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Spatial distribution of apiaries in the municipality of Ribeira do Pombal, Bahia, Brazil: Implications for honey production

Distribuição espacial de apiários no município de Ribeira do Pombal, Bahia, Brasil: Implicações para a produção de mel

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ABSTRACT

The number of beehives installed per apiary should take into account the potential of bee pasture, the existence of nearby apiaries and ease of management. The study aimed to analyze the spatial distribution of apiaries in the municipality of Ribeira do Pombal, State of Bahia, Brazil, in order to estimate the production of honey per apiary based on the relationship between the number of hives established and the distance between apiaries. For the analysis of spacing, a image of the municipality was acquired by the Landsat-8 satellite and the location points of the georeferenced apiaries. The apiaries were grouped into Classes according to the number of hives: <25 hives.apiary^{-1} (I), 25-30 (II) and> 30 hives.apiary^{-1} (III). The apiaries were projected on a map with 1,500 m buffer corresponding to the radius of action of the bees' flight. A total of 7,198 hives were computed in 290 apiaries distributed in classes: I (47.58%), II (23.45%) and III (28.96%). There were 4.14% apiaries without overlap; and class I apiaries (97%) showed greater overlap. We recommend zoning the beekeeping potential and planning the distribution of apiaries in order to meet the carrying capacity, logistical optimization and for higher productive yield.

Palavras-chave:
Abelha africanizada
Apis mellifera
Pasto apícola
Raio de ação
Sobreposição

RESUMO

A quantidade de colmeias instalada por apiário deve levar em conta o potencial do pasto apícola, a existência de apiários nas proximidades e a facilidade de manejo. O estudo objetivou analisar a distribuição espacial de apiários no município de Ribeira do Pombal, Bahia, Brasil a fim de estimar a produção de mel por apiário com base na relação do número de colmeias estabelecidas e a distância entre apiários. Para as análises de espaçamento, adquiriu-se uma imagem do município pelo satélite Landsat-8 e os pontos de localização dos apiários georeferenciados. Os apiários foram agrupados em *Classes* por número de colmeias: < 25 colmeias.apiários^{-1} (I), 25-30 (II) e > 30 colmeias.apiários^{-1} (III). Os apiários foram projetados em mapa com *buffer* de 1.500 m correspondendo ao raio de ação do vôo das abelhas. Computou-se 7.198 colmeias em 290 apiários distribuídas nas classes: I (47,58%), II (23,45%) e III (28,96%). Registrou-se 4,14% dos apiários sem sobreposição, sofrendo maior sobreposição os apiários da classe I (97%). Recomenda-se o zoneamento do potencial apícola e planejamento da distribuição de apiários a fim de atender a capacidade de suporte, a otimização logística e o maior rendimento produtivo.

INTRODUCTION

Since the phenomenon of Africanization of the subspecies of honey bee *Apis mellifera* Linnaeus, 1758 (Hymenoptera: Anthophila: Apidae: Apinae) already introduced in Brazil during the colonization, with the African subspecies brought to Brazil in 1956 by Professor Warnick Estevam Kerr, a researcher at the University of São Paulo, beekeeping activity took an important professional change with worldwide productive competitiveness, contributed by the highly productive character of these bees (LENGLER et al., 2011).

Currently, beekeeping is an activity of the agricultural sector with great relevance, not only from the point of view of the production of bee products, but mainly, through plant pollination, promoting greater production and quality of fruits and grains where, from the total U$ 45 billion of agricultural revenue generated in Brazil 12 billion correspond to crops dependent on pollination, of which *Apis* spp. bees are the

main responsible visitors (LENGLER et al., 2011; GIANNINI et al., 2015).

Regarding the honey product, the mean productivity in Brazil has been around 15 kg.hive.year^{-1} which is considered low compared to other countries, such as Argentina with 35 kg. hive.year^{-1} (PONCIANO et al., 2013). This is the reason why Freitas et al. (2004) reaffirm that the achieved productivity is mainly related to the appropriate forms of management, the conditions of the bee flora and the type and use of the available technologies. Similarly, authors such as Pereira et al. (2014) point out that the prior knowledge of the availability of bee pasture and the place of installation of apiaries mainly reflects better yields, since bees need good sources of food.

The State of Bahia, in turn, in the national beekeeping scenario, is among the 10 states of the federation in honey production, with emphasis on the municipality of Ribeira do Pombal, located in the semi-arid region, which in 2014 was the municipality with the highest honey production of the country, representing 14.3% of production in the State (BRASIL, 2015).

