UNIVERSIDADE FEDERAL DE LAVRAS

LUDIMILLA PORTELA ZAMBALDI LIMA

INFLUÊNCIA DA ESTRUTURA DE PAISAGENS EM PARÂMETROS DA BIODIVERSIDADE COM FOCO EM PEQUENOS FRAGMENTOS E CORREDORES DE VEGETAÇÃO NO BIOMA DA MATA ATLÂNTICA, MINAS GERAIS, BRASIL

LAVRAS - MG

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Tese apresentada à Universidade Federal de Lavras, como parte das exigências do Programa de Pós-Graduação em Ecologia Aplicada, área de concentração em Ecologia e Conservação de Recursos em Paisagens Fragmentadas e Agrossistemas, para obtenção do título de Doutor.

Orientador

Dr. Eduardo van den Berg

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RESUMO GERAL

A área de vegetação remanescente, a matriz, o isolamento, a conectividade entre as manchas florestais são fatores estruturais intimamente relacionados à biodiversidade. Com o avanço da fragmentação e perda de habitat, os pequenos fragmentos e conectores de manchas florestais são considerados importantes meios de manutenção de espécies. Apesar do tamanho, estes elementos possibilitam o aumento da conectividade da paisagem e o incremento da área disponível às espécies. Os remanescentes da Floresta Atlântica estão distribuídos em pequenos fragmentos (menores que 50 hectares), muitas das vezes inseridos em uma matriz antropogênica. Mesmo sob ameaça, este bioma possui uma elevada riqueza de espécies e endemismo. Embora os pequenos elementos da paisagem sejam importantes na manutenção da biodiversidade ainda existente, estudos geralmente focam na quantificação e análise de fragmentos preservados e pouco se sabe sobre a abundância e arranjo espacial dos demais. O objetivo deste estudo foi analisar a abundância e os padrões espaciais de fragmentos e corredores de valos em 49 paisagens fragmentadas distribuídas no bioma Floresta Atlântica, no estado de Minas Gerais. Avaliamos a relação entre a estrutura das paisagens e à vegetação remanescente, matriz, corredores, isolamento e conectividade da paisagem. Nós mapeamos as paisagens através da classificação de imagens multiespectrais de alta resolução espacial (5m) aplicando o método semi automático de classificação orientada a objeto. Resultados mostraram uma porcentagem variável de vegetação remanescente nas paisagens (de 4,1% to 69,7%), a maior parte distribuídos em fragmentos menores que 1 ha (de 45 a 97% do total de fragmentos). O maior número de corredores foi encontrado no sudeste do estado. Análises estatísticas baseadas no critério AICc de seleção de modelos indicaram influência dos fatores físicos, estruturais e de divisões políticas na quantidade de vegetação, isolamento e no tamanho dos corredores das paisagens. Pequenos fragmentos (<100 ha) e corredores de valos (largura ≤ 15 m) são importantes elementos na conexão entre os fragmentos.

ABSTRACT

Structural factors as like vegetation remnants, isolation and connectivity between forest patches are intrinsic related to biodiversity. Small patches and connectors are considered important in maintaining species in landscapes with high level of fragmentation and habitat loss. Despite the size, these element increase the landscape connectivity, and the available area to species. Atlantic Forest remnants are distributed in small fragments (less than 50 hectares), often inserted into an anthropogenic matrix. Even threatened , this biome presents a high species richness and endemism. Despite they importance, studies usually have focused on the analysis and quantification of preserved fragments, and there is a lack of information about the abundance and spatial arrangement of small features. The aim of this study was to quantify and analyze the spatial distribution of small features in 49 sample sites in Atlantic Forest fragmented landscapes at Minas Gerais State, Brazil. We tested the relationship between the remnant vegetation, isolation and hedgerows length with distance to landscape features, slope, altitude, number and fragments area. We also tested the connectivity for several capacity to cross the matrix, the relation of fragments with the surrounding matrix and the importance of small fragments to landscape isolation. We mapped the landscape features using a multispectral classification of high spatial resolution images (5m) applying a object-based semi automatic method. Results showed a variable percentage of remaining vegetation in the sample sites (4.1% to 69.7%), most of them with fragments smaller than 1 h (from 45 to 97%). The largest number of hedgerows was found in the southeastern state. Statistical analyzes based on the AICc model selection indicated the influence of physical, structural and political divisions in the amount of vegetation , isolation and size of corridors landscapes factors. Small fragments (< 100 ha) and hedgerows (width ≤ 15 m) are important elements in the connection between the fragments.

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1 INTRODUÇÃO GERAL

Perda de habitat e fragmentação estão intimamente relacionadas à conservação da biodiversidade (FAHRIG, 2003; WILCOX; MURPHY, 1985); desta forma, área, distribuição espacial e conectividade dos fragmentos são considerados fatores chaves na persistência de espécies em paisagens (BEIER; NOSS, 1998; METZGER; DE´CAMPS, 1997). O aumento da população humana conjuntamente à expansão de atividades antropogênicas provocam amplas alterações nas paisagens como remoção de fragmentos, redução no tamanho e incremento do isolamento das manchas de vegetação (FAHRIG, 2001). Os resultados são mosaicos de pequenos fragmentos (menores que 50 ha) inseridos em uma matriz antropizada, (FAHRIG, 2003; NEEL; MCGARIGAL; CUSHMAN, 2004; TABARELLI et al., 2010).

Apesar da influência que a matriz exerce sobre os remanescentes vegetacionais (UEZU; BEYER; METZGER, 2008; UMETSU; METZGER; PARDINI, 2008), pequenos fragmentos e corredores ecológicos são importantes elementos em paisagens, sendo muitas das vezes relacionados à riqueza de espécies (DUELLI; OBRIST, 2003) e à influência que eles exercem no grau de fragmentação, conectividade, migração e dispersão de espécies (BENNET et al., 1994). Corredores de paisagens são estruturas lineares de vegetação que podem ser utilizados pelas espécies como habitat ou como conectores entre duas manchas florestais (ROSENBERG; NOON; MESLOW, 1997; TISCHENDORF, 2001) possibilitando o uso múltiplo de fragmentos pelas espécies. Dentro da classe de corredores, podemos destacar os corredores de cercas e valos de divisa (*hedgerows*), gerados a partir da colonização natural de plantas em valos de três metros de largura, formando uma cobertura de dossel de até 15m (CASTRO; VAN DEN BERG, 2013). No sudeste do Brasil, estes corredores são elementos proeminentes na paisagem, formando habitat e conectores de fragmentos para pequenos mamíferos (CASTRO; VAN DEN BERG, 2013; MESQUITA; PASSAMANI, 2012; ROCHA; PASSAMANI; LOUZADA, 2011).

