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Contribution of agroecosystems to the conservation of bird diversity in the department of Caldas

Aporte de los agroecosistemas a la conservación de la diversidad de las aves silvestres en el departamento de Caldas

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ABSTRACT

Keywords:
Avifauna
Secondary forests
Structural complexity of the vegetation
Mixed-cropping
Mono-cropping
Plantations

In tropical regions, the contributions and limitations of agroecosystems have been identified with respect to bird diversity conservation. It has been suggested that agroecosystems can have different conservation values, according to the structural complexity of the vegetation (e.g., higher number of vegetation strata, cultivated species diversity, among others). Therefore, agroecosystems, especially those with a smaller area (e.g., small-holdings), could be crucial for developing bird conservation strategies. In order to establish the contribution of different agroecosystem types to bird conservation in the department of Caldas (Colombia), we compared bird richness, abundance, and similarity associated to three types of habitats: (1) type I agroecosystems (mono-cropping with bare soil), (2) type II agroecosystems (mixed-cropping, grazing pastures with weeds and dispersed trees, and plantations with understory), and (3) secondary forests. Type II agroecosystems did not differ in bird richness and similarity compared to secondary forests, and species with high sensitivity to disturbance were registered (*Zentrygon frenata*, *Phaetornis guy*, *Phaetornis syrmatophorus, Lepidocolaptes lacrymiger* and *Sphenopsis frontalis)*. Additionally, we registered a species of global conservation interest (*Chloropipo flavicapilla*) and four migratory species (*Catharus ustulatus*, *Parkesia noveboracensis*, *Setophaga fusca* and *Setophaga striata*) in this type of agroecosystem. Thus, type II agroecosystem habitats are not completely negative on avifauna, and they could serve an important role within conservation strategies in rural landscapes.

RESUMEN

Palabras clave:
Avifauna
Bosques secundarios
Complejidad estructural de la vegetación
Cultivos mixtos
Monocultivos
Plantaciones

En las regiones tropicales se han identificado los aportes y limitaciones de los agroecosistemas en el contexto de la conservación de la diversidad de las aves. Se ha sugerido que los agroecosistemas pueden presentar un valor diferente para la conservación, de acuerdo con la complejidad estructural de la vegetación (e.g., mayor número de estratos de la vegetación, diversidad de las especies cultivadas, entre otros). En este sentido, los agroecosistemas de una menor área (e.g., minifundios), pueden ser claves en el desarrollo de estrategias encaminadas a la conservación de la avifauna. Con el objetivo de establecer el aporte de diferentes tipos de agroecosistemas a la conservación de las aves en el departamento de Caldas (Colombia), se comparó la riqueza, abundancia y similitud de las aves asociadas a tres tipos de hábitats: (1) agroecosistemas tipo I (monocultivos con suelo limpio), (2) agroecosistemas tipo II (cultivos mixtos, potreros enmalezados con árboles dispersos y plantaciones con sotobosque) y (3) bosques secundarios. Los agroecosistemas tipo II no difirieron en la riqueza y en la similitud de las aves con respecto a los bosques secundarios, además se registraron especies con alta sensibilidad a la perturbación (*Zentrygon frenata*, *Phaetornis guy*, *Phaetornis syrmatophorus, Lepidocolaptes lacrymiger* y *Sphenopsis frontalis)*. Adicionalmente en este tipo de agroecosistemas se registró una especie de interés para la conservación global (*Chloropipo flavicapilla)* y cuatro especies migratorias (*Catharus ustulatus*, *Parkesia noveboracensis*, *Setophaga fusca* y *Setophaga striata*). Los agroecosistemas tipo II no son hábitats completamente negativos para la avifauna y podrían desempeñar un rol importante dentro de las estrategias para la conservación en paisajes rurales.

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Agroecosystems cover approximately 28% of the arable land surface; 31% of which is occupied by crops and the remaining 69% by low pastures (Wood *et al.*, 2000). In particular, approximately 61% of the arable area is found in tropical regions (Wood *et al.*, 2000), which contain most of the biodiversity of the planet (Gentry, 1992). In the next 30 years, a 13% increase in the area covered by agroecosystems will be necessary, prompted by the increasing demand of space for the production of food, wood, and other goods and services (Sala *et al.*, 2000; Bruinsma, 2003). It is known, though, that land use change (e.g., conversion of native forests to agroecosystems) is an important driver of global species extinctions (Díaz *et al.*, 2006; Dent and Wright, 2009); while, native forests are clearly fundamental for biodiversity conservation in the tropical region (Chazdon *et al.*, 2009; Gibson *et al.*, 2011). However, some agroecosystems could be contributing to conservation, since they contain several elements of the biodiversity found in forests (Castaño-Villa *et al.*, 2008; Gibson *et al.*, 2011), and the presence of wildlife in agroecosystems represents an opportunity to incorporate these lands into conservation plans (Simonetti *et al.*, 2012).