Otherwise, from the point of view of competitiveness, the adoption of innovative technologies, breeding, better use of the potential of the national bee flora and effective management, will not result in better production if there is no viable mechanism for ordering the activity (SOUZA et al., 2012; ANJOS et al., 2013; FERNANDEZ et al., 2013; DOMINGOS et al., 2016).

In this context, a spatial analysis methodology elaborating maps of the apicultural potential of the region, identification maps of possible conflicts of geographical location of apiaries, pesticide target areas and maps of spatial distribution of possible occurrences or outbreaks of diseases in hives become important elements in the support to the beekeeping ordination also serving as essential for the decision making of multicriteria for a greater efficiency of the beekeeping activity (MARIS et al., 2008; ANJOS et al., 2013; FERNANDEZ et al., 2013), in addition to contribute to studies of population growth of Africanized honey bee *Apis mellifera* competing for floral resources with native bees, which may affect their ecological functions, such as specific pollination, depending on the density of consumption, foraging range and size of the area of occurrence of Africanized honey bee *Apis mellifera* (ROUBIK; WOLDA, 2018).

It is noteworthy, on the other hand, that the distribution of apiaries introduced in a certain region for the purpose of commercial exploitation in a dense concentration of colonies of the Africanized honey bee *Apis mellifera* tends to cause, in the medium and long term, serious environmental damage, especially on the native bees, since *A. mellifera* has extremely populous colonies (more populous than colonies of all known native social bee species), presents a quite generalist behavior in foraging, collect pollen in large amounts potentially compromising the availability of food for native bees when colony densification extrapolates the environment support capacity, and may even impact the native flora by compromising the reproduction of plant species that are exclusively dependent of native pollinators (GELDMANN and GONZÁLEZ-VARO, 2018). In this case, Geldmann and González-Varo (2018) still emphasize that bees may be necessary for crops pollination, but beekeeping is an agrarian activity that should not be confused with wildlife conservation.

For installation of apiaries according to the number of hives that an area can support, also according to the local potential available of nectar and pollen (COSTA; FREITAS, 2009; PEREIRA et al., 2014), authors such as Braga (1998) suggest 40-50 beehives per apiary in regions of strong bee pasture and regions like Atlantic Rainforest. In turn, Wolff et al. (2006) recommend from 25 to 30 hives for semi-arid regions in order to optimize the pasture, management and logistics employed. On the other hand, it is necessary to take into account, besides the carrying capacity of the area, the existence of other apiaries above 3 km distance, since the bees work within a normal radius of action of 1.5 km (COSTA; FREITAS, 2009), and distances smaller than this may make the activity unfeasible.

In this specific aspect, geographic information systems (GIS), as a management tool, becomes an alternative to determine the localization, identification and interpretation of scenarios and situations of apiaries, according to several indicators of beekeeping activity (ANJOS et al., 2013), and information developed in the form of thematic maps used correctly, contributes to compatible and adequate guidelines for an integrated and economically sustainable utilization of the occupied space (FREITAS et al., 2004; MARIS et al., 2008; ANJOS et al., 2013; FERNANDEZ et al., 2013).

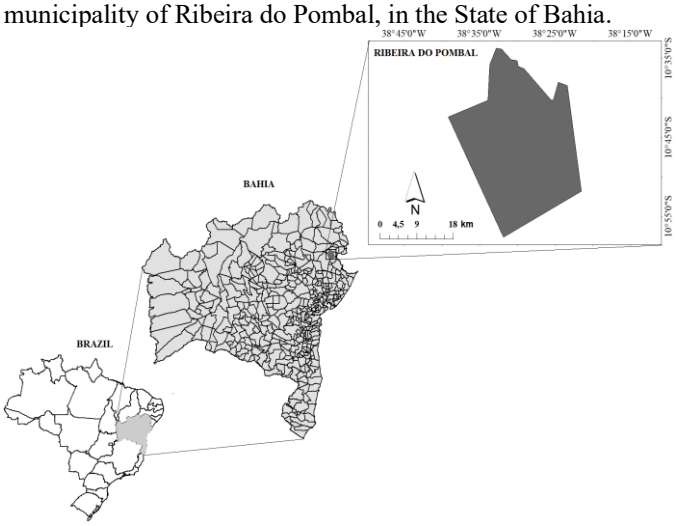
Some Brazilian Northeast regions, especially in the States of Ceará and Rio Grande do Norte, already have higher population densities of Africanized honey bee *Apis mellifera* (GUPTA et al., 2014), and there is still no information on beekeeping in the State of Bahia.

