Research Article

Domestic dog invasion in an agroforestry mosaic in southern Bahia, Brazil

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Abstract
Although the value of agroforests for biodiversity conservation has been frequently highlighted, little is known about the susceptibility of this production system to biological invasions. Drawing on a camera-trap dataset obtained in 39 sites in an agroforestry mosaic in southern Bahia, Brazil, we investigated whether the conversion of native forests into agroforests and management intensification in agroforests favor the invasion by the most common carnivore worldwide, the domestic dog. We also examined whether domestic dog invasion is more associated with human activity in agroforests than in native forests. While the number of invading dogs was higher in agroforests than in native forests (11 compared to 7 dogs per site), management intensification in agroforests led to a higher mean number of visits per dog. In both habitats (not only agroforests) visits by domestic dogs tended to be concentrated on times of the day (around midday) and days of the week (Monday to Saturday) when there is greater human activity. Despite being permeable to native species, agroforests may act as sink or trap areas given their higher susceptibility to invasion, potentially limiting the value of this production system for biodiversity conservation. Moreover, local management intensification, which has been expanding worldwide, increases the intensity of such invasions, further decreasing the value of agroforests. The value of agroforestry mosaics for conservation thus depends on the management of invasive species and at least in the case of dogs, one of the most common and widely distributed invasive species, this management should focus on the habits and behavior of humans.

Keywords: alien species; Atlantic forest; *Canis familiaris*; land-sharing strategies; wildlife-friendly agriculture.

Resumo
Embora o valor das agroflorestas para a conservação da biodiversidade tenha sido freqüentemente destacado, pouco se sabe sobre a suscetibilidade deste sistema de produção à invasão biológica. A partir de um banco de dados obtido através de amostragem com armadilhas fotográficas em 39 sítios de um mosaico agroflorestal no Sul da Bahia, Brasil, nós investigamos se a conversão de florestas nativas em agroflorestas e a intensificação do manejo das agroflorestas favorecem a invasão pelo carnívoro mais comum no mundo, o cachorro doméstico. Nós também verificamos se a invasão por cachorros domésticos está mais associada à atividade humana nas agroflorestas do que nas florestas nativas. Enquanto o número de cães invasores foi maior nas agroflorestas do que nas florestas nativas (11 contra 7 cachorros por sítio), a intensificação do manejo das agroflorestas levou a um maior número médio de visitas por cachorro. Nos dois habitats (não apenas nas agroflorestas), as visitas de cachorros tenderam a se concentrar nos horários do dia (próximo ao meio dia) e nos dias da semana (segunda a sábado) em que existe maior atividade humana. Embora permeáveis às espécies nativas, as agroflorestas podem atuar como áreas sumidouro dada sua maior suscetibilidade à invasão, potencialmente limitando o valor deste sistema de produção para a conservação da biodiversidade. Além disso, a intensificação do manejo local, que vem se expandindo mundialmente, aumenta a intensidade dessas invasões, diminuindo ainda mais o valor das agroflorestas. Assim, o valor de mosaicos agroflorestais para conservação depende do manejo de espécies invasoras e, pelo menos no caso do cão, uma das espécies invasoras mais comuns e bem distribuídas, este manejo deveria focar nos hábitos e comportamentos humanos.

Palavras-chave: espécie introduzida; Mata Atlântica; *Canis familiaris*; estratégias “land-sharing”; agricultura “wildlife-friendly”.

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Introduction

Reconciling biodiversity conservation with farming production is presently one of the great challenges of mankind [1,2]. This reconciliation has been discussed from two distinct perspectives: (1) the *land-sparing* approach, based on agriculture intensification, so that larger areas of native vegetation can be set aside for conservation [3,4] and (2) the *land-sharing* approach, based on *wildlife-friendly* agricultural systems [5,6]. One of the main production systems associated with the *land-sharing* approach is agroforestry, a system of extensive management where agricultural products are cultivated in association with native or exotic trees [7]. Nowadays, extensive areas of native forests in the tropics have been converted into cacao and coffee agroforests [8,9]. Several studies have suggested that these agroforestry mosaics may favor the reconciliation of agricultural production and biodiversity conservation [6,10,11], but worldwide management intensification of agroforests may limit such benefits. [11,12]. To increase short term income levels, agroforests shaded by native trees have been converted into plantations shaded by few species of exotic trees or unshaded monocultures [11,13].

Agroforests shaded by native trees harbor a significant component of native faunas [14-16], especially in comparison to more intensively-managed areas. However, given that disturbance facilitates colonization by invasive species [17,18], agroforests, especially those more intensively-managed, should be more susceptible to invasion than native forest remnants. This greater susceptibility may limit the conservation value of agroforestry systems. Biological invasions have been growing worldwide [19,20], and are today the second greatest threat to biodiversity [21,22], affecting different levels of ecological organization, from individual behavior [23] to ecosystem processes [24]. It has already been shown that native generalist species tend to increase and forest specialist species decrease in agroforests compared to native forests [25,26]. Although scarce, evidence in the literature indeed indicates that these systems are more susceptible to invasions than native forests [27-29].