In this context, diverse studies in the Tropics have identified the contribution and limitations of agroecosystems (e.g., forest, cocoa, coffee plantations, among others) for bird diversity conservation (Faria *et al.*, 2006; Barlow *et al.*, 2007; Philpott and Bichier, 2012). The structural complexity of the vegetation within an agroecosystem (e.g., higher number of vertical strata) is a key factor that can promote the use of these habitats by birds, including those associated to native forests (Nájera and Simonetti 2010; Castaño-Villa *et al.*, 2014; Vergara-Paternina *et al.*, 2017). However, few studies have considered the importance of bird diversity conservation in agroecosystems at a smaller spatial scale in rural landscapes, such as smallholding agroecosystems (Petit and Petit, 2003; Cárdenas *et al.*, 2003). Rural landscapes cover 62% of the Colombian Andes (Arango *et al.*, 2003) and these are considered a key element in the development of biodiversity conservation strategies (Lozano-Zambrano *et al.*, 2009).

The department of Caldas presents the greatest habitat transformation rates, as well as 48% of the Colombian bird diversity (Corporación Autónoma Regional de Caldas y Asociación Calidris, 2010; Corpocaldas, 2016). This poses an ideal setting to assess the value of different agroecosystems for bird diversity conservation. Accordingly, this study compared avifauna associated to agroecosystems and secondary forests of the department of Caldas, with the aim of establishing the contribution of different agroecosystem types to bird conservation. Our hypothesis is that agroecosystems with a greater structural complexity of the vegetation contain some bird species associated to native forests, and consequently, contribute to the conservation of this group.

MATERIALS AND METHODS

Study area

The department of Caldas is located in the central west Andes of Colombia (4 4'19"N; 75 57'26"W). It is composed of mountainous areas belonging to the Central and Western Andes Mountain Ranges and the inter-Andean valleys of the Cauca and Magdalena Rivers. The department covers a surface area of 7457 km^2, with an altitudinal range between 140 to 5350 m of altitude. It presents an annual precipitation average of 2800 mm, with two rainy seasons (March – June and September – December) and two less rainy periods (January – February and July – August), and a temperature that varies from 13 °C – 27 °C (Jaramillo-Robledo *et al.*, 2011). In Caldas, agriculture spans 69.26% of the territory, with seasonal and permanent crops, while 21.88% is covered by native and/or planted forests. Coffee (*Coffea arabica* L.) is the main productive system in the department, followed in order of economic importance by plantain (*Musa* sp.), fruit trees (citric), and cocoa (*Theobroma cacao* L.) (Ministerio de Agricultura y Desarrollo Rural, 2006). In order to encompass this environmental diversity, we conducted bird surveys in 11 municipalities of the department: Pácora, Victoria, Samaná, Pensilvania, Manizales, Palestina, Chinchiná, Villamaría, Marmato, Riosucio, and San José, throughout an altitudinal range of 551 to 2679 m.

Habitats Selection

For sampling habitats selection, we used images from Google Earth version 7.1. Three types of habitats were selected from the images: type I agroecosystems (ATI, *n*=8), type II (ATII, *n*=5), and secondary forests (SF, *n*=8) (Figure 1). Eight habitats were defined as type I agroecosystems, namely mono-cropping with bare soil (ATI_1: cocoa; ATI_2: avocado; ATI_3: lemon; ATI_4: pasture; $ATI_{5:}$ papaya; ATI_6: citric; $ATI_{7\text{-}8:}$ coffee; Table 1). Five habitats were assigned as type II agroecosystems, including mixed-cropping, grazing

