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Sensing and Bee Flora Inventory in a Caatinga Area in Northeast Brazil

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Abstract - The unsustainability context of Brazilian ecosystems, specifically the Caatinga biome, has been marked by human pressure that puts its biodiversity at risk. Bee flora thus becomes vulnerable and the life of native bees is threatened, as they depend exclusively on the flowering of certain species and contribute by pollinating the ecosystem. Given the relevance of this biome's conservation, this study aimed to identify the uses and land cover through the NDVI, LST, and WSVI indexes, in a Caatinga area in the Sertão region of Paraíba State, in a dry and a rainy season, and to evaluate its influence on the richness of the bee flora through its inventory. We used satellite imagery and remote sensing to analyze these indexes and survey bee flora. Results showed variability of vegetation and exposed soil areas for the examined periods. The LST and WSVI indexes showed, respectively, low temperatures (27ºC) and higher humidity in areas with vegetation in the rainy season. It presented another landscape with greater diversity, especially of herbaceous species, which influenced the increase in flowering, furthering the activity of bees that need vegetation to feed.

Keywords: Semiarid. Conservation. Sustainability.

Sensoriamento remoto e inventário da flora apícola em uma área de Caatinga no nordeste brasileiro

Resumo - O contexto de insustentabilidade dos ecossistemas brasileiros, no caso específico o bioma Caatinga, vem sendo marcado pela pressão antrópica que coloca em risco sua biodiversidade. Assim, a flora apícola torna-se vulnerável e a vida das abelhas nativas, ameaçada, já que dependem exclusivamente da

floração de determinadas espécies, além de contribuírem com o serviço ecossistêmico de polinização. Diante da relevância da conservação deste bioma, este trabalho objetivou identificar os usos e cobertura da Terra através do Índices NDVI, TST e WSVI, numa área de Caatinga no Sertão Paraibano, em um período seco e outro chuvoso, e avaliar a sua influência na riqueza da flora apícola através do seu inventário. Utilizou-se de imagens de satélites e do sensoriamento remoto para a análise desses índices e levantamento da flora apícola. Os resultados apresentaram uma variabilidade da vegetação e áreas de solo exposto para os períodos analisados. Os índices TST e o WSVI evidenciaram baixas temperaturas (27ºC) e maior umidade nas áreas com presença de vegetação, respectivamente, no período chuvoso, apresentando outra paisagem com maior diversidade, principalmente de espécies herbáceas, o que influenciou no aumento da floração, potencializando a atividade das abelhas que precisam de vegetação como alimento.

Palavras-chave: Semiárido. Conservação. Sustentabilidade.

Teledetección e inventario de la flora melífera en un área de Caatinga en el noreste de Brasil

Resumen - El contexto de insostenibilidad de los ecosistemas brasileños, en el caso específico del bioma Caatinga, ha estado marcado por la presión humana que pone en riesgo su biodiversidad. Asimismo, la flora melífera se vuelve vulnerable y la vida de las abejas nativas se ve amenazada ya que dependen exclusivamente de la floración de determinadas especies, además de contribuir al servicio ecosistémico de polinización. Dada la relevancia de la conservación de este bioma, este trabajo tuvo como objetivo identificar los usos y cobertura del suelo a través de los índices NDVI, TST y WSVI, en un área de Caatinga en el Sertão Paraibano, en un período seco y un período lluvioso, y evaluar su influencia en la riqueza de la flora melífera a través de su inventario. Se utilizaron imágenes de satélite y teledetección para analizar estos índices y estudiar la floramelífera. Los resultados mostraron una variabilidad de la vegetación y las áreas de suelo expuesto para los períodos analizados. Los índices TST y WSVI mostraron temperaturas bajas (27ºC) y mayor humedad en áreas con vegetación, respectivamente, en el período lluvioso, presentando otro paisaje con mayor diversidad, especialmente de especies herbáceas, lo que influyó en el aumento de la floración, potenciando la actividad de las abejas que necesitan vegetación como alimento.

Palabras clave: Semiárido. Conservación. Sostenibilidad.

Introduction

Brazil is known as the holder of the greatest biodiversity on earth, with around more than 350 thousand cataloged species constituting only a fraction of the Brazilian flora biodiversity (Sousa et al. 2017). Among the 17 countries that are home to 70% of the planet's species richness, Brazil is the most megadiverse (Scarano and Ceotto 2016).

Scarano and Ceotto (2016) state that this biodiversity is the assurance of provisioning ecosystem services vital for human survival and well-being. Although, Manes e Vale (2022) demonstrated the concern for the conservation of global biodiversity, in the face of threat of climate change, especially in tropical forests, in Central and South America, highlighting consequences such as increased temperature and loss of endemic species.

This diversity includes Caatinga, existing in the semiarid region of northeastern Brazil, which comprises 912.529 km², which presents a mosaic of different physiognomies (Silva et al. 2017), encompassing different types of vegetation in a dry climate (Santos et al. 2014).

Like the other Brazilian plant formations, Caatinga also undergoes an extensive process of environmental devastation caused by the unsustainable use of its natural resources. It results in the existence of large areas with low fertility soils, making it one of the most degraded areas in Brazil, with the presence of desertification nuclei (Trovão et al. 2009; Castro and Arnóbio 2011).

This process of changing the landscape affects the existing biodiversity in this biome, causing the loss of the main food supplying plants, such as trees with mass flowering or those that bloom in the dry season, which makes it difficult or even prevents the survival of bees in Caatinga. It is known that bees play a key role in pollination, especially native bees (Hrncir et al. 2017). These authors highlight the relevance of the economic services of pollinators as a foundation for flora conservation.

In Caatinga, beekeeping expansion has been intensifying, with a considerable extension of the Brazilian territory (Oliveira et al. 2012). Thus, it is essential to carry out studies on the bee flora, once preserving this biodiversity provides ecosystem services related to the exploitation of beekeeping activity in the region, as well as income generation and value-adding to production. Franco (2013) says that knowledge about this region comes as a factor to understand and manage to conserve the bee flora, as well as the creation of conservation, identification, and preservation programs of the region's bee fauna and flora. Reis et al. (2021, p.1) also emphasize that beekeeping has an essential ecological characteristic, as it provides regional conservation of bee species and honey-producing plants.