The domestic dog - the most abundant carnivore in the world [30], introduced wherever man has settled [31] - can be considered an invasive species by all three perspectives on biological invasions [32]: biogeographical, ecological-evolutionary, and nature conservation. The first is based on the breakdown of geographic barriers to dispersal, which in the case of dogs was indeed only possible after their association with humans [33]. The second focuses on novel interspecific interactions resulting from the spread or even the increase in the dominance of a species in a community. Because domestic dogs explore natural environments and interact with native fauna [30,34,35], they also fit the ecological-evolutionary perspective of invasive species. Finally, the nature conservation perspective specifically requires a negative impact of the invasive species on native species, and this is well-established for domestic dogs, which impact native species through lethal and non-lethal effects of predation [36,37], competition [38,39], and disease transmission [40,41].

Indeed, it has been proposed that, although considered a domesticated species, dogs are better understood as a subsidized predator, which is maintained at much higher population density than native predators by its association with humans [37]. This is because in vast areas where it now occurs, especially rural landscapes, dogs are free-ranging, occupying home ranges that include areas of native vegetation and preying upon wildlife [42].Moreover, because dogs in these rural landscapes usually follow men at work [43], frequency of occurrence in different habitats may be influenced by human activities. In agroforests, the presence of domestic dogs may thus be facilitated by human activities, which are more frequent in more intensively-managed systems.

However, although recent studies have shown that domestic dogs frequently use native vegetation in the tropics [*e.g.* 44-46], little is known about the presence of dogs in agroforestry mosaics. In a previous study conducted in one of the most important agroforestry regions in Brazil, we found that the number of records of domestic dogs better explains the decline of native mammals in agroforests than either the reduction of native forest cover in the surroundings or the local vegetation simplification [47]. Despite this evidence that dogs pose a threat to wildlife in agroforests, we still do not know which factors drive the distribution and abundance of dogs in agroforestry mosaics. We address this knowledge gap by investigating three interrelated hypotheses: (1) the conversion of native forests into agroforests and (2) management intensification in agroforests favor the invasion by domestic dogs, and (3) the invasion by these exotic animals is more associated with human activity in agroforests than in native forests. We draw on a standardized sampling protocol with camera-traps in 30 cacao agroforests and nine native forests throughout a 64,000-ha agroforestry mosaic. With this dataset, we examined whether the number of domestic dogs and the mean number of visits per dog (1) are higher in agroforests than in native forests and (2) increase in agroforests as management intensifies, and (3) whether days and times of visits by dogs are more concentrated in the periods of greater human activity in agroforests than in native forests.

Methods

Study area and sampling sites

The study was carried out in a 64,000-ha agroforestry mosaic in the Una and Arataca municipalities, in the cacao-growing region of southern Bahia, Brazil [48]. The climate is hot and humid, with no well-defined dry season [49]; average annual precipitation varies between 1,200 and 1,800 mm, and average annual temperature is 24.5^{o}C [50]. The region was originally covered by Atlantic Forest, classified as "Southern Bahian Moist Forest" [51]. Nowadays 50% of the landscape is covered by native forests and 15% by cacao agroforests (Fig. 1). The studied agroforests, locally known as *cabrucas*, are cacao plantations where native trees from the original forest are left for shade; the understory is composed predominantly of cacao trees, and the herbaceous vegetation is absent or periodically removed [52]. The studied native forests are well-conserved old-growth forests, but may have suffered different levels of selective logging in the past.

Despite harboring a simplified mammal fauna, from which large felids (jaguar - *Panthera onca*, and puma - *Puma concolor*) and ungulates (tapir - *Tapirus terrestris*, and peccaries - *Tayassu pecari* and *Pecari tajacu*) are rare or locally extinct, the studied mosaic of native forests and agroforests is an important area for species of conservation concern, especially small primates (golden-headed lion tamarin - *Leontopithecus chrysomelas*, and Wied's marmoset - *Callithrix kuhlii*) [16].