Apesar da importância dos pequenos fragmentos e corredores, pouco se é conhecido sobre sua abundância, distribuição e função na paisagem (HARVEY et al., 2005). Informações sobre a distribuição espacial e presença de conectores de fragmentos em grandes áreas geográficas podem ser obtidas através da análise de imagens de sensoriamento remoto de alta resolução espacial e espectral. A classificação das imagens possibilita o acesso a informações estruturais sobre a vegetação e áreas do entorno, assim como área e isolamento de fragmentos e as relações a outros componentes da paisagem (NEEL; MCGARIGAL; CUSHMAN, 2004; WITH; KING, 1997). A quantificação da estrutura espacial da paisagem é um importante aspecto da ecologia da paisagem, justificado pela relação entre a estrutura da paisagem e processos ecológicos (NEEL; MCGARIGAL; CUSHMAN, 2004; TURNER, 1989).

A Floresta Atlântica originalmente cobria 150 milhões de hectares, hoje distribuídos em paisagens altamente fragmentadas (RIBEIRO et al., 2009). A perda de habitat e fragmentação reduziram este bioma a paisagens dominadas por pequenos fragmentos (<100 ha) (RANTA et al., 1998) com um alto grau de isolamento (METZGER, 2000; RIBEIRO et al., 2009). No entanto, apesar de ameaçada, a Floresta Atlântica é considerada *um hotspot* da biodiversidade com elevado grau de endemismo e riqueza de espécies (MYERS et al., 2000; RIBEIRO et al., 2009).

Devido à dependência de processos ecológicos à variabilidade espacial dos remanescentes florestais e aos demais componentes da paisagem, o presente estudo teve como objetivo analisar a estrutura de paisagens do Bioma Mata Atlântica em Minas Gerais, avaliando a relação das variáveis estruturais de manchas e corredores florestais com fatores que influenciam a vegetação remanescente, conectividade, e isolamento das paisagens, resultando na identificação de padrões na relação dos componentes da paisagem a processos ecológicos que podem afetar a biodiversidade.

Os resultados deste trabalho são apresentados em dois artigos escritos na língua inglesa e estruturados nas normas da revista Biological Conservation. No primeiro artigo foi quantificado e mapeado os elementos de paisagens no estado de Minas Gerais, no domínio da Floresta Atlântica, analisando a distribuição dos pequenos fragmentos e corredores de valos.

No segundo artigo o remanescente de vegetação, isolamento e conectividade foram relacionados a fatores físicos e antropogênicos. Avaliamos também a importância dos menores fragmentos e da conectividade das paisagens.

2 REFERENCIAL TEÓRICO

A perda e fragmentação do habitat são consideradas as principais causas de redução da biodiversidade (FAHRIG, 2003; HERRMANN, 2011; LAURANCE, 1999). Isto é resultado da insuficiência em área disponível aos organismos seguidos pelo incremento no isolamento dos fragmentos e a consequente redução na conectividade da paisagem, inviabilizando as relações ecológicas entre as espécies e afetando negativamente o tamanho das populações (AWADE; METZGER, 2008; FAHRIG, 2003). Manchas isoladas de habitat podem não ser suficientes para suportar populações viáveis a longo prazo (FAHRIG, 2003; SOULÉ, 1987), tornando-as suscetíveis à extinção decorrente de fatores tais como endogamia ou flutuações ambientais (ANDERSON; JENKINS, 2005). Modificações e extinções de manchas florestais reduzem o número de imigrações de espécies que agem como vetores na realização de funções ecológicas como dispersão e polinização de espécies vegetais (BROOKER; BROOKER; CALE, 1999).

Neste sentido, a conectividade, definida como o grau no qual uma paisagem facilita ou restringe o movimento de organismos, gametas e propágulos entre fragmentos (TAYLOR et al., 1993; URBAN; SHUGART, 1986), é um elemento vital a ser avaliado na paisagem, pois está diretamente ligado à viabilidade de populações, sendo considerada crítica para a sobrevivência das espécies (NOSS, 1987; PRIMACK, 1993). A conectividade de uma paisagem pode ser mensurada de duas maneiras, pela ligação estrutural entre as manchas florestais ou pela conectividade funcional. A conectividade estrutural representa a distância entre as manchas, densidade de corredores e permeabilidade da matriz (ANTONGIOVANNI; METZGER, 2005; BEIER; NOSS, 1998) e a conectividade funcional considera as respostas comportamentais das espécies aos elementos da paisagem juntamente com a estrutura espacial (GOBEIL; VILLARD, 2002; GOODWIN, 2003).

Corredores de vegetação, compostos por estruturas lineares que ligam manchas de vegetação (FORMAN; GODRON, 1986) são elementos da paisagem que desempenham um papel fundamental em termos de conectividade (PARDINI et al., 2005). Esta interligação apresenta-se como alternativa importante na conservação de paisagens, permitindo o movimento de organismos entre manchas (FORMAN; COLLINGE, 1997) e reduzindo os efeitos do isolamento estrutural especialmente em paisagens dominadas por matrizes pouco permeáveis (BEIER; NOSS, 1998; PARDINI et al., 2005). Quando estes conectores estão presentes, o tempo gasto pelas espécies para colonizar ou recolonizar *habitats* de fragmentos onde se tornariam extintas pode ser minimizado (ANDERSON; JENKINS, 2005), resultando no incremento da abundância, da riqueza e diversidade alfa de espécies em pequenos fragmentos florestais (PARDINI et al., 2005) e podendo funcionar também como habitat para diferentes táxons (BENNET, 1990; DOWNES; HANDASYDE; ELGAR, 1997). Entretanto, alguns autores citam funções negativas de corredores como: facilitação de propagação de distúrbios, aumento à exposição de predadores, chegada de espécies exóticas (HOBBS, 1992; LIDICKER, 1999) e propagação de doenças (ANDERSON; JENKINS, 2005).