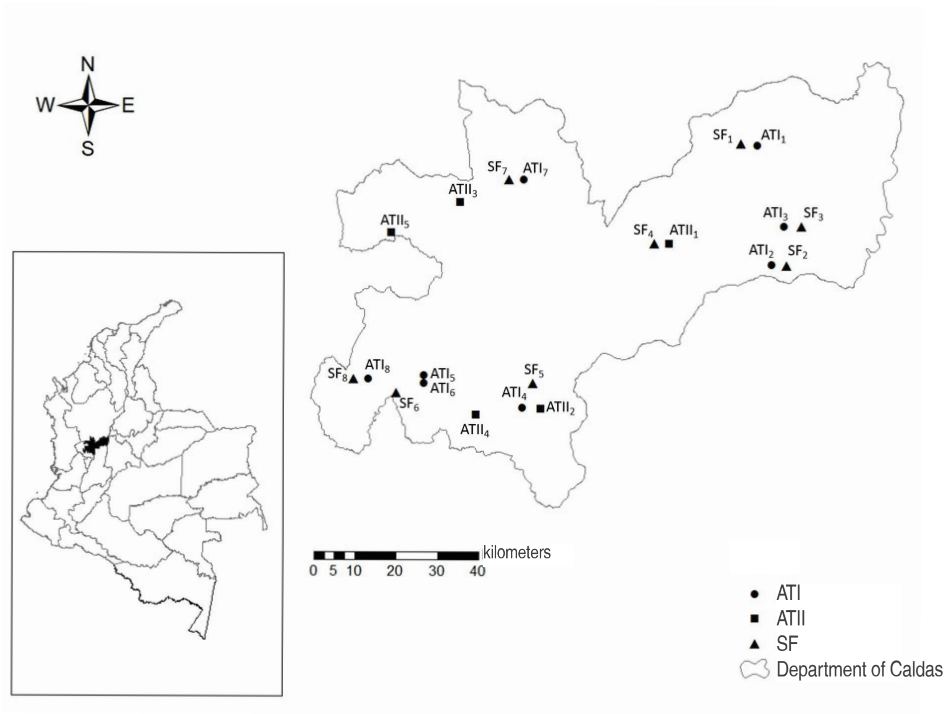

Figure 1. Map of the sampling habitat types in the department of Caldas, Colombia. ATI (type I agroecosystems); ATII (type II agroecosystems); SF (secondary forests).

pastures with dispersed trees, and forest plantations with developed understory (ATII$_1$: corn, cassava, plantain, and forage species; ATII$_2$: coffee and plantain; ATII$_3$: grazing pastures with weeds and dispersed tree cover; ATII$_4$: urapán (*Fraxinus chinensis*) plantation; and ATII5: patula pine (*Pinus patula*) plantation; Table 1). Finally, eight secondary forests were also selected (SF$_1$-SF$_8$; Table 1). All of the selected agroecosystems were located at a distance no greater than 245 m from a secondary forest. The distance between agroecosystems varied from 10 to 120 km, except for ATI$_5$ and ATI$_6$ that were located in the same sampling site. A detailed description of each habitat is given in Table 1. All agroecosystems included a secondary forest (control) within the same site.

Table 1. Habitat description (type I and II agroecosystems and secondary forests) of avifauna of the department of Caldas.

Habitat type	Coordinates	Description		
		Altitude (m) / Temperature (°C) / Precipitation (mm)	Habitat size (ha)	Observations
ATI$_1$	5 35´46,53"N; 74 56´46,09"W	866/23-27/4000	0.4	Cocoa monocrop (*Theobroma cacao* L.) of 4 m in height, in productive phase. Municipality of Samaná.
ATI$_2$	5 20´05,42"N; 74 54´49,56"W	999/25-27/3000	0.4	Avocado monocrop (*Persea americana* M.) of 5 m in height. Municipality of Victoria.
ATI$_3$	5 25´08,79"N; 74 53´09,60"W	551/25-27/3000	1.3	Lemon monocrop (*Citrus x limon* L.) of 2 m in height. Municipality of Victoria.
ATI$_4$	5 01'18,62"N; 75 25'24,52"W	2284/15-17/1500	0.7	Abandoned pasture (*Holcus lanatus* L.). Municipality of Villamaría.