Bees are essential components for the maintenance of ecosystems and act as fundamental living organisms for the perpetuation and maintenance of flora within the Caatinga biome (Silva et al. 2008). Aleixo et al. (2014) emphasize that the vast bee flora has several plants from which these insects visit to collect pollen and nectar, constituting their staple food. According to Franco (2013), even being aware of the primordial importance of bees for the conservation of ecosystems, and as an agent for the maintenance and perpetuation of species, studies on the bee flora in a given region are still scarce. It is the case of the semiarid region of Paraíba State. This becomes even more serious when Sá et al. (2004) emphasize Paraíba State as a region with desertification areas, which enhance environmental problems, caused mainly by changes in the landscape of the Caatinga biome. Regrettably, seasonally dry tropical forests – SDTFs have received less attention compared to rainforests concerning research and conservation efforts, and, this has been contributing to increase threats to dry forests (Santos et al. 2011).

According to Tavares (2018), it is noticeable that the use of inappropriate practices such as the occurrence of fires has raised a series of problems aimed at the extinction of plant and animal species from the Caatinga biome in the Sertão region of Paraíba State. The impact of this practice is clear, as it impacts the bee fauna, causing an imbalance in the foraging of bees, a decrease in their species, and, as a result of it, the inexistence of local hives in several areas.

According to Sousa et al. (2012), beekeeping activity in Brazil nowadays comes as a factor directly linked to the country's agriculture. It generates income for small and medium producers, in addition to its fundamental importance in maintaining ecosystems and essential processes for production, such as pollination, which is essential for many species. The presence of a rich flora that Brazil has linked to the existence of Africanized bees and good blooms continuously increases the potential to develop the beekeeping activity, and even more with a climate that favors this activity (Sousa et al. 2012).

In this work, as a way to aid the bee flora inventory, we combined the use of remote sensing techniques using vegetation indices (VIs). According to Xue and Su (2017), these indices are obtained from canopies based on very simple and effective algorithms for quantitative and qualitative assessments of vegetation cover, vigor, and growth dynamics, among other uses. These authors further argue the importance of these tools to provide information for use in environmental monitoring, biodiversity conservation, agriculture and forestry, among others. As regards the inventory of bee flora and soil with remote sensing techniques, it can be an important tool to characterize and map the available bee forage resources, leading to an efficient and sustainable use (Adgaba et al. 2017).

Based on the knowledge of the water scarcity in the semiarid region and the loss of forests caused by human actions that greatly affect the foraging of bees by the disappearance of certain species, the objective of this work is to identify the classes of land use and land cover and evaluate the influence of the bee flora through carrying out its inventory in a Caatinga area located in the Sertão region of Paraíba State, Northeastern Brazil.

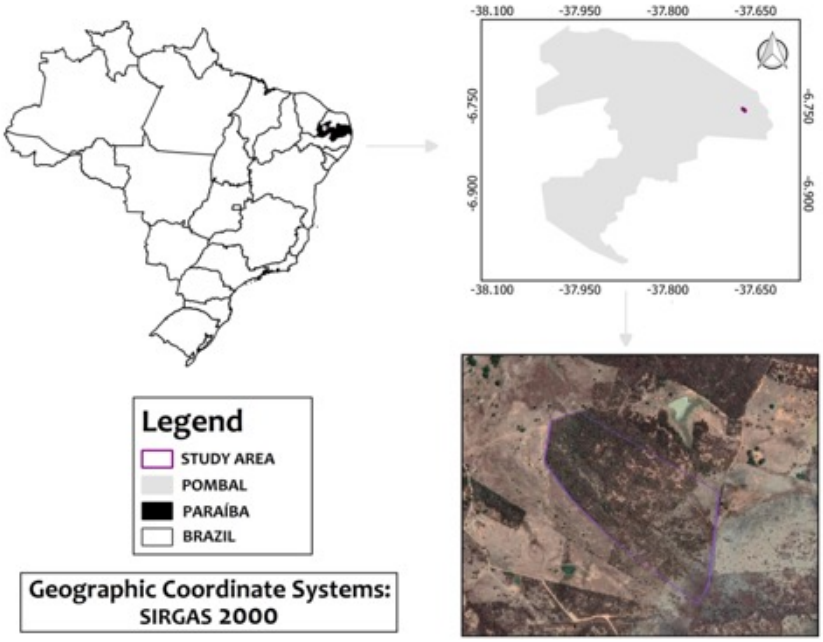
Furthermore, this work emphasizes the importance of the bee flora biodiversity conservation against the scenario of the use of these resources for the most diverse purposes. Such as in research and development of other products to synthesize a result that may bring a perspective on the importance of the Brazilian bee flora in the sustainable development of the semi-arid region. In addition, these results aim to contribute to the Sustainable Development Goals (SDGs), specifically, SDG 15 – life on land "protect, restore and promote the sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss" (UN 2016).

Material and Methods

Study area

This research was carried out in the Gadelhas Stream located in the municipality of Pombal, in Paraíba State. It has approximately 31.57ha of area (Figure 1) and is located at the geographic coordinates 6º45'42.42"S, 40º40' 13.74W. It is within the Caatingas Domain, in northeastern Brazil, which has a large extension, high diversity of climatic, pedological, and geomorphological variables that originate different types of vegetation. Among these types are the shrubby-arboreal, deciduous and thorny vegetation, which occurs in low altitude areas of the semi-arid region (Lima et al. 2019), typical characteristics of the Sertão region of Paraíba State, present in the study area.

Figure 1. Gadelhas Stream located in the municipality of Pombal, in Paraíba State, Northeast of Brazil.



Source: Prepared by the authors with data provided by IBGE (2019) and Google Earth Pro (2021).

Processing of vegetation index and temperature index

This study area was analyzed using remote sensing tools to determine the vegetation and temperature indexes along with field visits to check out some information. We used images from the Google Earth software, vector data provided by IBGE (2019), two Landsat 8 satellite images provided by the United States Geological Survey (USGS) captured at 12:41:46 on October 17, 2020, and 12:41:09 on May 29, 2021, comprising the dry and the rainy seasons, respectively. For the elaboration of indexes and image treatment, we used the open-source software Qgis 2.18.

These images initially underwent atmospheric correction digital processing, using the feature of Qgis – SCP – Semi Automatic Classification Plugin, which converted the raw images into better quality by-products (Coelho et al. 2021).

