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How Do Crop Area and Management Intensity Influence Tropical Lizard Species Diversity?

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Abstract

Crop area (CA) and agricultural management intensity (AMI) are the two main factors associated with agricultural systems that can negatively affect the diversity of animal communities. Despite existing knowledge, the effect of both factors has not been analyzed for all biological groups. In this study, we evaluated the effect of CA and AMI in two types of crop farming (intensive and semitraditional) on the diversity of tropical lizards in a mosaic of agricultural land and subdeciduous tropical forest. The results of this study show that by grouping crops, CA reduces lizard species richness and diversity, while lizard abundance is not related to either CA or AMI. However, when crops are assessed separately, AMI and CA are found to reduce richness and diversity in semitraditional crops. Lizard abundances in both types of crops are unrelated to any factor. Our results show that lizard diversity is more affected by CA than AMI; however, the magnitude of the effect depends on the type of crop farming.

Keywords

agricultural systems, species richness, species composition, land-use coverage, lizards

Replacement of natural vegetation with agricultural systems exerts a strong pressure on the dynamics of plant and animal communities (Deheuvels et al., 2014; Gascon et al., 1999). Currently, rapid replacement of native vegetation with agricultural fields has increased the number and size of landscapes dominated by a matrix of crop fields (Maas et al., 2015; Perfecto & Vandermeer, 2008). This rapid expansion of agricultural areas makes necessary to evaluate the changes that occur within the native communities of animals that inhabit agricultural sites (Gallego-Ropero, 2005; Gonthier et al., 2014; Maas et al., 2015; Williams-Guillen & Perfecto, 2010). Relatively few studies have been carried out to evaluate the impact exerted by agroecosystems on species diversity (Gallego-Ropero, 2005; Gonthier et al., 2014); these have shown that there are several factors associated with agricultural systems that can reduce diversity (Sanz, 2007), among which crop area (CA) and management intensity are the most notable (Gonthier et al., 2014; Tscharntke et al., 2012).

In general, comparative studies conducted in different types of crops have shown that the size of the cultivated area can negatively influence richness (*S*), abundance (*ab*), and diversity (*D*) of native species (Tscharntke et al., 2012) as a result of changes in microenvironmental conditions that reduce microhabitat quantity and quality (Berriozabal-Islas et al., 2017; Gonthier et al., 2014). On the other hand, small areas transformed into agricultural systems can even favor the arrival of novel native or alien species, which increases the *S*, *ab*, and *D* of some taxa (Barbaro et al., 2014; Bobo et al., 2006; Gascon et al., 1999). Therefore, an increase in the heterogeneity of the landscape can promote the arrival of species that occupy the new available spaces (Tscharntke et al., 2012). Agricultural management

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intensity (AMI) exerts differential influences on species diversity, as it can vary widely between different types of crops or among crops of the same species, depending on the agricultural techniques used (traditional, semitraditional, or intensive; Gallego-Ropero, 2005; Henderson & Powell, 2001). Traditional agricultural systems (e.g., those with high plant diversity and low chemical use), such as some traditional coffee and cocoa farming methods, show higher *S, ab*, and *D* than intensive monocultures such as lime and sugarcane (Glor et al., 2001; Henderson & Powell, 2001; Mas & Dietsch, 2003).

The knowledge about the effect of agricultural systems on vertebrate and invertebrate species diversity comes mainly from studies of birds, pollinating insects, butterflies, and mammals, while other biological groups have been understudied (e.g., reptiles: 50 case studies; Thomson et al., 2015). Lizards are a good model for evaluating the impact of agricultural practices as they represent a high percentage of the vertebrate terrestrial and arboreal fauna (Palacios et al., 2013), they have low dispersal capacity (Smart et al., 2005), their communities are composed of a large variety of species with different responses to disturbance (Berriozabal-Islas et al., 2017), they are abundant within and outside agricultural systems, and they can be found relatively easily throughout the year (Berriozabal-Islas et al., 2017; Macip-Ríos & Muñoz-Alonso, 2008). Some studies that have evaluated the effect of different types of agroecosystems on lizard diversity have found that croplands with low AMI have greater diversity than those with higher AMI (Glor et al., 2001; Henderson & Powell, 2001; Macip-Ríos & Muñoz-Alonso, 2008; Wanger et al., 2010). However, Deheuvels et al. (2014) noted that lizard species, particularly those inhabiting the leaf litter, are relatively tolerant to changes in AMI. On the other hand, the effect of CA size on lizard species has not yet been directly evaluated (Thomson et al., 2015). Thus, it is still uncertain how the area devoted to crops affects the species richness, abundance and diversity of lizard species, although some studies in other biological groups have observed that crops can modify microenvironmental conditions, reducing species richness, abundance, and diversity (Gonthier et al., 2014). Therefore, the goal of this study is determine how and in what degree the size of CA and AMI in two types of crop agriculture influence species richness, abundance, and diversity of tropical lizards. Our prediction is that both AMI and CA will negatively affect lizard richness, abundance, and diversity regardless of crop type.