No estudo do valor biológico dos corredores e manchas de vegetação, é imprescindível a avaliação dos aspectos da paisagem (MACDONALD; RUSHTON, 2003; SIMBERLOFF; COX, 1987) sendo as imagens de sensoriamento consideradas as primeiras fontes de informação para tal fim (HERRMANN, 2011). A dependência da funcionalidade de paisagens e corredores de vegetação à sua estrutura, escala e contexto (SAUNDERS; HOBBS, 1991) indicam a relevância do uso de ferramentas de sensoriamento remoto, podendo resultar em um indicativo do movimento e migração de organismos (HERRMANN, 2011; SAUNDERS; HOBBS, 1991). Apesar de não oferecerem dados para testar diretamente a hipótese de corredores de vegetação como corredores ecológicos, o sensoriamento remoto é uma poderosa ferramenta para a efetiva representação de corredores na paisagem e sua interpretação no contexto da conectividade (SAUNDERS; HOBBS, 1991), pois a maior parte dos processos ecológicos são inerentemente espaciais, interagindo em unidades vizinhas (VENEMA; CALAMAI; FIEGUTH, 2005; WAGNER; FORTIN, 2005), conectando padrões espaciais à biodiversidade (DIAMOND, 1975).

Os padrões da estrutura da paisagem podem ser analisados através da aplicação de índices (TISCHENDORF, 2001; TURNER, 1989) onde, além do contexto da localização dos remanescentes, métricas sobre a inferência de persistência de espécies podem ser avaliadas, como o tamanho, forma e o grau de isolamento das manchas florestais (HERRMANN, 2011; SAUNDERS; HOBBS, 1991).

A área disponível para a colonização pode ser um preditor à persistência de espécies, desde que áreas grandes e conectadas provavelmente manterão grandes populações (CARVALHO; JÚNIOR; FERREIRA, 2009).

A Floresta Atlântica brasileira, considerada um *hotspot* de biodiversidade (MITTERMEIER et al., 1998), é um dos biomas mais perturbados do Brasil, apresentando o maior número de espécies ameaçadas por unidade de área (FONSECA et al., 1994; MYERS et al., 2000). A degradação deste bioma já atingiu níveis extremos, restringindo os remanescente a pequenos fragmentos, localizados, em sua maioria próximos a áreas abertas (RIBEIRO et al., 2009). O histórico de devastação desde a época do descobrimento condicionou a maior concentração dos remanescentes florestais em áreas onde o terreno dificulta a ocupação humana (RANTA et al., 1998; RESENDE; LANI; REZENDE, 2002).

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SEGUNDA PARTE - ARTIGOS

ARTIGO 1

THE IMPORTANCE OF SMALL FRAGMENTS AND HEDGEROWS FOR FRAGMENTED LANDSCAPES IN SOUTHEASTERN BRAZIL

Artigo estruturado nas normas da revista “Biological conservation”

Quantification and qualification of small fragments and hedgerows in Southeastern Brazil

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Abstract

The high level of fragmented landscapes emphasizes the value of small fragments and connectors to biodiversity conservation. Despite the size, these elements have proved to play important roles in the conservation of biodiversity by enhancing landscape connectivity. Although reduced to less than 12% of its original extension, the Atlantic Forest still has a high species richness and endemism, currently distributed in landscapes dominated by small fragments (<50ha). However, studies have focused on quantifying the preserved fragments and little is known about small fragments and corridors abundance and their spatial arrangement. Therefore, the objective of this study was to characterize the abundance and spatial patterns of small fragments and hedgerows in fragmented landscapes distributed in Atlantic Forest domain in Minas Gerais State. Semi automated hierarchical classification rules were established using an object-based classification of multispectral RapidEye images, implemented in 49 landscapes, mapping all sizes of fragments, hedgerows and agricultural areas, with a high level of accuracy. The results showed a variable percentage of remaining vegetation (from 4.1% to 69.7%) distributed mainly fragments smaller than 1ha (from 45 to 97% of total fragments). High density of hedgerows was found in the south of Minas Gerais State, and the hedgerows connections to one or more fragments have different distributions in the landscapes. This paper classified small and linear vegetation features in landscapes, which allows for an understanding of the appropriate spatial resolution and methods required to extract these patches when mapping using remote sensing imagery. In the present scenario of fragmentation of the Atlantic Forest, the quantification and spatial distribution of small and linear fragments are essential for the study and management for species conservation.

1. Introduction

Habitat loss and fragmentation are main concerns to biodiversity conservation (Fahrig 2003; Wilcox and Murphy 1985) causing, among other things, a reduction on habitat amount and an increase on isolation and number of patches with small area (Carvalho et al. 2009; Fahrig 2003). Under this scenario, remnant size and structural connectivity are considered key factors on species persistence (Beier and Noss 1998; Fahrig and Merriam 1985, 1994; Metzger 2000; Metzger and De´camps 1997). Small remnants and hedgerows have an ecological value that is proportionally greater than their real extension (Hou and Walz 2013). Several studies imply in a close relation between small-scale landscape structures and species richness, e.g. birds and arthropods (Duelli and Obrist 2003; Hou and Walz 2013), explained by the presence or absence of small remnants and linear vegetation patches and their influence on degree of fragmentation, connectivity, species migration and dispersal (Bennet 1990). Habitat patches connectivity is thought to be important for movement of genes, individuals, populations, and species over multiple scales (Minor and Urban 2007)

Spread across landscapes around the world, small fragments and hedgerows are also important features in the Brazilian Atlantic Forest biomes, one of the largest rainforest biome of the New World. Originally, this biome covered around 150 million hectares, in highly heterogeneous environmental conditions (Ribeiro et al. 2009). The Atlantic Forest extension was extremely reduced, the estimates vary from 11 to 16% (Ribeiro et al. 2009) , 7 to 8% according to SOS Mata Atlântica/INPE (1993, 2000) and Galindo-Leal and Câmara, (2003b) and 10.6% according to SOS Mata Atlântica/INPE (2008); more than 80% of the fragments with areas below 50 ha (Metzger et al. 2009). This biome is considered a hotspot for biodiversity conservation, due to its species richness (both plant and animal), high level of endemism (Myers et al. 2000) and for being probably one of the most highly threatened tropical forests in the world (Metzger et al. 2009).