Given the above, the present study investigated the spatial distribution of apiaries in the municipality of Ribeira of Pombal in order to estimate potential implications in honey production, seeking methods to improve the beekeeping activity in the region in line with managements aimed at environmental conservation and the maintenance of beekeeping potential in the long term.

MATERIAL AND METHODS

Ribeira do Pombal is located in the northeastern region of the State of Bahia (UTM: 536800/8834566 e 570493/8786768) with territorial extension of the 753.9 km² (Figure 1).

Figure 1. Map showing the geographical location of the municipality of Ribeira do Pombal, in the State of Bahia.



The municipality is located in medium altitude of the 227 m, is characterized by semi-arid climate, with a rainfall index of 711 mm.year^{-1} and temperature 24.2 ºC.year^{-1}, deep sandy soils with predominant shrubby-arboreal caatinga vegetation (GAMA; JESUS, 2018). The economy is based on the commerce and the agricultural activity, emphasizing the beekeeping, where were registered in 2013, 325 beekeepers and 16,272 hives (CECOAPI, 2014), having a honey production chain with consolidated entities; honey processing industries, inputs and the Individual Protection Equipment manufacturing industries. As well as counting on 09 carpentries producing an annual medium of 2,600 Langstroth hives (GAMA et al., 2016).

Data of the apiaries georeferenced by GPS (Global Position System), as well as the amount of hives per apiary and the estimated honey production per apiary, used in the present study were made available by the Beekeeper Cooperative Center of the State of Bahia (CECOAPI), as reference the year 2013, the period considered in this article.

Based on data provided by CECOAPI, a thematic map of the location of the apiaries was developed for spatial analysis of conflicts and identification of overlapping of the zones exclusive to each apiary, using the QGIS 2.18 software for analysis.

The apiaries were identified on the map in *Classes* according to their number of hives installed, namely: "lower" class (I), those that had less than 25 hives (<25); "medium" class (II), those that had between 25 to 30 hives; and "large" class (III), those apiaries that had more than 30 hives (<30).

For each apiary included in the aforementioned location thematic map, a buffer of 1,500 m was generated, which was adopted as the radius of action of flight performed by the bees, associating this measure with the area of bee pasture available for each apiary to obtain its maximum productive efficiency and less competition between the bees of other surrounding apiaries. It was considered as the radius (1,500 m) the distance from the center (apiary) to a point on the circumference formed according to the buffer.

The means productivity values were subjected to analysis of variance (ANOVA) and, when a significant difference was detected, the mean test was performed using Tukey ($p \leq 0.05$), using SISVAR® (FERREIRA, 2014).

RESULTS AND DISCUSSION

According to the data provided by CECOAPI, the 290 apiaries identified and spatially distributed in the municipality of Ribeira do Pombal were grouped into *Classes* per number of hives, standing out Class I, represented by 47.59% of local apiaries, followed by Class III (28.97%) and Class II (23.45%), which together totaled 7,198 hives computed for the municipality of Ribeira do Pombal, as observed in Table 1.

Table 1. Distribution of the number of apiaries, hives and relationship with honey production per classes of apiaries in the municipality of Ribeira do Pombal, State of Bahia, Brazil.

Classes*	Distribution		
	Apiaries	Hives	Overlapped apiaries
I	138 (47.59%)	1.841 (25.57%)	134 (97.10%)
II	68 (23.45%)	1.882 (26.15%)	65 (95.59%)
III	84 (28.97%)	3.475 (48.28%)	79 (94.05%)
Total	290 (100.00%)	7.198 (100.00%)	278 (95.86%)
Classes*	Relation		
	Mean (hive.apiary^{-1})	Production (kg)	Productivity (kg.hive^{-1})
I	13.34	34.180 (23.52%)	18.6b
II	27.68	42.665 (29.35%)	22.7a
III	41.37	67.500 (46.44%)	19.4b
Total	25.20	145.345 (100.00%)	20.2

*Classes: I (<25), II (25-30) and III (>30), corresponding to the number of hives per apiary. Means of the same letter do not differ by Tukey test ($p \leq 0.05$).