Table 1. Continuation

Habitat type	Coordinates	Description		
		Altitude (m) / Temperature (°C) / Precipitation (mm)	Habitat size (ha)	Observations
ATI_5	5 04'27,88"N; 75 40'22,05"W	1037/19-21/2000	0.1	Papaya monocrop (*Carica papaya* L.) of 5 m in height and in fruiting phase. Located in Montelindo farm of the Caldas University. Municipality of Palestina.
ATI_6	5 04'31,35"N; 75 40'22,95"W	1037/19-21/2000	0.6	Mandarine monocrop (*Citrus nobilis* Lour.) of 7 m in height and in fruiting phase. Located in Montelindo farm of the Universidad de Caldas. Municipality of Palestina.
ATI_7	5 31'13.75"N; 75 27'18.64"W	1870/17-19/2000	0.8	Coffee monocrop (*Coffea arabica* L.) of 2 m in height. Municipality of Pácora.
ATI_8	5 5´5,08"N; 75 47´39,43"W	1774/19-21/2500	0.5	Coffee monocrop (*C. arabica* L.) of the varieties Colombia and Caturra, of 2 m in height. Municipality of San José.
$ATII_1$	5 22´53,77"N; 75 08´16,32"W	15/11/1905/2000	0.6	Mixed-cropping: corn (*Zea mays* L.), cassava (*Manihot esculenta* Crantz), plantain (*Musa* sp.), and forage species such as bore (*Alocasia* sp.), guandul (*Cajanus cajan* L.), botón de oro (*Tithonia diversifolia* Hemsl), kudzú tropical (*Pueraria phaseoloides* Roxb.) and sericura (*Pennisetum* sp.). Located in the Reserva Forestal de la Sociedad Civil La Gaviota. Municipality of Pensilvania.
$ATII_2$	5 00´23,41"N; 75 33´33,56"W	1712/19-21/1500	1.4	Coffee (*C. arabica* L.) and plantain (*Musa* sp.) crops of 1 and 3 m in height, respectively. Municipality of Manizales.
$ATII_3$	5 28'11.68"N; 75 35'41.30"W	1109/23-25/1500	0.7	Grazing pasture with weeds and dispersed tree cover of 7 m in height (35 years). Municipality of Marmato.
$ATII_4$	5 01'11,17"N; 75 25'06,62"W	2284/15-17/1500	4.1	Urapán (*Fraxinus chinensis* Roxb.) plantation of 25 m in height, with a developed understory. Located in the Reserva Forestal Protectora Bosques de la CHEC. Municipality of Villamaría.
$ATII_5$	5 24'17.92"N; 75 44'46.33"W	2331/15-17/2000	4.3	Patula pine (*Pinus patula* Schltdl. & Cham) plantation of 25 m in height. It has a dense understory as a result of natural regeneration. Municipality of Riosucio.
SF_1	5 36´01,92"N; 74 56´50,61"W	866/23-27/4000	27.3	Secondary forest with a height of 8 m. Municipality of Samaná.

Table 1. Continuation

Habitat type	Coordinates	Description		
		Altitude (m) / Temperature (°C) / Precipitation (mm)	Habitat size (ha)	Observations
SF_2	5 19´59,46"N; 74 54´50,94"W	999/25-27/3000	4.0	Secondary forest with a height of 25 m., connected to a secondary forest that is part of a regional protected area (Distrito de Manejo Integrado de los Recursos Naturales Cuchilla de Bella Vista). Municipality of Victoria.
SF_3	5 25´12,17"N; 74 52´54,89"W	551/25-27/3000	3.1	Secondary forest for the conservation of water resources, with a height of 20 m. Municipality of Victoria.
SF_4	5 22´50,58"N; 75 08´08,96"W	1905/11-15/2000	2.3	Secondary forest for the conservation of water resources, with a height of 15 m, located in the Reserva Forestal de la Sociedad Civil La Gaviota. Municipality of Pensilvania.
SF_5	5 4’30,08”N; 75 26’08,63”W	2150-3700/15-17/2500	70.6	Secondary forest for the conservation of water resources, with a height of 20 m. Located in the Reserva Forestal Protectora de Río Blanco, property of Aguas de Manizales. Municipality of Manizales.
SF_6	5 03´12,49"N; 75 44´00,73"W	1039/23-25/2000	70.6	Secondary forest for the conservation of water resources, with a height of 25 m. Located in San Francisco Reservoir, property the Central Hidroeléctrica de Caldas (CHEC). Municipality of Chinchiná.
SF_7	5 31'12,09"N; 75 27'14,92"W	1870/17-19/2000	0.9	Pasture of 3 m for the conservation of water resources. Municipality of Pácora.
SF_8	5 5´0,68” N; 75 47´35,04”W	1774/19-21/2500	3.0	Secondary forest with a height of 20 m Municipality of San José.

Bird capture

The avifauna present in each habitat type (type I and II agroecosystems and secondary forests) was assessed by mist net sampling, which has been previously used in agroecosystem and secondary forest studies (Blake and Loiselle, 2001; Barlow *et al*., 2007; Castaño-Villa *et al*., 2014). Between November to December of 2015 and January to April of 2016, we established 12 capture points within each site, and at each point, a mist net (12 2.5 m 36 mm) was extended for 10 hours. The nets were randomly installed at each site and operated between 600 h and 1730 h. Each site was visited for four to five days until completing 120-net hours. Within each habitat type, mist nets were extended in an area of 0.1 ha. The total sampling effort for ATI was 960-net hours, 600-net hours for ATII, and 960-net hours for SF. The nets were not operated under rainfall, wind, or intense cold or heat. The birds captured were individualized through a small cut on the first tail rectrix in order to prevent counting more than once, and then released in the capture site. Birds were identified using the identification guide of Birds of Northern South America (Restall *et al*., 2007). Taxonomic classification of bird species was done according to Remsen *et al*. (2017).