Then, we performed the calculation of the Normalized Difference Vegetation Index-NDVI originated by Rouse (1973), in which the values range on a scale from +1 (plus one) to -1 (minus one), where those close to + 1 indicate the presence of vegetation in the area, while -1 is the value with no vegetation. From this, two NDVI maps were generated highlighting the existence of vegetation in the municipality of Pombal, focusing on Gadelhas Stream, enabling the visualization of areas with vegetation predominance. Equation 1 presents the calculation of the NDVI.

It should be noted that there are numerous other indices that provide an understanding of vegetated areas, such as the Soil Adjusted Vegetation Index (SAVI), which in turn is similar to the NDVI, but more specifically, the vegetation variations present in areas, for be a sensitive index and widely used in environmental studies that aim or hold as a methodological means of interpretation of vegetation. Based on this premise, geoprocessing indices are instruments that provide knowledge of areas, often remotely, when they are not agents that verify the existing scenario of an already known reality.

$$NDVI = \frac{(NIR-R)}{(NIR+R)} \quad (1)$$

NIR: Spectral reflectance related to near infrared;
R: Spectral reflectance related to red.

Then, we calculated the land surface temperature (LST) with the generation of two maps covering the visualization of the study area, as well as the surrounding areas at the municipal level. Where, the estimated temperatures differ according to the presence and absence of vegetation, which enabled passive sub-areas of anthropization at the municipal level and within the study area. Equation 2 shows the variables to obtain such information (Pereira 2020):

$$LST = \frac{BT}{\left(0{,}00115\frac{BT}{1{,}4388}\right)+1} \quad (2)$$

BT: Brightness temperature at the top of the atmosphere;
E: Earth Surface Emissivity of NDVI

The Water Supplying Vegetation Index - WSVI establishes how much water the vegetation is provided with, on a scale ranging from plus four (+4) to minus four (-4), where values less than –4 indicate the lack of vegetation with water storage, and for values close to +4 they represent wetter areas (Alshaikh 2015). In this understanding, two WSVI maps were generated, dated with the same structures seen in the NDVI and LST indexes, aiming to visualize the scenarios with the existence of vegetation with significant moisture propitious to be areas with vegetation density. In equation 3 we have the variables that reach the WSVI.

$$WSVI = \frac{NDVI}{LST} \quad (3)$$

NDVI: Normalized Difference Vegetation Index;
LST: Land Surface Temperature.

Identification of the bee flora

The identification and collection of species in the study area through the technique called random collection based on the work developed by Santos et al. (2006). It consisted of walking around the area, observing, noting, and collecting the species that were flowering and with the presence of fruits, as well as those that received visits from pollinators, mainly bees, which, by the way were seen in some plants. Species that receive visits from bees were classified according to the scientific literature of studies developed by Silva et al. (2008), Aleixo et al. (2014), Silva et al. (2020), Reis et al. (2021), Vasconcelos et al. (2021).

Field observations and collections were carried out in the morning of June 19, 2021, removing parts of the plant with leaves, flowers, and fruits. Species observations, as well as collections, were registered by photographs and geographic coordinates through GPS (Global Positioning System), and species data such as location point, growth habit, and the area in which it was collected, were recorded in a table.

The collected botanical materials were taken to the Animal Nutrition Lab of the Agri-food Sciences and Technologies Center of the Federal University of Campina Grande (UFCG) - Pombal Campus, where they were subjected to the dehydration process in an air circulation oven at a temperature of 65°C for two days, and then the exsiccatae were assembled. Next, the exsiccatae were transferred and deposited to the Parque das Dunas Herbarium (RN) – Natal/RN, which were identified by the botanist curator of the herbarium collection and listed with a number for the species.

The samples were identified through consultations with specialized bibliography, sending material to specialist botanists in certain families, as well as by comparison with exsiccates from the collections of the state of Rio Grande do Norte (RN) and Federal University of Rio Grande do Norte (UFRN) RN herbarium. The species were distributed in families according to APG III (2009) for angiosperms and the spelling of the names of the families and species was verified through electronic consultation on the website Flora do Brasil 2020 (2021), currently the most popular Brazilian database updated.

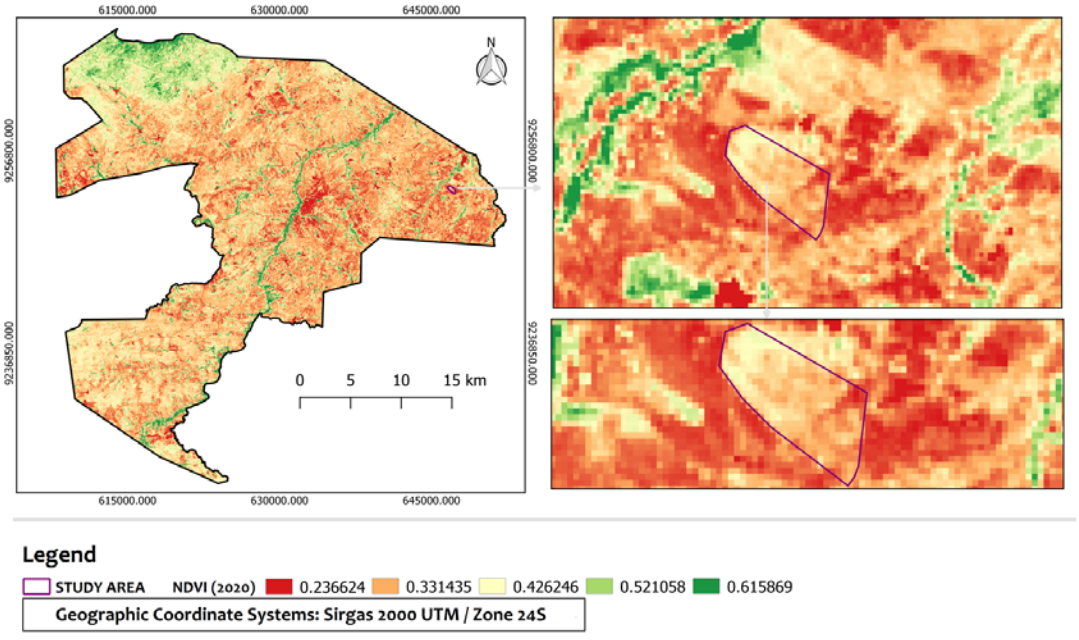
Results and Discussion

Analysis of vegetation and temperature indexes

Results presented in these analyzes resulted from the Normalized Difference Vegetation Index (NDVI), the Water Supplying Vegetation Index (WSVI), and the Land Surface Temperature (LST), converting into maps from satellite images of different time frames, one from the year 2020, in the dry season, and another from the year 2021, in the rainy season.

