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REVIEW ARTICLE

Veredas (*Mauritia Flexuosa* palm swamps) in the southeast Brazilian savanna: Floristic and structural peculiarities and conservation status

Veredas da região sudeste: peculiaridades florísticas e estruturais e situação de conservação

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Abstract

The *Mauritia flexuosa* L. f. (Arecaceae) palm swamps (known as *veredas* in Brazil) are hygrophilous communities associated with hydromorphic soils in areas of headwaters, and feature special importance for water and biodiversity maintenance in the Cerrado biome. In northern Minas Gerais, the *veredas* have more complex structure and floristic composition in comparison with the *veredas* located in other parts of central Brazil, in the same biome. However, these areas are less studied and suffering various environmental impacts, which can uncharacterize them even before they are properly known. In the present work, a literature review was carried out, in which the age and the development of vegetation in the *veredas* of central Brazil and north of Minas Gerais were addressed. The conservation status and the importance of these areas for the biome were also discussed. Hence it was concluded that the *veredas* of the north of Minas Gerais are older than the *veredas* of central Brazil, suggesting that they are in a more advanced stage of ecological succession. However, many factors can influence the floristic composition and structure of these plant communities, requiring further studies involving ecological processes in *veredas* in order to elucidate those matters.

Keywords: vegetational structure, ecological succession, palynological analysis.

Resumo

As veredas são comunidades higrófilas associadas a solos hidromórficos em áreas de nascentes, e apresentam importância singular para a manutenção hídrica e da diversidade biológica no bioma Cerrado. No norte de Minas Gerais, as veredas possuem estrutura e composição florística consideravelmente mais complexa do que as veredas localizadas em outras partes do Brasil central, dentro do mesmo domínio fitoecológico. Porém, são áreas pouco estudadas e que sofrem diversos impactos ambientais, que podem descaracterizá-las, antes mesmo que elas sejam conhecidas. No presente trabalho foi realizada uma revisão bibliográfica, na qual foram abordados a idade e o desenvolvimento da vegetação das veredas do Brasil central e do norte de Minas Gerais. São discutidos, ainda, a situação de conservação e a importância dessas áreas para o bioma. Assim, concluiu-se que as veredas norte mineiras são mais antigas do que as veredas do Brasil central, podendo estar em um estágio mais avançado de sucessão ecológica. No entanto, muitos fatores podem influenciar a composição florística e a estrutura dessas comunidades vegetais, sendo necessários mais estudos envolvendo os processos ecológicos em veredas para que essa questão seja elucidada.

Palavras-chave: análise palinológica, estrutura da vegetação, sucessão ecológica.

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Introduction

The Cerrado biome (Brazilian Savanna) is identified as one of the richest world's ecosystems, covering 21% of the country (about 2 million km²) and has more than 55,000 cataloged species plants, with a total of 5% of the world's biodiversity (Padovesi-Fonseca *et al*., 2015). The high biodiversity is mainly related to its connection with other Brazilian biomes, thereby generating biogeographic zones of tension (Azevedo *et al.,* 2014). In addition, biodiversity is also due to its great environmental heterogeneity, the variation of soil and its characteristics (chemical composition, depth, type of drainage), favoring the diversity of environments and supporting various vegetation types that alternate in the landscape (Klink and Machado, 2005). Most facies of the Cerrado biome present xerophytic vegetation, ranging from open areas such as grassland formations to closed formations as the cerradão (Ribeiro and Walter, 2008).

Despite the predominance of well-drained soils in the phytophysiognomy, the Cerrado also features wetlands, as the palm swamps (with *Mauritia flexuosa* L. f.), which are known as *veredas* in Brazil (Resende *et al*., 2013; Padovesi-Fonseca *et al*., 2015), with a floristic and structural complexity in contrast to the usual open formations (Rull and Montoya, 2014). *Veredas* are hygrophilous communities associated with hydromorphic or peat soil in headwater areas, where there are high water table (Guimarães *et al*., 2002; Ribeiro and Walter, 2008). In these environments, the floristic richness is favored by a gradient of humidity related to changes in soil drainage. The border zone is the driest area that occurs surrounding the *vereda*. The central portion or background of *vereda* is a saturated area near the stream, where *M. flexuosa* can be found (Ribeiro and Walter, 2008). The moisture gradient thus permits the establishment of species with different ecological requirements, ranging from flooded experts, generalist species, and species common at the dry soils (Kurtz *et al*., 2013). Thus, *veredas* have several species associated with distinct water saturation regimes, and large number of endemic species, which are more vulnerable to extinction (Rosolen *et al*., 2015).