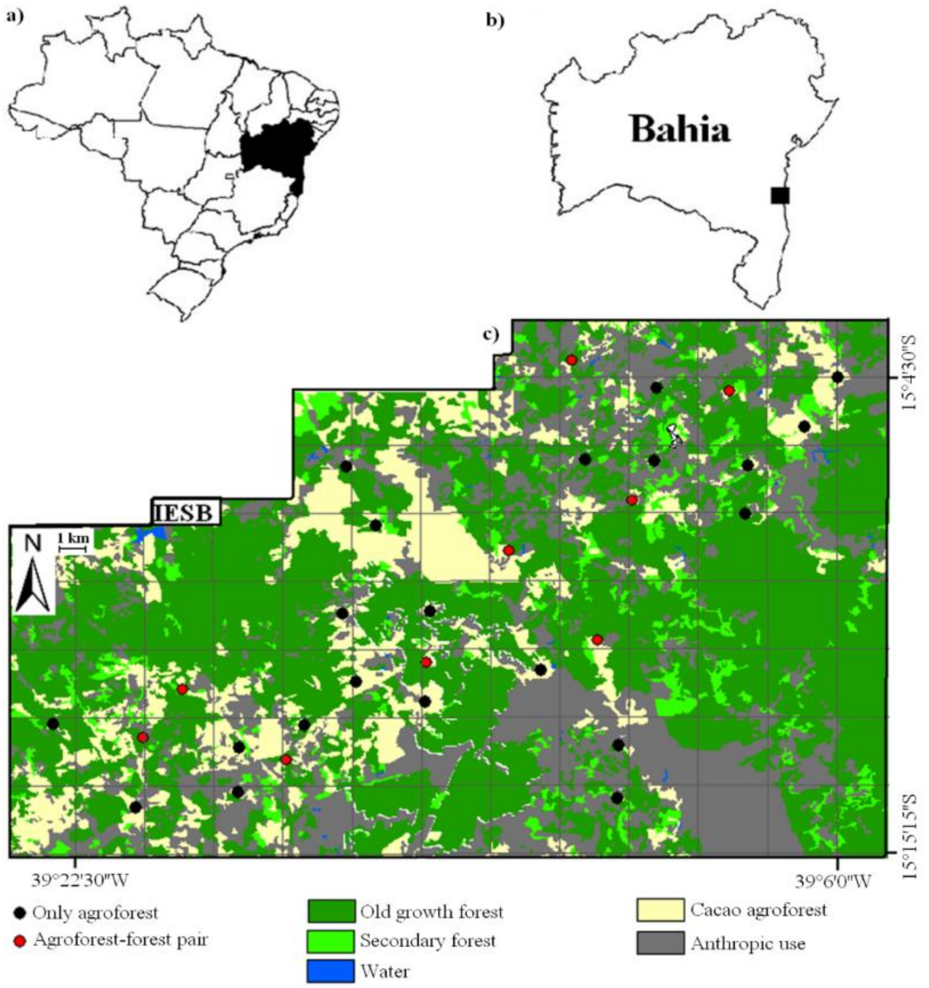

Fig. 1. Map of Brazil outlining the State of Bahia (a), map of Bahia showing the location of the study agroforestry mosaic (b), and land use in the study agroforestry mosaic, indicating the location of sampling sites (c).

We sampled 39 sites throughout the agroforestry mosaic, 30 in agroforests and nine in native forest remnants adjacent to nine of these agroforests (Fig. 1). The 30 agroforest sites were chosen to capture the variation in management intensification. Criteria for site selection were: (1) shaded cacao agroforests where exotic trees did not exceed 50 percent of the canopy layer (*cabrucas*), but which varied widely in management intensification associated with tree density and composition in the canopy layer, cacao density, and the clearance of herbaceous vegetation (these aspects were verified in the field, Appendix 1); (2) a minimum distance of 1.5 km between sites; and (3) sites that could be accessed (*i.e.,* avoiding remote areas too far from any roads) [47]. For nine of these 30 agroforests sites, we sampled also an adjacent native forest in a paired design. Sites within a agroforest-native forest pair were between 200 and 450 m from each other, but a minimum distance of 100 m from the edge between native forest and agroforest. The nine agroforests with paired native forests were a minimum distance of 2.5 km apart; the sampled native forests were old-growth well-conserved forests, and the size of native forest and agroforest patches varied among the nine pairs.

Data collection

A camera-trap was installed in each of the 39 sampling sites, placed at 20-30 cm from the ground, baited with a small piece of sardine and bananas to increase the detection of dogs and ensure the precision of abundance estimates, while not affecting habitat use [53]. In all 39 sites, traps were active over four sampling sessions of ~ 30 days each, which occurred (for all sites) from July to October 2007 and 2008, and from January to April 2008 and 2009. Due to trap malfunctions, the sampling effort varied from 94 to 127 camera-days among the nine sites in native forest remnants, and from 90 to 126 camera-days among the 30 agroforests, totaling, respectively, 1,021 and 3,325 camera-days in each habitat and 4,346 camera-days in the agroforestry mosaic. Recorded dogs were identified from characteristics such as fur color, sex, size, breed, scars, and markings to obtain the number of individuals per sampling site, and the days and times of visits (Fig. 2). From a total of 716 photos of domestic dogs, only 23 (3.2%) did not allow individual identification.

During camera-trap data collection, in all 30 agroforest sites we measured 14 vegetation structure variables to quantify management intensification (Appendix 1). Measurements were taken in four plots of 10 x 25 m, every 20 m, in an area of 25 x 100 m around the camera trap of each site.

Fig. 2. Domestic dogs recorded in camera traps in cacao agroforests in southern Bahia, Brazil.

Data analysis

Agroforests versus adjacent native forests

All the analyses comparing agroforests and native forests considered only the nine agroforest-native forest pairs. We used abundance models [54] modified from occupancy models [55], to investigate the effect of habitat type on the number of invading dogs. These models contain two parameters: abundance (λ) and probability of detection (*r*, the probability that an individual is detected), estimated from the capture history of individuals among the four sampling sessions [54]. The set of candidate models included a constant model (both parameters, *r* and λ, constant), and three models with *r* as a function of sampling effort and λ either constant, as a function of habitat type or as a function of the nine agroforest-native forest pairs.

We also used generalized linear mixed-effects models (GLMM) to investigate the effect of habitat type on the mean number of visits among individuals recorded at each site (modeled as a variable with normal distribution using log as the link function). The set of candidate models included a constant model (no fixed factors), and models with either sampling effort, habitat type, or both sampling effort and habitat type as fixed factors. In all models the nine agroforest-native forest pairs were considered as a random factor. The number of visits was calculated for each individual at each site considering all records except the sequential ones (*i.e.,* those in intervals shorter than 1 hour) and averaged among all individuals recorded at a site.

