Floresta e Ambiente 2019; 26(4): e20170664
https://doi.org/10.1590/2179-8087.066417
ISSN 2179-8087 (online)

Review Article

Conservation of Nature

Biodiversity Conservation in Agricultural Landscapes: the Importance of the Matrix

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ABSTRACT

Agricultural matrices can lead to landscape homogenization, culminating in losses of biodiversity and ecosystem services. Agricultural management is determinant for developing conservation strategies. In this review, we discuss the influence of the agricultural matrix on biodiversity at different scales. Intensive agriculture under agrochemicals and synthetic fertilizers aggravates forest fragmentation processes, compromising conservation habitats. On the other hand, managed matrixes with greater agricultural biodiversity and reduced synthetic inputs tend to favor species' persistence. There is discord regarding the best model to conserve biodiversity in agricultural landscapes, but the land sharing system increases the landscape heterogeneity, ensures food production, and constitutes a safer approach from the socioecological perspective. Future studies should consider the matrix identity and management to assess fragmentation effects and its ability to harbor biodiversity.

Keywords: edge effects, land sharing, land sparing.

1. INTRODUCTION

One of the major challenges of the 21st century is producing food combined with minimizing environmental damage. In the tropics, 83% of the agricultural production areas originated from forest conversion only in the period from 1980-2000 (Gibbs et al., 2010). About 40% of the land surface was modified for developing agricultural activities, while only 12% of the area was destined to nature protection (Foley et al., 2005; Perfecto & Vandermeer, 2010; Ramankutty et al., 2008). Forest area reduction has raised concerns mainly regarding landscape homogenization (Verburg et al., 2013), losses in biodiversity (Barlow et al., 2016) and reduced ecosystem services (Laurance et al., 2014).

In many regions of the world, the only remaining natural habitats are fragments embedded in landscapes dominated by agriculture. The proportion between agricultural land and forests in Asia and Europe is (52%, 19%) and (21%, 46%), respectively (FAO, 2016). In global terms, agriculture occupies 37.7% of the land, and the forest areas and "other" uses have only 30.7% and 31.6%, respectively. Forests are still a constant target of land conversion in the tropical domain. In Latin America, 90% of forest conversion was for agricultural expansion (FAO, 2016; Hosonuma et al., 2012).

It is necessary to consider that there are different forms of agriculture, and that they have different roles for biodiversity and land conservation. Large-scale commercial agriculture is identified as the major precursor of land conversion (Hosonuma et al., 2012), soil degradation (FAO, 2011) and loss of biodiversity (Laurance et al., 2014), when compared to small agriculture. Thus, the identity, configuration and management of agricultural matrices can affect biodiversity differently, with strategic areas for investment in actions aimed at the conservation at different scales.

Agricultural areas composed of biodiversity systems can provide greater landscape heterogeneity and consequently greater resource availability for maintaining biodiversity over time and space. In this sense, agricultural matrices play a decisive role in consolidating structure and sustainable operation of the landscapes (Forman, 1995; Hanski & Ovaskainen, 2003; Lindenmayer & Franklin, 2002; Ricketts, 2001).

In this study, the influence of the agricultural matrix on biodiversity at different analysis scales is reviewed: the forest fragments, the edges of the fragments, the matrix itself and the landscape.

2. MATRIX: DEFINITION AND RELATED CONCEPTS

The matrix has already been considered as the functionally dominant unit of the landscape (Forman, 1995; Forman & Grodon, 1986), a concept that presupposes a clear distinction between habitat fragments and the matrix, with a certain homogeneity of the latter. This definition, however, became limited as it made difficult to understand the role of the matrix as a secondary habitat and its influence on the biodiversity of forest fragments. A second definition was proposed by Lindenmayer & Franklin (2002), where the matrix is understood as the set of non-habitat areas or where the original habitat has already been modified, having lost quality or its capacity to host the studied species.

The matrix can influence the dispersal capacity of the species within the landscape (Kennedy & Marra, 2010), the persistence of native species in forest fragments (Dallimer et al., 2012; Prevedello & Vieira, 2010; Viveiros de Castro & Fernandez, 2004) and the extension of the edge effects (Driscoll & Donovan, 2004), in addition to intensifying disturbances in forest fragment areas (Hobbs, 2001; Laurance & Cochrane, 2001; Peres, 2001).

In this study, we call agricultural matrix areas where anthropic activities related to agriculture, livestock and forestry are developed, therefore, agroecosystems with different compositions and management forms.