Data analysis

We compared species richness, abundance and similarity between the two agroecosystem types and their corresponding secondary forests, in order to describe the contribution of agroecosystems to avifauna conservation. Species were categorized based on the criterion of sensitivity to disturbance (high, moderate, low), according to Stotz *et al.* (1996). Species with a high sensitivity to disturbance are known to be most affected by anthropogenic habitat modification (Castaño-Villa *et al.*, 2014), so they are considered vulnerable and relevant to conservation at a local level. To determine if bird species richness statistically differed between the three habitats studied, we graphed lower and upper confidence intervals at 84% of the estimated species richness (S_{est}), using Mao Tao SD values, according to MacGregor-Fors and Payton (2013) and subsequent applications (Hanula *et al.*, 2015; Fontúrbel *et al.*, 2016). Mao Tao SD values were obtained from rarefaction analysis using EstimateS version 9.1.0 (Colwell, 2013). When the confidence intervals did not overlap, these were considered statistically significantly different with an alpha of 0.05. We considered the capture points within each site to be replicas (12 points per site). Habitats were compared by the same number of replicates (60), which was the minimum number of replicates obtained for ATII. Additionally, observed species richness was compared between type I and II agroecosystems, according to sensitivity to disturbance, through Fisher's Exact Test. The number of individuals captured within each habitat (i.e. abundance of all species captured, standardized for the sampling effort), shown as medians, was compared through of a Generalized Linear Model (Poisson distribution). Abundance data referred to the number of captures, not to real abundance, which is unknown. The differences in bird assemblage similarity (in terms of species abundance) between habitats were assessed by a One-Way Analysis of Similarity (ANOSIM), which constitutes a non-parametric permutation test (Clarke, 1993). For this analysis, a Bray-Curtis distance was used, which has been previously used in other studies to compare bird assemblages (Barlow *et al.*, 2007; Castaño-Villa *et al.*, 2014). The ANOSIM test was carried out with PAST 2.15 (Hammer *et al.*, 2001). Additionally, we used a Non-metric Multidimensional Scaling analysis (NMDS) to visualize differences in the composition among habitat types. GLM and NMDS analyses were carried out on R version 3.4.3 (R Development Core Team, 2017).

RESULTS AND DISCUSSION

We captured 538 birds in the three habitats, belonging to 139 species from 24 families; type I agroecosystems (S=72), type II (S=59), and secondary forests (S=70). From those, 14 bird species were captured in the three habitat types (Table 2). Estimated bird species richness (S_{est}) shows a wide variation among all sampling sites (Figure 2a). Within type I agroecosystems, citric crops (ATI_6) showed the highest estimated species richness (S_{est}=21), while the grazing pasture with weeds and dispersed trees ($ATII_3$) showed the highest estimated richness (S_{est}=24) among type II agroecosystems. Estimated birds richness was 58.62 (ATI), 59.00 (ATII), and 52.66 (SF) for a similar sampling effort. No significant differences in S_{est} were found between the three habitats (Figure 2b). Regarding sensitivity to habitat disturbance, highly vulnerable species were not captured in type I agroecosystems, while in type II, five species with this characteristic were registered (*Zentrygon frenata*, *Phaetornis guy*, *Phaetornis syrmatophorus, Lepidocolaptes lacrymiger*, and *Sphenopsis frontalis*). Similar results have been reported for other agroecosystems, which have shown that structural complexity of the vegetation (e.g., higher number of vegetation strata, cultivated species diversity, among others) could possibly offer a greater variety of microhabitats and resources used by birds, including those typical of forests (Greenberg *et al.*, 1997; Petit *et al.*, 1999; Petit and Petit, 2003; Nájera and Simonetti 2010; Díaz-Bohórquez *et al.*, 2014). However, mixed-cropping (included in type II agroecosystems) harbor low species richness compared to the other agroecosystems assessed herein, which could be attributed to its rotational nature that does not allow long term bird species establishment (Petit and Petit, 2003) ($ATII_1$, Figure 2a). The number of species with moderate sensitivity to disturbance found in type I and II agroecosystems was 12 in both cases, belonging to the families Trochilidae, Furnariidae, Tyrannidae, Turdidae, Thraupidae, Emberizidae and Parulidae (Table 2). Accordingly, observed species richness, based on sensitivity to disturbance, differed between type I and type II agroecosystems (Fisher's Exact Test, P=0.02). Overall, it seems likely that type II agroecosystems, surrounded by native forests and areas such as the ones described in this study, are not completely negative on avifauna. In respect, agroecosystem bird diversity is favored when native forest surrounding to agroecosystem, because the landscape heterogeneity can favor the diversity of this group (Lindenmayer and Hobbs, 2004; Gardner *et al.*, 2009).