To examine whether visits by dogs are more concentrated at times of greater human activity in agroforests than in native forests, we used the following tests: the Watson test of homogeneity between two circular samples [56] to test if the time of visits differs between the two habitats (agroforests and native forests), the Rayleigh test [57] to determine whether visits in each habitat are uniformly distributed throughout the day and, if not, the Von Mises estimate [56] to estimate the time when visits are concentrated. Finally, to test whether the days of visits by dogs are more associated with working days in agroforests than in native forests, we used Chi-square tests, considering two classes, working days (Monday to Saturday) and rest days (Sunday) and calculating the expected number of visits from the proportion of weekdays in each of these two classes. To guarantee independence, in both analyses of time of the day and day of the week we excluded sequential records of the same individual and used the median time or day of record for each individual.

Agroforests with varying management intensification

We ran a PCA in a correlation matrix to rank the 30 agroforest sites according to the 14 measured vegetation variables, and used the scores of the sites on the first two axes of this analysis (PCA1 and PCA2) as variables representing management intensification (see Results). To investigate the influence of management intensification on the number of invading dogs, we used abundance models modified from occupancy models [54]. The candidate set included a constant model (with abundance λ and detectability *r* constant), and four models with *r* as a function of sampling effort and λ either constant, as a function of only PCA1, only PCA2 or both PCA1 and PCA2.

We also used generalized linear models (GLM) to investigate the influence of management intensification on the mean number of visits among individuals recorded at each site (calculated as previously described and modeled as a variable with normal distribution using log as the link function). The set of candidate GLM models included a constant model, and seven models with only sampling effort, only PCA1, only PCA2, both PCA1 and 2, PCA1 and sampling effort, PCA2 and sampling effort, and PCA1, PCA2 and sampling effort as independent variables.

In all abundance models, given the small size of sampling sites in relation to the home range of dogs, we interpreted the parameter abundance as the number of individuals that use the sampling sites [58]. In all model selections, we compared candidate models using the Akaike Information Criterion (AICc) corrected for small sample size [59]. Models that present a difference in their AICc values relative to the first-ranked model (ΔAICc) smaller or equal to 2 were considered equally plausible. All the analyses were performed in Program R, using the packages “bbmle”, ”car”, “CircStats”, “chron”, “MASS”, and “Unmarked” [60].

Results

Agroforests versus adjacent native forests

In the nine agroforest-native forest pairs, we observed 80 dogs, with only three of them recorded in both habitats. Of this total, 65 dogs were recorded in agroforests and only 18 in adjacent native forests. Indeed, only the model with abundance as a function of habitat type and detectability as a function of sampling effort was selected (Appendix 2), indicating that the number of invading dogs is higher in agroforests than in native forest remnants (Fig. 3a). The estimated number of invading dogs was 11 per site and 99 in the set of nine sites in agroforests, and seven per site and 63 in the set of nine sites in native forests. In contrast, the mean number of visits among individuals recorded at each site did not differ consistently between habitats (Fig. 3b), with only the constant model being selected (Appendix 3).

In both habitats visits by dogs were not homogeneously distributed during the day (Rayleigh test: for native forests $p<0.01$; for agroforests $p<0.01$), concentrating at 13:14 h in native forests and 12:43 in agroforests (Fig. 4), and the time of visits did not differ between habitats (Watson homogeneity test: $p=0.15$). Similarly, in both habitats (and not only in the agroforests as predicted) visits by dogs tend to be concentrated on working days (marginally significant result of Chi-square tests in both cases; native forests $\chi^2=0.70$; $p=0.08$; agroforests $\chi^2= 0.67$; $p=0.08$) (Appendix 4).

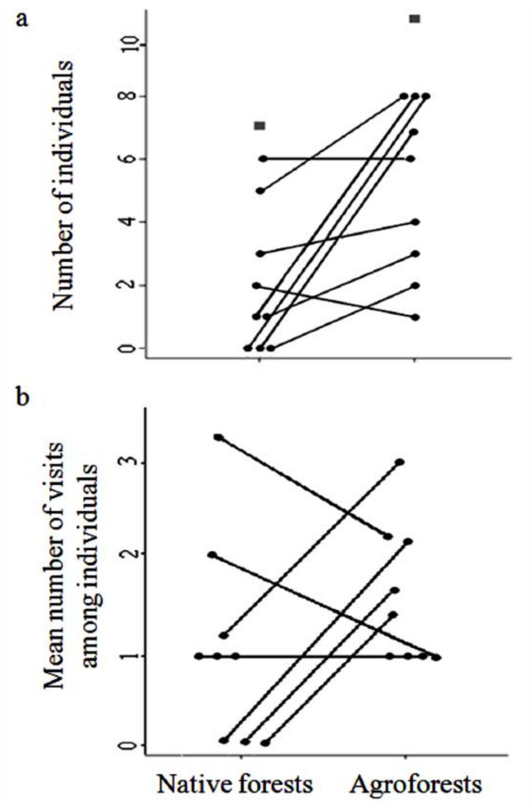

Fig. 3. Number of individuals of domestic dogs (a) and mean number of visits among individuals (b) recorded in nine pairs of agroforests and adjacent native forests. Values of adjacent sampling sites are interconnected. Squares in (a) represent estimates obtained by the selected abundance model (Appendix 2).

