Diversity and composition of medium and large mammals in commercial tree plantations of the Altillanura, Colombia

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Abstract

The Colombian Orinoco region is one of the most important areas for agricultural development in the country. The department of Vichada, in particular, has experimented a continuous growth of commercial tree plantations, which covered around 110.589 ha by 2021. However, the potential effects of these land use changes on native mammals are not well understood. Here, we compared the diversity and composition of terrestrial mammals between tree plantations, gallery forests, and natural savannas of Puerto Carreño. We deployed 64 camera traps for eight months (5.840 camera days) between August 2023 and March 2024, obtaining 1.087 independent records of 23 medium and large-sized mammal species (forest: 775, plantations: 295, savanna: 17). Diversity measures indicated that gallery forest almost double folded the diversity of tree plantations, with an estimated richness of 26 and 13 species, respectively, while in the savannas we only detected four species (5 estimated). The difference in species richness between savannas and plantations was not significant. The most common species in the forest were the spotted paca (*C. paca*) and white-lipped peccary (*T. pecari*). On the other hand, white-tailed deer (*O. virginianus*) and crab-eating fox (*C. thous*) were common in savannas and plantations. Our results reaffirm the importance of riparian forests for the conservation of mammals in productive landscapes of the Altillanura and confirm that forest plantations are used by several species, two of which, were even more frequently detected in plantations than in the other covers. Our results reflect a similar composition of mammals as in non-productive landscapes, and the presence of five threatened species highlights the importance of this study area and the need for implementing conservation programs. We recommend strengthening the monitoring of natural savannas to analyze the potential effects of afforestation on this land cover.

Keywords: Vichada, Orinoco region, biodiversity, habitat use, forestry, Llanos

Resumen

La Orinoquía colombiana es en una de las regiones más importantes para el desarrollo agrícola del país. El departamento del Vichada, en particular, ha experimentado un incremento de plantaciones forestales comerciales, alcanzando 110.589 ha en 2021. Sin embargo, son pocos los estudios que permiten entender los posibles efectos que tienen estos cambios de uso del suelo sobre los mamíferos. En este estudio, se comparó la diversidad y composición de mamíferos terrestres entre plantaciones forestales, bosques de galería y sabanas naturales en Puerto Carreño (Vichada). A través de un muestreo con 64 cámaras trampa durante ocho meses (5840 días/cámara) entre agosto-2023 y marzo-2024, se obtuvieron 1.087 registros independientes de 23 especies (bosque: 775, plantación: 295, sabana: 17). Los indicadores de diversidad mostraron que el bosque de galería es casi el doble de diverso que las plantaciones forestales, con una riqueza estimada 26 y 13 especies, respectivamente, mientras que en la sabana se estimaron solo cinco especies. La diferencia en riqueza de especies no fue significativa entre la sabana y las plantaciones. Las

especies más comunes en los bosques fueron la lapa (*C. paca*) y pecarí (*T. pecari*), mientras que, en las plantaciones fueron comunes los venados (*O. virginianus*) y los zorros (*C. thous*). Los resultados demuestran la importancia del bosque para la conservación de mamíferos en paisajes productivos de la Altillanura colombiana, y al mismo tiempo permiten confirmar que las plantaciones forestales son usadas por varias especies, incluso unas pocas fueron detectadas con mayor frecuencia en plantación que en las otras coberturas. Así mismo, la presencia de cinco especies amenazadas resalta la importancia de implementar estrategias de conservación en estos paisajes productivos. Se recomienda fortalecer el monitoreo en la sabana natural para analizar con mayor precisión los posibles efectos de la forestación en este tipo de cobertura.

1. INTRODUCTION

Tree plantations are an increasingly important resource worldwide. This type of production allows to obtain wood, energy generation, and carbon capture, among others (FAO, 2020). Globally, 44% of tree plantations are composed of introduced species, although there are large differences between regions (FAO, 2020). On the American continent, for example, plantations consist mostly of native species in the North and Central, while in South America they consist entirely of Exotic species. The expansion of this type of crop has generated debate about the potential effects they may have on biodiversity (Villa et al. 2008). However, information about these landscapes is very limited at the national level and there is still no general diagnosis that allows us to understand the ecological dynamics within these landscapes (Barlow et al. 2007).

In Colombia and Costa Rica, some studies have pointed out the usefulness of planted areas for bird and mammal conservation. In this way, it is suggested that this type of cover can contribute to reducing the effects of fragmentation in anthropogenic landscapes by presenting a greater diversity of species compared to other productive systems, such as pastures (Renjifo 2001; Cárdenas et al. 2004; Sánchez-Londoño et al. 2021). On the other hand, forest plantations can complement existing habitats by providing new structures in the landscape for these groups, hosting both generalist and specialist species (Duran and Kattan 2005; Sánchez-Londoño et al. 2021). Nevertheless, it has also been suggested that since these systems are homogeneous, forest plantations are not capable of offering shelter and/or adequate resources for some species, limiting their diversity (Barlow et al. 2007; Lentijo and Kattan, 2005) or habitat use (Rodrigues & Chiarello, 2018). As with other crops, evidence has shown that not all species respond equally to landscape change, and some of them are more tolerant than others to monocultures (e.g. oil palm plantations or forest plantations). Therefore, species show different patterns of habitat use, richness, and abundance between covers and depending on landscape contexts (Felton et al. 2010; Pardo & Campbell et al. 2018; Paviolo et al. 2018; Sánchez-Londoño et al. 2021). This debate highlights the need to further investigate the role of tree plantations on biodiversity conservation and their relationship with populations of different groups, such as mammals.

The Orinoco region is an important area for agroindustry growth at the national level (Departamento Nacional de Planeación, 2014; Serrato-Álvarez and Ramírez-Daza, 2018).

Vichada, for example, is the second department in Colombia with the largest area destined for the expansion of plantations, reaching 110,589 hectares planted by 2021 (Minagricultura, 2021). Nevertheless, there is little evidence of the effects of tree plantations on mammal communities. Lasso et al. (2011), suggest that this agroindustry has decreased the quality and quantity of habitats to sustain the diversity and composition of wild populations in this region. However, clear evidence of the potential effects of agriculture intensification on biodiversity is still scarce in this department and across Colombia. Therefore, it is important to understand the responses of wild populations to land-use change to visualize management strategies in agricultural areas and develop effective wildlife conservation plans and policies (Rodrigues and Chiarello 2018).

