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SUSTAINABLE AGRICULTURAL SYSTEMS AND FAUNAL DIVERSITY:

THE CASE OF ORGANIC SUGARCANE UNDER AGRO-ECOLOGICAL MANAGEMENT

José Roberto Miranda

INTRODUCTION

The presence of wild fauna in agricultural areas has received scant attention in research. In conservation efforts for wild species, research has traditionally focused on the biodiversity of remnants and natural ecosystems (forests, savannas, riparian forests etc.), or research on restoration. Little attention has been paid to the effective role of agro-ecosystems on the maintenance of animal diversity (GLIESSMAN, 2001). The type of management employed in these systems should make a difference in fauna populations and organic farming associated with agro-ecological management should show greater biodiversity (BEECHER *et al.*, 2002).

Populations of plant and animal species in tropical agro-ecosystems vary according to land use and occupation, the temporal and spatial stability of the production systems, nature and spatial division of the natural vegetation remnants and the availability of water resources (SUÁREZ-SEOANE; OSBORNE; BAUDRY, 2002). The evolution of biodiversity in Brazilian tropical agriculture areas is a relatively new dimension and very different from land cultivated in temperate regions (MALCOLM, 1997). The scientific knowledge gleaned from the results of the processes of land use and occupation on fauna richness is still very incipient in our country.

Brazil has one of the largest potentials in the world for intensifying agriculture because of its abundance of solar energy and water, and crops capable of generating large quantities of food and "clean" fuel, such as biodiesel, ethanol and charcoal. Sugarcane fixes more than 50 tons of atmospheric carbon per hectare in its biomass, and can produce ethanol, a renewable fuel, which can serve as a gasoline substitute in addition to reducing the release of carbon into the atmosphere. There are various production systems that can be used in the cultivation of sugarcane, each with different impacts on the physical and biotic environment (KAHINDI, 1997). The most conventional method uses pre-harvest burning, although the use of mechanized harvesters for raw sugarcane is rising. There are organic farming systems that are associated with agro-ecological land management (BACCARO, 1999). Each of these systems offers different environmental conditions and different possibilities for colonization and implantation of wild fauna populations. On the other hand, the use of pesticides can be worrisome in terms of food chain contamination (ALTIERI, 2002). Research on this range of opportunities and limitations for wild animals can help guide initiatives to preserve biodiversity.

With a view to learning more about this environment, the EMBRAPA Satellite Monitoring team monitored the progress of fauna biodiversity and organic production systems on a rural property covering 7,868 hectares from 2001 to 2008, of which approximately 82% is planted with sugarcane, in the Ribeirão Preto region, in the state of São Paulo. The mapping of land use and occupation was conducted in 2003, based on satellite imagery, and after analysis the area was divided into fauna *habitats*. These *habitats* served as the basis for guiding sampling strategies and data collection protocol for fauna and ecological conditions in field surveys (MIRANDA, 2006). To enable comparison, conventional sugarcane cultivation systems on other properties of the region that use pre-harvest burning were prospected.

This innovative research had a two-fold objective: first, to test, adapt and develop a methodology for evaluating biodiversity in delimited areas. Second, it aimed to analyze the richness of terrestrial vertebrate fauna on a property planted with organic sugarcane and in adjacent *habitats* under agro-ecological management. Prospecting in conventional sugarcane farms was also carried out to determine similarities between the fauna populations. In addition to the results of richness and diversity indicators, special emphasis was given to the occurrence of species threatened with extinction in the state of São Paulo, based on the criteria established by the International Union for Conservation of Nature (IUCN), by the Brazilian Institute of the Environment (IBAMA) and according to the list of fauna species threatened with extinction in the state of São Paulo (State Decree n. 42 838, dated February 4, 1998, Secretariat of the Environment of the State of São Paulo. 1998).