Methods

Study Area

The study was conducted inside the Santuario del Manatí Natural Protected Area (18°46′–18°32′N by 88°11′–88°30′W), Quintana Roo, Mexico. Originally, the native vegetation was composed of subdeciduous tropical forest, but currently this landscape is a mosaic of native forest, cropland, grazing lands, and urban areas, as well as small patches of halophyte vegetation and tropical dry forest (Díaz-Gallegos & Acosta-Velázquez, 2009). Within this area, we selected four sites on coconut and lime farms (Figure 1A).

Sampling Sites

To evaluate the effect of AMI and CA on *S*, *ab*, and *D*, we selected four sites of 2, 4, 9, and 19 ha in two contrasting farming types. To maintain independence between sites, fields were selected at least 2 km apart (Sánchez, 2011). Site selection was based on satellite images (Google Earth, 2014) and direct sampling of the study area. The owners of the farms were interviewed in order to obtain survey permission and information on agricultural management techniques of each crop field. To avoid bias from surrounding vegetation, all selected crop fields analyzed were surrounded by at least 75% native vegetation.

Coconut fields (semitraditional crops) selected were characterized by adult palms of *Cocos nucifera* var. hybrid approximately 9 years of age. Palm age was estimated by dividing the number of scars on the trunk by nine, which represents the average number of leaves lost per year (Duarte-Reynoso, 2010). Within fields, all trees were 8 m apart (Duarte-Reynoso, 2010) and were associated with different fruits, such as banana, mango, mamey, and zapote, among others, and some herbaceous plants. The tallest canopy in all sites was approximately 10 m, with 40% canopy coverage throughout the year. All sites presented four vegetation strata: leaf litter (organic material in decomposition), herbaceous, shrub, and arboreal, as a result of the combination, the coconut crops have trunks with a large range of different diameters (Figure 1A).

Lime fields (intensively managed crop) were characterized by monocultures of *Citrus* × *latifolia*. Lime trees in all fields were approximately 5 years of age (informed by the owners), 3 m apart, with few or no associations with other cultivated plants, and a low herbaceous stratum (Bonilla, 1992). Canopy height in all sites was approximately 3 m, and canopy coverage was less than 20% throughout the year. Most of the sites had only two strata: herbaceous and arboreal, as the ground had no leaf litter (Figure 1C).

Data Collection

Data were collected in three sampling events, in April and October 2014 and April 2015. We selected a 600 m^2 plot (40 × 15 m) within each crop field to avoid edge