When analyzing the study area regarding the Normalized Difference Vegetation Index (NDVI), in 2020, during the dry season, a change is observed in the colors red, orange, and light yellow, located throughout the municipality. However, it differs from zones with higher vegetation density found outside the study area (Figure 2).

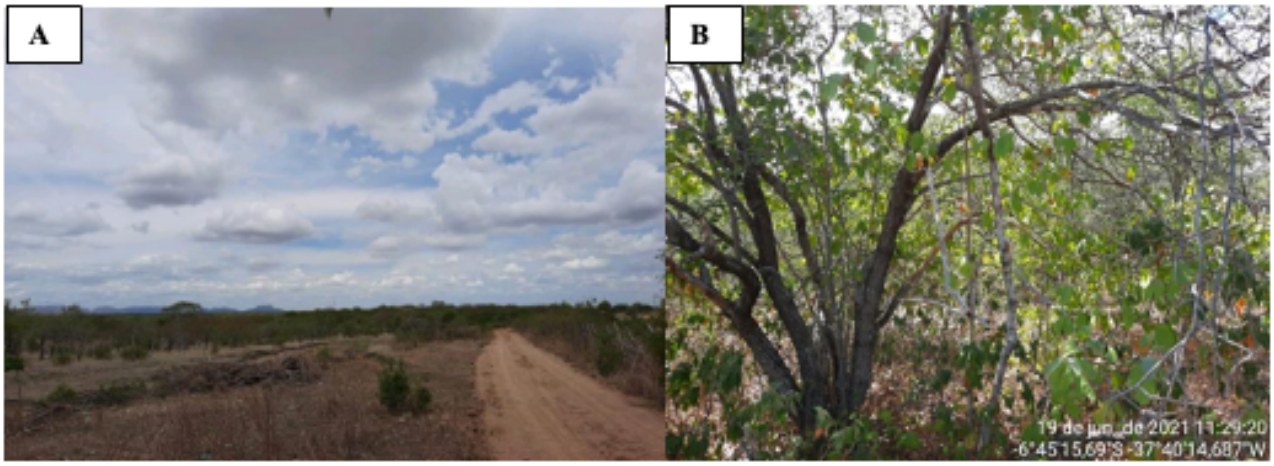
Figure 2. NDVI Map of the Gadelhas Stream.



Source: Coelho et al. (2021)

In the polygon that borders the Gadelhas stream, there is a suggestive area in red color with values of 0.236624, which in loco was verified the presence of an anthropized area (Figure 3A). Regarding the vegetation density within the polygon, the most predominant colors are orange and light yellow, with values of 0.331435 and 0.42646, respectively, indicating the preservation of vegetation compared to areas surrounding the polygon (Figure 3B). In a study by Bezerra et al. (2019), results showed a similar behavior regarding the seasonal variation of data with low values resulting from the dry season and the consequent reduction of vegetation foliage, as well as the presence of exposed soil.

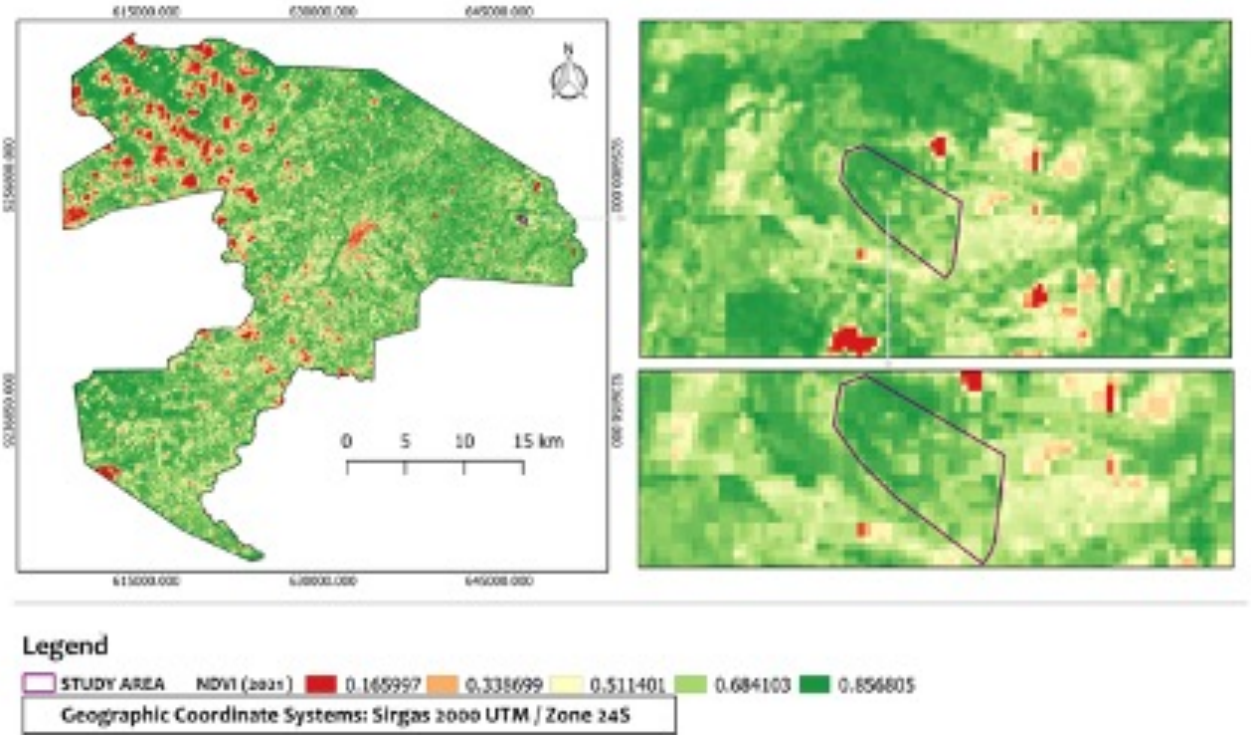
Figures 3. A) Area of exposed soil in Gadelhas Stream; B) Conserved area in Gadelhas Stream.