MATERIAL AND METHODS

The area under study covers various farms belonging to the São Francisco Mill, all situated in the Sertãozinho region (Figure 1), in the northeastern part of the state of São Paulo (latitude of 21° and 13” South and longitude of 48° and 11” West), totaling 7,868 hectares of farmland and other environments. The area is located in the Mogi-Guaçu River basin, which is part of the Pardo River basin, a tributary of the Paraná River.

Analysis of satellite images from LANDSAT 7 and SPOT 5 enabled the mapping and classification of land use and occupation. Analysis of the land use map yielded ten different types of fauna *habitats*. The ten classifications are as follows:

- *Habitat* 1 – Organic Sugarcane Fields;
- *Habitat* 2 – Exotic Forests;
- *Habitat* 3 – Floodplains with Herbaceous Plants;

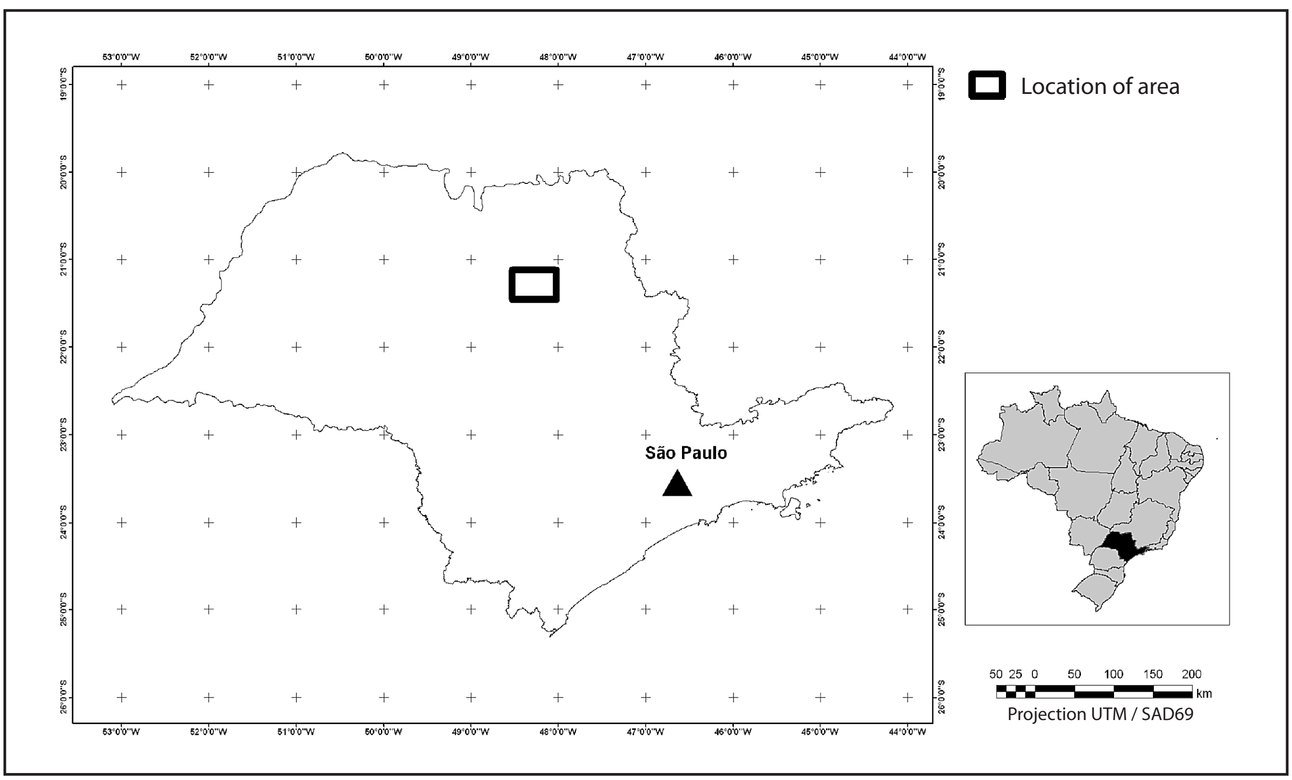

FIGURE 1 Location of the area studied in the Sertãozinho region in SP.

