazilian Cerrado, including: Northwestern Minas Gerais, Triângulo Mineiro and Southeastern Goiás, regions classified as “Domain of the Plateaus covered by Cerrados and penetrated by gallery forests” according to Ab’Saber (1971). Regarding the form and physical characterization of the veredas, all authors are concordant, but they have divergent hypotheses as to their origin. In this perspective, the works of Boaventura (1974, 1981, 2007) and Lima (1996) are highlighted, which contradict each other regarding the hypotheses of origin and stages of evolution of the veredas.

During assessment of natural resources in Sagarana, Northwestern Minas Gerais, Brazil, Boaventura (1974) related the origin and evolution of veredas with: Existence of different planation surfaces that shape the plateaus of the region, occurrence of wetter climate after the formation of surfaces and occurrence of sandy soils. Also according to the author, the evolution of veredas is due to the interconnection of circular or semicurcular depressions accompanying the fall of the planed surface and/or controlled by preexisting fractures according to Figure 3. Boaventura (1974) concluded that the vereda is a transitory phase of the evolution of the drainage network, which remains stable due to the low slope and the occurrence of impermeable layers in the subsurface, which prevents deepening of the thalweg.

Figure 3. Formation of veredas by interconnection of semicircular depressions



Source: Boaventura (2007), adopted by the author.

In the 2nd Integrated Development Plan of Northwest Minas Gerais, Boaventura (1981) resumed research on the origin of veredas, amplifying initial analyses to classify typologies according to the evolutionary stage of the relief and reassessing the conditions for their occurrence, which are: existence of a planation surface, occurrence of a permeable surface layer superimposed on an impermeable layer, exorreic conditions, local base level and a fundamental climatic factor: the occurrence of two well defined seasons (dry and rainy) in the interval of one year, defined according to the Köppen classification as tropical AW.

Regarding hypotheses on the origin of veredas most are focused in two lines of thought, the first developed by Boaventura (1978), which shows the processes that formed the planation surfaces and later erosion of the relief as responsible for the formation of these environments. According to the author, veredas originated from the interconnection of closed depressions (poorly drained areas) on the planation surfaces, where there was overflow and surface runoff during the rainy periods following the inclination of the slope, or structural lines. Fluvial carving causes a reworking of the margins and the erosion process. Thus, according to Ferreira (2008) the favorable environment is created for development of the typical vegetation of veradas in different evolution stages according to the attributes of the relief.

The second hypothesis of origin was developed by Lima (1996), inspired by works conducted by Filizola and Boulet (1993, p.70, apud Lima, 1996, p.8) carried out in the African continent in the dambos valleys, environments similar to the veredas of the Brazilian Cerrado. According to the author the veredas were primarily formed from geochemical and pedogenetic processes, where iron and mineral precipitations occurred, from continuous processes of leaching and hydromorphism, resulting in abatement of the relief in certain locations on the planation surfaces in a first moment. Subsequently, the water accumulated in small depressions begins to penetrate the thalweg, also due to geochemical loss, conditioned by small fractures and preexisting lineaments, directed by slope of the topography that possibly suffered a reduction of tilted blocks of the plateau. According to Lima (1996), only a long time after these geochemical processes is the fluvial morphogenesis installed, being secondary to the formation of the veredas and the valley itself.

Theories on the origin and evolution presented by the two authors are coherent and only disagree in the final stage of the origin of veredas, being important references for investigation and application of the proposed methodologies stipulated in this work.

THE DIFFERENT TYPES OF VEREDAS AND THEIR EVOLUTION STAGES

From the discussions on origin, Boaventura (2007) proposed classification of the types of veredas according to their place of occurrence, agents of formation, geomorphology and stage of evolution in the landscape. According to current environmental conditions, the author classified veredas as:

- On level surface veredas: Generally composed of clayey soils, frequently peaty in wetlands and sandy or silty soil in drier areas, with or without the presence of buriti or gallery forests.

- Floodplain vereda: Found in an area of alluvial sediment accumulation, typical of floodplains or backswamp, with transitional vegetation of herbaceous and buriti species to gallery forest.

- Hillside vereda: Generally consists of sandy soil, possibly clayey, with herbaceous cover, with or without buritis, occurring at the edges of the plateaus or on little accented slopes, in shapes similar to a half moon.

- Terrace vereda and v-shape valley vereda: These are stages posterior to those previously described, when fluvial geomorphological processes have already taken place on the relief, where posteriorly the vereda was installed by adapting to the new environmental conditions.

According to Boaventura (2007) these are the basic typologies that progress in succession, following the evolutionary stages of the relief. However these evolutionary phases may vary, indicating an incomplete evolution, presenting transient characteristics or those that have already been partially destroyed by supervenient geomorphological processes.