3. INFLUENCE ON FOREST REMNANTS

Forest fragments were compared to "islands" for many years because in most cases they were structurally different from the matrix in which they were inserted. This approach was influenced by the publication of the theory of island biogeography (MacArthur & Wilson, 1963, 1967), and has become central to the conservation biology. In this view, forest fragments or habitats and their characteristics, such as size and isolation degree, were considered the main predictors of species' richness (Fahrig, 2013). However, with the evolution in knowledge about habitat loss and fragmentation, the importance of the matrix for maintaining species' richness and abundance in the fragments was widely recognized (Laurance, 2008).

There is a strong interaction between habitat remnants and the other units that make up the landscape. The contrast between the remaining areas and the type of surrounding matrix, as well as the developed management forms are determinant factors of the matrix effects on the populations and communities of the species in forest fragments (Kennedy & Marra, 2010; Perfecto & Vandermeer, 2010). In the case of agricultural landscapes, the use of agrochemicals and mineral fertilizers, the grazing level and the pressure of invasive species can severely degrade the fragments (Didham et al., 2015).

The use of agricultural inputs promotes effects that extrapolate the agricultural system, influencing natural areas at different scales of the landscape (Didham et al., 2015), as presented in Figure 1. One of the main aspects evidenced by agriculture intensification is the accumulation of nutrients in the remnants of natural habitats (Gardner et al., 2007; Marshall & Moonen, 2002; Monadjem & Garcelon, 2005), especially when the fragments are very small. This results in altering the soil properties, mainly compaction, pH increase, reduced carbon/nitrogen ratio, nitrogen saturation, and an increase of phosphorus, in addition to contamination by heavy metals (Laliberté & Tylianakis, 2012).

In a study in Atlantic Forest areas in Southeastern Brazil, Uzêda et al. (2016) evaluated the effect of soil eutrophication on the arboreal species community of fragments located in agricultural landscapes. In this study, the authors classified the environment of the fragments as being of intensive use (corn rotated with cassava, the use of chemical fertilizers and pesticides, and soil preparation) or extensive (pasture), and found calcium contents about seven times higher in the sites adjacent to intensive use when compared to fragments adjacent to extensive use. Phosphorus levels were 1.5 to 2.5 times higher in the small and medium fragments adjacent to intensive use areas. The study also indicates that the increase in the phosphorus, potassium and calcium contents can cause changes in the tree species community.

The increase of productivity caused by the entry of nutrients into the fragments influences the composition of species in them, generally leading to reduced plant richness and changes in the composition of other organisms (Honnay et al., 2002; Kleijn & Snoeijing, 1997; Marrs, 1993). Favoring some species to the detriment of others can reduce the stability and resilience of the remnants, making them more susceptible to invasion of species adapted to other environments and/or exotic species (Didhan et al., 2015; Honnay et al., 2002; Kleijn & Snoeijing, 1997). Thus, favoring tolerant species to these changes can compromise the quality of forest remnants, leading to a predominance of systems in initial stages of succession, a phenomenon called "retrosuccession" (Lôbo et al., 2011; Melo et al., 2013; Tabarelli et al., 2010).

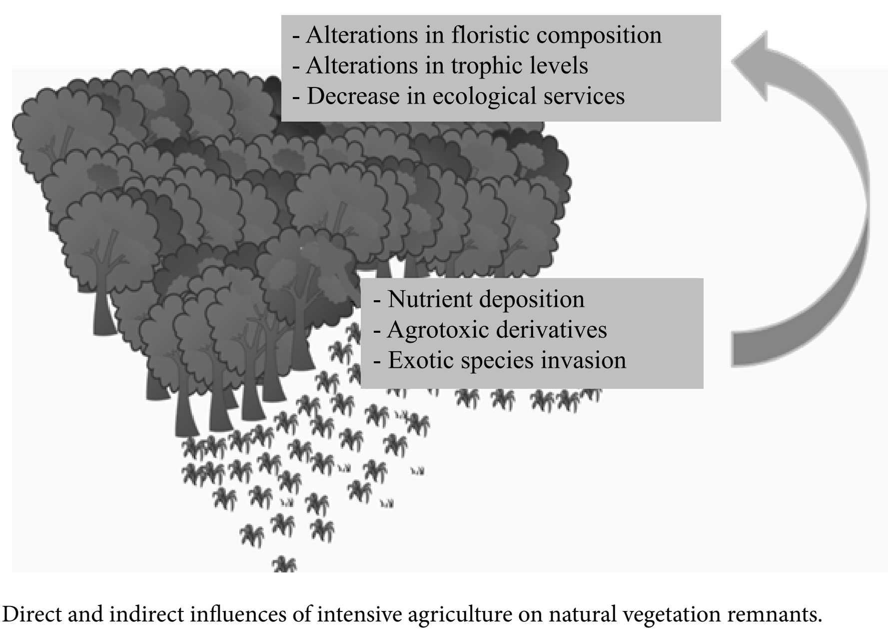

Figure 1. Direct and indirect influences of intensive agriculture on natural vegetation remnants.