- *Habitat* 4 – Floodplains with Riparian Forests;
- *Habitat* 5 – Restored Native Forests;
- *Habitat* 6 – Mixed Forests Undergoing Regeneration;
- *Habitat* 7 – Native Forests;
- *Habitat* 8 – Drainage Gullies;
- *Habitat* 9 – Forests Undergoing Spontaneous Regeneration;
- *Habitat* 10 – Fields Undergoing Spontaneous Regeneration.

The detection and identification of fauna in the study area involves a series of techniques and practical procedures, including binoculars, camouflaged blinds, traps, nets etc. In addition to direct detection, both visual and audible, presence was also detected through animal signs, including tracks, feces, feathers, nests, dens, fur and regurgitation pellets. Various identification guides and classification systems were used (PETERS, OREJAS MIRANDA, 1970; DUNNING, 1987; EMMONS, 1990; SOUZA, 1998; BECKER, DALPONTE, 1999).

The map of the fauna *habitats* led us to choose the stratified random sampling strategy. This strategy considers the heterogeneous nature of the study area and ensures a judicious comparison of the fauna populations from the different *habitats* (FRONTIER, 1983). A pre-codified survey card was created due to the large number of observations required. The objective and uniform description of ecological conditions in the field ensured the subsequent statistical treatment (DAGET, GODRON, 1982; MIRANDA, 1986, 2003).

The fauna populations and *habitats* were characterized, using indexes that take into consideration the **composition**, defined in terms of specific richness and delineated **structure** for the relative abundance. Four types of richness were established: total, average, cumulative and exclusive, each one presenting its own characteristics (BLONDEL, 1979). To study the structure of the populations various diversity indexes were calculated derived from the function $H' = -\Sigma\, pi \log_2$ by Shannon and Weaver based on the theory of information (MAC ARTHUR, R.; MAC ARTHUR, J. 1961). This index takes into account the number of species in a population according to their relative abundance (MARGALEF, 1982), allowing three diversity types to be discerned (WHITTAKER, 1972). The **alfa ($H'\alpha$)** type, or intra-*habitat* diversity, the **gama ($H'\gamma$)** type, or setorial or macro-cosmic diversity and the **beta ($H'\beta$)** type, representing a Jaccard similarity index, and inter-*habitat* diversity (DAGET; GODRON, 1982).

RESULTS AND DISCUSSION

Countless surveys were conducted between July 2002 and March 2008 in the ten mapped *habitats*, for a total of 1,474 animal ecology surveys distributed in a balanced manner over the 10 mapped *habitats*. A total of 312 terrestrial vertebrate species were detected and identified: 26 amphibians, 17 reptiles, 230 birds and 39 mammals (MIRANDA, J; MIRANDA, E., 2004). Birds were the richest in species and represented approximately 74% of the fauna identified, while mammals represented 12.5%, reptiles 5.5% and amphibians 8%.

Among the most frequently encountered species were the Picazuro Pigeon (*Patagioenas picazuro*), Smooth-billed Ani (*Crotophaga ani*) and the Great Kiskadee (*Pitangus sulphuratus*). The Sayaca Tanager *(Thraupis sayaca*), Southern Lapwing (*Vanellus chilensis*), Southern Caracara (*Caracara plancus*), Southern House Wren (*Troglodytes musculus*), and others were moderately frequent, while the Maned Wolf (*Chrysocyon brachyurus*), Crab-eating Fox (*Cerdocyon thous*), Red Brocket (*Mazama americana*), Toco Toucan (*Ramphastos toco*), Whistling Heron (*Syrigma sibilatrix*), and others were infrequently found. Rare species were responsible for 78.5% of the total number.