Ecological corridors are linear features in landscapes working as habitats or as connectors between patches (Baudry et al. 2000; Forman and Baudry 1984; McCollin et al. 2000; Metzger and De´camps 1997; Pardini et al. 2005). As ecological corridors, hedgerows can play an important role for the conservation of flora without negatively impacting agriculturally landscapes. In the Southeastern Brazil, hedgerows can be originated from natural colonization of land plot boundary ditches are prominent features of the landscape (Castro and van den Berg 2013). These hedgerows hold a high diversity of plant species inside a three meters wide ditches (Castro and van den Berg 2013), creating a maximum 15 meters of canopy cover, working as well as a fragments connectors or habitat for mammals (Castro and van den Berg 2013; Mesquita and Passamani 2012; Rocha et al. 2011). Others hedgerows include strip vegetation on fences.

Although small and linear patches play an important role in landscapes structure and ecological process, remarkably little information is available about their abundance, distribution and function (Harvey et al. 2005; Hou and Walz 2013; León and Harvey 2006). The assessment of landscape features over large geographic regions is possible by mapping these structures using passive sensors with high spatial and multispectral resolution (Goossens et al. 1991; Vogt et al. 2007). Inclusion of small features in mapping remnants it is limited by the images spatial resolution and classification methods. Satellite images with less than 10 meters of spatial resolution are computationally efficient, reliable, and valid for detecting small landscape features over large areas (Vannier and Hubert-Moy 2008). Small features classifications in large areas require an efficient classification methodology to enable the different size and characteristics of landscape elements.

Object-based methods for image analysis have the advantage of incorporating spatial context and mutual relationships between objects (Concheddaa et al. 2008). It is possible to classify objects using information about each individual object and also about the relations existing between the objects (Lewinski and Zaremski 2004) enabling to define corridors in terms of a threshold patch width and local context (Metzger and De´camps 1997; Vogt et al. 2007).

Quantifying spatial landscape structure remnants an important aspect of landscape ecology justified by the fundamental reciprocal relationships between landscape structure and ecological processes (Neel et al. 2004; Turner 1989). To analyze landscape elements with different sizes and contexts, a multi-scale strategy was applied to detect different habitat types and quantify the abundance and spatial arrangement of small fragments and hedgerows. Presumably abundant in the southeast of Brazil (Castro and van den Berg 2013), hedgerows' distribution and quantification was for the first time analyzed in this study. We also mapped features (soil use, e.g. agriculture, pastures and urban occupation, and hydrography) associate with agriculture areas, urban areas and water.

2. Methodology

2.1 Study Area

Our survey consisted of 49 12×12 km sample square areas randomly distributed over the Atlantic Forest domain in Minas Gerais State, Southeast Brazil (Figure 1). The sampled area covered 3% of the Atlantic Forest domain in the State. Our random selection of sites obeyed the following restrictions: (1) the areas had to be completely included in the domain (not overlapping its edges) and (2) no square areas could share boundaries. For every sample site, we used high spatial resolution image extracts composed of RapidEye images acquired in 2011 with spatial resolution of 5 m. This resolution enabled the inclusion a large range of fragment sizes and connectivity conditions, required for detecting hedgerows.

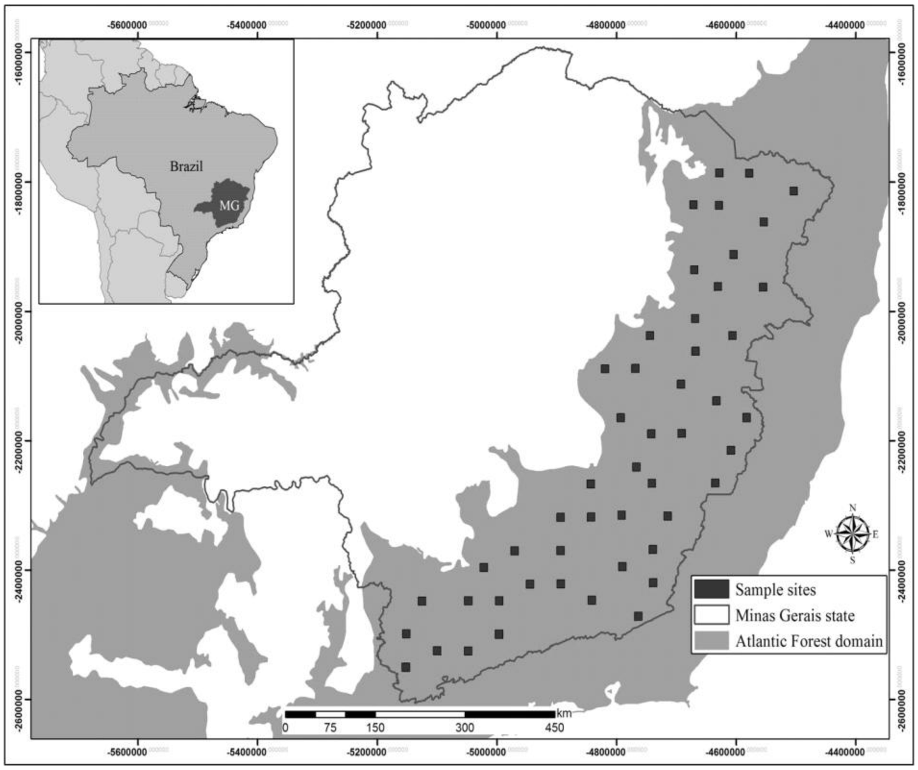

Figure 1. Location of the study sites. The black squares indicates the sample sites used for the classification.

We did not differentiate fragments composed by vegetation in secondary, intermediate or advanced stages of succession. The distinction between old growth and secondary forest is particularly difficult for the entire Atlantic Forest region because information about forest age is very scarce and available only at local scales (Ribeiro et al. 2009). The sampling design covered the different kinds of vegetation included in the Atlantic Forest domain and the different kinds of human pressure.

2.2 RapidEye Acquisition and processing

We used multi-spectral RapidEye images with five spectral bands: Blue (440-510nm), Green (520-590nm), Red (630-685nm), Red Edge (690-730nm) and Near Infra Red (760-850nm) to map land cover and hedgerows. Orthorectified and atmospherically corrected images were obtained through a partnership between the Federal University of Lavras (UFLA) and Forest Federal Institute of Minas Gerais (IEF). Acquisition errors, clouds and shadows were removed in the pre-processing phase (Coppin et al. 2004), which also included visual evaluation of image registration.