Some studies have also reported the damage caused by the use of airborne pesticides to soil, water and air contamination, as well as the reduction of species diversity in forest fragments, including in areas of conservation units (Kleijn & Snoeijing, 1997; Öckinger et al., 2012). A study in the Itatiaia National Park (RJ) and São Joaquim National Park (SC) reported that air and water at an altitudinal gradient are contaminated with organochlorine residues of agrochemicals (Meire et al., 2012).

Intensive management with the use of fertilizers, agrochemicals and soil rotation in the matrix can also influence different animal groups present in the fragments. In a study comparing the diversity and abundance of terrestrial amphibians in semi-deciduous forest fragments in Southeastern Brazil, D'Anunciação et al. (2013) found about seven times fewer amphibians in fragments with sugar cane than in pasture. The authors attributed these results to the more intensive management of sugarcane, which is carried out through annual cutting, controlled burning and intense pesticide use that affect the amphibian community directly.

Negative effects have also been reported in groups that act as important ecological service providers, such as pollinators. Through a meta-analysis, Montero-Castaño & Vilá (2012) demonstrated that the disturbances promoted in the agricultural matrix reduced pollinator diversity and activity, and that this factor was more important than the size of the fragments. The authors concluded that, when the matrix becomes more hostile, pollinators become more vulnerable and have fewer visits, probably due to a decrease in their abundance. In intensively managed agricultural areas there was a reduction in the abundance of pollinators up to 150 m into the interior of the fragments (Kohler et al., 2008).

Regarding the abovementioned information, it is possible to perceive that the activities developed in the agricultural matrix have effects that reverberate in the remaining areas, which has been called spillover. Blitzer et al. (2012) synthesized this relationship of managed areas "overflowing" to natural vegetation systems from published studies into five important functional groups (herbivores, pathogens, pollinators, predators and seed dispersers). The authors demonstrated that the number of studies that analyzed this effect was less than five per trophic group. Thus, they suggest that the spillover of managed areas to natural areas has been underestimated.

With continued habitat modification resulting in increasingly fragmented landscapes, spillover effects may increase due to the use of intensive activities and lead to more severe degradation processes. It is necessary to consider that these regions can be compromised even with the maintenance of natural habitat areas for conservation, depending on the management developed in the surrounding matrix (Didhan et al., 2015). Land-use patterns over time can promote negative effects on soil processes in border/edge areas that extend into the fragments and are potentially irreversible (Dupouey et al. 2002; Flinn & Marks, 2007). Therefore, special attention should be directed to the edges, which is the fragment environment immediately affected by the matrix disturbances. These zones can act as mitigators of the matrix influences on forest remnant interiors.

4. MATRIX FRAGMENT INTERFACE: EDGE EFFECTS

Edge effects are the main promoters of many changes in fragmented landscapes and represent an inevitable and important consequence of habitat loss and fragmentation (Laurance et al., 2007). These effects occur at the interface between the natural vegetation remnant and the surrounding matrix, and are described as physical and biological changes (Murcia, 1995; Saunders et al., 1991). Due to these changes, there is the formation of an inner-edge gradient of environmental variables, biological composition and structural complexity (Harper et al., 2005; Laurence et al., 2002).

Despite the recognized role played by the surrounding matrix in mediating ecological processes within habitat fragments (Fagan et al., 1999), it is surprising that matrix parameters are often overlooked in edge effects studies. Most studies that evaluate these effects use the penetration of effects as a response variable, without explicitly considering the identity and influence of the adjacent matrix (Ewers et al., 2006; Ries et al., 2004). The intensification of edge effects through the matrix is mainly due to two characteristics of the agricultural systems: a) species composition; and b) management intensity (use of inputs, mainly synthetic fertilizers, agrochemicals and transgenic seeds, land, grazing, among others) (Didham et al., 2015; Rodenhouse et al., 1995).