Ferreira (2008) added four different typologies of veredas in relation to those already reported, based on his works in the region of Chapadões do Cerrado Goiano, denominated:

- Foothill vereda: Developed in the foothills, originating from extravasation of the deep aquifers;

- Enclave vereda: Develop in the form of an enclave between two elevations in the soil of occupied areas, formed by the outcropping of the deep aquifers;

- Groundwater vereda: Originate from the extravasation of more than one aquifer simultaneously;

- Asymmetric valley vereda: Originate in valleys where lithological contact occurs, responsible for the asymmetry of the outcropping of aquifers on the slopes;

These types of veredas illustrate cases outside the general model, where local characteristics define the shape of aquifer outcroppings. Ferreira (2008) also noted the veredas which are supplied by deep groundwater levels, showing that they do not always depend only on free groundwater.

Regarding the period of formation of the veredas, Ferreira (2008) reported that the last deepening of the regional drainage network occurred in the Holocene period which established the current base levels that maintain the veredas on the plateaus of Goiás, Brazil. This consolidates the characteristics of the veredas that we currently know.

Using absolute radiocarbon dating complemented by palynological analysis, Lorente et al. (2010) described the paleoenvironmental characteristics of the sediments of a vereda in the municipality of Buritizeiros. They arrived at the conclusion that only at 6000 years B.P. was a significant quantity of buriti pollen (Mauritia flexuosa) identified, suggesting the emergence of veredas in that region after the establishment of more humid climatic conditions in the Holocene.

Also supported by palynological data and radiocarbon dating, Boaventura (2007) concluded that the veredas reached their current characteristics at about 5,000 years B.P. and that they are still in evolution, constituting very fragile environments to any type of anthropic intervention.

RESULTS AND DISCUSSION

While passing along the various roads that intersect the area of study, different veredas were photographed and analyzed, where some correlations between relief, soil, lithology and typology were evident. Due to the very ample scale of analysis, Feltran Filho (1997) classified the entire Bom Jardim river basin as a single compartment or transition area between two plateau, but when using a larger more detailed scale, we identified that there are two compartments that present different characteristics in the studied basin.

Brito (2002) had identified part of this correlation in his work, where he concluded that in the Bom Jardim river basin, in locations presenting more elevated plains associated with Cenozoic Coverage the Latosols of clayey texture are formed (RYLw and RLw).

Amplifying the results shown by Feltran Filho (1997) and Brito (2002), it is highlighted that the highest topographies of the Bom Jardim river basin (above 900 meters) have distinct characteristics, corresponding to the Uberlândia-Uberaba plateau delimited by Moreira and Perez Filho (2017). This plateau is mainly associated with the typologies of floodplain and on level surface veredas as depicted in Figures 4 and 5.

From the physical and chemical analyses on several samples within the area with many veredas in the municipality of Uberlânida, Ramos et al. (2006) found that the soils of veredas in the plateaus (higher areas of the Bom Jardim basin) present worse drainage, clayey texture, higher organic matter content and lower natural fertility in relation to the soils of veredas that occur in the sandstone of the Bauru Group (medium and low portions of the Bom Jardim river basin).

Figure 4 and 5. Vereda on level surface and floodplain vereda

The upper portion of the Bom Jardim river basin presents the classical environmental conditions expressed in the definitions of Boaventura (2007) for on level surface veredas, differing only in relation to soil texture. The veredas in this landscape unit begin at the springs and extend through the floodplains of the river channels that still have little energy and flow.