Colombia has 551 species of mammals (Ramírez-Chaves et al. 2024), of which, at least 196 species have been recorded in the Orinoco region (Pardo-Martínez and Rangel-Ch. 2014). Despite recent studies on this group, and even the description of new native bats such as *Vampyressa voragine* (Morales-martínez et al. 2021) and *Lonchorhina orinocensis* (Páez-Vásquez et al. 2020), as well as the marsupial *Didelphis imperfecta* (González et al. 2020), this region remains one of the least studied in the country (González-Orozco et al. 2023; Mosquera-Guerra et al. 2018). Although protected areas are irreplaceable in protecting nature, by themselves they will not be able to maintain viable vertebrate populations, due to external pressures around them (Laurance et al. 2012). For this reason, the importance of understanding the matrices across human-dominated landscapes is being increasingly recognized to achieve effective management of biodiversity (e.g. Franklin and Lindenmayer 2009). Therefore, alliances with the private sector allow new opportunities for expanding knowledge of biodiversity within heterogeneous and productive landscapes. In the present study, we aimed to describe the diversity and composition of medium and large mammals in different land-use covers of a landscape dominated by commercial tree plantations in the Vichada department to contribute to this knowledge gap and foresee biodiversity management recommendations and research needs in this area.

2. MATERIALS AND METHODS

2.1. Study area

We carried out this research on seven properties of Forest First Colombia (FFC), a tree plantation company in the municipality of Puerto Carreño (Vichada) that expanded to approximately 40.000 hectares in total. Some of the surveyed properties (camps) are close to important Orinoco River tributaries such as the Meta River, Bita River (Ramsar Site), Caño Juriepe, Caño Muco, among others (FIGURE 1). FFC's properties are located in the Altillanura subregion at an average elevation of 88 m. a. s. l. (58-110) and an average annual temperature of 26ºC. Its soils have low fertility, high acidity, and aluminum saturation (Lavelle et al. 2014; Serrato-Álvarez and Ramírez-Daza 2018). The climate is bimodal with a dry season between November and April (16% of rain), and a rainy season that extends from May to October which represents 84% of the total annual rainfall (Rangel-Ch et al. 2019). The Company has environmental certification from the Forest Stewardship Council®.

Studied properties (Toro 1, 3, Delicias, Tierra Adentro, Hato Nuevo, Paraiso, and San Cristobal; FIGURE 1) have three main types of vegetation cover. Riparian or gallery forests

along the riverbanks (hereafter collectively referred to as gallery forests regardless of their flooding pattern) cover an area of approximately 3.500 ha, natural savannas (~ 6.200 ha), and tree plantation, which covers the largest area with around 16.150 hectares. Tree plantations (hereafter plantations) are dominated by exotic species such as acacia (*Acacia mangium*), eucalyptus (*Eucalipto pellita*), and pine (*Pinus caribaea*), the latter species being the oldest (18 to 20 years old). In all cases, plantations only replaced areas of natural savanna with different vegetation/grass types and levels of anthropogenic intervention. Currently, acacia and pine plantations are not being managed with chemicals or fertilizers as the company is focused on eucalyptus, which they manage with different authorized products to control pests (e.g. ants) and weeds.
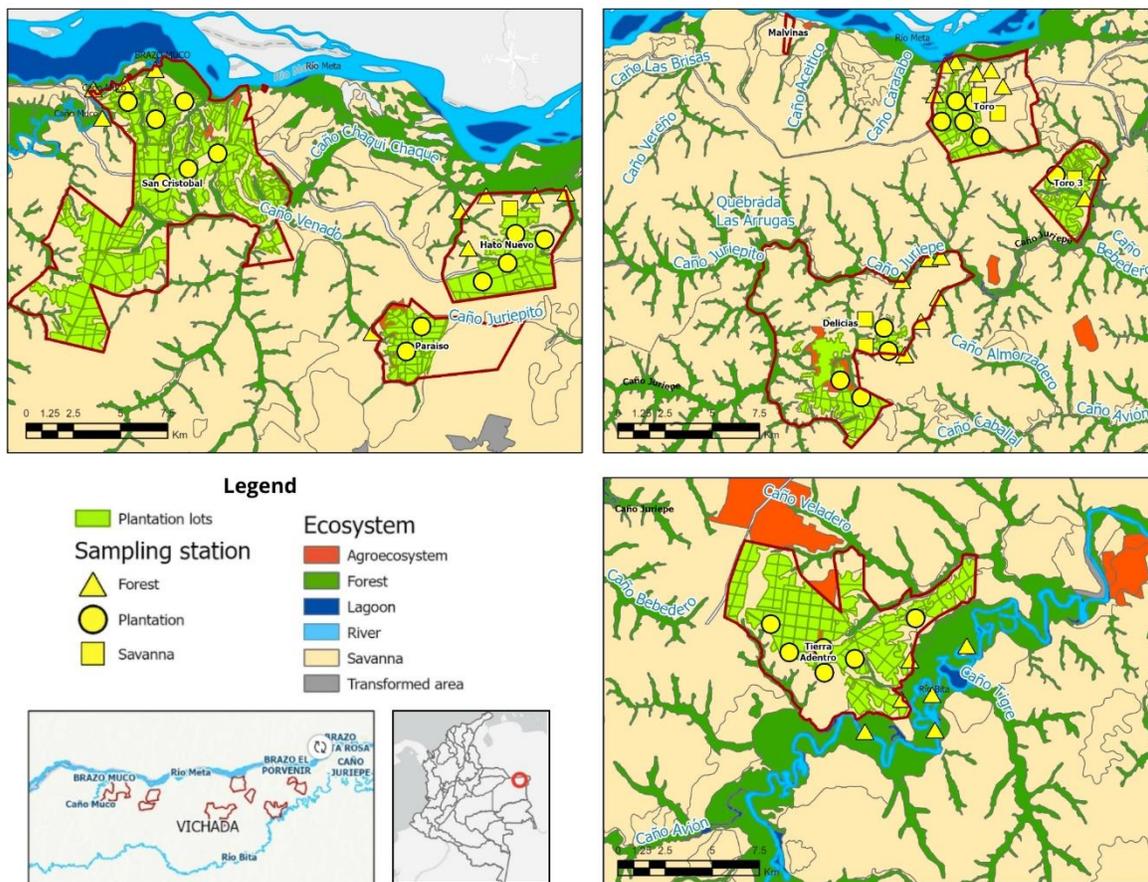

FIGURE 1. Location of the study area showing natural covers, tree plantations, and camera trap sampling design.