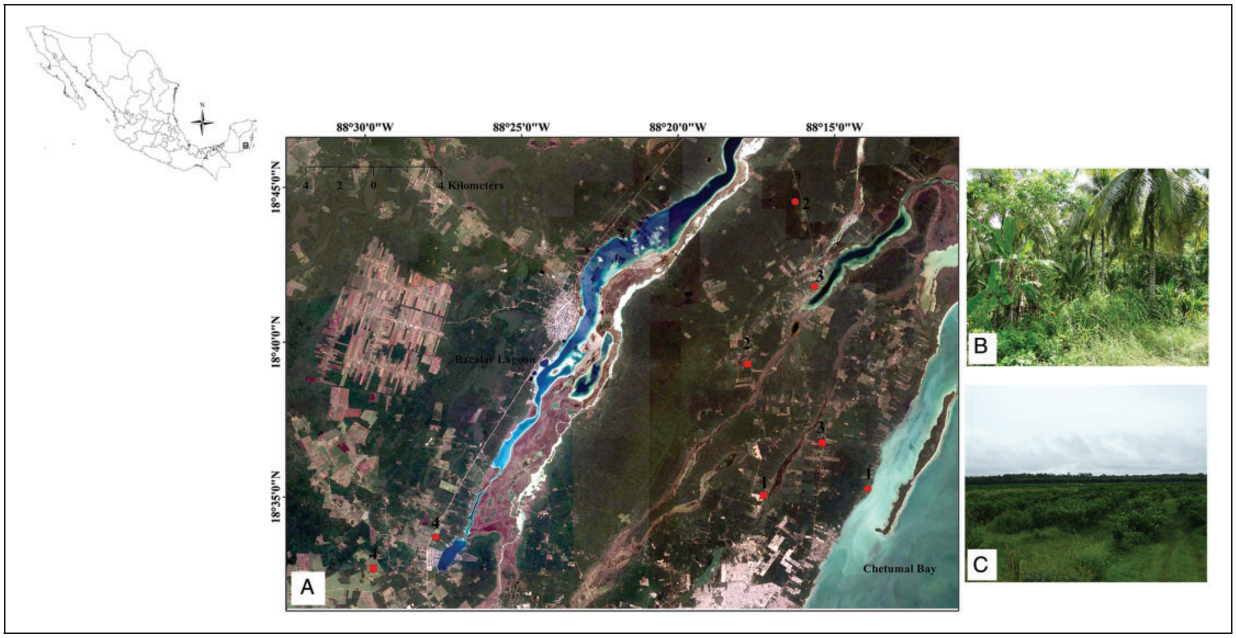

Figure 1. Panel A: Satellite image of the study area obtained from Google Earth. Squares = lime fields; Circles = coconut fields. The numbers indicate field size; 1 = 2 ha, 2 = 4 ha, 3 = 9 ha, 4 = 19 ha. Panel B: Coconut crop. Panel C: lime crop.

Table 1. Categories and assigned values used to measure agricultural management intensity.

Variable	Category/values (0–1.0)				
Number of fumigations per year	0/0	1/0.25	2/0.5	3/0.75	>4/1.0
Weed control method	None/0	Manual/0.33	Mechanical/0.66	Chemical/1.0	
Herbivory control method	None/0	Lime-coating/1.0			
Harvest frequency	None/0	Seasonal/0.5	Annual/1.0		
Pruning frequency	None/0	Occasional/0.5	Regular/1.0		
Associated tree species	>4/0	3/0.25	2/0.5	1/0.75	0/1.0
Number of strata	>4/0	3/0.33	2/0.66	1/1.0	
Tree density	>100/0	61–80/0.25	41–60/0.5	21–40/0.75	0–20/1.0
Average canopy height (m)	>3.1/0	3–2.1/0.33	2–1.1/0.66	<1/1.0	

Note. Values range from 0 (*completely "pristine"*) to 1.0 (*fully intensive*).

effects. The plots were relocated at each sampling site in such a way that 1,800 m^2 were sampled in each crop field. Each sampling was performed by three people with experience in monitoring herpetofauna. Lizards were sampled using the direct sampling technique, which consisted in examining all possible microhabitats, including trees, from ground level to a height of 3 m (Amador, 2010). Individuals were captured and marked with red nail polish to avoid counting them more than once during each sampling period. Sampling was scheduled according to the periods of greatest activity of the lizards; it was divided into two periods: morning (09:00–14:30 hr) and afternoon/evening (16:00–21:00 hr), thus obtaining a sampling effort of 94.5 person-hours for each CA (Manzanilla & Péfaur, 2000).

Agricultural Management Index

To measure management intensity, the AMI index proposed by Mas and Dietsch (2003) for coffee crops was used and modified by us in order to account for additional anthropic pressures. Five variables related to human activity, three to farming practices, and one to canopy cover were included (Table 1). A principal component analysis was used to determine which of the variables would be included in the AMI index. Variables retained were weighted equally, with a value of 0 to 1 assigned to each category (Table 1). The variable took on values on a gradient from *minimum* (0) to *maximum* (1) management intensity (Gallego-Ropero, 2005; Mas & Dietsch, 2003; Rivera & Armbrecht, 2005). Therefore, the agricultural management index value for each site could range from 0 (*completely* *"pristine"*) to the number of variables retained (*completely intensive*).

Data Analysis

Inventory completeness was calculated using sample coverage, which represents the fraction of the abundances of the community. The inverse of this index estimates the probability that a new species would be added to the list during a later sampling (Chao & Jost, 2012). Values of richness (*S*) and abundance (*ab*) from each type of crop were the number of species and the total number of individuals registered within each plot, respectively.

Table 2. Statistics from principal component analysis for intensity management variables.

Variable	PC1	PC2
Number of fumigations per year	.81	.52
Weed control method	−.62	−.73
Harvest frequency	−.72	−.65
Pruning frequency	.85	−.04
Associated tree species	.77	−.65
Number of strata	−.93	−.05
Tree density	.93	−.21
Average canopy height (m)	−.93	−.05

Note. PC1 is mostly related to vegetation strata, and PC2 is related to agricultural management. PC1 = principal component 1; PC2 = principal component 2.

Diversity (D^1) was calculated based on the number of effective species ($\exp(H')$). This index was chosen because it considers diversity (q^1) as the number of equally dominant species within a hypothetical community; therefore, it proportionally weights the abundances of the species that make up the community (Jost, 2006). Values obtained from each sampling are therefore comparable with each other (Jost, 2006). This index also represents the diversity values in a simpler and more intuitive way, enabling species losses and gains to be compared between two environments as percentages (Moreno et al., 2011).