2.3 Methods

We classified the landscape elements obtained from satellite images using an object-based approach using multi-scale image segmentation (Figure 2). Image segmentation is the process of partitioning an image into groups of pixels that are spectrally similar and spatially adjacent (Desclée et al. 2006; Duveiller et al. 2008). Boundaries among these pixel groups delineate ground objects in a similar way a human analyst would do based on their shape, tone and texture (Duveiller et al. 2008). Multi-scale segmentation (MSS) has been introduced by (Baatz et al. 2000) and allows the extraction of image objects at different resolutions to construct a hierarchical network of image objects in which each object has information about its context, its neighborhood and its sub-objects (Benz et al. 2004).

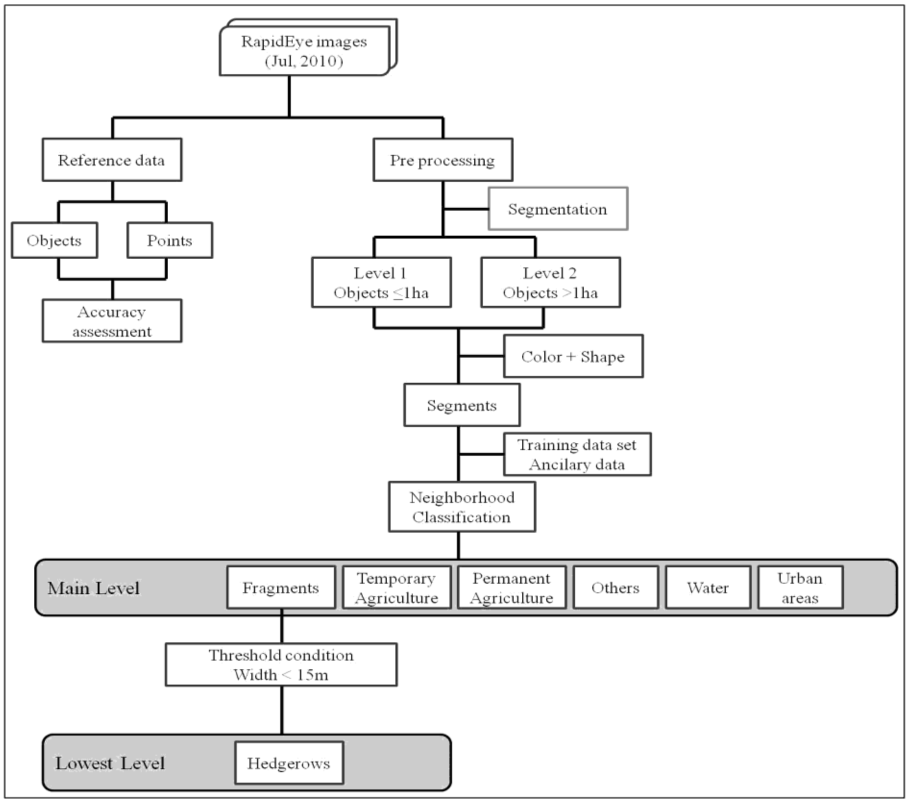

Figure 2. Classification scheme providing an overview of the methodological process. The classification result consists of two spatial levels.

We segmented the images into two levels using a multi-scale image segmentation algorithm (eCognition software), applied to all RapidEye image bands using equal weights for all bands. The segmentation of the images is influenced by three parameters: 1) the global size of desired areas also called scale; 2) their homogeneity in terms of color 3) a "shape" parameter that is related with smoothness and compactness (Broich et al. 2009). We determined these parameters using a systematic trial and error approach validated by the visual inspection of the quality of the output image objects (Anders et al. 2011; Dragut et al. 2010; Mathieu et al. 2007).

Before an appropriate scale factor was identified, the shape and color criterion were modified to refine the shape of the image objects (Mathieu et al. 2007) (Mathieu et al. 2007)(Mathieu et al. 2007). For both levels, a weight of 0.4 was assigned to the color parameter, 0.3 to the shape parameter, and 0.6 to the compactness parameter the color was assigned a weight of 0.4, whereas the shape received the remaining weight of 0.3 (compactness 0.6). We chose the scale factor, determining the size of the objects, in such a way that the edges of the delineated areas would correspond with the feature patterns (classes of land cover) visible in the image (Lewinski and Zaremski 2004). A first level of segmentation was produced with object sizes ranging from 1.01 ha to the largest object in the image. A second level of segmentation was computed to produce finer objects ranging in size from 0.025 ha to 1 ha. The first level was used to stratify the larger patches, using a scale factor of 70 and a second, more detailed level, was created to map smaller patches with a scale factor of 40.

Once a successfully segmented image was obtained, we applied an object-based using Nearest Neighborhood (NN), trained by image samples, to the segmentation image in order to assign a class label to each segment. The NN classifier allows quick and straightforward classification and can use a variety of variables related to spectral, textural, shape and/or contextual properties of the image objects (Mathieu et al. 2007) . On a higher hierarchical level, defined as the main level, land cover classification was based on object samples using Nearest Neighborhood (NN) classification identifying major land-use types (forest, permanent agriculture, temporary agriculture, water body, urban areas and others). We based our NN supervised classification on a training dataset comprised of 50 visually independent objects in each land cover class, in each scene. These training sites were based on RGB (543) composite and were selected using published data and field knowledge. At the lowest hierarchical level, vegetation patches was further divided into the classes hedgerows or fragments, using threshold conditions (Figure 1). Ancillary data included rivers and roads maps (IBGE – Instituto Brasileiro de Geografia e Estatística 2004), forest inventory data (Scolforo and Carvalho 2007), GIS topomaps and the Digital Elevation Model (DEM).

Hedgerows have similar spectral characteristics of forest patches. Nevertheless, the hedgerows are long and narrow with an almost constant width, since the dimension for the man-made ditches (3 m wide) which originated them are very similar between the areas and also mostly invariable (Castro and van den Berg 2013). We applied a merge process using a threshold condition to only merge the objects with width bigger than 15 m. The objects not merged were then hedgerows and vegetation objects inside fragments. Therefore, we applied the process to find the objects that are surrounded by vegetation and classified as vegetation. Finally, remain objects were classified as hedgerows. This rule enable us to identify not only the isolated hedgerows but also the ones connected to the vegetation patches. For each mapped hedgerows, a buffer of 5m was created identifying if they had one, two or neither extremities linked to a fragment. The beginning and end tips of individual hedgerows were defined as where the corridor crossed with another corridor, or where the corridor joined another habitat (forest patch, agriculture area, or other land use) or landscape feature (road or river).

A few wrongly-classified image objects were reassigned manually to the correct classes based on knowledge and the RapidEye image.