Of the 312 terrestrial vertebrate species identified, 35 are present in the catalogue of "Threatened Fauna Species in the State of São Paulo." The Cougar (*Puma concolor*), Ocelot (*Leopardus pardalis*), Jaguarundi (*Herpailurus yagouaroundi*), Maned Wolf (*Chrysocyon brachyurus*), Giant Anteater (*Myrmecophaga tridactyla*), Blue-Fronted Amazon (*Amazona aestiva*), Creamy-bellied Gnatcatcher (*Polioptila lactea*), Cuvier's Dwarf Caiman (*Paleosuchus pal-

pebrosus) Green Anaconda (*Eunectes murinus*) are examples of some of the species.

The logarithmic curve of the total cumulative richness was obtained from the cumulative allocation of the 312 species detected (y-axis) in the 1,474 animal ecology surveys conducted (x-axis) (Figure 2). After half of the animal ecology surveys had been conducted, 77% of the terrestrial vertebrate species had already been detected. During the final 30% of the surveys, 47 of the 312 species were detected, or in other words, approximately 15% of the total reported.

All the indexes of biological richness (total, average and exclusive), presented a wide variability in the *habitats* (Table 1). The total richness was highest in the Floodplains with Herbaceous Plants, with 150 species. In descending order there were: 137 species in the Restored Native Forest; 127 species in the Native Forest; 126 species in the Floodplains with Riparian Forests; 119 species in the Drainage Gullies; and 92 species in the Spontaneous Regeneration Forests. The Exotic Forest was the poorest *habitat* in terms of biodiversity with 82 species, a number far lower than the 88 found in the Organic Sugarcane Fields.

The average richness varied widely. The highest average gain in species was recorded in the Floodplains with Riparian Forests *habitat*, indicating a large supply of niches for the species, as opposed to the agricultural areas with Organic Sugarcane Fields, where there is greater homogeneity of ecological conditions on offer for the fauna (Table 1).

The exclusive richness showed that all of the *habitats* have original populations or, in other words, the fauna is determined by and sensitive to the ecological conditions offered by each of these environments. The Floodplains with Herbaceous Plants *habitat* had the richest exclusive species populations (26 sp); the others presented much lower figures, around ten species, except for Exotic Forests where only four exclusive species were found (Table 1). This appears to be the least original or differentiated environment in terms of fauna.

The alfa intra-*habitat* diversity index (H'α) values, were relatively close together, but do present a certain variability (Table 2). The complete table, with all the figures obtained for each species, can be found in the Embrapa Series n. 27 (MIRANDA, J.; MIRANDA, E., 2004).

The highest alpha type (H'α) intra-*habitat* diversity indexes were found in populations located in Drainage Gullies and Native Forests. These *habitats* are considered very stable in terms of