To evaluate the influence of CA or AMI on species richness, abundance, and diversity overall and separately for each type of crop, we performed simple linear regression analyses using Statistica 7.0 (StatSoft, Inc., Tulsa, OK, USA). A canonical correspondence analysis was carried out with Past (v.3.0) to determine which environmental factors influence species richness and abundance in each crop. This analysis also shows species distributions in terms of their main relationships (species preferences) to environmental factors (García-Rojas et al., 2017; Kent & Coker, 1992; Toro-Ramírez et al., 2017).

Results

The AMI index included eight variables. Principal component analysis showed that the eight variables explained 88% of the total variation (PC1 eigenvalue

Table 3. Species Richness and Cumulative Abundance (Total of Samples) by Crop Area for Each Type of Crop.

			Coconut fields				Lime fields			
		Area	2 ha	4 ha	9 ha	19 ha	2 ha	4 ha	9 ha	19 ha
		AMI	2.8	3.4	3.1	3.7	5.2	6.1	7	7
Family	Genus	Species	*ab*							
Phyllodactylidae	*Thecadactylus*	*rapicauda*	2							
Sphaerodactylidae	*Sphaerodactylus*	*glaucus*	2	5						
Gekkonidae	*Hemidactylus*	*frenatus*	3	3	2		1	3	2	
Dactyloidae	*Anolis*	*ustus*					2	3		8
		lemurinus	5	3		1				
		rodriguezii	12	47	6	2	17	13	2	
		sagrei					1			
Teiidae	*Aspidoscelis*	*angusticeps*		3				2		4
Corytophanidae	*Basiliscus*	*vittatus*		5	1			1		
Iguanidae	*Ctenosaura*	*similis*		1						
Scincidae	*Sphenomorphus*	*cherriei*	2							
Phrynosomatidae	*Sceloporus*	*chrysostictus*	2		1		17	5	5	
		serrifer	1							
		Richness	8	7	4	2	5	6	3	2
		Abundance	29	67	10	3	38	27	9	12
		Diversity	5.5	3.1	2.9	1.9	2.9	4.3	2.7	1.8

Note. ha = hectares; AMI = agricultural management intensity; ab = abundance.

0.804, 68.9% variance, PC2 eigenvalue 0.230, 19.8% variance). The first component was positively related to the number of fumigations per year, pruning frequency, associated tree species, and tree density and negatively related to harvest frequency, number of strata, and average canopy cover. The second component was negatively related to the weed control variable (Table 2).

Inventory completeness was greater than 91% (between 91% and 99% in coconut and between 99% and 100% in lime). Thus, the average probability of adding new species in future samples was 0.05 (5%) for the coconut and 0.005 (0.5%) for the lime fields. In the coconut fields, we registered 11 species and 108 individuals, while in the lime fields, 7 species and 86 individuals were registered (Table 3).

In general, lizard species diversity (D^1) was higher in smaller fields and lowest AMI, while the lowest D^1 was observed in fields with the largest areas and highest AMI. In the coconut fields, the highest D^1 was found in fields with the smallest areas and lowest AMI; while in the lime fields, the greatest D^1 was observed in the 4-ha fields (Table 3).

When evaluating both crops pooled, we observed a negative relationship between CA and species richness (*S*), and diversity (D^1; Wilk's lambda = 0.49, $F = 5.05$, $p = 0.01$; Figure 2) but not between AMI and *S*, *ab*,