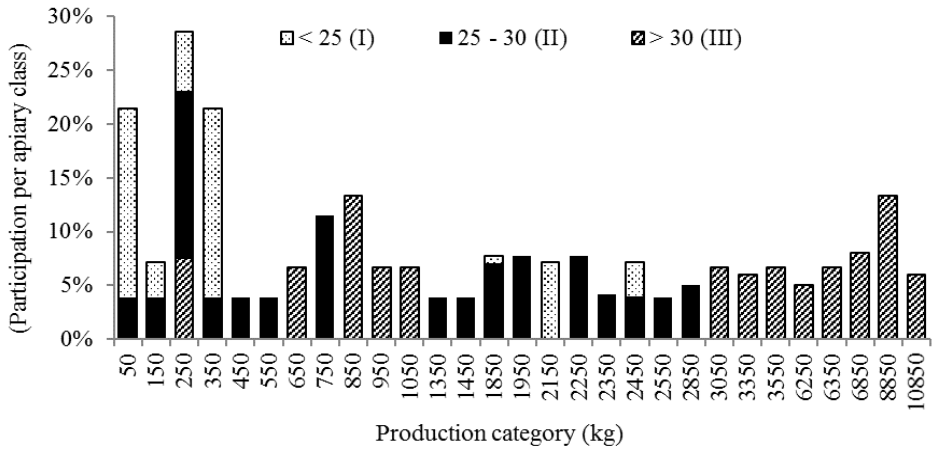
Considering the ideal number of 25 hives.apiary^{-1} for the semi-arid region (WOLFF et al., 2006), it can be seen that the areas of Class I apiaries may theoretically be underutilized by these apiaries, since they are composed of an mean of 13 hives.apiary^{-1}. In a study on beekeeping activity in the Campos do Jordão, State of São Paulo, microregion, it was observed that 80% of the apiaries had less than 20 hives (BENDINI et al., 2014), which can be considered a number far below the ideal because it is in a region located in an area of Atlantic Rainforest (BRAGA, 1998).

Monteiro et al. (2014) found in the municipality of São Bento do Sul, State of Santa Catarina, an mean productivity of honey of 7.53 kg in which 24.5% of beekeepers had 51 hives.apiary^{-1} and 49.1% had a number below 20 hives, and according to the authors, the incorrect management and low technology used were the main reasons for low productivity, since the municipality and region have bee pasture and favorable climatic conditions.

Thus, it is understood that apiaries with a number of beehives below the ideal converge, possibly, to a low productivity in the medium term because there are few bees to forage and thus, they do not maximize the exploitation of available nectar in the existing flowering in a timely manner, tending proportionally to a relatively unsatisfactory cost-benefit.

This may possibly explain the lower honey production of this Class I, even though it represents almost half of all georeferenced apiaries in the municipality (47.59%). Class II, with a hive.apiary^{-1} mean within the recommended one, responded with a honey production higher than Class I, although with little difference in production of approximately 5%, even though the Class II, with the lowest number of apiaries (approximately 24%). That is, the number of hives per apiary represented a more significant aspect than just the number of apiaries, as observed for Class I

Figure 2. Participation of apiaries (Classes I, II and II) in honey production in 2013 according to different production categories in the municipality of Ribeira do Pombal, State of Bahia, Brazil.



Class III, represented by almost 29% of apiaries, responded with honey production superior to the others (47%), probably favored by the considerable number of hives per apiary (48% of the total), however, their mean honey productivity per hive.year^{-1} (19.4 kg) was lower than that of Class II, which can be explained by the competition in foraging exerted by a greater number of bees in a bee pasture not adequate to the size of the apiaries. In another aspect, considering the resulting productive potential in each Class, it is noticed that the production generated in quantity is directly proportional to the number of hives per apiary. The total mean honey productivity of hives in Ribeira do Pombal, considering all Classes of apiary, was 20.2 kg hive.year-1. Value significant, compared to the national mean (15 kg hive.year^{-1}). It is observed that the mean productivity found for Class II was higher than the other Classes I and III. And that, between these two classes I and III, there was no significant difference ($p \leq 0.05$). Evidencing that apiaries with a number of hives below or above Class II (25-30), compromise the expected productivity.