2.4 Validation

Independent data source, randomly located within each class and equitably distributed over the 49 scenes was used as reference for the accuracy assessment. We used 14083 objects and points stratified according to the size of the area covered by each class (Table 1).

Descriptive statistics of user's, producer's and overall accuracy (Table 1) were computed and analyzed. The overall accuracy is computed by dividing the total correct by the total number of pixels in the error matrix (Congalton 1991). The overall kappa coefficient represents a measure of agreement between the classes represented in the image and the true reality on the ground for the whole map, estimating what level of agreement is due to chance (Concheddaa et al. 2008).

Another validation method consisted in overlap each object used as reference to the accuracy assessment to the corresponding object classified (Benz et al. 2004). If the complete reference polygon is covered by automatically achieved segments, a highest score of 100% are given. For the objects that are not completely covered, the percentage was based on the cover percentage. We also used visually inspection comparing the reference objects to high resolution images available on the web (2006 Google EarthTM). Google EarthTM combines different resolution images and updates them on a rolling basis (Concheddaa et al. 2008).

Table1. Accuracy assessment from the main and lowest level.

Validation indices		Fragments > 1ha	Fragments ≤ 1ha	Water	Urban areas	Permanent Agriculture	Temporary Agriculture	Hedgerows	Others
Prod. Accuracy (%)	Min.	69	78	80	79	81	68	85	68
	Med.	78	80	85	84	85	70	87	70
	Max.	83	81	88	84	87	71	89	75
User's accuracy (%)	Min.	75	69	75	69	78	65	81	69
	Med.	77	70	77	69	79	68	83	74
	Max.	78	73	78	70	81	70	85	77
Overall accuracy (%)	Min.	87	84	78	81	81	67	82	77
	Med.	89	86	80	82	84	70	85	79
	Max.	92	89	82	84	85	72	88	80
Kappa	Min.	0.83	0.81	0.75	0.79	0.75	0.63	0.81	0.75
	Med.	0.86	0.83	0.77	0.8	0.77	0.7	0.84	0.76
	Max.	0.89	0.85	0.8	0.82	0.79	0.75	0.86	0.78
Object accuracy (%)	Min.	81	83	86	81	75	69	82	77
	Med.	84	85	88	84	78	71	84	78
	Max.	87	87	92	87	80	72	85	81
Reference totals		2450	4900	245	108	1410	1110	1410	2450

3. Results

3.1 Validation

All kappa measures, overall accuracy and object validation showed a high level of agreement and confirmed the good accuracy of our classification (Table 1). The overall accuracy higher than 80% and the kappa coefficient larger than 0.76 for vegetation and hedgerows are considered robust results (Bock et al. 2005; Fielding and Bell 1997). Data used to validate the results corresponded to 3.8% of total area, which is above the one percent generally recommended (Congalton 1991; Mathieu et al. 2007). Fragments larger than 100 ha present the most accurate results, all above 77%. Temporary agriculture present the worst values (65%), which suggests that the methodology used in this study was not completely efficient to differentiate the agriculture types. Accurate results have been obtained in mapping the class hedgerows thanks to the integration to the contextual information.

The object-based method achieved satisfactory results for mapping land cover classes in the study area, identifying the main elements in each landscape, including small and linear features, as well as secondary and disturbed vegetation (Figure 3).

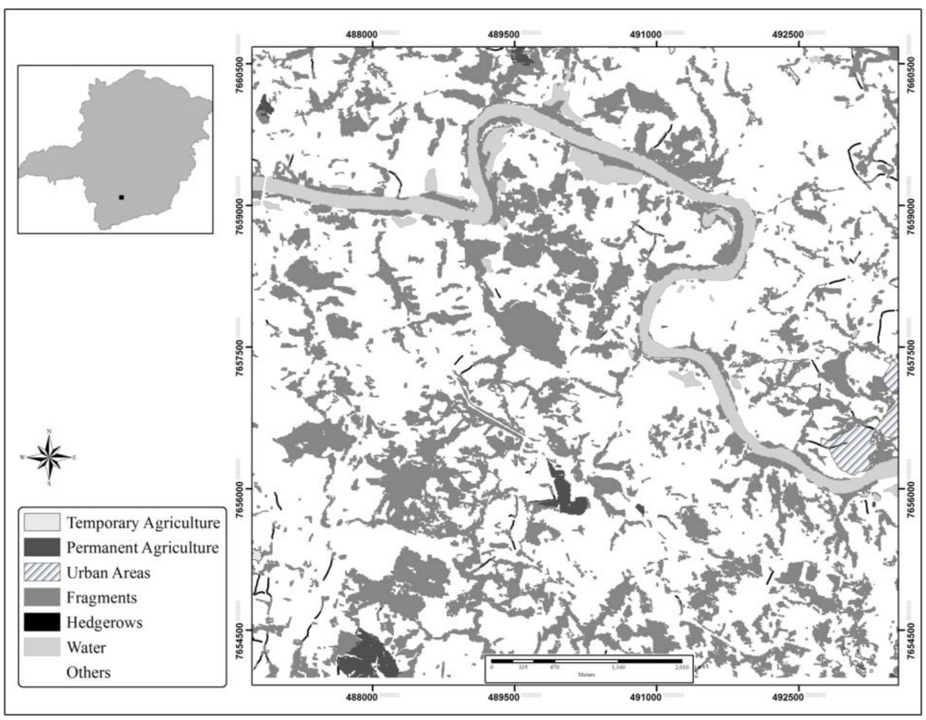

Figure 3. Example of a the land cover classification for a landscape.

Spatial Structure

3.2 Forest patches abundance and distribution

The sample sites cover a total of 705,600 ha, with 211,778 ha (30%) of forest vegetation in fragments and 992 ha (3%) of forest located in hedgerows. The other features comprise 12,984 ha of temporary agriculture, 23,566 ha of permanent agriculture, 1,733 ha of urban areas, 2,033 of areas covered by water.

The largest fragment mapped reached 9,071 ha, inserted in the best-preserved landscape analyzed (69.7% of remaining forest cover) located in the north of the MG state (Figure 4). Just one landscape presented less than 15%, with 4.1% of the original vegetation cover (Figure 4).