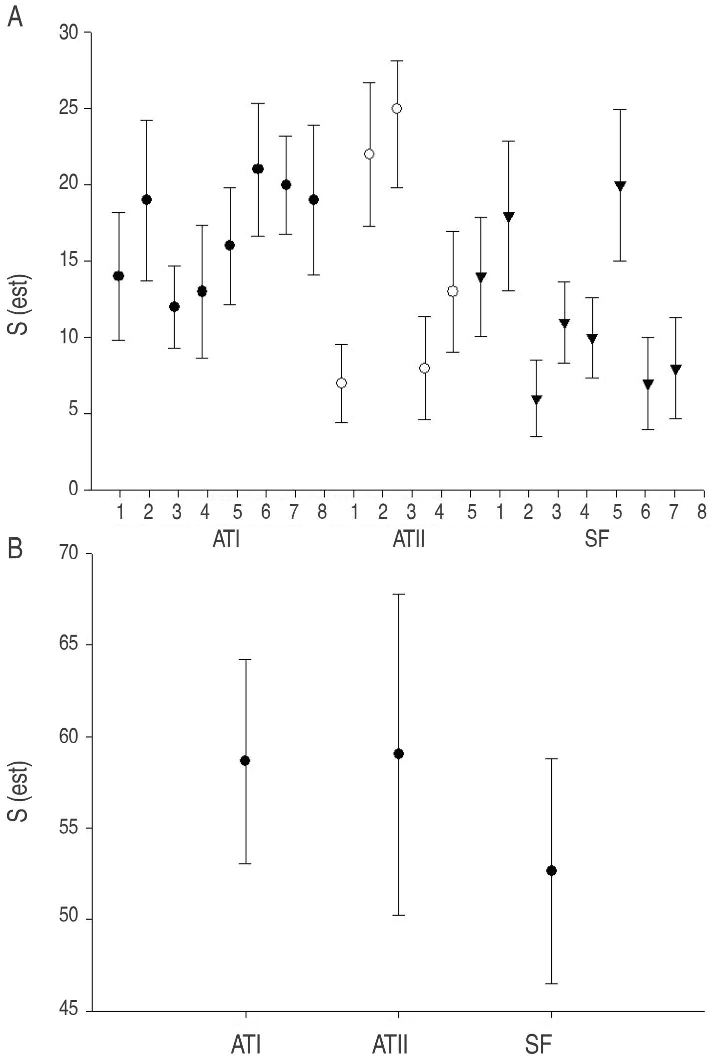

Figure 2. Estimated species richness (S_{est}), A. for all habitats sampled, ATI_1: cocoa; ATI_2: avocado; ATI_3: lemon; ATI_4: pasture; ATI_5: papaya; ATI_6: citric; ATI_{7-8}: coffee; $ATII_1$: cassava, plantain and forage species; $ATII_2$: coffee and plantain; $ATII_3$: grazing pasture with weeds and dispersed trees; $ATII_4$: urapán plantation; and $ATII_5$: patula pine plantation. SF_1-SF_8: secondary forests; B. for the three habitat types. ATI (type I agroecosystems); ATII (type II agroecosystems); SF (secondary forests).

Bird abundance for each of the habitats assessed was 27.50 (ATI), 18.00 (ATII), and 19.00 (SF), with significant differences found among these (P<0.05). A similar result was found when we compared the abundance of birds with moderate and low sensitivity to disturbance among the three habitats (P<0.05). Finally, differences in similarity were found between type I agroecosystems and secondary forests (ANOSIM, r=0.26; P=0.01), and not between type II agroecosystems and secondary forests (ANOSIM, r=0.12; P=0.16) (Figure 3). The differences in the abundance and species composition between agroecosystem and secondary forest can be explained by the greater abundance of typical birds of open and disturbed areas present in the agroecosystem, not found in the secondary forest (Bellocq *et al*., 2011). Although birds associated with agroecosystem type I are less relevant to conservation, these birds carry out important functions within agroecosystems, by controlling pests, pollinizers, and seed dispersers (Pejchar *et al.,* 2008; Gardner *et al*., 2009; Philpott and Bichier, 2012).

Table 2. Sensitivity to disturbance and habitat type of the bird species.

Species	Sensitivity to disturbance	Habitat type		
		ATI	ATII	SF
Columbidae				
Leptotila verreauxi	Low	X	X	
Zentrygon frenata	High		X	
Zenaida auriculata	Low		X	
Columbina passerina	Low	X		
Columbina talpacoti	Low	X		X
Cuculidae				
Crotophaga ani	Low		X	
Trochilidae				
Eutoxeres aquila	Medium			X
Glaucis hirsutus	Low	X		X
Phaethornis anthophilus	Medium			X
Phaethornis guy	High		X	X
Phaethornis syrmatophorus	High		X	X
Colibri coruscans	Low	X	X	
Anthracothorax nigricollis	Low	X		
Heliangelus exortis	Low			X
Adelomyia melanogenys	Medium	X	X	X
Coeligena coeligena	Medium	X	X	
Coeligena torquata	Low	X	X	X
Lafresnaya lafresnayi	Medium	X		
Boissonneaua flavescens	Medium			X
Chlorostilbon gibsoni	Low		X	
Chlorostilbon mellisugus	Low	X	X	
Chalybura buffonii	Low			X
Thalurania colombica	Low		X	X
Amazilia tzacalt	Low	X		
Amazilia franciae	Medium			X
Amazilia amabilis	Low			X
Amazilia saucerrottei	Low	X		X
Accipitridae				
Accipiter striatus	Medium		X	
Momotidae				
Momotus aequatorialis	Low		X	
Bucconidae				
Malacoptila mystacalis	High			X
Capitonidae				
Capito hypoleucus	Medium	X		
Picidae				
Melanerpes formicivorus	Low	X		
Melanerpes rubricapillus	Low	X		