2.2. Sampling design and data collection

To detect medium and large-sized mammal species (> 1 kg) we deployed camera traps (sampling site) across two survey seasons. In the first season we installed 29 cameras between August and November 2023 (rainy season), while in the second survey season (November 2023 to March 2024; dry season), we installed 66 cameras (one camera per site in both seasons). Most of the sites sampled during the first season were maintained during the second (so they are not considered additional sites). However, given that during the

dry season, access to the forest is easier, for the second season we moved six cameras further into the forest (e.g. Bita River). Since the relocation of the above cameras did not exceed 1.5 km from the previous site, we considered these two seasons as a single site in analyses. That is, by joining some forested sites, the final number of replicates we analyzed as independent sampling units was 62 sites (also discounting some sites where the cameras did not activate correctly, i.e. 3). Cameras were systematically installed across the three predominant land covers, gallery forest (n=30), natural savanna (n=6), and commercial forest plantations (acacia=20, eucalyptus=4, and pine=2) with an interspace distance of ~1.5 km in a straight line to interpret each camera as an independent replicate. The number of cameras was primarily selected trying to balance de availability of devices and maximize the coverage per cover.

We used Panthera V6 and Cuddeback X-Change™ Color 1279 camera traps. We deployed the cameras at a height between 30 and 60 cm from the ground and programmed them to take sequences of three photos with an interval of three seconds. We organized and stored photos of detected species through the online platform Wildlife Insights (Ahumada et al. 2020). To generate a list of species with the updated taxonomy, we followed (Ramírez-Chaves et al. 2024) and only those species with absolute certainty of their classification were included in the analysis. To identify the threat categories of each species at the national level we used resolution 0126 of 2024 (Minambiente, 2024), and at a global level the IUCN red list (www-iucnredlist.org).

2.3. Diversity

To understand the diversity and composition of species in the different land-use cover types we used two approaches: 1) true diversity indicators or Hill numbers (Hill, 1973; Jost, 2006) and 2) Nonmetric Multidimensional Scaling (NMDS), respectively. The true diversity index represents the equivalent number of species in the different communities or assemblages (i.e. depending on land-use cover type). Therefore, it allows a more direct comparison between communities than other indexes. At the same time, it provides a quantification of sampling success through rarefaction/extrapolation curves. True diversity is composed of the following three estimators: zero-order diversity (q = 0 or richness), representing the total number of species, and diversity of order 1 (q=1 or Shannon exponential) which describes the number of common effective species maintaining the average abundance of the community. This index can be interpreted as equity, that is, how similar are the relative abundances of species in the assemblage. The third estimator is the diversity of order 2 (q = 2 or Simpson's inverse), which is equivalent to the number of effective dominant species in a community (i.e. those with the highest abundances (Jost 2006).

We estimated different diversity parameters (q0, q1, q2) through extrapolation using independent events through the abundance-based calculation (Chao et al. 2014). Since the sampling effort was different between each land-use cover, we estimated these parameters with a sample of 1000 individuals. We did not use the sample size of the least sampled land-used cover (i.e. that with the fewest individuals) since it would have been the savanna, and this cover had very few individuals and a relatively low completeness. After we estimated the above parameters, we constructed a diversity profile using the 95%

confidence intervals as an approximation to community structure (Chao et al. 2014; Sánchez-Londoño et al. 2021). If confidence intervals did not overlap, we considered it as evidence that diversity between land-use types was significantly different. We performed these analyses using the 'iNEXT' package (Chao et al. 2016) in the R programming environment (R Core Team, 2020).

2.4. Relative abundance and composition

We used catch rates as an approximation to the relative abundance of species. Relative abundance indexes (RAIs) refer to the number of detections or independent photos (i.e. events) of each species taking into account the camera's sampling effort. We calculated two forms of RAIs. The first one considers the total effort with the sum of all days cameras were active (RAIgral) (i.e. days/cameras) and the other one takes into account the days each camera was active (IARalt) (Mandujano 2024). This last index is useful to compare sites and see data dispersion (e.g. mean and associated error). In this study, the term relative abundance (RAI) was used because it is more intuitive for the reader, but it is important to keep in mind that these indices do not strictly represent population size (see (Mandujano 2024) and should be interpreted only in terms of how common are species in the area. As a criterion for independence in records (photos) of the same species, we used 60 minutes between consecutive photos (Hernández-Díaz et al. 2012). When a group was detected, it was considered as a single individual.

Finally, to analyze the difference in composition of the assemblages (i.e. distribution of the relative abundance of each species between land-use cover types and sites), we used the Nonmetric Multidimensional Scaling (NMDS) technique based on a Bray Curtis similarity matrix (Clarke and Gorley 2006). NMDS is an ordination technique that separates RAIs into ranges of distances instead of absolute values, which allows a better interpretation of results and corrects for the high mean-variance relationship common in this type of count data (Clarke and Gorley 2006). We conducted this analysis using the ggvegan package of the R statistical software (R Core Team, 2020).