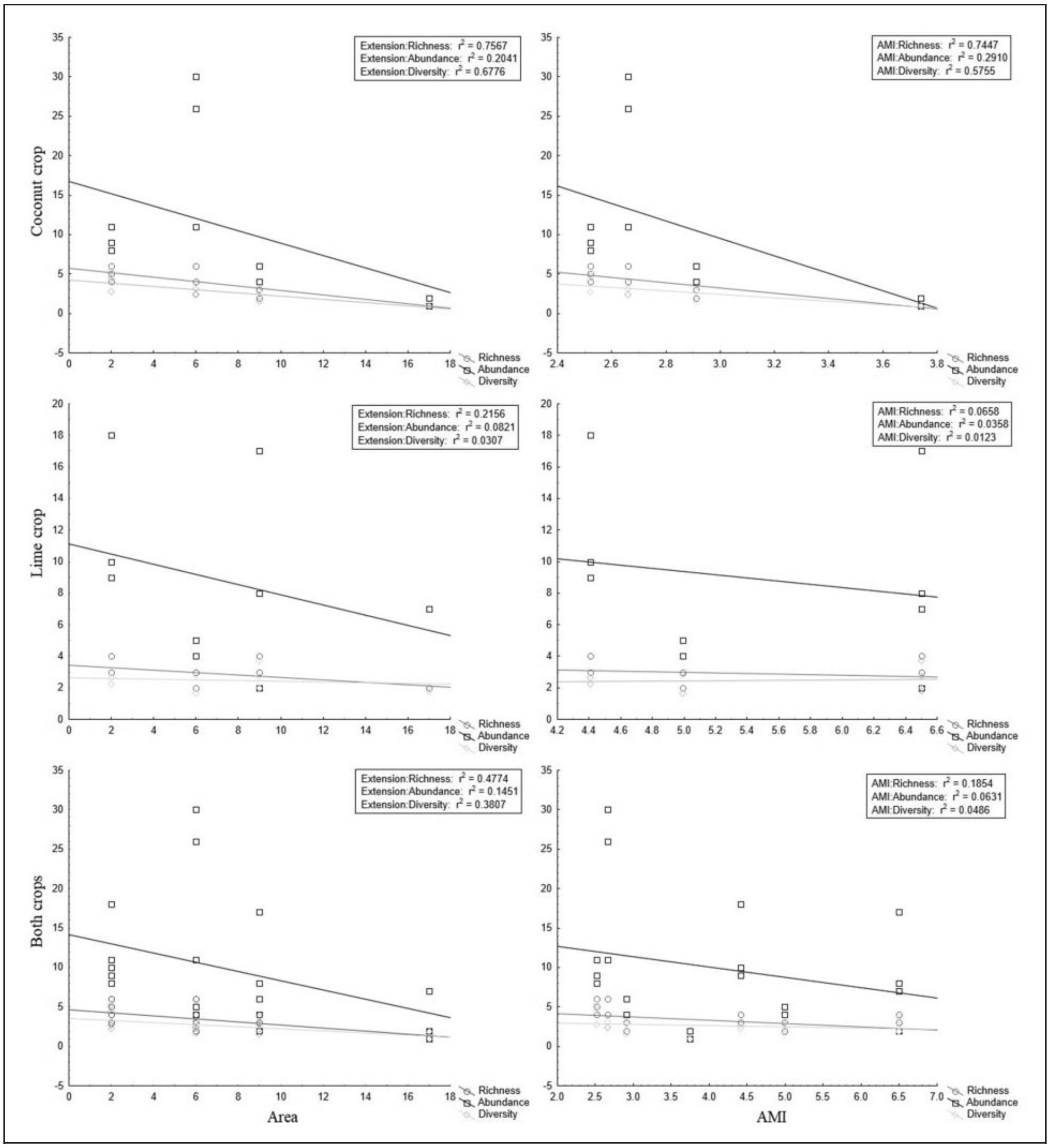

Figure 2. Regression Analyses. First column corresponds to regression analyses between crop field area and lizard species richness, abundance and diversity and second column to regression analyses between AMI and lizard species richness and diversity. Lines represent the fitted linear regressions. AMI = agricultural management intensity.

and D^1 (Wilk's lambda = 0.61, $F = 3.15$, $p = 0.6$; Figure 2). On the other hand, when the crops were evaluated separately, both CA and AMI were negatively related to S, ab, and D^1 in the coconut fields (Wilk's lambda = 0.2, $F = 7.5$, $p = .01$ and Wilk's lambda = 0.24, $F = 6.1$, $p = 0.02$, respectively). However, in lime fields, neither CA nor AMI was significantly related to S, ab, or D^1 (Wilk's lambda = 0.6, $F = 1.0$, $p = 0.45$ and Wilk's lambda = 0.72, $F = 0.63$, $p = 0.6$, respectively; Figure 2). AMI was positively related to CA in both types of crops (coconuts, $R^2 = 0.74489$, $p = 0.01$; lime, $R^2 = 0.8874$, $p = 0.0006$).

The canonical correspondence analysis showed that *Anolis sagrei*, *Sceloporus chrisostictus*, and *Hemidactylus frenatus* have preferences for high AMI environments (i.e., highly disturbed sites), while *Anolis ustus* and *Aspidoscelis angusticeps* prefer large fields. The remaining species are susceptible to an increase in field area and AMI (Figure 3).

Discussion

In general, when assessing both crops in the same analysis, only increase in CA is related to reduction of lizard richness and diversity. When analyzing crops separately, both CA and AMI reduced richness and diversity in semitraditional crops (coconut crops), but neither had an effect in intensively managed crops (lime crops). On the other hand, lizard abundance did not show any significant relationship with either AMI or CA, both when analyzing the crops as a group and separately (Figure 3).