In relation to the annual honey production of each apiary per category of production (Figure 2), it is observed that the honey production of Class I apiaries was represented by the lower production rates, once about 80% of apiaries of this Class reached a production considered low, since 22% of the apiaries had an mean production around 50 kg of honey, 7% of them an mean production of 150 kg, 28%, a production of 250 kg and 23% of the apiaries with a production of 350 kg honey.year^{-1}. Only about 20% of Class I apiaries achieved a fairly reasonable production (1,850 kg, 2,150 kg or 2,450 kg).

In the case of Class III apiaries, these reached the highest production rates, where 58% of the apiaries reached a production of over 3,050 kg per year, with 6% of their apiaries being able to reach the maximum rate of 10,850 kg honey.

In Class II, 45% of the apiaries had annual production between 1,350 kg (4%) and 2,850 kg honey (6%), as seen in the intermediate region of Figure 2, where 42% of apiaries of this same Class corresponded to the categories of lower production throughout the year, highlighting 23% of apiaries with only 250 kg of honey each.

In another aspect, as presented in Table 1, the production values of Classes II and III were inversely proportional to their respective numbers of hives, possibly attributable to a combination of different factors, such as population differences of hives, differences in the quality of the available bee pasture or the quality of the management techniques employed.

Studying aspects of beekeeping in three municipalities of the State of Ceará, Freitas et al. (2004) found a productive increase in apiaries using appropriate technologies. This fact was also observed by Poncioano et al. (2014), where they noticed low productivity in 75 municipalities of the State of Rio de Janeiro due to the low level of technology employed. In a similar way, in the Vale do Paraíba, State of São Paulo, it was observed that not only the technological level, but also the rational management and adequate infrastructure stimulated honey productivity (PASIN; TERESO, 2008).

Thus, although the use of appropriate technologies contributes to the increase of honey productivity in hives, other factors need to be considered, such as conflicts/overlap between nearby apiaries, since proximity between apiaries can lead to low productivity through bee competition for the same bee pasture available, which may be even more relevant for those apiaries with fewer hives.

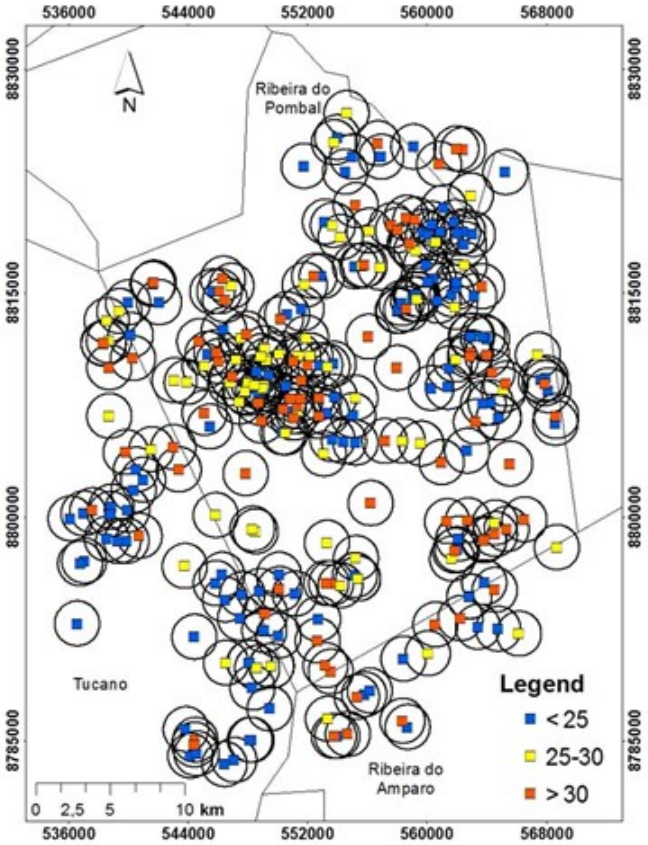
Delonzek et al. (2014), in a study in the Paraná region, found an mean productivity of 18.67 kg hive.year^{-1} for 464 apiaries, and, for the authors, factors such as quantity and quality of flowering and climate had a direct influence on the increased productivity. Both et al. (2009), on the beekeeping activity in 2007 in the municipality of the State of Pará, found a considerable mean production of honey (25.4 kg hive.year^{-1}) for 3,670 hives distributed in a area of 2,714.85 km².

In this sense, analyzing the distribution of the georeferenced apiaries in the municipality of Ribeira do Pombal, we observed an overlap between almost 100% of the apiaries (95.86% of the local apiaries are overlapping), considering an ideal theoretical area for each apiary projected by buffer (Figure 3). What must also have been the cause of the low productivity seen for Classes I and III (Table 1), due to competition from nearby apiaries.