In the case of abiotic effects, the matrix composition will define the level of structural contrast between the surrounding matrix and the natural vegetation fragment. The structural contrast will determine whether the edges will be abrupt or gradual. These differences influence the microclimatic changes (incidence of light, wind and temperature variation) that usually occur in the remnant edges (Cadenasso & Pickett, 2000; Didham & Lawton, 1999).

Gradual edges aid in the decelerating and deflecting of wind flow, inducing lower wind speed and less turbulence in the lower part of the forest canopy (Magura, 2002; Wermelinger et al., 2007; Wuyts et al., 2009). Wuyts et al. (2009) evaluated the attenuating effect of gradient edges on the atmospheric deposition of inorganic nitrogen (N) and other potential acidifying pollutants. The study was conducted on three different types of edges (open, abrupt and gradual). There were differences in N+S interception between the edges, where the gradient edges intercepted on an average of 80 to 100% of the residues in winter and summer, respectively.

In relation to the biotic effects, the biodiversity level in the composition of the productive systems also influences the species composition and their interactions in the habitat fragments. In a study in South Africa, Hurst et al. (2013) reported that sugar cane areas promoted reductions in the richness and heterogeneity of small mammal species, increasing similarity and promoting a more homogenized community. Agricultural practices seem to favor communities with high generalist species density, while isolating specialist species (Hurst et al., 2013).

On the other hand, productive systems with greater diversity and structural similarity to the remaining areas may be important to minimize edge effects for some organisms. This was found by Santos-Barrera & Urbina-Cardona (2011) for amphibians in agroforestry coffee plantations in Mexico. The authors reported that the diversity and abundance of amphibians in the forest mainly depended on the type of matrix adjacent to the forest fragments. Areas with shaded coffee were preferred over planted corn areas, and these results were attributed to the maintenance of native forest tree elements, low management rate and less disturbance intensity in coffee plantations than in corn lots. Areas with shaded coffee reduced edge effects, improved connectivity between the fragments, and increased habitat quality for inland forest amphibian species (Santos-Barrera & Urbina-Cardona, 2011).

In spite of the importance of structural similarity to diversity (Prevedello & Vieira, 2010), structurally similar matrices may have distinct influences on the composition of native species communities (Kennedy & Marra, 2010). Thus, caution is required when considering matrix permeability or making predictions about community responses to edges by only using this factor (Pe´er et al., 2011). Analyzing the variation of edge diversity should also consider the available resources in the matrix (Vanreusel & Van Dyck, 2007), the functionality and the potential complementarity of the different habitats according to the species needs (Levanoni et al., 2010; Pe´er et al., 2011; Walker et al., 2003). Management practices are therefore determinant for maintaining biodiversity levels, structural contrast, and the amount of chemical inputs, which influence colonization dynamics and plant extinction along the edges (Didham et al., 2015; Frost et al., 2015).

Agricultural management using transgenic varieties increased globally, with the highest increase in Brazil (3.7 million hectares) (ISAAA, 2016). The effects of transgenic plants on non-target organisms are still highly controversial. However, it is important to consider that the use of transgenic varieties can intensify fragmentation processes (Campos & Hernández, 2015). An edge-border study comparing matrices with conventional and transgenic corn showed that communities of dung beetles on transgenic GM corn edges are affected by chronic exposure to Bt toxin and/ or their ingestion (Campos & Hernandez, 2015). Such changes have not diminished community diversity, but are promoting changes in the distribution of functional groups, suggesting that the role of these organisms in ecosystems may change. Thus, in the South of Brazil, management with genetically modified corn can accelerate diversity loss in the Atlantic Forest areas, and consequently important ecosystem services provided by dung beetles may be lost (Campos & Hernandez, 2015).

Grazing intensity near fragment edges, for example, can determine the species composition of that environment. A study comparing matrices composed by grazing with and without cattle showed that the composition of edge tree species was better explained by the presence of cattle than by the matrix structure (Benítez-Malvido et al., 2014). Therefore, identifying the quality of the agricultural matrix is an essential factor to mediate the conservation of natural resources and ecosystem services in fragmented landscapes (Perfecto & Vandermeer, 2010).

5. THE AGRICULTURAL MATRIX IN ITSELF

The fact that agriculture is considered a vector of environmental degradation (Pascual & Perrings, 2007; Tscharntke et al., 2005) is mainly due to the industrial agricultural development model initiated in the late 19th century, implemented with the perspective of raising food production levels. This model has spread worldwide and is based on intensive agriculture in external inputs (fertilizers, agrochemicals, genetically improved varieties and mechanization) (Holt-Giménez & Altieri, 2013). This model adoption ignored many of the environmental peculiarities and the diversity of agriculture forms that were developed in the different continents (Toledo & Barrera Bassols, 2008).