The *veredas* have a great environmental importance, especially in the northern region of Minas Gerais, which has a semiarid climate with marked seasonality and drought period of approximately eight months, or more (Neves, 2011). In the dry season, the *veredas* may represent the only sources of water, food and shelter for the associated species and the humans who inhabit these surroundings (Neves, 2011; Silva and Maillard, 2011; Resende *et al*., 2013). This happens in detriment of the fact that *veredas* act as great reservoirs: peat soil stocks the water which is released over time, making the rivers and streams downstream become perennial, mitigating the effects of flooding and minimizing erosion (Moss, 2012). Peats also function as a filter, removing pollutants and agricultural inputs in the water seeping from dry areas to the *vereda* (Moss, 2012).

In Brazil, several authors characterize the *veredas* as a savanna formation (Ribeiro and Walter, 2008), a mostly grassy field, where the forest cover ranges from 5-10% of the territory (Meirelles *et al*., 2002; Resende *et al*., 2013). The Brazilian Forest Code defines *veredas* as a "savanna vegetation type found in hydromorphic soils, with palm tree *Mauritia flexuosa* without forming canopy, among clusters of shrub and herbaceous species" (Brasil, 2012). This classification where the *veredas* appears as a grassy field in the presence of *M. flexuosa* palms is prevalent and observed in the studies in central region of Brazil, in Goiás (Resende *et al*., 2013), in the Distrito Federal (Meirelles *et al*., 2002) and the region of *Triângulo Mineiro* (Minas Gerais State) (Araújo *et al*., 2002; Guimarães *et al*., 2002; Oliveira *et al*., 2009; Ramos *et al*., 2014; Rosolen *et al*., 2015).

Indeed, Ribeiro and Walter (2008), and Guimarães *et al*. (2002) reported that, with the growth of vegetation, the *veredas* may have dense hygrophilous vegetation associated, forming islands of woody vegetation amid the savanna plains, as it happens in the *veredas* in northern Minas Gerais. In an attempt to fit these areas on a ranking system that classifies their forest physiognomy, the *veredas* of the northern Minas Gerais were classified by some authors as flooded riparian forests, gallery forests or simply riparian forests (Silva and Maillard, 2011; Gaya, 2014). However, the main defining feature of the *veredas* environment is the strong presence of the *M. flexuosa* palm, associated with the peat and hydromorphic soil (Guimarães *et al*., 2002; Ribeiro and Walter, 2008; Bahia *et al*., 2009a), which is observed in the *veredas* of the region.

For the purpose of making scientific comparisons, guiding public policy and environmental management (Gaya, 2014) or even to guide projects for environmental restoration, there is a need to have uniformity in the terminologies used for characterization and classification of phytoecological units. However, there is a lack of scientific studies for this purpose in the *veredas* system, and even works related to the characterization of vegetation are scarce (Araújo *et al*., 2013; Rosolen *et al*., 2015). *Veredas* areas suffer various environmental impacts, culminating in their mischaracterization and degradation (Guimarães *et al*., 2002; Bahia *et al*., 2009a), even before species composition, structure and provided ecological services are known. Therefore, this study aims to conduct a literature review on the *veredas* (*M. flexuosa* palm swamps) of the northern Minas Gerais, inferring about the processes that determine the floristic and structural differentiation and discussing their importance and conservation status.