Considering the analysis of the satellite image from 2021, in the rainy season, the NDVI index, it is verified the presence of clouds, which in turn have values similar to non-vegetated areas (0.165997 and 0.338699) by red and orange tones, considering the whole municipality of Pombal (Figure 4). Regarding the study area, it was not affected by cloudiness, it can be seen that a large part is found in light green and dark green tones (0.684103 and 0.856805) respectively, highlighting how rains shaped the vegetation, intensifying them, distinctly from the indexes of the NDVI map from 2020. Expressive values up to 0.8 were found in a study by Bezerra et al. (2019) by the fact that it presents greater water availability in rainy seasons.

One may note on this map, in the study area, the predominance of values in light green tone (0.684103) possibly being an expression of small-sized grass and shrubs, and the dark green area (0.856805) gives-due to the concentration of denser trees, in which natural resilience acted.

Figure 4. NDVI Map of the Gadelhas Stream



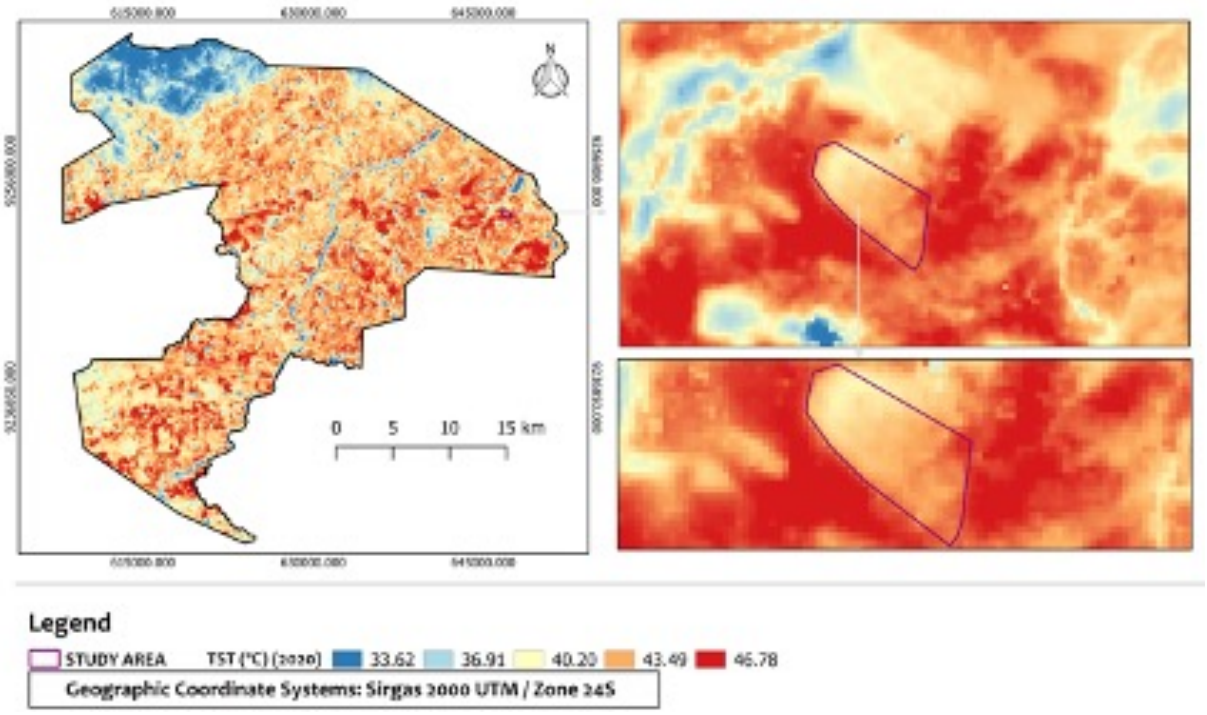
Source: Prepared by the authors with data provided by IBGE (2019) and USGS (2021).

These data highlight the importance of conserving the caatinga vegetation areas once during the rainy seasons there is a considerable increase in biomass, as well as an increase in ecosystem services. According to Neiva (2015), an environment with great vegetation diversity tends to provide a more diversified diet for bees. This enables them to find all the by-products necessary for their existence and permanence in the area, and consequently, also manage to harbor greater diversity of these insects. As well as food resources present there also contribute to the maintenance of the existing bee's diversity.

This diversity of food for bees is related to the presence of vegetation and moisture, in this case, the presence of rain in the period under analysis. Moreover, it is associated with the variation in the land surface temperature.

Regarding the behavior of the land surface temperature in the municipality in 2020, there was a variability of 33.62°C to 46.78°C. So that, in Gadelhas Stream there was a temperature predominance of 40,20°C, equivalent to the maximum temperature in the area (Figure 5). Thus, it is observed that the more vegetated zones provided a temperature attenuation, remaining in the range of 40.20°C to 43.49°C. It is different from the anthropogenic zone verified in loco, which had the highest temperature recorded in the study area due to exposed soil, causing greater heat concentration, distinctly from the vegetated areas.