The size of cultivated areas can exert a selective pressure over species that are not tolerant to the new microenvironmental conditions produced by croplands (Berriozabal-Islas et al., 2017); therefore, CA can act as an ecological filter that shapes community structure (Gonthier et al., 2014; Tscharntke et al., 2012). On the other hand, when each crop type was analyzed separately, lizard species richness and diversity decreased only inside the semitraditional CAs but not in the intensively managed crops, probably because thermal conditions within intensively managed crop fields tend to resemble those of more open sites, even if the area is small. Therefore, the composition of the lizard assemblages observed across all CAs of the intensively managed crop in this study is mainly dominated by species highly tolerant of high temperatures or open sites, such as *A. ustus*, *S. chrysostictus*, and *A. angusticeps* (Hertz et al., 2013; Lee, 2000). On the other hand, increase in semitraditional CAs can modify internal thermal conditions of crops of similar those of pristine forests to thermal conditions more similar to open sites (without plant cover), which can exclude species with low thermal tolerance, as is the case of *Leamanctus serratus* (Lee, 2000).

The opening of small areas within native forests can provide new ecological conditions (e.g., thermoregulation, microhabitats, reduction of competition) that favor an increase in the density of some species (Gonthier et al., 2014; Palacios et al., 2013; Tscharntke et al., 2012). In this study, greater abundance of *A. rodriguezii* was observed within 4-ha semitraditional crop fields, compared with 2-ha fields. This increase in *A. rodriguezii* density can modify the overall null relationship found between lizard abundance and AMI and CA, as individuals of this particular species have a high representation within these CAs. Similar patterns have been observed in other studies, where lizard abundance is greater within moderately disturbed sites than pristine

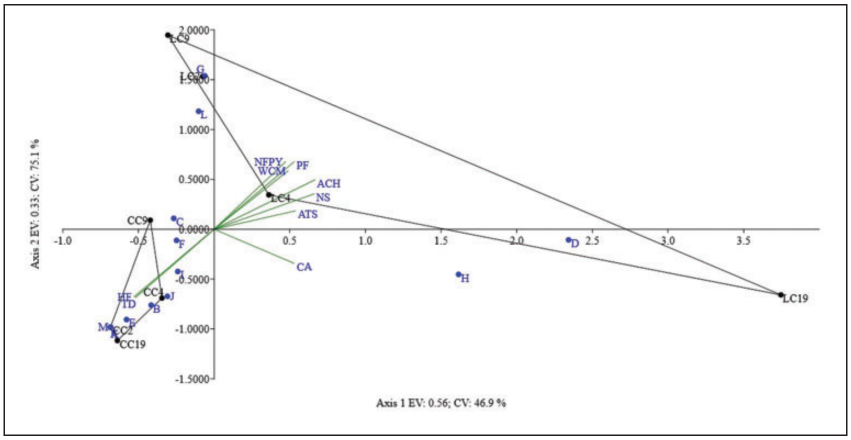

Figure 3. Canonical Correspondence Analysis. A = *Thecadactylus rapicauda*, B = *Sphaerodactylus glaucus*, C = *Hemidactylus frenatus*, D = *Anolis ustus*, E = *Anolis lemurinus*, F = *Anolis rodriguezii*, G = *Anolis sagrei*, H = *Aspidoscelis angusticeps*, I = *Basiliscus vittatus*, J = *Ctenosaura similis*, K = *Sphenomorphus cherriei*, L = *Sceloporus chrysostictus*, M = *Sceloporus serrifer*; NFPY = number of fumigations per year; WCM = weed control method; HF = harvest frequency; PF = pruning frequency; ATS = associated tree species; NS = number of strata; TD = tree density; ACH = average canopy height; CC = canopy cover; CA = crop area; CC = coconut crop; LC = lime crop; EV = Eigenvalue; CV = Cumulative variation.

or less disturbed sites, possibly due to the intrinsic ecological characteristics of the group (Berriozabal-Islas et al., 2017; Smart et al., 2005). On the other hand, within intensively managed crop fields, the observed low correlation between abundance and AMI and CA may be due to the fact that the available resources can be exploited efficiently by the few species that make up the lizard assemblage, which increases the abundance of species that are maintained in the sites (Tscharntke et al., 2012), or the scarcity of predators or competitors (Smart et al., 2005), which was not evaluated in this study.

The positive relationship between CA and AMI observed in our study is mainly due to large agricultural areas requiring more agricultural inputs such as insecticides, fertilizers, and herbicides; to avoid losses from insect pests; to increase crop production; and to reduce nutrient competition from other plants (Sanz, 2007). This increase in AMI can affect the quality and quantity of food and microhabitats available for lizard species (Macip-Ríos & Muñoz-Alonso, 2008; Wanger et al., 2010). Therefore, AMI could likely be indirectly affecting the richness, abundance, and diversity of lizard species, even though in general we do not find significant relationships. However, we did not measure the quantity or quality of food or micro habitats directly, so it is still necessary to conduct studies that evaluate whether food availability within crop fields is a determining factor in the composition of lizard communities within agricultural systems.