Table 2: Continuation

Species	Sensitivity to disturbance	Habitat type		
		ATI	ATII	SF
Picoides fumigatus	Medium		X	
Veniliornis kirkii	Medium			X
Colaptes punctigula	Low	X		
Psittacidae				
Forpus conspicillatus	Low	X		
Thamnophilidae				
Thamnophilus atrinucha	High			X
Formicivora grisea	Medium			X
Furnariidae				
Glyphorynchus spirurus	Medium		X	X
Dendrocolaptes picumnus	Medium		X	
Xiphorhynchus guttatus	Low			X
Dendroplex picus	Medium			X
Lepidocolaptes souleyetii	Medium	X		
Lepidocolaptes lacrymiger	High		X	
Synallaxis albescens	Low		X	
Synallaxis azarae	Low	X		
Tyrannidae				
Tyrannulus elatus	Low	X		
Myiopagis viridicata	Medium			X
Elaenia flavogaster	Low	X	X	X
Zimmerius chrysops	Low	X	X	
Mionectes striaticollis	Medium		X	
Mionectes oleagineus	Low	X		X
Leptopogon amaurocephalus	Medium	X		
Todirostrum cinereum	Low		X	X
Myiophobus fasciatus	Low		X	
Empidonax virescens	Medium			X
Empidonax traillii	Low	X		
Contopus virens	Medium	X		X
Pyrocephalus rubinus	Low	X		
Legatus leucophaius	Medium			X
Myiozetetes cayanensis	Low	X		
Myiozetetes similis	Low		X	
Pitangus sulphuratus	Low	X		
Tyrannus melancholicus	Low	X	X	X
Tyrannus tyrannus	Low	X		
Pipridae				
Chloropipo flavicapilla	Medium		X	
Lepidothrix coronata	Medium			X
Manacus manacus	Low			X
Machaeropterus regulus	Medium			X
Ceratopipra erythrocephala	High			X
Tityridae				
Pachyramphus polychopterus	Low			X
Vireonidae				
Cyclarhis nigrirostris	Medium	X		
Hylophilus flavipes	Medium	X		

Table 2: Continuation

Species	Sensitivity to disturbance	Habitat type		
		ATI	ATII	SF
Vireo olivaceus	Low	X		
Vireo flavoviridis	Medium	X		
Hirundinidae				
Stelgidopteryx ruficollis	Low		X	
Troglodytidae				
Microcerculus marginatus	High			X
Troglodytes aedon	Low	X	X	
Cinnycerthia olivascens	Medium			X
Henicorhina leucosticta	Medium		X	
Turdidae				
Myadestes ralloides	Medium		X	
Catharus aurantiirostris	Low			X
Catharus minimus	Medium			X
Catharus ustulatus	Low	X	X	X
Turdus leucomelas	Low	X	X	X
Turdus ignobilis	Low	X		X
Turdus fuscater	Low	X		
Thraupidae				
Chlorophanes spiza	Low	X		X
Sicalis flaveola	Low	X		
Diglossa albilatera	Low	X		
Diglossa sittoides	Low		X	
Diglossa cyanea	Low			X
Volatinia jacarina	Low	X	X	X
Eucometis penicillata	Medium			X
Ramphocelus dimidiatus	Low	X	X	
Ramphocelus flammigerus	Low	X		
Sporophila funerea	Low	X		
Sporophila crassirostris	Low		X	
Sporophila intermedia	Low	X		
Sporophila nigricollis	Low	X	X	
Saltator maximus	Low			X
Saltator striatipectus	Low		X	
Sphenopsis frontalis	High		X	
Thlypopsis superciliaris	High			X
Coereba flaveola	Low	X		
Tiaris olivaceus	Low	X	X	X
Tiaris obscurus	Low	X	X	X
Tiaris bicolor	Low	X		
Tangara heinei	Low			X
Tangara vitriolina	Low	X	X	X
Tangara cyanicollis	Low			X
Tangara inornata	Low	X		X
Tangara gyrola	Low	X	X	X
Thraupis episcopus	Low	X	X	X
Thraupis palmarum	Low	X	X	X
Emberizidae				
Arremonops conirostris	Low	X		
Arremon torquatus	Low			X