3. RESULTS

With a sampling effort of 5.840 camera days, we obtained 1.087 events (independent photos) from 23 medium and large-sized wild mammals, in addition to three domestic/feral species such as feral pigs (*Sus scrofa feralis*), dogs (*Canis lupus familiaris*) and cows (*Bos indicus*). Wild species were grouped into nine orders and 18 families (TABLE 1). All these species were detected in gallery forests, accounting for 775 events, while in plantations, 12 species were detected (295 events), and in natural savannas only four (17 events). The most common or frequent species were the spotted paca (*Cuniculus paca*, 203 events), and white-lipped peccary (*Tayassu pecari*, 173 events), while the least frequent were jaguar (*Panthera onca*) and Jaguarundi (*Herpailurus yaguaroundi*) that were restricted to the forest with only one and two records respectively (FIGURE 2). There were no species exclusively recorded in the plantation or the savanna. Some species were recorded only once in plantations, such as the ocelot (*Leopardus pardalis*) and the giant armadillo (*Priodontes maximus*), while two species were more common in the plantation than in the forest or savanna, the white-tailed deer (*Odocoileus virginianus*) and crab-

eating fox (*Cerdocyon thous*) in terms of independent events and sites occupied, followed by the giant anteater which appeared in ~54% of the sites inside plantations. Only four species were detected in the three covers (TABLE 1). We also detected giant otters (*Pteronura brasiliensis*) in the Caño Muco and the Bita River by direct observation, but these records were not included in the formal analysis.

TABLE 1. Detected species in Puerto Carreño, Vichada showing the number of independent events and the proportion (%) of occupied sites (in parentheses) in different land use types. Asterisks are the threat category according to the list of threatened species in Colombia (Minambiente, 2024): * = VU (Vulnerable), ** = NT (Near Threatened), *** = EN (Endangered). Caution is suggested when interpreting independent events since they do not consider sampling effort.

Order	Family	Common Name	Scientific Name	Tree Plantations	Native Forest	Savanna
Didelphimorphia	Didelphidae	Common Opossum	*Didelphis marsupialis*	2 (7)	11 (17)	0
		Brown Four eyed Opossum	*Metachirus myosurus*	0	27 (13)	0
Cingulata	Chlamyphoridae	Giant Armadillo	*Priodontes maximus* *	1 (4)	9 (17)	0
	Dasypodidae	Pastaza Longnosed Armdillo	*Dasypus pastasae*	0	2 (7)	0
Pilosa	Myrmecophagidae	Southern Tamandua	*Tamandua tetradactyla*	1 (4)	14 (27)	0
		Giant Anteater	*Myrmecophaga trdctyla* *	30 (54)	35 (37)	1 (17)
Rodentia	Cuniculidae	Spotted Paca	*Cuniculus paca*	0	205 (80)	0
	Dasyproctidae	Black Agouti	*Dasyprocta fuliginosa*	0	88 (33)	0
	Caviidae	Capybara	*Hydrochoerus hydrochaeris*	0	12 (20)	0
	Sciuridae	Northern Amazon Red Squirrel	*Hadrosciurus igniventris*	0	3 (10)	0
	Echimyidae	Spiny Rat	*Proechimys sp.*	0	1 (3)	0
Lagomorpha	Leporidae	Eastern Cottontail	*Sylvilagus floridanus*	6 (4)	1 (3)	0
Carnivora	Felidae	Puma	*Puma concolor*	6 (7)	14 (33)	0
		Ocelot	*Leopardus pardalis*	5 (14)	47 (57)	0
		Jaguar	*Panthera onca* **	0	1 (3)	0
		Jaguarundi	*Herpailurus yagouaroundi*	0	3 (7)	0
	Canidae	Crab-eating Fox	*Cerdocyon thous*	50 (60)	7 (7)	1 (17)
	Mustelidae	Tayra	*Eira barbara*	3 (7)	28 (43)	0
Perissodactyla	Tapiridae	Lowland Tapir	*Tapirus terrestris* *	10 (21)	75 (70)	2 (17)
Artiodactyla	Tayassiudae	White-lipped Peccary	*Tayassu pecari* ***	2 (7)	173 (70)	0
	Cervidae	White-tailed Deer	*Odocoileus virginianus*	177 (89)	10 (83)	13 (67)
Primates	Atelidae	Colombian Red Howler Monkey	*Alouatta seniculus*	0	1 (3)	0
	Cebidae	Humboldt's White-fronted Capuchin	*Cebus albifrons*	0	3 (3)	0

3.1. Diversity and composition

Species rarefaction curves indicate that sampling effort was sufficient, reaching clear asymptotes for each land-use cover type (FIGURE 3). This suggests that we captured more than 98% of the probable species in the area. However, for the savanna, the curve of observed species did not reach a clear asymptote, which suggests caution when interpreting the results (although sample coverage was ~87%, see Appendix 1: Figure 1A). Curves and diversity profiles also show that gallery forests were more diverse in each diversity indicator (q0, q1, q2) (FIGURE 2). As such, approximately twice as many species were detected inside the forests as in plantations, and their confidence intervals suggest that this difference was significant. On the contrary, differences between plantation and savanna were not significant, although in the savanna we detected 30% of the species found in plantations but only 17% of species from forest. In plantations, we detected approximately 52% of species recorded in the forest.
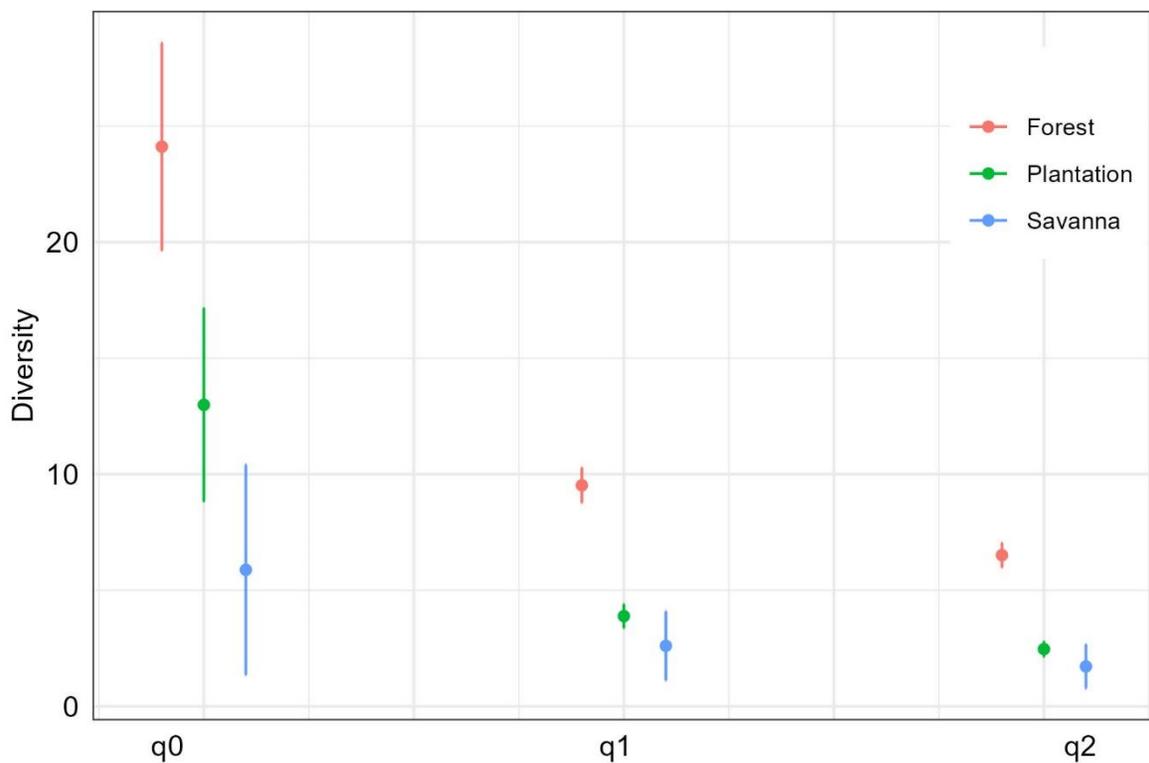
FIGURE 2. Diversity profile with three diversity indicators (q0, q1, q2) estimated with a sample of 1000 independent events ("individuals"). Bars indicate the 95% confidence intervals.