Although it has raised productivity, this agriculture model has also promoted losses in biodiversity and associated ecosystem services (Butchart et al., 2010). Among the main aggravating factors is the consolidation of simplified matrices which are poor in biodiversity and have low quality of conservation (Didhan et al., 2015; Vandermeer & Perfecto, 2007). Such impacts on biodiversity have been reported for at least half a century and a classic study was that by Carson (1962), referring to the consequences of using agrochemicals to birds.

Despite this reality, agriculture can be the key for preserving natural resources in fragmented landscapes (Perfecto & Vandermeer, 2010). Some authors consider that the management forms developed from the agroecological perspective, mainly based on the local sociocultural and environmental reality, could raise biodiversity indices, energy flows, ecological services, and guarantee food production (Gaigher et al., 2015; Gliessman, 2016). The combination of different management practices such as subsistence agriculture, cattle ranching with low pasture densities, extractivism/logging, agroforestry yards, no-tillage systems and agroforestry provide greater heterogeneity of secondary habitats, increasing the capacity to shelter biodiversity (Haenke et al., 2014; Madeira et al., 2016).

Thus, agricultural matrices can be as important for conservation as remnant areas (Perfecto & Vandermeer, 1997; Rösch et al., 2015; Tscharntke et al., 2012). The composition and management of the matrices turn them into facilitators or barriers to the species permanence and dispersion in the landscape. Reducing the use of inorganic inputs such as mineral fertilizers and agrochemicals also facilitates the use and permanence of species in agricultural matrices. Through a meta-analysis, comparing the effects of organic and conventional agriculture on biodiversity, Tuck et al. (2014) show that organic agriculture has increased species richness by about 30%. The authors point out that the increase in the proportion of plowed land was the parameter responsible for increasing the diversity differences between organic and conventional agriculture.

Geiger et al. (2010) emphasize that, among the evaluated agricultural intensification components, the use of agrochemicals (insecticides and fungicides) produced the most negative effect on biodiversity, and also reduced the potential of biological control. Areas managed with organic agriculture and other systems to mitigate the negative effects of intensive agriculture assist in increasing the diversity of wild plant and beetle species. For pollinator species, the effect of organic farming is limited by the increase in the intensity of land use in the environment. This is due to the relationship between local and regional actions and the movement of organisms, which are sensitive to agrochemical application throughout the landscape. Thus, even increasing species diversity at local scale, pollinators can be affected by agrochemical application on other scales, both by the drift of these chemicals and by visitation in those areas (Tuck et al., 2014).

Land-use systems that provide semi-natural habitats present high value for biodiversity (Neumann et al., 2016). These areas have additional features which ensure greater functional connectivity, and thus help to maintain landscape heterogeneity. Neumann et al. (2016) identified that the composition and configuration of matrix habitats helped to explain the community composition of forest carabid beetles. Some systems which maintain arboreal elements in their cultivation form (such as live fences, fruit trees or timber) are characterized as semi-natural, functioning as a refuge environment and connectivity between fragments. Live fences were essential to aid in the dispersal of slow-moving carabid beetles in fragmented landscapes. The authors suggested that some species may persist for decades in the landscape when representative elements from the original habitat are maintained (Neumann et al., 2016).

Agroforestry systems (AFSs), for example, are a management form that integrates agricultural production to the permanence and/or management of tree species, increasing the matrix's capacity to house species, meaning to increase their quality. Uezu et al. (2008) evaluated the role of AFSs in the diversity and distribution of birds in Atlantic Forest areas in Southeastern Brazil. AFSs were more important to promote the wealth of generalist species than monoculture areas.

Goulart et al. (2011) verified the habitat usage frequency of five species of frugivorous birds in agroforestry grounds, secondary forest and pastures in Pontal do Paranapanema, Brazil. The authors found that the total habitat usage frequency was higher in the secondary forest for almost all species, except for *Amazonas aestiva*. However, the number of feeding episodes was higher in agroforestry farms than in forests for all species, with the exception of *Cyanocorax chrysops*. Only one of the species was observed feeding on pasture areas. The authors state the importance of agroforestry systems as a resource-rich habitat for frugivorous birds. Therefore, matrices consolidated from management strategies and more biodiverse productive systems are an alternative to increase the permeability of the agricultural matrix (Goulart et al., 2011; Uezu et al., 2008).