Figure 5. LST Map of the Gadelhas Stream



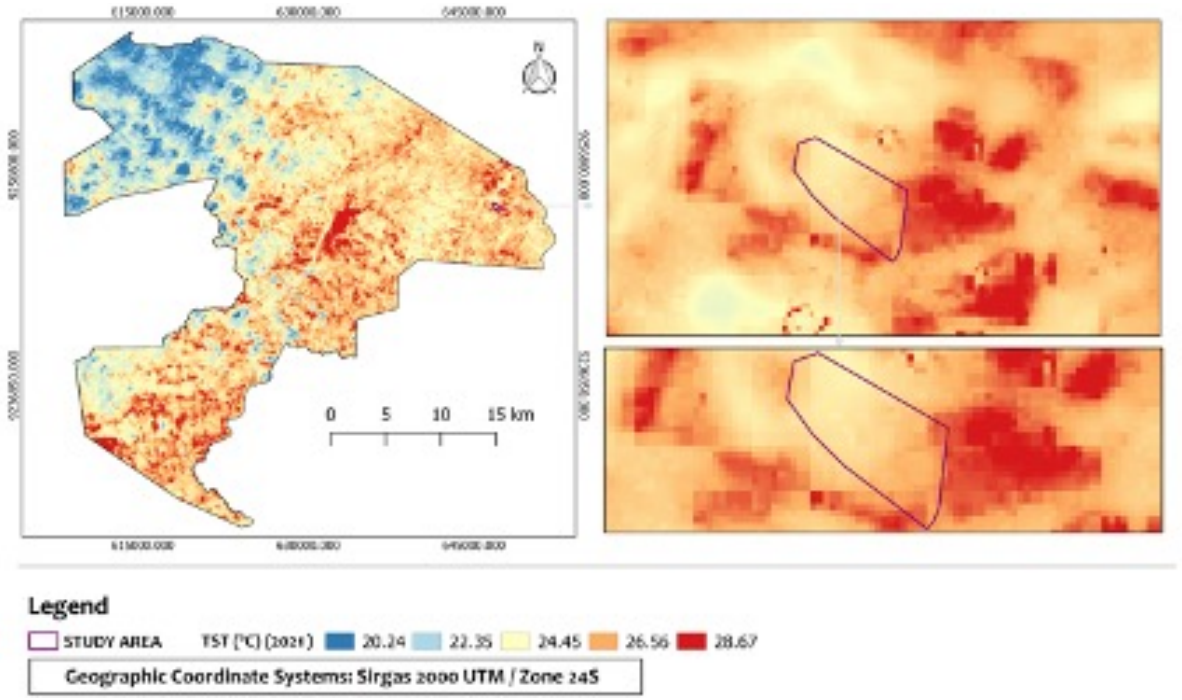
Source: Coelho et al. (2021).

Similar data to this study regarding temperature variability in the Sertão region of Paraiba State are found in the work by Pereira et al. (2020). When they analyze different areas, one vegetated and the other degraded or deforested, both studies expressed high temperatures for areas of exposed soil as a result of human actions.

Temperatures in the study area, for 2021, were predominantly orange (26.56 °C), and to a lesser extent, temperatures of 28.67 °C (Figure 6), indicating the natural resilience of the vegetation with the rain, attenuating the area's temperatures compared to the maximum estimated in the previous year, in the dry season. It may be noted that the image has cloudiness in the municipality of Pombal, since the lowest temperatures recorded (20.24 and 22.35) of dark blue and light blue tones, respectively, correspond to the cloudiness and possibly water bodies present in the municipality.

These temperature records show that rainy seasons are ideal for bee development and foraging. However, in dry periods, according to Ferreira et al. (2017), it becomes a physiological challenge for bees to survive both inside and outside the nest because, outside it, they run the risk of overheating. Thus, food collection and foraging activity become fatal activities if practiced at times with high temperatures. Thus, according to these authors, the ideal temperatures for hatching the brood vary between bee species, but for the most part, it does not exceed 36ºC; and that if higher than this average tend to cause morphological, physiological, and behavioral damage in developing individuals, even leading to the death of larvae and pupae. These authors also emphasize that there are few species suitable for the adverse climatic conditions existent in Caatinga, among them is a type of bee popularly known as Jandaíra (*Melipona subnitida*), with geographical distribution restricted to the Northeast region of Brazil.

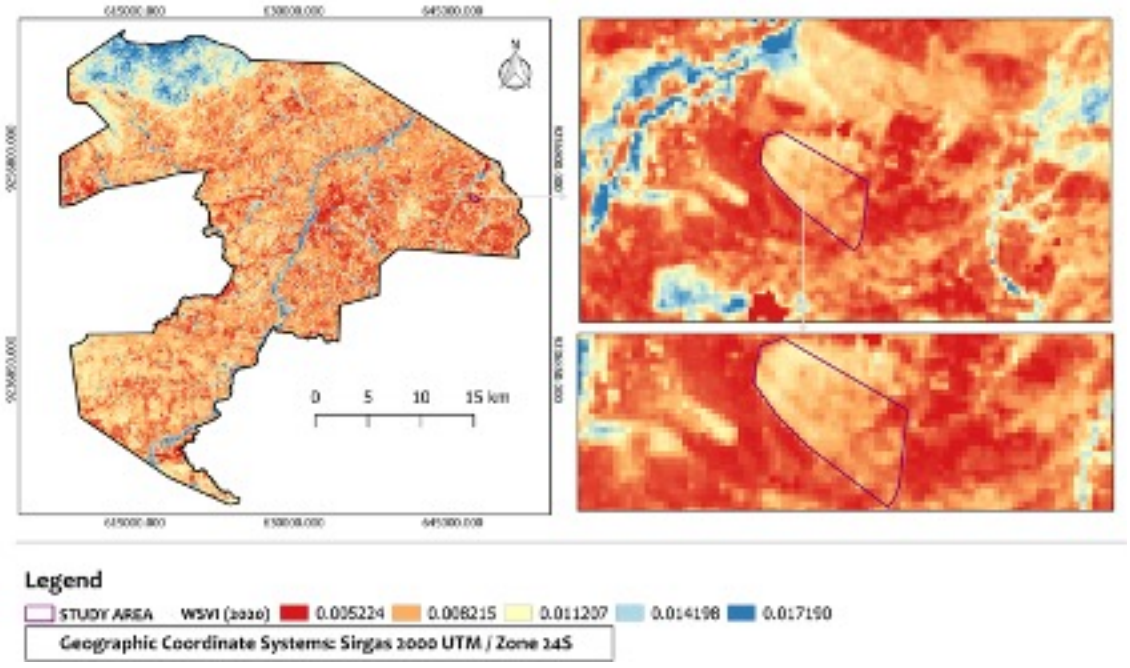
Figure 6. LST Map of the Gadelhas Stream



Source: Prepared by the authors with data provided by IBGE (2019) and USGS (2021).

In accordance with the NDVI and LST, the Water Supplying Vegetation Index (WSVI) was obtained for the study area, for 2020, highlighting the moist vegetated areas seen in orange and yellow, with values of 0.008215 and 0.011207, respectively, as well as the exposed soil area by the red color, since it has no vegetation and, consequently, presented the lowest moisture in the area (0.005224; Figure 7).