The NMDS (stress = 0.19) shows differences in composition between sites sampled in plantations and forests, while the savanna tended to have a more similar composition to plantations (FIGURE 5). The analysis also shows a wide uncertainty regarding savanna composition where sites are far from each other and the other cover types. The NMDS also indicates that sites within plantations and forests were very similar in. Regarding the distribution of species, the white-tailed deer, the lowland tapir (*Tapirus terrestris*), and the giant anteater (*Myrmecophaga tridactyla*) were the most widely distributed species in the study area, being detected in more than 20 sites (FIGURE 4, TABLE 1).
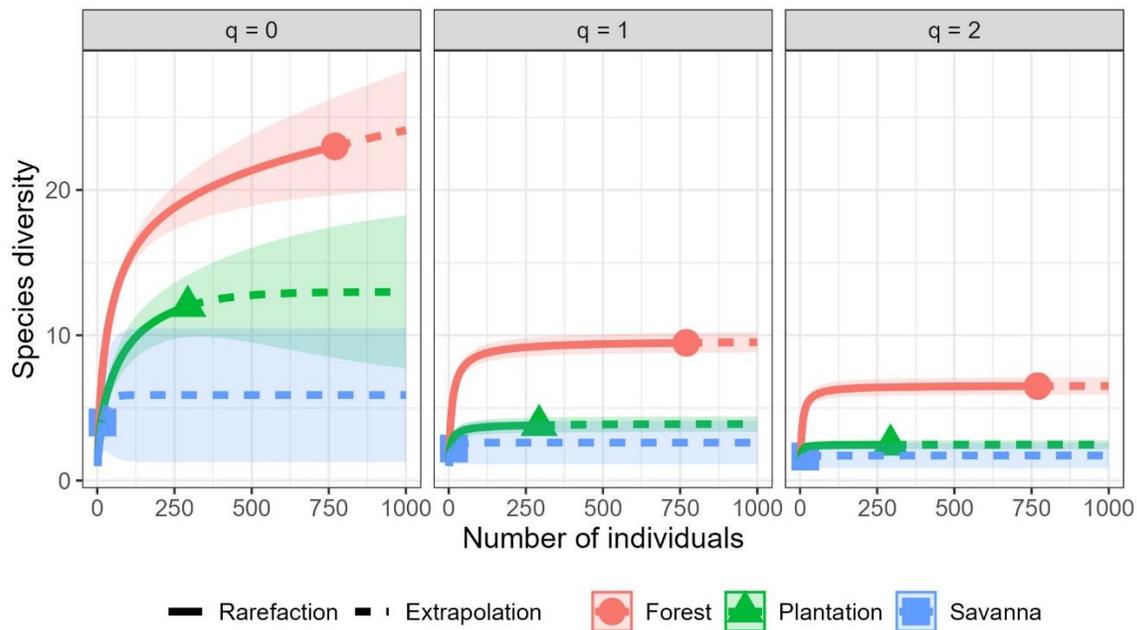
FIGURE 3. Rarefaction and extrapolation curves with estimates of three diversity indices calculated with the independent events of each species ("abundance") and a sample of 1000 individuals.
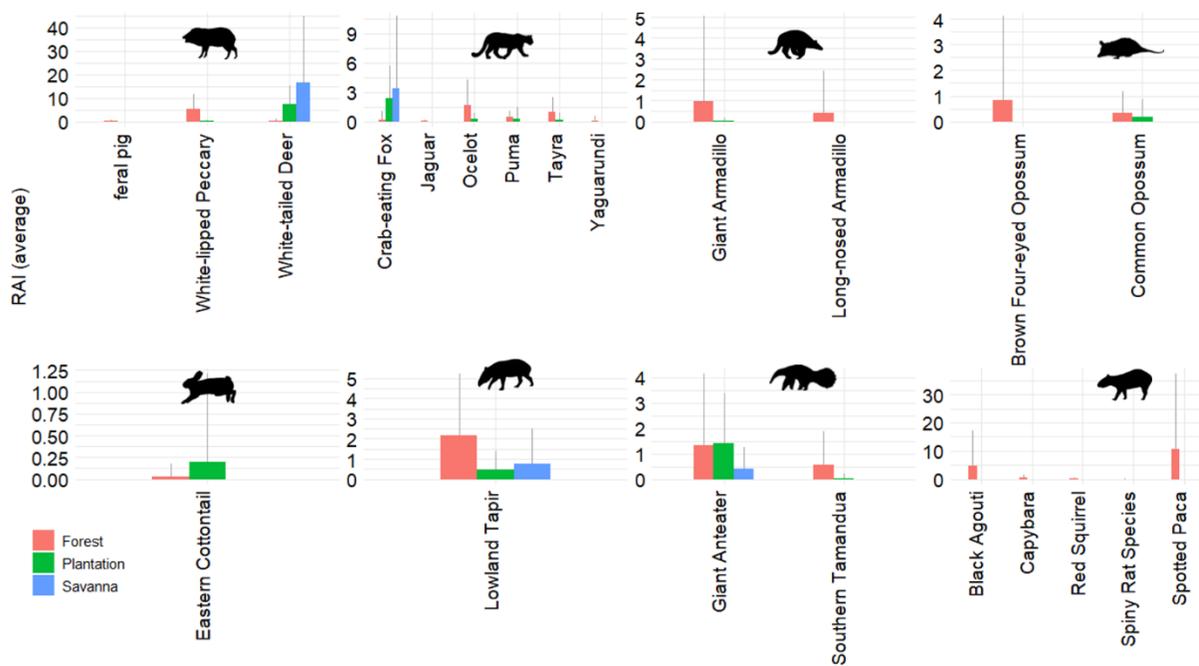