As highlighted by Birkhofer et al. (2015), matrices with greater heterogeneity over time and space guarantee greater biodiversity in productive areas. For these authors, the composition and configuration of agricultural areas in agricultural landscapes as well as their multiannual dynamics should be considered. In this sense, the habitat/matrix paradigm in landscapes ecology resulted in few studies in the agricultural areas. This highlights the importance in considering heterogeneity in studies on biodiversity in agricultural landscapes.

In summary, the diversity of production systems and low impact management are key in determining the matrix quality and the heterogeneity of agricultural landscapes. Thus, actions to conserve biodiversity on the landscape scale should also consider the management of areas converted to agriculture, in addition to ensuring that remnant areas of original vegetation remain. These areas help to maintain biodiversity patterns and resource availability over time and space (Benton et al., 2003), since species vary in their response patterns to habitat modification at the local and landscape scales (Pardini et al., 2009).

6. LANDSCAPE

The landscape is a complex mosaic of different types of land-use, where the species are not affected only by the size, shape and spatial location of the primary habitat, but also by the structure and composition of the surrounding matrix (Haila, 2002; Kupfer et al., 2006). Thus, conservation of forest cover remnants associated with management of anthropic areas could reduce biodiversity loss and guarantee food production, consolidating sustainable and multifunctional landscapes (Iverson et al., 2014; Perfecto et al., 2009).

Different models have been proposed in the landscape scale in order to reconcile agricultural activities with biodiversity conservation. Two of these models (namely the “land sparing” and the “land sharing” models) have distinct views on the management of agroecosystems and agricultural landscapes, and have become the most influential (Brussaard et al., 2010; Phalan et al., 2011; Tscharntke et al., 2012; Garnett et al., 2013). The first one proposes agriculture intensification based on investment in technologies that increase productivity per unit area, with a reduction in land conversion and/or the allocation of more areas for conservation. On the other hand, the second model is based on biodiversity conservation linked to production, considering the management of more biodiverse production systems adapted to different local realities, highlighting the quality of the agricultural matrix as fundamental for conservation (Tscharntke et al., 2012).

Understanding these two models involves understanding the role of the agricultural matrix in the conservation of biodiversity and ecological services. The “land sparing” system proposes conservation based on forest remnants, ignoring the role of the productive system for this purpose. On the other hand, the “land sharing” system considers the agricultural matrix as fundamental to help the conservation (Phalan et al., 2011; Tscharntke et al., 2012). Despite different understandings about the role of the matrix, as highlighted in previous sections, the landscape is a continuum where the quality of the original habitat and the matrix serves as a facilitator or barrier to the permanence and dispersion of species, rather than the binary habitat/non-habitat perspective (Perfecto & Vandermeer, 2010).

In a recent review, Goulart et al. (2016) pointed out that agriculture intensification (using monocrops, transgenics, synthetic inputs, agrochemicals and mechanization) in agricultural landscapes may lead to population declines in the original habitat fragments as it reduces the flow between habitats, as well as local impacts as a consequence of the reduced heterogeneity and the use of agrochemicals, leading to a loss of ecological species and services. This effect may be aggravated in regions where the original habitat proportion is less than 30%, as in many tropical biodiversity hotspots (e.g. Cerrado and Atlantic Forest). Authors who point to land sparing as more efficient argue that intensification may provide larger original vegetation areas for conservation by virtue of achieving higher productivity per unit area. Despite this, they recognize that this system may be unsustainable for agricultural production itself (Matson et al., 1997; Fischer et al., 2008; Scherr & McNeely, 2008).

On the other hand, it is recognized that agriculture of lesser intensity and with more incremental diversity in the productive systems could support greater associated biodiversity, along with the maintenance of forest fragments, gallery forests and trees in the agricultural area (Fischer et al., 2008). In some cases, this biodiversity can benefit the food production systems themselves with biological control, pollination and other ecosystem services (Perfecto & Vandermeer, 2010; Tscharntke et al., 2012) (Figure 2).

It is noted that the main issues of this debate are centered on the need to maintain high levels of original vegetation cover and guarantee food production to meet global demands. The total vegetation cover in landscapes is one of the most important factors for the permanence of species (Melo et al., 2013; Pardini et al., 2009), especially for forest interior specialists (Pardini et al., 2009). Although this is the main argument for the land sparing system, it is noted that agriculture intensification has been happening without causing an increase in forest cover or even reducing deforestation (Goulart et al., 2016). One example is the increase in soybean exports (282.9% in the last year), where the productive areas are driven by export demand. In addition, the maintenance of conservation areas in some regions could increase the pressure on others, as in the case of Amazon protection to the detriment of advancing the agricultural frontier in the Cerrado (Goulart et al., 2016).