Table 2: Continuation

Species	Sensitivity to disturbance	Habitat type		
		ATI	ATII	SF
Zonotrichia capensis	Low	X	X	X
Cardinalidae				
Piranga rubra	Low	X		X
Piranga olivacea	Low	X		
Cyanocompsa brissonii	Low		X	
Parulidae				
Parkesia noveboracensis	Low	X	X	
Leiothlypis peregrina	Low	X		
Oporornis agilis	Low	X		X
Setophaga pitiayumi	Low		X	
Setophaga castanea	Low	X		X
Setophaga fusca	Low		X	
Setophaga petechia	Low	X		
Setophaga striata	Medium		X	
Myiothlypis fulvicauda	Low			X
Myiothlypis coronata	Medium		X	X
Basileuterus rufifrons	Low	X		
Basileuterus culicivorus	Medium			X
Cardellina canadensis	Low	X		X
Myioborus miniatus	Medium	X		
Icteridae				
Icterus chrysater	Low		X	
Fringillidae				
Spinus xanthogastrus	Low		X	
Spinus psaltria	Low		X	
Euphonia laniirostris	Medium	X		

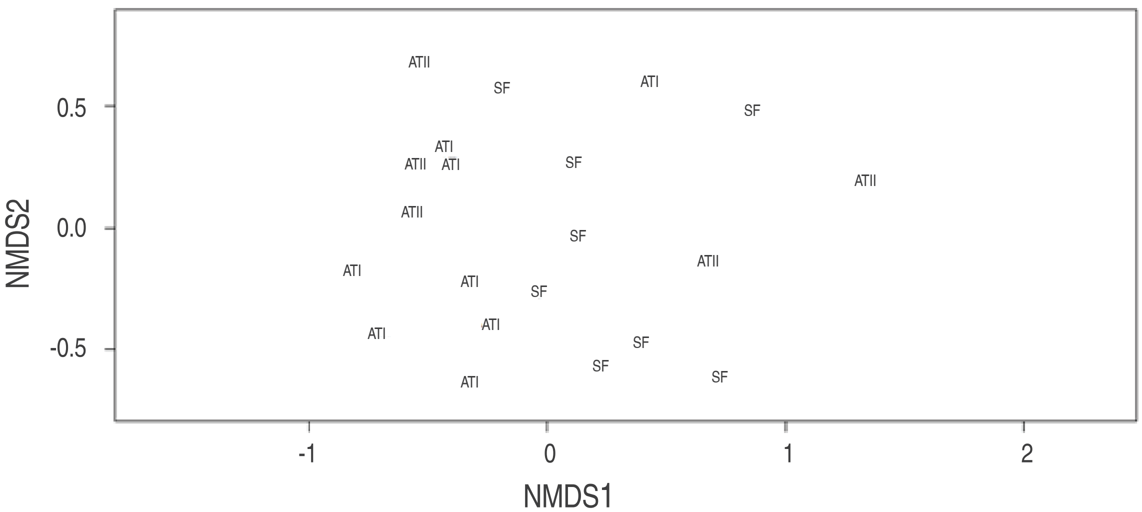

Figure 3. Non-metric Multidimensional Scaling Analysis (NMDS). All habitats sampled, ATI (type I agroecosystems); ATII (type II agroecosystems); SF (secondary forests).

Furthermore, in type I and type II agroecosystems, two endemic species of Colombia were found, *Capito hypoleucus* and *Chloropipo flavicapilla*. These two species are classified as Vulnerable (VU), due to reductions in their population sizes (International Union for Conservation of Nature, 2016). Finally, 14 migratory boreal species were registered in the type I and II agroecosystems, some of them (*Contopus virens* and *Setophaga striata*) showing moderate sensitivity to disturbance. Overall, this demonstrates that agroecosystems can be a part of the habitat used by species in need of global conservation (Díaz-Bohórquez *et al*., 2014).

CONCLUSIONS

The type II agroecosystem habitats are apparently not completely negative on avifauna. In these agroecosystems, we registered several species that inhabit forests of different regions of the department of Caldas. Therefore, it can be suggested that this type of agroecosystems could play an important role within bird conservation strategies in rural landscapes, where native forests are still conserved. Given this, agroecosystems could be an important element in stewardship planning of areas surrounding natural reserves, since these would cause fewer negative impacts on bird diversity in departments with areas destined for biodiversity conservation, such as Caldas. The conservation strategies in this region should involve farmers, government entities, non-governmental organizations and the general public.

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