Conclusion

Our results showed that lizard species richness and diversity are more affected by field size than by AMI in spite of the two being intimately related. However, larger field size and greater AMI in a semitraditional farm directly reduced the richness and diversity of lizards, while intensive farming did not show a negative relationship.

Implications for Conservation

The results of this study suggest that relatively small CAs (between 4 and 9 ha), with high structural complexity, high density of other plant species, a canopy coverage throughout the year, and reduced fumigation and pruning, can reduce the impact of agroecosystems on lizard communities. Therefore, conditions that are similar to those present in traditional polycultures or semitraditional farming increase habitat structure, which in turn reduce changes on microenvironmental conditions and allow the establishment of both native and alien species within crops, increasing the diversity of lizard species.

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References

Amador, L. (2010). *Techniques for vertebrate monitoring*. Escuela de Biología Facultad de Biología, Facultad de Ciencias Naturales, Universidad de Guayaquil.

Barbaro, L., Giffard, B., Charbonnier, Y., van Halder, I., & Brockerhoff, E. G. (2014). Bird functional diversity enhances insectivory at forest edges: A transcontinental experiment. *Diversity and Distribution*, *20*, 149–159.

Berriozabal-Islas, C., Badillo-Saldaña, L. M., Ramírez-Bautista, A., & Moreno, C. E. (2017). Effects of habitat disturbance on lizard functional diversity in a tropical dry forest of the Pacific coast of Mexico. *Tropical Conservation Science*, *10*, 1–11.

Bobo, K. S., Waltert, M., Fermon, H., Njokagbor, J., & Mühlenberg, M. (2006). From forest to farmland: Butterfly diversity and habitat associations along a gradient of forest conversion in Southwestern Cameroon. *Journal of Insect Conservation*, *10*, 29–42. https://doi.org/10.1007/s10841-005-8564-x

Bonilla, L. (1992). *Citrus cultivation. Manual técnico No. 10*. Fundación de desarrollo agropecuario, inc.

Chao, A., & Jost, L. (2012). Coverage-based rarefaction and extrapolation: Standardizing samples by completeness rather that size. *Ecology*, *93*(12), 2533–2547.

Deheuvels, O., Rousseau, G. X., Quiroga, G. S., Franco, M. D., Cerda, R., Vílchez-Mendoza, S. J., & Somarriba, E. (2014). Biodiversity is affected by changes in management intensity of coca-based agroforests. *Agroforestry Systems*, *88*, 1081–1099. https://doi.org/10.1007/s10457-014-9710-9

Díaz-Gallegos, J. R., & Acosta-Velázquez, J. (2009). *Soil use transformation tendencies and nearby vegetation*. In J. Espinosa-Ávalos, G. A. Islebe, & H. A. Hernández-Arana (Eds.), *The ecological system of the Chetumal/Corozal bay: Caribean Sea west coast* (pp. 226–237). Colegio de la Frontera Sur.

Duarte-Reynoso, J. L. (2010). *Technical manual for coconut cultivation (*Cocos nucifera *L.)*. Product system committee of the State of Nayarit A. C.

Gallego-Ropero, M. C. (2005). Management intensity of the coffee agroecosystem (*Coffea Arabica* L.) (monoculture and polyculture) and generalist ant species richness. *Boletín Del Museo de Entomología de la Universidad Del Valle*, *6*(2), 16–29.

García-Rojas, A., Vega-Bolaños, H., & Quesada-Phillips, V. (2017). Dinámica anual de tintínidos en las aguas estuarinas de dos áreas marinas de pesca responsable en el Golfo de Nicoya, Costa Rica. *Uniciencia*, *31*(1), 1–12.

Gascon, C., Lovejoy, T. E., Bierregaard, R. O., Jr. Malcolm, J. R., Stouffer, P. C., Vasconcelos, H. L., Laurance, W. F., Zimmerman, B., Tocher, M., & Borges, S. (1999). Matrix habitat and species richness in tropical forest. *Biological Conservation*, *91*, 223–229.

Glor, R., Flecker, A., Benard, M. F., & Power, A. G. (2001). Lizard diversity and agricultural disturbance in a Caribbean forest landscape. *Biodiversity and Conservation*, *10*, 711–723.

Gonthier, D. J., Ennis, K. K., Farinas, S., Hsieh, H., Iverson, A. L., Batáry, P., Rudolphi, J., Tscharntke, T., Cardinale, B. J., & Perfecto, I. (2014). Biodiversity conservation in agriculture requires a multi-scale approach. *Proceedings of the Royal Society*, *281*, 20141358. https://doi.org/10.1098/rspb.2014.1358

Google Earth. (2014). *Royal Roads University*. https://goo.gl/maps/m4YgMumThCM2

Henderson, R. W., & Powell, R. (2001). Responses by the West Indian herpetofauna to human-influenced resources. *Caribbean Journal of Science*, *37*, 41–54.