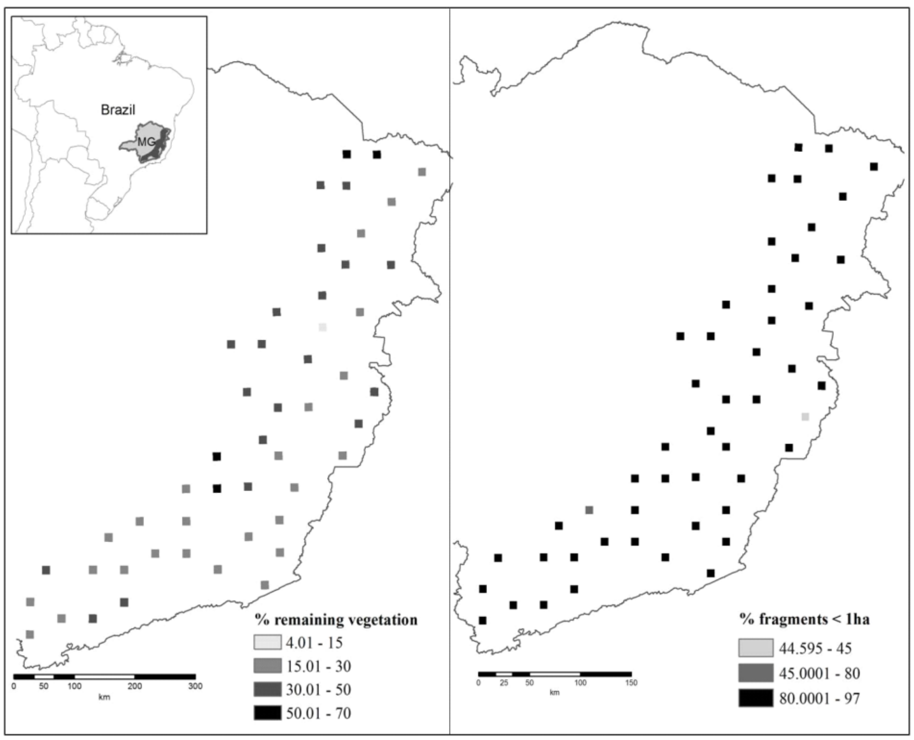

Figure 4. Percentage of remaining vegetation (left) and fragments smaller than 1ha (right) in landscapes analyzed at Atlantic Forest domain, in Minas Gerais State

The Atlantic Forest in the analyzed landscapes is distributed in 93,479 fragments with their size ranging from 0.005 ha to 9,071 ha. Fragments below 1ha represent the large majority (80%) (Figure 4), with just one landscape ninth less than 45% of fragments in this situation.

The fragments equal or below 1ha correspond to 0.5 to 3% of the landscape area analyzed (Figure 5), fragments larger than 1ha covered areas between 2.6 and 70% of the landscape, depending on the specific region. We can found a huge variation in the area of forest patches larger than 1ha, the largest one has 9,071.00 ha, followed by one of 6,606.00 ha.

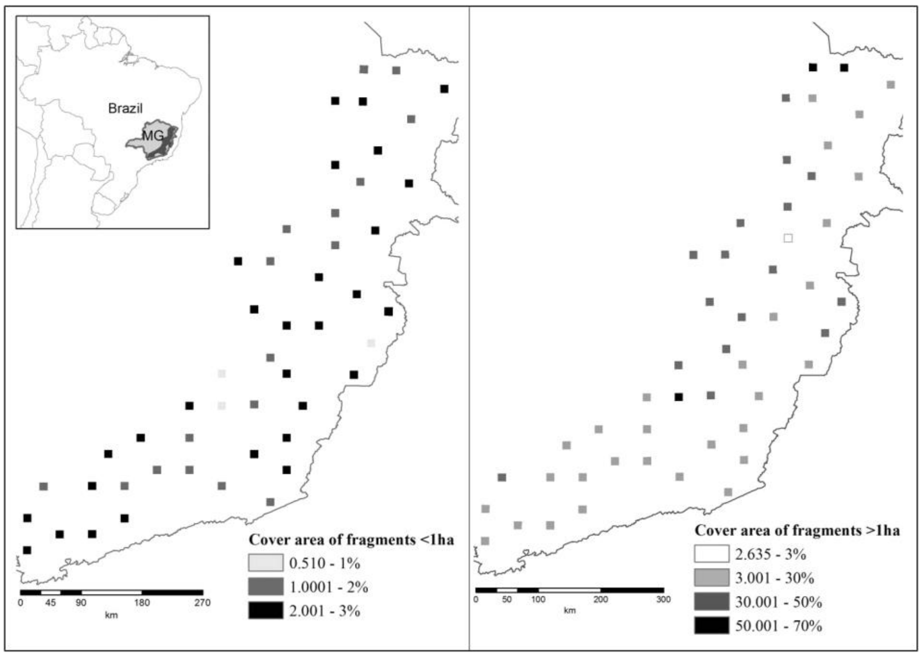

Figure 5. Vegetation cover percentage of fragments lower 1ha (left) and above 1ha (right).

Only two sample sites didn't have any hedgerow. We found 3347 hedgerows distributed over 47 landscapes. Hedgerows occurred in higher density in the south of the State (Figure 6), showing landscapes with more than 250 hedgerows distributed. Of the 3561 hedgerows mapped, 1547 connected at least two fragments, 1420 are linked to only a single fragment and 594 of the hedgerows were isolated, completely surrounded by anthropogenic matrix. We founded a variable classes of fragments size linked to hedgerows (Figure 6), they enhance the extension and/or the connectivity of fragments. The hedgerows are linked to a variety of classes of fragments size The hedgerows connected to at least one fragment, increase the size and extension of the fragments and when they are link at least two fragments, they also enable the connection between two fragments (Figure 6), increasing the available vegetation areas to organisms.