Agroforests with varying management intensification

The first axis of the PCA explained 27.3% of the variation in vegetation structure among the 30 agroforest sites, and represented a gradient of increasing management intensification associated with a decrease in tree shading and an increase in the frequency of clearance of the herbaceous vegetation and in the density of cacao shrubs and banana stems (Appendix 5). The second axis of the PCA explained 20.9% of the variation in vegetation structure and seems less directly related to management intensification, and more associated with the age of agroforests. Higher values of this axis represent mainly agroforests with smaller native trees, but with larger cacao shrubs (Appendix 5).

In total, we observed 145 dogs in the set of 30 agroforest sites, with none of them recorded in more than one agroforest. Only the model with detectability as a function of sampling effort and abundance constant was selected (Appendix 6). The estimated average number of dogs that use each agroforest was 12 individuals, with 360 dogs estimated to use the set of all 30 agroforests. It is noteworthy, however, that although not among the selected models, the model with abundance as a function of management intensification (PCA1) is ranked second (Appendix 6), indicating that management intensification has a positive, although weak, effect on the number of invading dogs (Fig. 5a). In contrast, the two models that were selected to describe the mean number of visits among individuals recorded at each site contained management intensification (PCA1) as an independent variable (Appendix 7), indicating that the number of visits per dog increases in more intensively-managed agroforests (Fig. 5b).

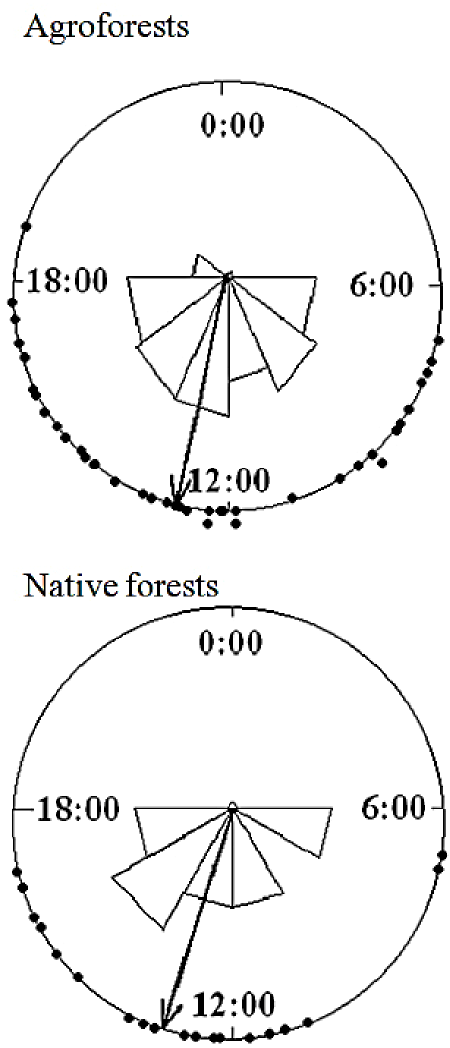

Fig. 4. Time of visits by domestic dogs to nine pairs of agroforests and adjacent native forests. Arrow: time at which visits concentrate; triangles: number of visits per 2-hour interval.

Discussion

The observed and estimated numbers of domestic dogs suggest that the intensity of invasion in agroforestry mosaics is high, representing a potential threat to the fauna of these landscapes. Not only dogs have been shown to impact native species through lethal and non-lethal effects of predation [36,37], competition [38,39], and disease transmission [40,41], but also we found in a previous study that the number of records of dogs was the main driver of the decline of native mammals in the studied agroforestry mosaic [47].

More importantly, our results corroborate the hypothesis of this study that the conversion of native forests into agroforests, as well as management intensification in agroforests, favor the invasion by domestic dogs. On the other hand, despite evidence that visits by dogs are associated with times and days of greater human activity, this association is not stronger in agroforests than in native forests, as we expected. Because only three of the 80 dogs recorded in the nine agroforest-native forest pairs were recorded in both habitats, this association of the presence of dogs with human activity is not just an artifact of the proximity of the sampled agroforest-native forest sites. Rather, despite the smaller number of dogs in native forests than in agroforests, the presence of dogs in native forests seems to be associated with human activity, although not necessarily with the activity of workers in the adjacent agroforests. Below we discuss each of these main results and their implications.

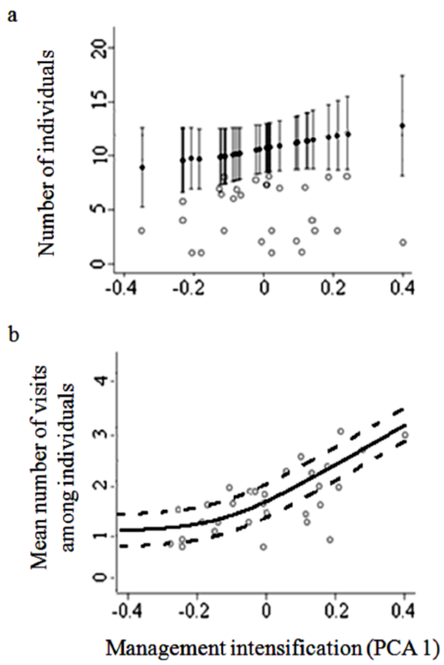

Fig. 5. Number of individuals of domestic dogs (a) and mean number of visits among individuals (b) as a function of management intensification (PCA1, Appendix 5) throughout 30 agroforests. Empty dots: observed numbers; solid line and filled dots: estimates from models with management intensification as a co-variable (Appendices 6 and 7); black bars and black dashed lines: standard deviations of these estimates.