FIGURE 4. Average relative abundance index (RAIalt) for each site with bars indicating the dispersion of data (SD). Primates are not shown. Animal icons from the package rphylopic (Gearty and Jones 2023, https://www.phylopic.org/).

In general, all species detected in the forest and plantation were much more common (frequently recorded) in the forest, except white-tailed deer and foxes, recorded more frequently in plantations (TABLE 1), while detections of the giant anteater were similar for

the two land-use types. Mesocarnivores such as tayras, ocelots, and foxes were present in plantations. As for felines, the most common was the ocelot detected in 17 forest sites (47 events) and four plantation sites (5 events), followed by the puma with 14 events in 10 forest sites and six events in two plantation sites. The jaguarundi was scarce with only three events in two forest sites. As for prey, rodents, such as squirrels (*Hadrosciurus igniventris*), black agouti (*Dasyprocta fuliginosa*), spotted paca (*Cuniculus paca*) and capybara (*Hydrochoerus hydrochaeris*), were restricted to forest cover (TABLE 1), while, rabbits (lagomorphs) were detected on few occasions and in a single forest and plantation sites.
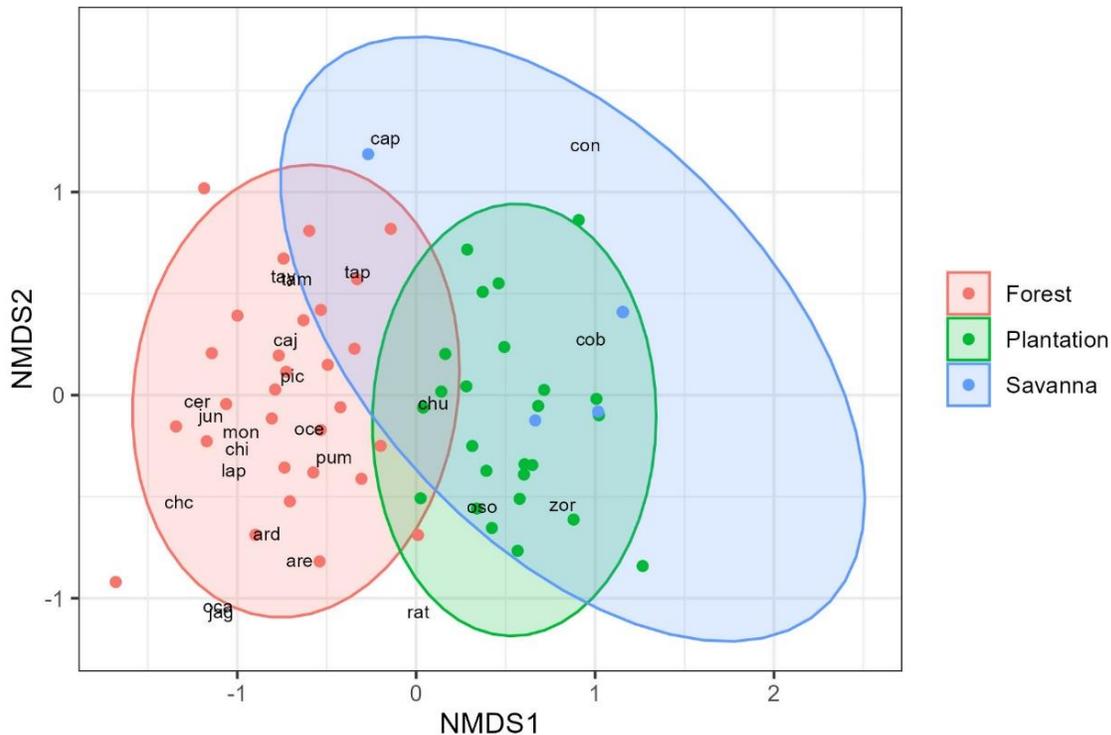
FIGURE 5. Composition of the community of medium and large-sized mammals in three land-use types. The graph shows the results of an NMDS (see text) using IARalt. Dots represent the sites and letters represent the species (to see the equivalence of the code, refer to Appendix 1: Table 1A). Stress = 0.19.

4. DISCUSSION

4.1. Diversity

This study described how communities of medium and large-sized mammals vary in landscapes dominated by tree plantations. Results indicate that richness, diversity, and composition are significantly higher in forests compared to plantations and, natural savannas, as expected. The species recorded in this work are equivalent to 68% of the probable species that can be detected by camera trapping in the area (34). Species that were not detected, but have been detected in other surveys include the porcupine (*Coendou longicaudatus*) detected by Ecolmod (2023) and Mosquera-Guerra et al. (2018), as well as wild curies (*Cavia aperea*), and the llanos long-nosed armadillo (*Dasypus*

sabanicola), that was mentioned by local people through participatory monitoring that is being carried out on these lands. Likewise, taking into account the distribution of species, as well as the records in GBIF and other sources, the following species could also be present in the area, but went undetected in our study: bush dog (*Speothos venaticus*) recorded in the Bita River, crab-eating raccoon (*Procyon cancrivorus*), neotropical otter (*Lontra longicaudis*) and ring-tailed coati (*Nasua nasua*) detected by Mosquera-Guerra et al. (2022), as well as white-eared opossum (*Didelphis imperfecta*), registered in Bojonawi nature reserve in Puerto Carreño, Vichada (González et al. 2020) and marmosa (*Marmosa robinsoni*) reported by Páez-Vásquez (2023).