Figure 7. WSVI Map for the Gadelhas Stream

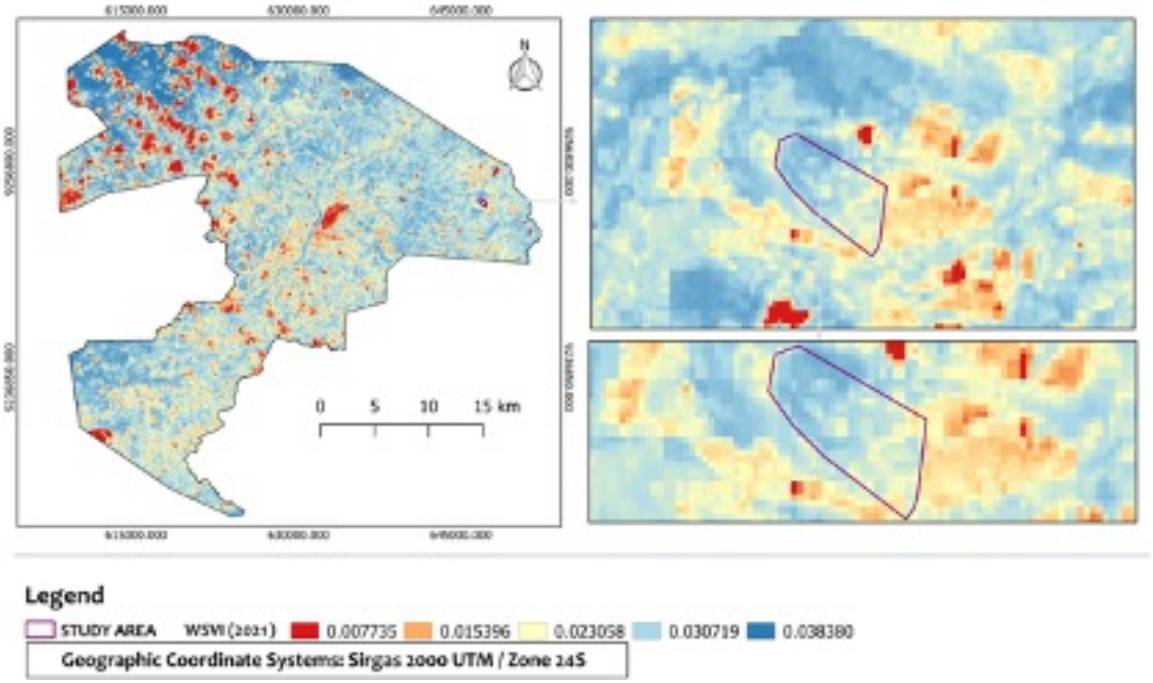


Source: Coelho et al. (2021).

A study carried out in the municipality of Sousa in the countryside of Paraíba State by Pereira et al. (2021), shown WSVI results similar to the study in Gadelhas stream, in which vegetated areas expressed more moisture, and areas of exposed soil showed a lack of moisture due to the absence or low existence of vegetation.

In 2021, the WSVI in the municipality of Pombal had an increase in vegetation moisture, due to rainfall during the periods preceding the capture of the image. Furthermore, we may highlight in its lowest values the presence of clouds in the municipality, and possibly places with exposed soil, and water bodies. In the study area, light blue tons predominate (0.030719) which represents the presence of moist vegetation. Thus, these data indicate that vegetation has higher moisture compared to the WSVI from 2020 (Figure 8).

Figure 8. WSVI Map for the Gadelhas Stream



Source: Prepared by the authors with data provided by IBGE (2019) and USGS (2021).

In the rainy season, higher moisture was verified through LST. This is significant for the food supply of bees since it is at this time with mild temperatures and rainfall that allows more intense flowering of herbaceous and shrub species. According to Brasil and Guimarães (2018), in this rainy period there is a significant amount of beekeeping species, as there are areas with greater availability of water and floral resources. It is different from the dry season, in which there is a reduction in the food supply, which also contributes to the decrease in beekeeping production. Moraes et al. (2020) found out in their work that, in addition to low precipitation rates, high temperatures, a maximum average of 35.7ºC, and low relative humidity can be limiting factors for bee visitation.

Therefore, Moraes op. cit. emphasizes the importance of conserving species that flourish in the dry season, such as *Mimosa tenuiflora* (Willd.) Poir. and *Croton blanchetianus* Baill, since rainfall index decreases the number of flowering species.

Thus, the application of remote sensing to analyze the vegetation and temperature indexes is essential to support the bee flora inventory, which allowed the identification of the most vegetated and moistened areas, favoring the collection of species.

Bee flora inventory

A total of 29 plant species were identified, belonging to 17 botanical families (Table 1), being 14 species recognized as bee flora and belonging to the *Apis mellifera* diet, according to studies carried out by Silva et al. (2008), Aleixo et al. (2014), Silva et al. (2020), Reis et al. (2021), Vasconcelos et al. (2021). *Apis mellifera* is an Africanized bee, and it is known as a pollinator of most species studied in Caatinga (Zanella and Martins 2003).

Table 1. Identification of species found in the study area: ARV- tree, HER- herbs, SHR- shrubs, Voucher- registration number of the herbarium Parque das Dunas (RN).

Families	Species	Habit	Voucher
Acanthaceae	*Dicliptera ciliaris* Juss.	herbs	RN 4503
Amaranthaceae	*Alternanthera brasiliana* (L.) Kuntze	herbs	RN 4504
Apocinaceae	*Aspidosperma pyrifolium* Mart. & Zucc.	tree	RN 4517
Asteraceae	*Acmella uliginosa* (Sw.) Cass.	herbs	RN 4506
	Centratherum punctatum Cass.	herbs	RN 4502
	sp. 01	herbs	RN 4501
Bignoniaceae	*Handroanthus impetiginosus* (Mart. ex DC.) Mattos	tree	-
Cactaceae	*Xiquexique gounellei* (F.A.C.Weber) Lavor & Calvente	shrubs	-
Combretaceae	*Combretum leprosum* Mart.	tree	RN 4514
Convolvulaceae	*Evolvulus* sp.	herbs	RN 4512
	Ipomoea longeramosa Choisy	herbs	RN 4515
Euphorbiaceae	*Croton blanchetianus* Baill.	tree	-
	Croton heliotropiifolius Kunth	shrubs	-
	Jatropha mollissima (Pohl) Baill.	shrubs	-
Erythroxylaceae	Erythroxylum sp.	tree	-
Fabaceae	*Amburana cearensis* (Allemão) A.C.Sm.	tree	-
	Anadenanthera colubrina (Vell.) Brenan	tree	RN 4516
	Mimosa tenuiflora (Willd.) Poir.	tree	-
	Piptadenia retusa P.G.Ribeiro, Seigler & Ebinger	tree	-
	Senna obtusifolia (L.) H.S.Irwin & Barneby	herbs	RN 4520
Gentianaceae	*Schultesia doniana* Progel	berbs	RN 4522
Lythraceae	*Cuphea campestris* Mart. ex Koehne	herbs	RN 4510