Considerations about vegetation and floristic peculiarities in *veredas*

Studies about the vegetation of *veredas* are scarce (Silva and Maillard, 2011; Araújo *et al*., 2013), making it difficult to classify these systems consistently. In Brazil, most works about vegetation on *veredas* indicate the occurrence of herbaceous and grasses formations with Poaceae, Cyperaceae and Asteraceae as the most abundant families (Guimarães *et al*., 2002; Meirelles *et al*., 2002; Oliveira *et al*., 2009; Araújo *et al*., 2013; Resende *et al*., 2013), although an exception is represented by studies conducted on the *veredas* of the north of Minas Gerais State, which have differentiated floristic composition with forest formations dominated by individual trees, especially Annonaceae, Anacardiaceae, Cecropiaceae and Fabaceae (Bahia *et al*, 2009a.; Gaya, 2014). Silva and Maillard (2011) highlighted the structural complexity inherent to this type of vegetal formation and indicated that the criteria used to classify these environments are incipient, mainly by the lack of studies aimed to characterize the vegetation of *veredas* and their development.

Because of their occurrence on hydromorphic soils, the *veredas* show floristic and structural peculiarities distinct from surrounding formations (Teixeira and Assis, 2005). In these areas, the waterlogged soil gives a swampy environmental aspect, and the varying levels of water saturation in the soil determine the environmental heterogeneity (Gaya, 2014), which can provide greater variety of habitats, and consequently more complex flora. Studies in the Venezuelan Amazon (Rull and Montoya, 2014) and Peru (Endress *et al*., 2013) showed *veredas* as forest systems of high floristic and structural complexity, different from those *veredas* with more open formations that usually occur in the Cerrado. However, the studies applied in the north of Minas Gerais showed the *veredas* not only as a shrub-grassy formations, but as hygrophilous forest formations with abundant occurrence of tree species characteristics of wetlands (Bahia *et al.*, 2009a; Lorente and Meyer, 2010; Araújo *et al*., 2013; Gaya, 2014).

Due to their floristic composition and distinct physiognomic structure, the *veredas* are classified by Araújo *et al.* (2002) as a "vegetation complex". Although other authors classify the *veredas* as "forests of flooded gallery" or "gallery forests", Gaya (2014) points out that the *veredas* of north Minas Gerais "do not fit, in part, to the sub-type of gallery forest (flooded) proposed by Ribeiro and Walter (1998)". It has been noticed that *veredas* are formed by two layers, i.e., woody and herbaceous strata, which percentages vary over time (Ribeiro and Walter, 2008). Thus, richness and dominance of shrub and herbaceous components decrease and the tree component gains expressiveness as the succession process progresses (Bahia *et al*., 2009b).

Development stages and their relationship with the structure and floristic composition in *veredas* of north of Minas Gerais

When comparing the studies with vegetation of *veredas* in north of Minas Gerais State and other *veredas* in Central Brazil, the *veredas* in north of Minas Gerais present floristic and structural peculiarities that distinguish them from one another, allowing inferences about their development stages. On a pollen analysis from *vereda* in Buritizeiro, north of Minas Gerais, through palinomorph identification and radiocarbon dating, Lorente *et al*. (2010) reconstructed two palynological zones that feature the paleoenvironment and paleoclimatic conditions of the study area. Between 13,120 and 11,640 years Before Present (BP), the studied area was characterized by a drier climate than the current field areas with open canopy, similar to *Campo Limpo* areas, currently taking place in Cerrado. The *M. flexuosa* pollen grains occurred first in 11,640 years BP, but had increased expressiveness between 6,000 and 1,500 years BP. This period was characterized by the increase of pollen grains from arboreal elements and the registration of new shrub and herbaceous and arboreal taxa, suggesting that the *vereda* is established only after 6,000 years BP, under more hot and humid climatic conditions (Lorente *et al.*, 2010). A floristic inventory in the same study area found a dense vegetation, with characteristic species of hygrophilous forest (Gaya, 2014). Also in Buritizeiro, north of Minas Gerais, and in the same sub-basin of the *vereda* studied by Gaya (2014), Cassino (2011) conducted a pollen analysis of sediments collected in a *vereda*. This author identified *M. flexuosa* pollen between 11,190 years BP (interpolated age) and up to 10,130 years BP when the *vereda* started to develop, but with the change of the hot and humid climate into a cold climate over time, the area was changed to a swamp. According to Cassino (2001), the *vereda* turned to develop and expanded between 8,330 years and 6,320 years BP, when the weather was again hot and humid, results corroborated by the study of Lorente *et al*. (2010).