The species richness found in this work is similar to that reported by (Mosquera-Guerra et al. 2018) who detected 24 species of mammals with an effort of 7.700 nights/traps in forests of the Bita River. In this study, we only detected 13 species in the Bita River sector (Tierra Adentro Plantation), which suggests that this river can host all the species that were detected across the seven plantations. It is important to note that this difference may be because the sampling effort in forest cover of the present study represents only 41% of the sampling effort done by (Mosquera-Guerra et al. 2018) which was about 200 km of the Bita River towards the upper basin. In the present study, the effort was concentrated only in the strip belonging to FFC properties in Tierra Adentro, covering approximately 12 km of forest.

The differences in diversity between gallery forests and plantations were more evident than reported in other studies. For instance, Sánchez-Londoño et al. (2021), found that the diversity profiles of terrestrial mammals in plantations in the Andes and the Caribbean were relatively similar, with an expected richness of 18 species in the native forest compared to 14 species in the teak plantation. However, as in the present study, the authors found that the proportion of records was higher in native forests. It should be noted that the majority of plantations in that study were in pine and teak crops, while in our study, the majority of plantations were in acacia and eucalyptus. Future studies should seek to understand whether age or variety of plantations influences the way wild species make use of these covers, as well as if the surrounding matrix could have an impact on the biodiversity host along gallery forests, such as the Bita River. In the case of the FFC area, acacia plantations tended to be more diverse with around 13 species, while pine and eucalyptus had five species each. This, however, may be due simply to the fact that there are few eucalyptus and pine plantations in the area, so other studies are needed to confirm this pattern.

4.2. Composition

Although the effect of agricultural expansion usually has negative effects, certain species find refuge or are very tolerant to these new ecosystems. For example, species richness in oil palm plantations in the Llanos region may represent about 48% of the species recorded in the forest (Pardo, et al. 2018) which is similar to what we recorded in this study (~50%). In this sense, it has been seen that species such as white-tailed deer, foxes, and giant anteaters, as well as ocelots and Jaguarundis, are common in these areas and even more abundant than in native forests, as is the case of the latter (e.g. Pardo, Campbell, et al. 2018; Pardo et al. 2019). Our results showed a similar trend, with deer and foxes being the

dominant species in tree plantations. Twelve species were found in both plantations and forest, while four of these were also found in savanna. However, there is no evident trend of the type of species shared with plantations, as they encompass different niches. For example, their food habits expand from very generalist species such as the foxes, to species with narrow diets such as the peccaries, and even insectivores such as the giant anteater. One of the most relevant differences between oil palm and tree plantations in the eastern plains or llanos region is the frequency of jaguarundi detections. This species was reported more frequently in oil palm plantations than in tree plantations, where it was not detected (although workers suggest that they have seen it occasionally). Our results agree with those of (Cruz et al. 2018) who did not obtain records of this species in areas with pine plantations, but in native continuous or fragmented forest covers in the Atlantic Forest (Brazil), and those of Sánchez-Londoño et al. (2021) in the Colombian Andes. Our results regarding felines' presence are similar to those of Sánchez-Londoño et al. (2021). However, these authors did not detect ocelots in plantations.

There are no biodiversity management protocols currently being implemented in the plantations apart from hunting banning. This banning might also influence the movements of species across plantations but whether plantations are only used as passways or habitats perse is still unclear. Our results show that forest is pivotal for maintaining mammal diversity, and it seems to be having a spillover effect on plantations, where even threatened species use plantations. Four threatened species were detected inside plantations (two of them not detected in savanna) which raises questions about the best practices required inside plantations to protect them. This also suggests that these species might not be displaced by changing savanna to tree plantations, and probably the coverage and microclimatic conditions offered by plantations might attract these species to move across this cover more often than savannas themselves (e.g. lower temperature, possibilities of being less detected by predators, etc.). Future research should elucidate the factors associated with this dynamic, and clarify if more species prefer to move through plantations instead of open savannas. In this sense, a monitoring program will help to understand if this trend holds and if passive or active management is necessary. We acknowledge that the sampling effort for savannas might not be sufficient and that the potential low detection probabilities for species in savannas might influence these results. Therefore, caution is advised when directly comparing savannas. However, our sampling coverage suggests that we captured at least 85% of the probable species.

In Chile, (Zúñiga et al. 2009) found that pumas preferred coniferous' plantations (with bushes) to native vegetation, while (Lantschner et al. 2012) did not find significant differences in the relative abundance of this species to other natural covers in Patagonia (Argentina). Similarly, there is evidence that puma is not affected by plantations and could even take advantage of this coverage, probably due to its ability to exploit a wider range of habitats compared to other felid species (De Angelo et al. 2011; Iriarte et al. 1990). In our study, the puma was not a rare species and moves interchangeably between plantations and forests (with a greater tendency to be detected in the forest), very similar to what was found by (Sánchez-Londoño et al. 2021) in the Colombian Andes. Another aspect that could benefit this species is the availability of prey such as white-tailed deer (Olarte-González et al. 2015) or rabbits (Zúñiga et al. 2009). On the other hand, the jaguar was recorded only

once in this study. However, three records were obtained in surveys conducted in 2022 and 2023 (Páez-Vásquez 2023). All records of this species, including the one in this study, occurred in the dry season. Because jaguar requires large, well-conserved areas (Boron et al. 2016), the presence of this species in gallery forests suggests its importance as movement corridors between unprotected forested areas of this region. The FFC area of influence is in a strategic location that could facilitate connectivity between Bita River (Ramsar site) and El Tuparro Natural National Park (NNP) in Vichada, and with Cinaruco National Management District in Arauca or El Tuparro NNP with the Capanaparo-Cinaruco NNP in Venezuela.