Families	Species	Habit	Voucher
Malvaceae	*Pseudobombax marginatum* (A.St.-Hil., Juss. & Cambess.) A.Robyns	tree	-
	Sida sp.	herbs	RN 4523
	Wissadula sp.	herbs	RN 4521
Onagraceae	*Ludwigia* sp.	herbs	RN 4508
Plantaginaceae	*Angelonia campestris* Nees & Mart.	herbs	RN 4509
	Bacopa sp.	herbs	RN 4511
Verbenaceae	*Stachytarpheta angustifolia* (Mill.) Vahl	herbs	RN 4507

Among the identified families, Fabaceae (17%), Asteraceae (10%), Malvaceae, and Euphorbiaceae (10%) stood out for having a greater number of cataloged species (Table 2), together amounting to 48% of the species found. The Fabaceae, Asteraceae, and Euphorbiaceae families predominated in the study by Moraes et al. (2020) showing a significant number of bee nectar, and pollen suppliers. In a study by Reis et al. (2021) the Fabaceae, Asteraceae, and Malvaceae families also contributed significantly to the honey composition and presented pollen types in all analyzed samples.

Table 2. Percentage of species found by family.

Families	*Species* (%)
Acanthaceae	3,44
Amaranthaceae	3,44
Apocynaceae	3,44
Asteraceae	10
Bignoniaceae	3,44
Cactaceae	3,44
Combretaceae	3,44
Convolvulaceae	6,89
Erythroxylaceae	3,44
Euphorbiaceae	10
Fabaceae	17
Gentianaceae	3,44
Lythraceae	3,44
Malvaceae	10,0
Onagraceae	3,44
Plantaginaceae	6,89
Verbenaceae	3,44

In the Assú region - RN, Amorim et al. (2016) reported that the Fabaceae family stood out in the number of species found in the Potiguar region, being one of the most widely known families in the Caatinga biome. Lopes et al. (2016) also state in their study in the Cerrado region in Piauí State, that the Fabaceae family stood out with the greatest richness of species found. In a riparian forest on the Cedro River, Montes Claros – MG, according to Durães et al. (2014), similarly to the results from these studies, the Fabaceae family had the greatest floristic representation. It demonstrates that this family has an important ecological performance in ecosystems, having its representation in plant communities in different regions of Brazil. In a study by Reis et al. (2021), it stood out as the most representative with 33 types of pollen identified.

In the plant species found, classifying them according to their growth habit, we obtained herbaceous with 55%, arboreal (35%), shrub (10%; Table 3). The herbaceous habit stood out with the highest result, thus indicating that the presence of its strata is important as a beekeeping material in the study area. This result was also found in a study by Moraes et al. (2020) with herbaceous plants predominating in the study area. The importance of biodiversity conservation is highlighted once again, since there are few studies in Caatinga about bee species, and according to the species that provide pollen to the diet of Africanized bees during the dry period are reduced (Muniz et al. 2020).

Table 3. Percentage of species in terms of growth habit.

Habit	*Total Species*	*(%)*	*Bee species*
herbs	16	55	4
shrubs	3	10	2
tree	10	35	8

The herbaceous species strata showed the best quality for light honey in flowering during the rainy season in the semi-arid region of Ribeira de Pombal – BA (Gama et al. 2018). These authors assume that the herbaceous strata type is usually preferred by the *Apis sp* genus. Herbaceous species were presented as sources of resources for bees, such as pollen and nectar (Silva et al. 2020). Thus, the herbaceous stratum appears again in a study as an important factor in sustainable regional development, having a great forage potential.

Getting knowledge of the species of beekeeping value in a given area is essential to achieve better use of beekeeping activities, thus making the property a possible center of honey production and other bee products to increase the income of farmers.

Thus, by combining remote sensing satellite images, in this case, to the analysis of vegetation indexes with the floristic inventory, it was possible to see the relevance of this technique as an indispensable tool for mapping land use and occupation. Where, it allowed the identification of areas with resources available for bee forage, thus providing farmers with its efficient and sustainable use. Furthermore, the conservation of areas that are still preserved and are subject to human actions.

Conclusion

Considering the data obtained by the Normalized Difference Vegetation Index (NDVI) in the dry season, it was noticeable that the area has a variability of vegetation, as well as parts of exposed soil due to human actions. When analyzed in the rainy season, in 2021, it presented a different situation with greater vegetation density, which enhances the activity of bees that need food.

Land Surface Temperature (LST) was in line with the vegetation map due to the features present in the area and the variability that behaved as a temperature attenuator. In the dry period, it highlighted a higher temperature in the area with no vegetation and no moisture. Thus, it became an overheated area, unlike the rainy season, in which the maximum temperatures recorded were lower when compared to the previous year. Thus, the presence of herbaceous plants was observed at this stage, which means greater availability of food and productivity in bee foraging.

Water Supplying Vegetation Index (WSVI) showed that the denser vegetation areas had higher moisture. In the rainy season, this reality contributed even more to the presence of vegetation, highlighting the presence of herbaceous plants in the study area, different from the dry season.

Thus, by using satellite images through remote sensing, it was possible to interpret land use. It enabled the visualization of vegetation features and usages, such as areas with greater or lesser vegetation density, with a greater presence of moisture, exposed soil areas, and the temperature index. This analysis allowed us to verify the potential of the bee flora present in the study area, showing the relationships between greater floristic diversity and beekeeping potential.

The floristic inventory revealed that there is a diversity of shrub, arboreal and herbaceous species with potential for beekeeping in the study area, with herbaceous species being the most representative, and with emphasis on the Fabaceae family. This means the importance of this stratum as food for bees, however, this vegetation predominates in the rainy season, and in its absence, food availability is reduced. Thus, studies about the bee flora as a way of conservation of the biodiversity in Caatinga show their importance.

In addition to the importance of flora conservation, and the fundamental role of bee pollination, we emphasize the potential of the beekeeping activity for the region. Thus, we suggest that new botanical collections may be carried out in these areas, and that this information can be available to family farmers so they can, from an activity planning over the years, make better use of this biome.

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