As expected, the number of invading dogs was higher in agroforests than in native forests. In contrast, the mean number of visits per individual did not vary between the two habitat types. As in other studies [44,61], most individuals were recorded only once, both in native forests and in agroforests. Thus, the higher number of records of dogs in agroforests than in native forests in the study region [16] results mainly from the entrance of a larger number of dogs, rather than from more frequent visits by the same individuals. The higher the number of individuals, the larger the probability of disease transmission to wild animals, adding to the expected negative effects of competition and predation by dogs [34,35,62,63].

Given that the number of people entering managed systems such as agroforests is much higher than in unmanaged native forests, the higher number of dogs in this agricultural system may be simply linked to the behavior of dogs following their owners to work [43]. This hypothesis is supported by our finding that there is an association between dog presence and the time of the day and the days of the week with greater human activity. Beyond the association with workers, however, the higher number of dogs in agroforests than in native forests may also be related to environmental factors. Compared to native forests, agroforests present a simplified vegetation structure, which may facilitate the access and movement of dogs, since these animals move preferentially through open habitats [64,65]. Also, vegetation thinning in agroforests may influence native fauna, with several native species becoming less frequent in agroforests than in native forests [16,29]. If large predators that may chase or kill domestic dogs are more susceptible to vegetation thinning than mid-sized and small vertebrates (preys), simplification of the native fauna may also contribute to the higher number of dogs in agroforests than in native forests.

By contrast, in agroforests the positive effect of management intensification was stronger on the mean number of visits per individual than on the number of invading dogs. More intensively-managed plantations, associated with a higher frequency of herbaceous vegetation clearance and a higher number of cacao shrubs, require a higher frequency of workers or longer working periods, and result in more open vegetation close to the ground. Both characteristics may lead to the increase in the number of visits per dog in more intensified agroforests, either because they follow their owners who enter more frequently or stay longer in these plantations, or because their movement is facilitated in more open environments [64,65]. However, these characteristics do not necessarily affect the number of dogs that visit agroforests, which may also depend on other factors, such as the quantity of dogs raised in surrounding areas (*i.e.* propagule pressure [66,67]) or on the number of workers, probably more associated with plantation size and other socioeconomic factors than with management intensification *per se*. It is important that future studies on the distribution and impacts of dogs in agroforestry mosaics focus on these socio-economic dimensions.

In summary, our findings suggest that the higher number of invading dogs in agroforests compared to native forests is associated with the larger number of people who enter and stay in these managed systems, while the higher number of visits in more intensively-managed agroforests may be associated with a higher frequency/length of stay of workers. Although both conversion of native forests into agroforests and management intensification in agroforests affect invasion by domestic dogs, they influence distinct aspects, which may be associated with differences in the presence of people between these two habitats. In fact, in both environments (and not only in agroforests) visits by domestic dogs seem to be associated with the period of human activity, concentrating during the day, as observed in other studies [*e.g.*44,46], and on working days during the week. This suggests that the control of invasion rests on conscious efforts by workers and local residents to limit the movements of their dogs - by keeping them home instead of allowing or stimulating dogs to follow them into agroforests.

Implications for conservation

Our results, as well as previous studies [27-29], indicate that, though permeable to wildlife [15,68], agroforests may act as trap or sink areas, given the higher intensity of invasion compared to native forests, which should restrict the conservation value commonly attributed to agroforests [6,10]. More importantly, our study suggests that agroforest management intensification, which is becoming more pronounced on a global scale [11,12], increases the risks of invasions, potentially limiting the value of this agricultural system for reconciling food production and biodiversity conservation. Indeed, the domestic dog record rate was one of the most important factors negatively associated with the distribution of wild mammals in agroforests of the study region [47].

Furthermore, our study suggests – both by the association of domestic dog visits with the periods of greater human activity, and by the fact that native forest conversion into agroforests led to an increase in the number of dogs while management intensification in agroforests led to an increase in the number of visits per dog - that there is a strong association between the invasion by domestic dogs and human activities. Yet, this association does not depend on the type of habitat, and apparently occurs also in unmanaged systems, such as native forests. Thus the value of agroforestry mosaics for conservation depends on the proper management of invasive species, and at least in the case of dogs, one of the most common and widely distributed invasive species, this management should focus on how workers and residents treat their dogs. In contrast to other aspects of agroforest management intensification that negatively affect wildlife (*e.g.* thinning of shade trees and higher frequency of herbaceous vegetation clearance [47]), increased invasion by domestic dogs can be avoided with no impairment to agroforest productivity. Although no management solution to avoid the impact of dogs on wildlife will be simple, awareness and education campaigns to discourage workers to allow their dogs to follow them into agroforests can be a step forward, and could be incorporated in action plans for increasing the conservation value of agroforestry mosaics.

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Appendix 1. Minimum, mean (± SD) and maximum values of the 14 vegetation structure variables quantified in 30 agroforests to characterize management intensification.