In palynological studies on *veredas* in Cromínia, Goiás State, Salgado-Labouriau *et al*. (1997) showed the appearance of *veredas* around 4,000 years BP, and the authors reported that the *veredas* have narrow spots of hygrophilous vegetation along the watercourses today. In Águas Emendadas, in the Distrito Federal, Barberi *et al*. (2000) showed the appearance of *veredas* around 1,600 years BP, and cited the palm *M. flexuosa* as the sole tree species occurring in the study area. Meirelles *et al*. (2002) also showed the shrub and herbaceous character of *veredas* in Distrito Federal. In turn, Cassino (2011) pointed out that the semi-moist climatic conditions found between 11,190 years and 6320 years BP in the *vereda* studied in Buritizeiro differ from semi-arid conditions found in the *veredas* of Distrito

Federal and Goiás State. These semi-moist and warm conditions were conducive to the development of *M. flexuosa* palm, and therefore, the *veredas*. Cassino (2011) emphasized that in Minas Gerais State (city of Buritizeiro), the period of cold and dry climate was much shorter than the *veredas* in Goiás State and Distrito Federal. Bahia *et al*. (2009a), in a floristic and phytosociological study of tree community on *veredas* of the Environmental Protection Area (APA) Pandeiros, north of Minas Gerais State, sampled two *veredas* at different stages of conservation. These *veredas* have dense hygrophilous vegetation, a structure similar to other *veredas* from north of Minas Gerais.

Through the palynological studies metioned above, it is clear that the formation of the *veredas* of the north of Minas Gerais is older than the *veredas* studied in the Distrito Federal and Goiás. Despite the lack of studies on the vegetation of these *veredas*, we can infer that, due to biggest rise time, the northern *veredas* of Minas Gerais are in a more advanced stage of development. Nonetheless, the variation of vegetal cover can be a reflex of productivity gap between the areas, of the human disturbance or by the influence exerted by the vegetation domains since that the *veredas* of north of Minas Gerais are in an ecotonal area (Azevedo *et al*., 2014). Hence, more researches regarding ecological processes in *veredas* seem to be necessary in order to clarify these issues.

Veredas in the north of Minas Gerais: status and implications for conservation

Due to the ecological, landscape and social importance of the *veredas*, they are considered as Areas for Permanent Preservation (APP) by the State and Federal Laws (Bahia *et al*., 2009b). According to the New Forest Code (Federal Law number 12,651 / 12), the protection in *veredas* occurs from the marginal strip in horizontal projection, with a minimum width of 50 meters from the permanently swamp and drenched space (Brasil, 2012). By State Law number 9372 of December / 1986, Article 1 and the law 9682 of October / 1988 (Minas Gerais, 1988), the *veredas* of the São Francisco River Valley are considered to be of common interest and permanent preservation, constituting ecological reserves where the limit of preservation range is 80 meters. The State Law number 9,372/86 stresses further that "drainage, landfills, deforestation, use of fire, hunting, fishing, agricultural and industrial activities, settlements and other forms of human activities, which may cause instability to the ecosystem, are forbidden in *veredas* and their buffer strips". The law emphasizes that "livestock activities, use of water for watering livestock and domestic consumption, journey, leisure and research are allowed if not occasioning significant changes in natural conditions" (Minas Gerais, 1988).