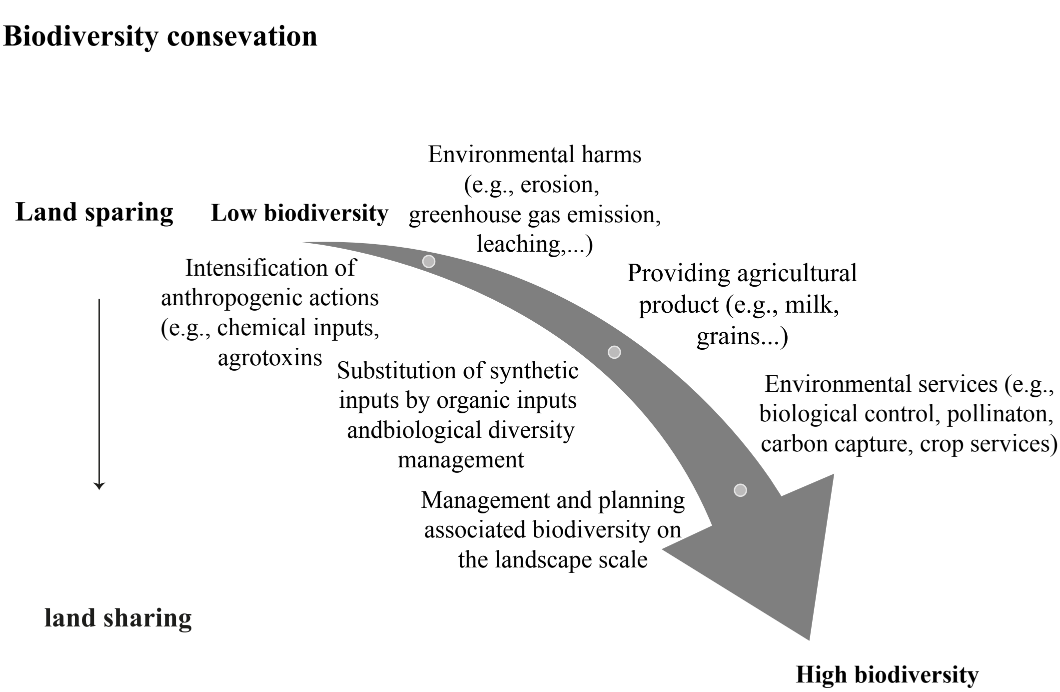

Figure 2. Relationship between productive systems and the provision of environmental services in land sparing and land sharing systems (Adapted from Tscharntke et al., 2012).

In addition, some studies have pointed out the potential of ecologically based agriculture for food production. In a work presenting the potential of organic agriculture in the 21st century, Reganold & Wachter (2016) show that the sale of organic food is growing rapidly, with a 15-fold increase between 1999 and 2013, and with a projection to double between 2013 and 2018. Only 1% of the world's agricultural land is occupied by organic agriculture, yet these areas contribute significantly to global food supply and still provide multiple benefits for ecological, social and economic services (Reganold & Wachter, 2016). Although they still produce lower yields per unit area compared to conventional agriculture, they provide equally or more nutritious foods with a reduction in (and even inexistence of) agrochemical wastes.

Although organic farming's role has yet to be explored to establish sustainable farming systems, a single approach would not be able to feed the planet safely. Instead, an integration of other innovative farming systems will be necessary. Nevertheless, a policy approach to minimize barriers to adopt such systems is necessary, since a variety of policy instruments will be needed to facilitate their development and implementation.

In view of the above, it can be said that biodiversity maintenance in fragmented landscapes is associated with habitat heterogeneity (Goulart et al., 2011), since species respond differently to habitat and landscape modification, where a greater number of habitat types is important to increase the resource availability over time and space (Benton et al., 2003). Thus, two aspects seem to be important to support maintaining heterogeneous landscapes: a) the maintenance of original vegetation cover; and b) an increase of biodiversity in the production systems. These aspects can ensure greater biodiversity and the maintenance of ecological services, thereby ensuring higher ecological quality of the matrix and fragments (Figure 3).