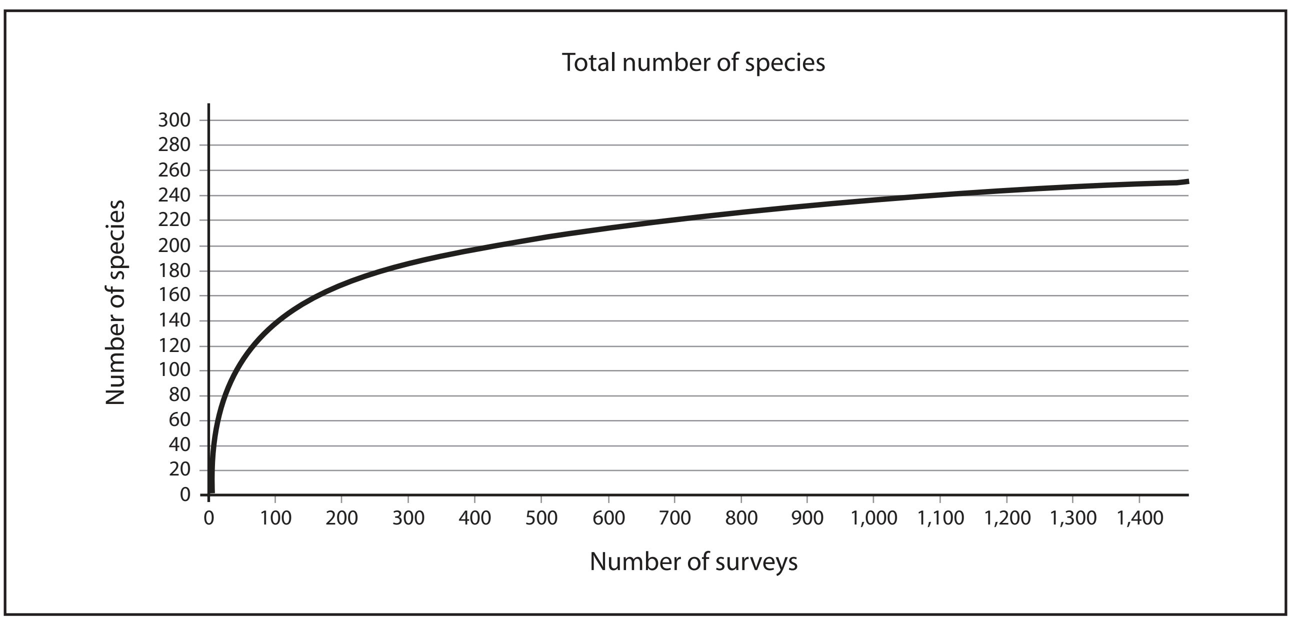

FIGURE 2 Cumulative richness curve for the 312 terrestrial vertebrate species detected in 1,474 animal ecology surveys in the area surrounding the São Francisco Mill-SP.

TABLE 1 Total, average and exclusive richness in the ten *habitats* in the areas surrounding the São Francisco Mill in SP.

Richness	1	2	3	4	5	6	7	8	9	10	Totais	%
Total Richness	88	82	150	126	137	77	127	119	92	87	312	100
Average Richness	0.4829	0.6259	0.857	1.086	0.62	0.7475	0.712	0.759	0.8611	0.7981	–	–
Exclusive Richness	8	4	26	14	15	8	15	10	9	7	116	37

Key:
Habitat 1 – organic sugarcane fields;
Habitat 2 – exotic forests;
Habitat 3 – floodplains with herbaceous plants;
Habitat 4 – floodplains with riparian forests;
Habitat 5 – restored native forests;
Habitat 6 – mixed forests undergoing regeneration;
Habitat 7 – native forests;
Habitat 8 – drainage gullies;
Habitat 9 – forests undergoing spontaneous regeneration;
Habitat 10 – field undergoing spontaneous regeneration.

total richness. However, it is unlikely that new species will be added since the resources provided by these *habitats* are being used practically up to their limits. Consequently, population figures are not expected to vary much over time.

The Floodplains with Riparian Forests, Restored Native Forests and Floodplains with Herbaceous Plants had very high intra-*habitat* diversity indexes, but presented signs of potential for increasing their total richness, especially in the case of the Restored Native Forest areas where a balance between immigration and extinction rates has not been established.

The index amounts for Exotic Forests, Forests Undergoing Spontaneous Recovery, Mixed Forests Undergoing Regeneration, Organic Sugarcane Fields and the Fields Undergoing Spontaneous Regeneration suggest populations with a lower total richness, but with stable population numbers. In other words, the present species are relatively well established in these *habitats*.

Beta type (H'β) fauna similarity indexes were also calculated for the ten *habitats* studied in the area of the São Francisco Mill based on the 1,474 surveys carried out and the occurrence of 312 species. The results are shown in Table 3. The lowest index, 20%, was observed in Organic Sugarcane Fields and Mixed Forests Undergoing Regeneration; the other *habitats* had amounts that ranged from almost 30% to less than 40%. The highest similarities were greater than 40%, with the highest index, 44%, observed between Floodplains with Riparian Forests and Forests Undergoing Spontaneous Regeneration and between Floodplains with Herbaceous Plants and Restored Native Forests, followed by Floodplains with Riparian Forests and Restored Native Forests (42%).