Variable identification	Variable description	Minimum	Mean ± SD	Maximum
ht_cacao	Average height of cacao shrubs (m) ‡	2.6	4.1 ± 0.7	5.5
ht_exot	Average height of exotic woody trees (m) †	0	12.1 ± 8.4	26.8
ht_nat	Average height of native trees (m) †	12.4	20.0 ± 5.6	38.5
ht_herb	Average herbaceous vegetation height (cm)*	22.0	69.9 ± 31.5	140.0
cacao.BA	Sum of basal area of cacao shrubs (m^2) ‡	0.1	0.3 ± 0.1	0.6
exot.BA	Sum of basal area of exotic woody trees (m^2) †	0	0.3 ± 0.5	2.1
nat.BA	Sum of basal area of native trees (m^2) †	0.2	1.4 ± 0.7	2.7
n_cacao	Number of cacao shrubs ‡	18	69.9 ± 31.5	140
n_exot	Number of exotic woody trees †	0	3.4 ± 3.8	15.0
n_nat	Number of native trees †	4	10.5 ± 6.9	34
n_banana	Number of banana stems †	0	4.0 ± 4.2	15
can.con	Sum of canopy connectivity index †	1.0	27.5 ± 24.7	119.0
cacao.con	Sum of cacao connectivity index ‡	24.0	87.6 ± 28.7	143.0
slash	Frequency of herbaceous vegetation clearance ($times*year^{-1}$)	0.5	1.3 ± 0.6	2.5

†Variables measured in four plots of 10 x 25 m, every 20 m, in an area of 25 x 100 m. In these plots, we computed banana stems, computed and measured the height and diameter of all shade trees with at least 10 cm in diameter at breast height (DBH), classifying them as native or exotic trees, and estimated the proportion of canopy of each of them that was connected to the canopy of adjacent trees through an index that varied from 0 to 4 (corresponding to the number of tree crown quadrants connected to adjacent trees).

‡ Variables measured in four half plots (5 x 25 m) inside main plots describe above. In these plots we counted and measured the height and diameter of all cacao trees and we estimated the proportion of canopy that was connected to the adjacent cacao trees.

* Variable measured in12 sub-plots of 0.5 x 0.5 m, arranged at every 5 m along one of the sides and in the center of each main plot. In these sub-plots we measured the height of the herbaceous vegetation, through the height of the tallest herbaceous plant inside each of them.

The shade trees and the cacao trees were quantified at the end of the second sampling sessions with camera-traps, and the herbaceous vegetation height, which varies temporally, was quantified three times, at the end of the second, third and fourth sampling sessions.

Appendix 2. Results from the selection of abundance models for domestic dogs in nine pairs of agroforests and adjacent native forests. Models are ordered from the most plausible (the lowest to the highest AICc value), and the selected model is highlighted (light grey). For each model, information is provided on the number of parameters (K), maximum likelihood estimation (log-Lik), Akaike Information Criterion for small samples (AICc), difference in AICc relative to the best model (ΔAICc), weight of evidence (wi), and coefficients of co-variables (+ positive; - negative). Eff= Sampling effort; Pairs= nine agroforest-native forest pairs; Habitat= agroforest versus native forest; λ= abundance; r= detectability; (.) constant parameter.

Models	**K**	**log-Lik**	**AICc**	**ΔAIC**	**wi**	**Coefficients**	
						Habitat	**Eff**
λ(Habitat) r(Eff)	5	-36.25	87.5	0	0.700	-	+
λ(.) r(.)	3	-41.29	90.3	2.9	0.153		
λ(Pairs) r(Eff)	5	-37.85	90.7	3.2	0.121		+
λ(.) r(Eff)	4	-41.01	93.1	5.6	0.026		+

Appendix 3.

Results from the selection of generalized linear mixed-effects models (GLMM) for the mean number of visits among individuals recorded in nine pairs of agroforests and adjacent native forests. Models are ordered from the most plausible (the lowest to the highest AICc value), and the selected model is highlighted (light grey). For each model, information is provided on the fixed factors, number of parameters (K), maximum likelihood estimation (log-Lik), Akaike Information Criterion for small samples (AICc), difference in AICc relative to the best model (ΔAICc), weight of evidence (wi), and coefficients of fixed factors (+ positive; - negative). Eff= Sampling effort; Habitat= agroforest versus native forest. All models had the nine agroforest-native forest pairs as a random-factor.

Fixed factors	K	log-Lik	AICc	ΔAIC	wi	Coefficients	
						Habitat	Eff
Constant	3	-30.79	69.3	0	0.736		
Habitat	4	-30.23	71.5	2.3	0.238	-	
Eff	4	-32.77	76.6	7.3	0.018		+
Habitat + Eff	5	-31.98	79	9.7	0.005	-	+