Balmford et al. (2012) suggest that transitioning land sparing to land sharing systems could reduce biodiversity if the original vegetation cover were fragmented for association with productive systems, thus moving from a large contingent to a dispersed distribution (Figure 3). Thus, they suggest that a better strategy would be to concentrate large blocks of original vegetation where efforts would be concentrated and there would be greater benefits for biodiversity. However, conservation efforts could follow a different course, reconciling the remaining areas and increasing biodiversity in the productive systems, highlighting practices such as: agroforestry, live fences, silvopastoral systems, spontaneous vegetation management, among others (Figure 3d).

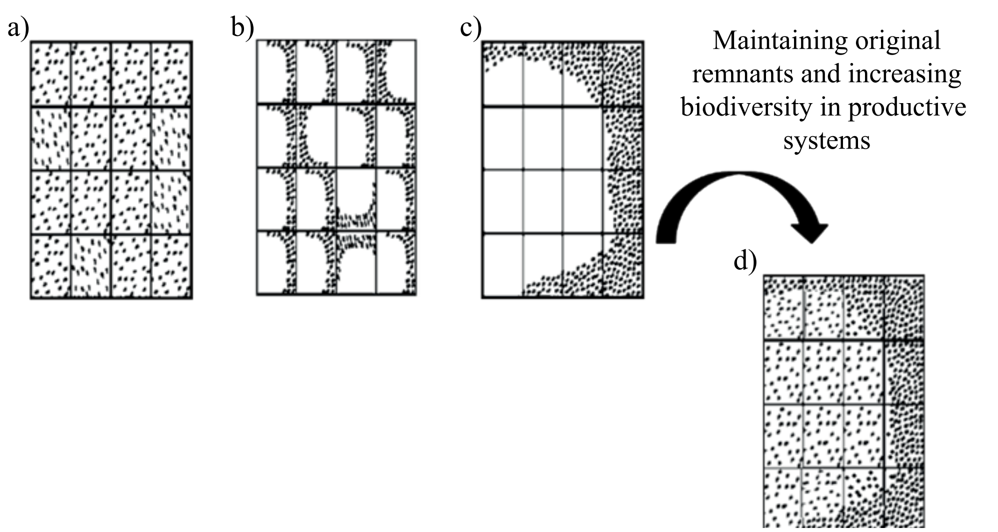

Figure 3. Graphical representation of the different systems (land sparing *b* and *c*; land sharing *a* and *d*) considering that all figures have the same area; the graphs *b* and *c* synthesize land sparing at the local and regional scale; and *a* the land sharing system where the vegetation cover would be distributed in a dispersed manner; and *d* increase biodiversity in the productive systems and maintenance of large contingents of natural vegetation. Adapted from Balmford et al. (2012).

Thus, in addition to the fragment sizes and the levels of total original vegetation cover, the composition of the agricultural matrix is also a determining factor for the species richness in the landscape. Sánchez-de-Jesús et al. (2016) conducted a study with dung beetles in Selva Lacandona in Mexico, and verified that these factors were the main predictors of the beetle community. Landscapes dominated by small fragments with lower total forest cover percentage and matrices composed of open areas had lower species richness, abundance and biomass. The community equability was also smaller in this type of landscape, since there was a loss of rare species. The authors suggest that the loss of forest cover, the reduced size of the fragments and the matrix composition impact the dung beetle species more than the spatial configuration of the forest. Thus, they suggest that conservation initiatives should prioritize reducing deforestation and increasing the matrix heterogeneity adjacent to forest remnants.

Summarily, the results of the studies show that the land sharing system would be able to offer greater capacity to increase the landscape heterogeneity and also guarantee safer food production levels from ecological and social perspectives. However, it is necessary to recognize that local factors such as biological diversity, public policies and investment in studies are necessary to increase agricultural efficiency.

7. CONCLUSIONS

The way the agricultural matrix is managed has a direct influence on biodiversity conservation, acting on different spatial scales ranging from the matrix itself, the edge and the interior of the fragments adjacent to it, as well as the landscape in which these systems are inserted. The high mechanization degree, planting of transgenic varieties and the intense use of fertilizers and agrochemicals are among the main factors responsible for the biodiversity losses observed in the forest remnant areas. Despite this, only a minority of the studies conducted consider these parameters and evaluate their effects at different distances of the matrix within forest fragments, as well as under different landscape scales. Therefore, the spillover effect of matrices for forest areas has been largely underestimated. Future studies on habitat fragmentation effects on biodiversity cannot neglect the identity and management of the matrix adjacent to forest remnants. In addition, further studies are necessary to characterize the biodiversity and the capacity of agricultural matrices as a complementary habitat considering different landscape scales.

SUBMISSION STATUS

Received: 30 May, 2017

Accepted: 26 Oct., 2017

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