The gamma type (H'γ) sector ecological diversity index calculated for the group of the ten fauna *habitats* of the São Francisco Mill was 6.383, which is considered a very high index. It will rise further due to the arrival of new species colonizing existing *habitats*. This is expected to occur since almost all present *habitats* are growing in terms of natural resources available for wildlife (food, shelter and reproduction), leading to an increase in biodiversity.

A comparative study of two sugarcane production systems conducted 57 prospective surveys of animal ecology in organic crops and detected 88 vertebrate species, compared with 101 surveys of conventional crops that identified 73 species. First of all, a Jaccard similarity index of 0.27 was determined between the two populations. This index shows a difference of specific composition between the two types of sugarcane crops of more than 70%, leading us to believe that the production and farming system of the same agricultural crop can lead to very different populations and biodiversities. Trophic guilds were also established for every situation and the proportions between insectivore and omnivore species were 38% and 21% for conventional sugarcane, while organic farming without burning yielded percentages of 44% and 17% respectively. These amounts are very close. However, when we compare the occurrence

TABLE 2 Examples of intra-*habitat* diversity index values, alfa type (H'α), obtained in areas surrounding the São Francisco Mill in SP.

Species	1	2	3	4	5	6	7	8	9	10
Patagioenas picazuro	-0.165	-0.302	-0.234	-0.242	-0.196	-0.293	-0.173	-0.214	-0.286	-0.237
Crotophaga ani	-0.165	-0.052	-0.259	-0.231	-0.196	-0.080	-0.165	-0.214	-0.213	-0.368
Pitangus sulphuratus	-0.099	-0.331	-0.191	-0.209	-0.217	-0.151	-0.201	-0.165	-0.175	-0.192
Tyrannus melancholicus	-0.042	-0.231	-0.220	-0.112	-0.287	-0.263	-0.104	-0.114	-0.175	-0.138
Coragyps atratus	-0.233	-0.072	-0.227	-0.242	-0.109	-0.100	-0.283	-0.104	-0.286	-0.117
Ammodramus humeralis	-0.345	-0.030	-0.121	-0.158	-0.162	-0.058	-0.180	-0.173	-0.032	-0.192
Thamnophilus doliatus	0.000	-0.072	-0.121	-0.262	-0.069	-0.219	-0.214	-0.073	-0.201	-0.117
Caracara plancus	-0.262	-0.122	-0.078	-0.055	-0.109	-0.058	-0.221	-0.149	-0.161	-0.138
Zenaida auriculata	-0.262	-0.122	-0.183	-0.095	-0.109	-0.080	-0.061	-0.132	-0.147	-0.208
Thraupis sayaca	0.000	-0.090	-0.121	-0.032	-0.236	-0.253	-0.084	-0.073	-0.097	-0.069
Vanellus chilensis	-0.218	-0.122	-0.111	-0.184	-0.130	-0.033	-0.049	-0.187	-0.057	-0.138
Todirostrum cinereum	0.000	-0.106	-0.078	-0.143	-0.202	-0.166	-0.061	-0.061	-0.225	-0.069
Furnarius rufus	0.000	-0.188	-0.111	-0.095	-0.144	0.000	-0.073	-0.149	-0.078	-0.117
Troglodytes musculus	-0.042	-0.221	-0.065	0.000	-0.069	-0.273	-0.084	-0.094	-0.147	-0.040
Columbina talpacoti	-0.145	-0.052	-0.121	-0.076	-0.144	-0.080	-0.104	-0.084	-0.131	-0.069
Tringa flavipes	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.020	0.000	0.000
Tyto Alba	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.020	0.000	0.000
Uropelia campestris	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.032	0.000
Total	**5.126**	**5.542**	**5.728**	**5.732**	**5.729**	**5.356**	**6.011**	**6.063**	**5.507**	**5.122**

Key:
Habitat 1 – organic sugarcane fields;
Habitat 2 – exotic forests;
Habitat 3 – floodplains with herbaceous plants;
Habitat 4 – floodplains with riparian forests;
Habitat 5 – restored native forests;
Habitat 6 – mixed forests undergoing regeneration;
Habitat 7 – native forests;
Habitat 8 – drainage gullies;
Habitat 9 – forests undergoing spontaneous regeneration;
Habitat 10 – field undergoing spontaneous regeneration.

of carnivores in the two farming systems, the index amounts are 17% for raw cane and 5% for conventional cane. While this difference should be further studied, it does point, in principle, to a greater environmental sustainability in raw or organic sugarcane for populations of wild vertebrates.