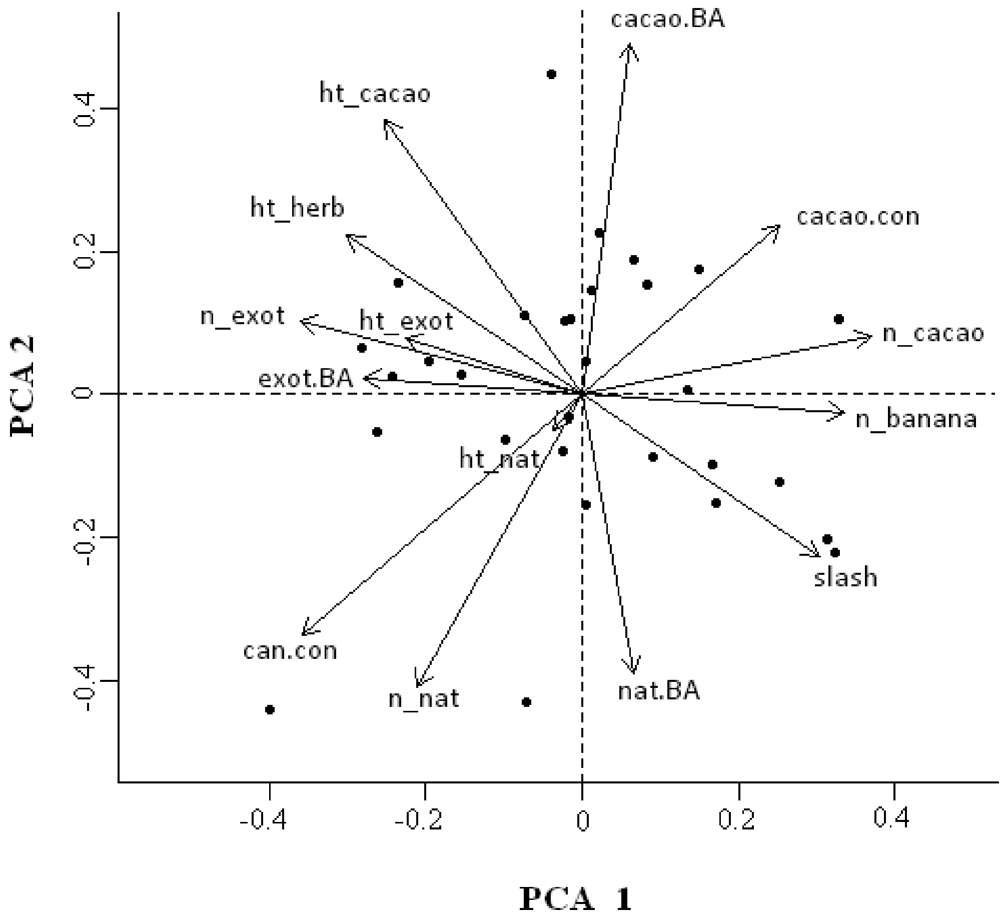
Appendix 4. Observed and expected number of visits by dogs in native forests and agroforests on working days (Monday to Saturday) and rest days (Sunday). The expected value was calculated through the proportion of days in each class (work and rest).

Native forests

	Observed		Expected	
	n	**(%)**	**n**	**(%)**
Working days	17	(94)	6	(86)
Rest days	1	(6)	1	(14)
Total	18	(100)	7	(100)

Agroforests

	Observed		Expected	
	n	**(%)**	**n**	**(%)**
Working days	61	(94)	6	(86)
Rest days	4	(6)	1	(14)
Total	65	(100)	7	(100)



Appendix 5. Ordination of the 30 sampled agroforests (black dots) on a biplot of the first and second axes of the Principal Component Analysis (PCA) using the 14 vegetation structure variables (see Appendix 1).

Appendix 6. Results from the selection of abundance models for domestic dogs in 30 agroforests. Models are ordered from the most plausible (the lowest to the highest value of AICc), and the selected model is highlighted (light grey). For each model, information is provided on the number of parameters (K), maximum likelihood estimation (log-Lik), Akaike Information Criterion for small samples (AICc), difference in AICc of relative to the best model (ΔAICc), weight of evidence (wi), and coefficients of co-variables (+ positive; - negative). Eff= Sampling effort; PCA1 and PCA2= first and second axis from Principal Component Analysis on agroforest management intensification (Appendix 5); λ= abundance; r= detectability; (.) constant parameter.

Models	K	log-Lik	AICc	ΔAIC	wi	Coefficients		
						PCA1	PCA2	Eff
λ(.) r(Eff)	4	-208.02	425.6	0.00	0.636			+
λ(PCA1) r(Eff)	5	-207.87	428.2	2.59	0.174	+		+
λ(PCA2) r(Eff)	5	-207.99	428.4	2.84	0.153		-	+
λ(PCA1 + PCA2) r(Eff)	6	-207.84	431.3	5.68	0.037	+	-	+
λ(.) r(.)	3	-216.52	439.9	14.32	0.000			

Appendix 7. Results from the selection of generalized linear models (GLM) for the mean number of visits among individual recorded in 30 agroforests. Models are ordered from the most plausible (the lowest to the highest value of AICc), and the selected models are highlighted (light grey). For each model, information is provided on the independent variables, on the number of parameters (K), maximum likelihood estimation (log-Lik), Akaike Information Criterion for small samples (AICc), difference in AICc relative to the best model (ΔAICc), weight of evidence (wi), and coefficients of independent variables (+ positive; - negative). Eff= Sampling effort; PCA1 and PCA2= first and second axis from the Principal Component Analysis on agroforest management intensification (Appendix 5).

Independent variables	K	log-Lik	AICc	ΔAIC	wi	Coefficients		
						PCA1	PCA2	Eff
PCA1	3	-37.84	82.6	0	0.309	+		
PCA1 + EFF	4	-36.75	83.1	0.5	0.24	+		+
EFF	3	-38.94	84.8	2.2	0.109			+
PCA2	3	-38.94	84.8	2.2	0.107		-	
PCA 1 + PCA 2	4	-37.75	85.1	2.5	0.09	+	-	
PCA2 + EFF	4	-37.90	85.4	2.8	0.078		-	+
Constant	2	-41.23	86.9	4.3	0.035			
PCA 1 + PCA 2 + EFF	5	-37.45	87.4	4.8	0.028	+	-	+