The concentrations of apiaries formed clusters with a minimum distance between apiaries of up to 7.19 m, probably apiaries of the same beekeeper. Thus, it can be observed that Class I apiaries (<25 hives.apiary^{-1}), located only in the clusters, were those that presented smaller productions, around 50 to 250 kg of honey per year. In other words, in addition to the smaller number of beehives per apiary, and probably with low technology employed, we observed the aggravation of the overlap in 97.1% of the apiaries, being the overlap in Class II apiaries (25-30) around 95%, and for Class III (> 30) around 94%. Thus, it is observed that the overlap of apiaries occurred in all Classes, connecting apiaries of different Classes, in addition to apiaries of the same Class. Class II, the one with the highest mean productivity (22 kg

hive.year^{-1}), was the one that suffered from less overlap although with little difference, which contributed positively to its productivity.

Figure 3. Spatial distribution of apiaries per classes I (<25 hives.apiary^{-1}), II (25-30) and III (> 30 hives.apiary^{-1}) in the municipality of Ribeira do Pombal, State of Bahia, Brazil highlighted with a buffer of 1,500m, referring to the radius of action of the flight of bees.



Bendini et al. (2014), in spatial characterization of beekeeping activity in four municipalities of the microregion of Campos do Jordão, State of São Paulo, also identified concentrations (clusters) of apiaries in certain localities, although the authors were not able to determine possible impacts generated in honey productivity in each apiary. In this respect, it is understood that failure to meet an ideal distance between apiaries, adequate to the number of hives in each apiary, can be detrimental to production, especially if flowering is scarce.

The classes of apiaries II and III were the most dispersed, in which, class III, even with overlap of 94%, obtained high production rates, probably favored or compensated by the largest number of hives distributed (mean of 41 hives.apiary^{-1}), allowing a greater number of bees to forage the bee pasture than apiaries of the other Classes, which may have favored their production.

The benefit of having apiaries located distant from each other, avoiding foraging conflicts in the same bee pasture, was reported by Luz et al. (2007), in a study on trophic resources of Africanized honey bee *Apis mellifera* in the region of Rio de Janeiro, investigating apiaries with higher production in regions with available bee pasture, free of competition. A similar situation was reported by Pereira et al. (2014) in a study of apiculture in the semi-arid region where satisfactory productive results were obtained in apiaries located in regions with a greater supply of bee pasture.

Although the mean total honey productivity was higher than the national, the poor distribution of apiaries indicates a rational underutilization of the available pasture for bees, where a better distribution could probably result in a greater increase in production, especially in the region, where the availability of bee grazing is limited most of the year due to severe weather conditions.

Roque et al. (2013) observed a high rate of apiaries located in areas with beekeeping potential in Vila Velha de Ródão, Portugal, noting that the higher density resulted in greater competition among the bees for floral resources, which was also verified by Souza et al. (2013) in a study on the use of *A. mellifera* Linnaeus, 1761 as an additional pollinator to melon.

Therefore, zoning to identify areas of beekeeping potential could contribute to a better distribution of apiaries and not generate unpleasant situations such as out-of-season migrations due to lack of available areas, as observed in the State of Sergipe by Silva et al. (2016), who verified that in some regions there are no more areas available for beekeeping, forcing beekeepers to move from apiaries to out of the State, besides unfavorable climatic conditions and expansion of areas available for agriculture.

The same situation was noted by Cerqueira and Figueiredo (2017), who evaluated aspects of beekeeping in the region of Matão, State of São Paulo and stated that one of the biggest problems of beekeeping has been the expansion of areas of sugarcane monocrops, with consequent loss of habitat with 76.9% of beekeepers practicing migratory beekeeping, probably as an alternative to offset the reduction of areas in the region.

CONCLUSIONS

The distribution of apiaries in the studied region of Ribeira do Pombal, behaved in an aggregated way, generating overlapping apiaries, underutilization of hives and high competitive potential in foraging.

Apiaries Classes I (<25) and III (>30) had low productivity, hampered by poor planning in the spatial occupation of the apiaries.

For the beekeeping activity in the studied region, better planning is suggested in the definition of locations and distribution of apiaries, taking into account the support capacity of the beekeeping pasture. Also avoiding the introduction of these colonies in protected areas.

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