FINAL CONSIDERATIONS

The mapping of *habitats* by land use and cover allowed us to observe different ecological macro-conditions in the spatial division of fauna populations in the studied area. More stable environmental conditions, in time and space, in the sugarcane areas and adjacent *habitats* are favorable factors for supporting greater biodiversity. The richness and diversity of inventoried and quantified fauna are exceptional for agro-ecosystems considering that there has not been any voluntary introduction of animal species into these properties. A total of 312 terrestrial vertebrate species were detected and identified (26 amphibians, 17 reptiles, 230 birds and 39 mammals) in the animal ecological surveys conducted.

TABLE 3 Fauna similarity index for the 10 *habitats* studied in the areas surrounding the São Francisco Mill in SP.

Habitats	1	2	3	4	5	6	7	8	9	10
1	1.00									
2	0.28	1.00								
3	0.29	0.36	1.00							
4	0.30	0.33	0.38	1.00						
5	0.30	0.37	0.44	0.42	1.00					
6	0.20	0.35	0.25	0.31	0.31	1.00				
7	0.27	0.36	0.31	0.35	0.40	0.38	1.00			
8	0.35	0.40	0.37	0.39	0.39	0.27	0.37	1.00		
9	0.30	0.35	0.30	0.44	0.39	0.34	0.39	0.42	1.00	
10	0.34	0.35	0.35	0.37	0.34	0.33	0.32	0.36	0.40	1.00

Key:
Habitat 1 – organic sugarcane fields;
Habitat 2 – exotic forests;
Habitat 3 – floodplains with herbaceous plants;
Habitat 4 – floodplains with riparian forests;
Habitat 5 – restored native forests;
Habitat 6 – mixed forests undergoing regeneration;
Habitat 7 – native forests;
Habitat 8 – drainage gullies;
Habitat 9 – forests undergoing spontaneous regeneration;
Habitat 10 – field undergoing spontaneous regeneration.

The most frequent and ubiquitous species in the group of *habitats* were the Picazuro Pigeon (*Patagioenas picazuro*), the Smooth-billed Ani (*Crotophaga ani*) and the Great Kiskadee (*Pitangus sulphuratus*). The Sayaca Tanager *(Thraupis sayaca*), the Southern Lapwing (*Vanellus chilensis*), the Southern Caracara (*Caracara plancus*), the Southern House-Wren (*Troglodytes musculus*), among others, was observed with average frequency, while the Maned Wolf (*Chrysocyon brachyurus*), the Crab-eating Fox (*Cerdocyon thous*), the Red Brocket Deer (*Mazama americana*), the Toco Toucan (*Ramphastos toco*), the Whistling Heron (*Syrigma sibilatrix*), among others, were not observed frequently. Rare species accounted for 78.5% of the total number of inventoried fauna. Total fauna richness is probably higher than the findings show, and this should be established in the future with more exhaustive and specific monitoring of some groups of species, such as reptiles, amphibians and bats.