Hertz, P. E., Arima, Y., Harrison, A., Huey, R. B., Losos, J. B., & Glor, R. (2013). Asynchronous evolution of physiology and morphology in *Anoli*s lizards. *Evolution*, *67*(7), 2101–2113.

Jost, L. (2006). Entropy and diversity. *Oikos*, *113*, 363–375.

Kent, M., & Coker, P. (1992). *Vegetation description and analysis, a practical approach*. Belhaven Press.

Lee, J. C. (2000). *A field guide to the amphibians and reptiles of the Maya world*. University of Miami, Cornell University Press.

Maas, B., Tscharntke, T., Saleh, S., Putra, D. D., & Clough, Y. (2015). Avian species identity drives predator success in tropical cacao forestry. *Journal of Applied Ecology*, *52*(3), 735–743.

Macip-Ríos, R., & Muñoz-Alonso, A. (2008). Lizard diversity in coffee plantations and primary forest in Chiapas Soconusco. *Revista Mexicana de Biodiversidad*, *79*, 185–195.

Manzanilla, J., & Péfaur, J. E. (2000). Field techniques and methods considerations for the study of amphibians and reptiles. *Revista de Ecología Latinoamericana*, *7*, 17–30.

Mas, A. H., & Dietsch, T. V. (2003). An index of management intensity for coffee agroecosystems to evaluate butterfly species richness. *Ecological Applications*, *13*, 1491–1501.

Moreno, C. E., Barragán, F., Pineda, E., & Pavón, N. P. (2011). Reanalyzing alpha diversity: alternatives to understand and compare information about ecological communities. *Revista Mexicana de Biodiversidad*, *82*, 1249–1261.

Palacios, C. P., Agüero, B., & Simonetti, J. A. (2013). Agroforestry systems as habitat for herpetofauna: Is there supporting evidence? *Agroforestry Systems*, *87*, 517–523.

Perfecto, I., & Vandermeer, J. (2008). Biodiversity conservation in tropical agrosystems a new conservation paradigm. *Annals of the New York Academy of Science*, *1134*, 173–200.

Rivera, L., & Armbrecht, I. (2005). Diversidad de tres gremios de hormigas en cafetales de sombra, de sol y bosques de Risaralda. *Revista Colombiana de Entomología*, *31*(1), 89–96.

Sánchez, O. (2011). *Evaluating and monitoring wild populations of reptiles*. In O. Sánchez, P. Zamorano, E. Peters, & H. Mora (Eds.), *Conservation themes of Mexican wild vertebrates* (pp 83–120). Secretaría del Medio Ambiente y Recursos Naturales, Instituto Nacional de Ecología.

Sanz, F. X. (2007). La diversidad de los agroecosistemas. *Ecosistemas*, *16*, 44–49.

Smart, R., Whiting, M. J., & Twine, W. (2005). Lizards and landscapes: Integrating field surveys and interviews to assess the impact of human disturbance on lizard assemblages and selected reptiles in a savanna in South Africa. *Biological Conservation*, *122*, 23–31.

Thomson, M. E., Nowakowski, A. J., & Donnelly, M. A. (2015). The importance of defining focal assemblages when evaluating amphibian and reptile responses to land use. *Conservation Biology*, *30*(2), 249–258.

Toro-Ramírez, A., Sosa-López, A., Ayala-Pérez, L. A., Pech, D., Hinojosa-Garro, D., & Del Río-Rodríguez, R. (2017). Abundance and diversity of the ichthyofauna in the Los Petenes biosphere reserve. *An association with nictemeral cycles and climatic periods. Latin American Journal of Aquatic Research*, *45*(2), 311–321.

Tscharntke, T., Clough, Y., Wanger, T. C., Jackson, L., Motzke, I., Perfecto, I., Vandermeer, J., & Whitbread, A. (2012). Global food security, biodiversity conservation and the future of agricultural intensification. *Biological Conservation*, *151*, 53–59.

Wanger, T. C., Iskandar, D. T., Motzke, I., Brook, B. W., Sodhi, N. S., Clough, Y., & Tscharntke, T. (2010). Effect of land-use change on community composition of topical amphibian and reptile in Sulawesi, Indonesia. *Conservation Biology*, *24*(3), 795–802.

Williams-Guillen, K., & Perfecto, I. (2010). Effects of agricultural intensification on the assemblage of leaf-nosed bats (Phyllostomidae) in a coffee landscape in Chiapas, Mexico. *Biotropica*, *42*, 605–613.