Despite the protection afforded by law, the *veredas* are still exploited for various purposes, and human impacts alter their biotic functions and compromise their resilience (Guimarães *et al*., 2002; Bahia *et al*., 2009a). In 1981, the Federal Government of Brazil created the National Program for Use of Irrigable Wetlands (*ProVárzea*) through the statute number 86,146/81, in order to promote drainage and agricultural use of floodplains by landowners (Brasil, 1981). This program has been responsible for decimating wetlands across the country, causing the degradation of several *veredas* in northern Minas Gerais. According to Neves (2011), some *veredas* in the APA Pandeiros, north of Minas Gerais State, had a loss of 50 to 99 percent of their forest cover for rice and eucalyptus plantations, besides the compromised stream flow by intense drainage of the area. Veldman *et al.* (2015) point out that conversion of savanna areas to tree plantations decreases plant and faunal diversity, decreases the groundwater, recharge and stream flow, and reduce soil-carbon storage. Neves (2011) evaluated the stream flow in the *veredas* studied by Bahia (2009a) in the basin of Pandeiros river, for a year, and noted that the preserved *veredas* did not suffer significant peaks in flow during the rainy season, and remain evergreen throughout the study period. The impacted *veredas* had irregular and intermittent flow in the dry season, and one of the impacted *veredas* showed no flow, even in the rainy season.

In fact, Rosolen *et al*. (2015) stated that the *veredas* are fragile ecosystems, and drainage and use of these areas for agriculture degrade vegetation, affect the hydrology, promoting erosion, and provide the change of chemical and morphological soil properties. They constitute poorly resilient ecosystems, so that human impacts may result in their degradation, preventing the performance of ecological services provided there (Guimarães *et al*., 2002; Resende *et al*., 2013). Bahia *et al*. (2009a) characterized the *veredas* in preserved and disturbed based on phytosociological, structural and compositional variations between them. The authors noted that anthropogenic disturbances have affected the composition of the tree community, promoting the loss of species, biomass reduction and changes in the natural process of *vereda* succession. The human impacts also affected the structure of the tree community, reducing the richness, abundance and diversity in *veredas* subjected to higher disturbances (Bahia *et al*., 2009a).

According to Silva and Maillard (2011), *veredas* have disproportionate importance to the area it occupies, as they take up a small area within the Cerrado biome, but represent ecological corridors, interlinking ecosystems and allowing the movement of gene flow (Bahia *et al*., 2009b). They are naturally fragmented systems that follow the stream flow and play the role of water source among situations of local water scarcity (Silva and Maillard, 2011; Resende *et al*., 2013). Several bird species land, shelter, nest

and forage in these areas, as well as other species of terrestrial and aquatic fauna (Padovesi-Fonseca *et al*., 2015). They are also essential for stocking water for the wildlife and for the local populations (Silva and Maillard, 2011). However, ecological and social importance of the *veredas* have been underestimated due to the lack of studies characterizing, investigating the peculiarity and attesting the complexity and fragility of these systems. This situation is worrying, once the systems of *veredas* are considered as "Cradle of Waters" (Boaventura, 2007) because they have a significant role for water maintenance, and consequently, for the maintenance of biodiversity in the Cerrado biome. The scenario is even more serious in the north of Minas Gerais, semiarid region where the *veredas* are peculiar systems and may represent the only perennial water sources in the region, including the supply of important rivers, such as the San Francisco river (Silva and Maillard, 2011; Neves, 2011).

Conclusion

Palynological studies in the *veredas* of central Brazil point to a long development of the *veredas* in north Minas Gerais State, compared to the *veredas* in Goiás State and the Distrito Federal. Also, the dense hygrophilous vegetation associated with *veredas* in north of Minas Gerais State suggests that they were in a more advanced successional stage. However, many factors can influence the floristic composition and structure of these plant communities, requiring further studies involving ecological processes in *veredas*.

Due to lack of scientific research in these areas, the criteria used to characterize the environment of *veredas* are incipient, and do not reach the floristic and structural complexity by the northern *veredas* of Minas Gerais. The lack of knowledge about these environments is a concern considering the degree of disturbance to which these areas are exposed. Although protected by law, the *veredas* suffer various human impacts that may result in their degradation. Also, the lack of public policies that ensure the conservation of these areas contributes to worsen this situation. Scientific studies aiming at better characterize the *veredas* in order to base public policies and actions for the conservation and restoration of these areas are needed, so that biodiversity and ecological services of these wetlands are not lost, even before they are known.

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