Although Llanos long-nosed armadillo (*Dasypus sabanicola*) has almost an exclusive habitat preference for natural savannas (Chacón-Pacheco et al. 2020), this species was not recorded in our study (however, we saw this species after retrieving cameras, pers obs.). This is a threatened species, so monitoring its populations could serve as a good indicator of the potential effect of transforming natural savannas into tree plantations. Pastaza long-nosed armadillo (*Dasypus pastasae*), on the other hand, is usually difficult to detect in the field, even with camera traps, and is restricted to forest habitats (Aya-Cuero et al. 2021). In this study, only two records of this species were obtained within forest cover, despite good sampling efforts. Finally, regarding giant armadillos, it has been suggested that they tolerate a certain degree of anthropogenic intervention (Carter et al. 2016; Silveira et al. 2009), but its presence in plantation covers is not frequent, so this species usually depends exclusively on forest and occasionally ventures into natural savannas. In this study, a giant armadillo was recorded only once in an acacia plantation. These results might reflect that this species only uses plantation as a sporadic transitory ecosystem and not a permanent one where they can build burrows (which we did not observe).

The two anteater's responses were different. On one hand, giant anteaters seemed to be tolerant and even thrive in plantations as it was found in more than half of the sites in this cover, while the Tamandua was more common in the forest in terms of capture frequencies and distribution. Despite being a vulnerable species adapted to savannas-type ecosystems, the giant anteater is also known for occupying anthropogenic landscapes and industrial production such as oil palm (Pardo et al. 2018) and pastures (pers. obs). However, this species cannot survive without the availability of forests (Mourao and Medri, 2007). Both species feed almost exclusively on ants and termites, although tamanduas use more canopy habitats in forested areas than savannas perse, where they can also consume ripe native palm fruits (Brown 2011), which could partially explain the pattern we observed. The same pattern has been observed in oil palm too (Pardo et al. 2019), but further research is needed to elucidate what resources are being used by these species, and if this pattern is associated with competition strategies or niche segregation.

It is interesting to note that in the middle basin of Planas River (border between Meta and Vichada departments), an investigation near the study area (separated by at least 400 km of open area without geographic barriers) detected Collared Peccary (*Dicotyles tajacu*) with a high detection rate (Aya-Cuero et al. 2019). However, we did not detect it in FFC area. On the contrary, the dominant species was white-lipped peccary, which, was not recorded in (Aya-Cuero et al. 2019) study. Our results are in concordance with those described by (Mosquera-Guerra et al. 2024). Both species belong to the same family and are very similar

to each other, with the difference that white-lipped peccary is larger and is in a threatened condition. However, collared peccary tends to use savannas more than white-lipped peccary, a cover type that is found in a lower proportion in the study area compared to the sampling area of Aya-Cuero et al. (2019).

We did not detect any primate species inside the plantations. However, some people suggest that white-fronted capuchins *(Cebus albifrons)* are rarely seen inside the plantations. This is a very tolerant species that have been registered inside other industrial plantations such as oil palm (Pardo et al. 2018) and in other tree plantations such as teak (Sanchez-Londoño et al. 2021). Contrary to the capuchins, the red howler monkeys seem not to cross tree plantations. However, other studies have found that howler monkeys can traverse eucalyptus plantations to feed on native vegetation, but the surrounding forest is preferred (Bonilla-Sánchez et al. 2012) We acknowledge, that camera trap is not the best technique for sampling arboreal species therefore suggest further studies about the responses of these species to increasing plantations in the Llanos.

The effect of natural cover transformation on biodiversity has been studied with greater emphasis on natural forests and processes associated with deforestation or reforestation. However, little is known about the effects of planting trees in ecosystems that evolutionarily do not have as many trees such as savannas of the Orinoquia (a process known as afforestation). In the study area, forest plantations are transforming natural non-undulating savannas, so our results are a first input to understand these potential effects. Although our design does not allow for more robust conclusions, since there is no study with the same design before the implementation of the plantation, some comments can be made. In this way, our results suggest that savanna per se does not host a high diversity of species, and plantations that today occupy savanna areas have more diversity. Although the effectiveness of the survey within the savanna was not less than 85%, it would be important to conduct a broader study of savannas with greater coverage to make more robust predictions.

Tree plantations are generating a new dynamic in these landscapes, therefore, conservation strategies in productive areas must be focused on the whole landscape configuration. That is, maintain the heterogeneity of habitats and ecosystems characteristic of the plains and not focus only on one type (e.g. forest). Our data suggest that plantations are used by several species, but relative abundance was higher only for two generalist species. This indicates the use of resources by a few species, whether as foraging areas, refuges, or areas that allow transit from one place to another. In this sense, it is possible that some species such as pumas, ocelots, and some prey such as white-lipped peccaries and tapirs, use plantations to move between the surrounding forests where they remain more regularly. Plantations are transforming natural savannas in the Llanos region. Therefore, further studies are needed to plan this development in an environmentally friendly manner. Savannas are a threatened ecosystem (Etter et al. 2020) that needs careful planning in terms of not just mammal species but biodiversity as a whole and water resources.

5. CONCLUSIONS

Here, we estimated the diversity and composition of terrestrial mammals in a large agro-industrial area of the Vichada department. Our results indicate a significant difference in species richness between forest and tree plantations, which hosted around 52% of species recorded in the forest, while differences in diversity were not so sharp between savanna and plantation land covers. Savanna, showed reduced richness, detecting only 17% of total species, although we recommended expanding sampling effort (and exploring different sampling techniques). Rodents, primates, and armadillos seem to have a clear preference for forest covers, so we recommend evaluating whether these species find plantations as barriers. The presence of threatened species, such as the jaguar, and specialists, such as the giant armadillo is an indicator of the health of ecosystems, as well as the potential of the area to serve as a refuge for the conservation of these and other species (threatened or not). Our results suggest that plantations could serve as a passage for some species and in this way perhaps contribute to maintaining connectivity of this area. This is one of the first studies on biodiversity in tree plantations in the Llanos region and will serve as a basis for visualizing conservation and management strategies in this area. Future studies should cover more specific questions and investigate possible factors that promote or limit the use of forest plantations in the Colombian Orinoquia and the effect of land use change from savannas to plantations.

ACKNOWLEDGMENTS

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