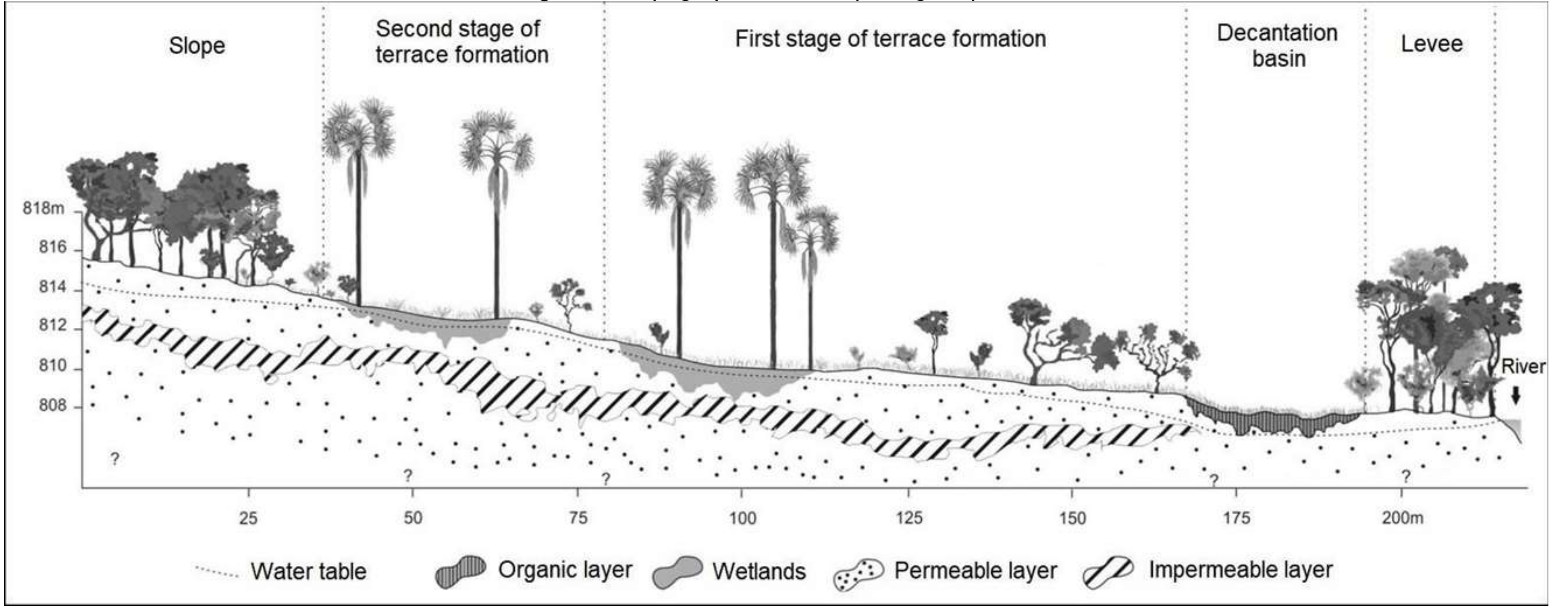
In the middle and lower altitudes of the Bom Jardim river basin there is a significant change in the landscape, since there is another set of correlations between relief, lithology and soils. The association of flat/undulating reliefs and Marilia/Adamantina Formations give rise to the medium texture soils RLd and RYLd according to Brito (2002). In this landscape unit there continues to appear the floodplain and on level surface veredas, mainly in the first and second order channels. However, terrace and hillside veredas were also identified, especially in the main channel of the river, which adds volume and flow, allowing for the construction of wide plains and terraces by means of fluvial morphodynamics, therefore, these veredas are morphologically more recent.

From this moment it was possible to identify small ruptures in relief and more landforms embedded in the valley-floor of the Bom Jardim river basin, where its middle stretch was selected as the location to perform the topographic and morphological profile according to Figures 6 and 7.

Figure 6 and 7. Ample valley-floor with terrace and hillside veredas

When constructing the transect of the topographic and morphological profile, Figure 8, four forms of relief were identified in the valley-floor, being: Levee, decantation basin, two river terraces and contact with the slope according to Perez Filho et al. (1980).

Figure 8. Topographic and morphological profile



The levee can be characterized by delimitation of the regular bed of the Bom Jardim river, where on it occurs a closed ciliary forest, typical of valley bottoms of the region. The decantation basin demarcates the level of exceptional floods of the river, where deposit of alluvial material occurs, characterized by the occurrence of a thick organic horizon layer. On the first level of the river terrace there is restricted Cerrado and permeable surface cover, and at the border between the first and second terrace levels there appears the first vereda precisely at the contact between the two levels, characterizing itself as a terrace vereda. The second terrace level is smaller than the first and is characterized by a small portion of Cerrado restricted between the next vereda that occurs at the contact of the slope with the valley-floor, considered a hillside vereda.

The impermeable layer is found more superficially when the veredas occur, constituting an important agent for its formation because it maintains the level of the surface water table. In all analyzed valley-floors the Gleissolos or Fluoric Neosols predominate, as described by Brito (2002), indicating the fluvial influence in this environment.

CONCLUSIONS

The relationship between relief, lithology and soils is fundamental to understand the spatial distribution of the typologies of veredas in the Bom Jardim river basin, which are distributed in two identified groups. The floodplain and on level surface veredas are associated with the first group, occurring mainly in a higher portion of the basin (above 900 meters) with smooth flat top relief, lithology of Cenozoic Coverage and clayey soils of RYLw and RLw. The terrace and hillside veredas are associated with the second group, occurring in medium and low areas of the basin, where the relief is more dissected with wavy forms, and predominance of Bauru Group lithologies and RYLd and RLd soils.

The results obtained by the topographic and morphological profile were sufficient to characterize the importance of the influence of rivers on veredas formation. The analyzed subsystems occur in an area of fluvial morphogenesis, having an intrinsic relationship with permeable and impermeable surface coverage, vegetation relief forms and hydrological dynamics, associated with the second group described.

Veredas are characterized as fragile and recent environments that are still in the process of evolution, considered as fundamental environments for the maintenance of water sources in the Triângulo Mineiro region. The maintenance of these subsystems affects spatial distribution and water quality, which affects downstream cities and communities dependent on this natural environment. It is therefore extremely important to have a good understanding of the dynamics to guarantee their preservation and maintenance.

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