All the quantified rates of biological richness (total, average and exclusive), presented high amounts and some variability among the various existing *habitats*. The accumulated richness curve confirmed that the overall fauna biodiversity identified in the 1,474 surveys conducted over the study's six-year period was satisfactorily inventoried. The alpha type (H'α) intra-*habitat* diversity index amounts obtained were relatively close. The highest amounts were found in populations located in the Drainage Gullies and Native Forests. These *habitats* are considered very stable in terms of total richness. The fauna similarity indexes or beta type (H'β) inter-*habitat* diversity between the ten studied *habitats* in the area ranged from a minimum of 20% for the Organic Sugarcane Fields and Mixed Forests Undergoing Regeneration, to the highest amount of 47% between Floodplains with Riparian Forests and Forests Undergoing Spontaneous Regeneration and between Floodplains with Herbaceous Plants and Restored Native Forests. The first major faunal dichotomy takes place between organic sugarcane fields and the nine other *habitats*. This indicates that organic sugarcane fields exert a selective and special pressure on fauna as an ecologically different *habitat*. Sugarcane fields provide unique ecological conditions since eight species are exclusively found there. The forests, whether native or not, tend to present similarities in the composition of their populations. The gamma type (H'γ) sector ecological diversity index calculated for the group of ten fauna *habitats* of the studied area was 6.383, which is considered an elevated index for an agro-ecosystem.

These initial results point to ongoing biological growth: forests and fields undergoing spontaneous reconstitution, areas being enriched with natural vegetation, vegetalization of paths, important plant chronosequences occurring in floodplain areas, dissemination of plant species by fauna etc. Fauna populations are also growing toward greater stability and better implementation. Various species are reproducing locally and the presence of offspring is frequently observed in the *habitats* as a whole. New species are being added annually to the animal community by means of natural processes; many of them will encounter conditions for permanent implementation. In addition to resident species, there are various species of ducks, sandpipers, swallows etc. that use the areas, including the sugarcane fields, as a place for rest, shelter and even food. The maintenance of organic practices associated with various agro-environmental practices, without the use of agrochemicals or fire, is also fundamental for conserving the high level of biodiversity. Close to 16% of the sugarcane fields are annually being grown (newly planted sugarcane) and are not harvested. They play a special role by providing shelter for fauna during the harvest period.

Despite the imminent expansion of ethanol production systems, the direct influence of the farming system type on the maintenance of fauna biodiversity can make a difference. There are signs that point to a greater stability in the trophic pyramid of organic and raw sugarcane systems, confirmed by the presence of carnivores, such as various species of felines, canidae, birds of prey, snakes etc., indicating that they are *habitats* with a high prey population. This is linked to an important predictability of ecological conditions provided over time in these farming environments. The plant biomass available as forage must be ensuring the food base of the entire vertebrate food chain, playing a significant role in providing food for the species' ecological niche. New scientific studies may uncover how these interactions between fauna biodiversity and agriculture take place. Apparently, the higher environmental sustainability in the raw or organic sugarcane systems is due to the stability of food resources created by the green biomass left on the soil following the harvest periods. Over time, the food chain also increasingly structures itself as a result of the predictability of the repetitive occurrence of this annual food resource, and there is a significant increase in carnivorous vertebrates at the top of the trophic pyramid.

The methodological itinerary used for evaluating the biodiversity of fauna populations and *habitats* has allowed us to meet the objectives of this study. The use of satellite imagery for the mapping and description of *habitats* was fundamental for defining a stratified random sampling strategy appropriate for the heterogeneity of the agro-ecosystems. The use of a protocol with pre-coded cards for animal ecological surveys ensured homogeneity in the collection of condition data and, consequently, its subsequent statistical treatment. The richness and diversity indexes used identified and ecologically defined the populations and their respective *habitats*. The established methodology can be used in other fauna studies within the outlined territory and added to other tools that may be adopted as needed for this type of research.

Wild fauna must be considered an integral part of the production process in agro-ecosystems. Most of the time, it has made a positive contribution in the control of "pest" insects, and played a role in soil nutrient cycles. We are only now beginning to understand positive interactions between fauna and the different agricultural production systems and how they can be enhanced through biodiversity-focused management. The first results from ongoing studies on biodiversity in agricultural areas point to the potential for an increasingly more symbiotic and equally conciliatory relationship between production and conservation. This may become an indicator of environmental sustainability for Brazilian agriculture in its pursuit of new markets. Investment in research of this scientific dimension could become an advantage for Brazilian agricultural products, particularly in the face of international competition for new markets, as well as contributing to public conservation policies and creating a positive image in the minds of consumers.

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