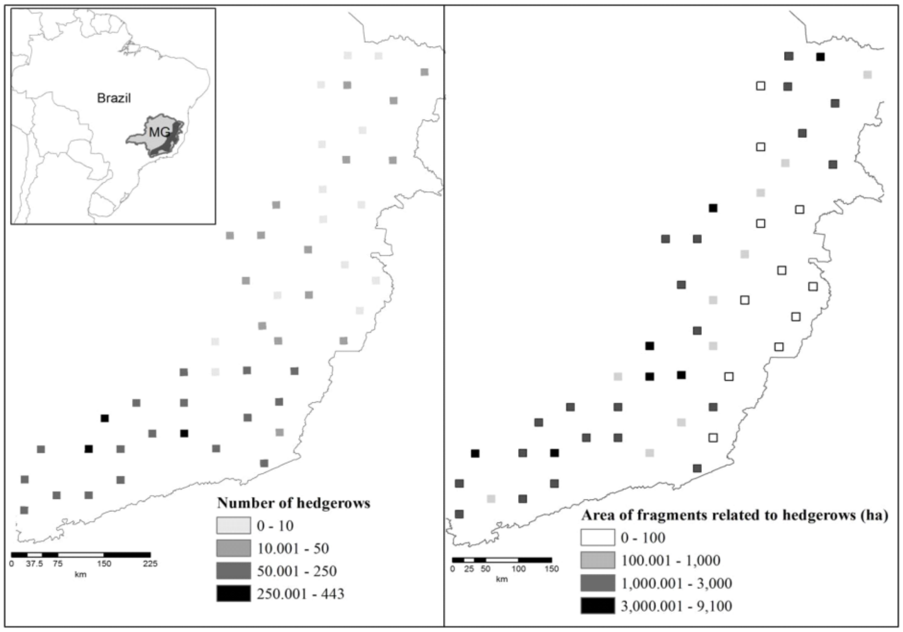

Figure 6. Distribution of landscapes by number of hedgerows and the area of fragments connect to hedgerows

4. Discussion

4.1 Classification of small fragments and hedgerows

Landscapes are widely recognized as complex systems having a hierarchical structure where dominant patterns and processes exist at specific scales (Meentemeyer 1989; O´Neill 1988; Wu and Marceau 2002). Forest fragmentation, as a huge environmental problem, cannot be handled at a single scale of observation (Silván-Cárdenas et al. 2009). The hierarchical approaches employed in the current study allowed an accurate classification for different type and size of habitats. This technique enabled the detection of different spatial scales structures on landscapes (Blaschke 2010; Hou and Walz 2013) particularly for the studied landscapes where the objects presented a large range of variation. Using this technique we were able to distinguish small objects from large ones and evaluate their intrinsic traits and patterns.

Because of the images with broad spatial resolution like Landsat (30m) are not adapted for mapping hedgerows (Vannier and Hubert-Moy 2008) and small fragments, high spatial resolution images (5m) used in this study were crucial for the interpretation of different features with variable size. If high-resolution data is used, feature boundaries are more accurately mapped (Anders et al. 2011). Despite the very high spatial resolution, sensors with low spectral resolution are not suitable to extract small and linear features (Vannier and Hubert-Moy 2008). For that matter, RapidEye images, thanks to their rich spectral information including a Red Edge band, allowed a precise classification of small and linear features. The spectral and spatial resolution of RapidEye data was appropriate for this study and the accuracy assessment showed that satisfactory results can be achieved.

The use of object-oriented and contextual rules in mapping linear landscape features was fundamental (Goossens et al. 1991) and need to be differentiate from remnants, composed by the same elements. Compared to traditional habitat mapping techniques (air photo interpretation, field study), object oriented methods provide accurate results whilst providing at the same time necessary spatial detail (Bock et al. 2005) and the possibility of mapping extensive areas. In the object-based approach, the segmentation process ensure the quality of the multispectral data to be submitted to the next step and the classification process offers the capacity of handling higher level of data heterogeneity and more complex spatial patterns (Mathieu et al. 2007). The hierarchical segmentation afforded the detection of large-scale fragments at higher segmentation levels while small-scale habitats such as small fragments and hedgerows could be detected at lower and finer segmentation levels. Therefore, segments in an image will never represent meaningful objects at all scales, for any application (Blaschke 2010) implying in the use of at least two levels of scales to cover all sizes of patches on mapping a fragmented landscapes. Moreover, we founded that segmentation reduces local spectral variation inducing a better discrimination between land cover types (Lobo 1997). Hedgerows have similar species composition and appearance to fragments which they are associated (Castro and van den Berg 2013), making the insertion of the additional feature knowledge during the classification process a requisite to differentiate hedgerows from fragments.

Given the heterogeneity and the large number of fragments, the image analysis by a skilled interpreter is indispensable to reduce wrong classification and improve the accuracy of the land cover map. In the present methodology, visual analyses were restricted to three crucial steps: the selection of the segmentation parameters, the choice of color and shape parameters and the selection of land cover sample.

The high accuracy reached in this study highlights the efficiency of using these techniques to map small and linear features, something that most studies fail to achieve. The user's and producer's accuracies of the individual classes variation is likely caused by a combination of varying segmentation accuracy and the quality of the samples for the nearest neighborhood classification. We obtained accurate results for mapping the class hedgerows thanks to the integration of contextual information. The combination of multi-scale segmentation, object-based techniques, supervised and contextual classification demonstrates that high spectral e spatial images can optimize the classification of fragmented landscapes, with different kind and size of features. We also found that the spatial relationship to other classified objects may help to improve our ability to classify specific features on landscape. The classification process could be further enhanced by implementing class-specific rules for the class temporary agriculture where the classification had lower accuracy.

Analysis using different scales leads to more realistic quantification of fragmentation (Hou and Walz 2013). Our results indicate that this analysis, based on the detailed spatial scale and the true surface geometries of fragments, produced a realistic and precise representation of landscape structure. Using the methods presented in here we also were able to integrate the particular traits of the hedgerows to the classification, developed from knowledge-based rules. These rules allowed us to distinguish the hedgerows from forest fragments, although both classes of objects had similar spectral traits.

4.2 The importance of small fragments and hedgerows

The amount of habitat and the fragmentation status are important variables to be considered on planning the management of the landscape for biodiversity conservation (Fahrig 2003; Ribeiro et al. 2009; Wilcox and Murphy 1985). The small number of large fragments on the analyzed landscape is related to the extensive and ancient human occupation. The largest fragments are restricted to locations where the steep terrain made human occupation particularly difficult (Ribeiro et al. 2009; Silva et al. 2007) . The landscape sampling scheme was designed for capturing the spatial heterogeneity of the fragmentation process oriented by anthropogenic activities. The scheme was also directed to evaluate the role of small fragments (≤ 1ha) and hedgerows on the whole Atlantic Forest landscape in Minas Gerais State. The high number of small fragments and the low percent of forest cover present in all landscapes corroborate the extreme degradation of the Atlantic Forest, already indicated in some studies carried out in this domain (Galindo-Leal and Câmara 2003a; Metzger 2000; Metzger et al. 2009; Ranta et al. 1998; Ribeiro et al. 2009)

Although many species require large fragments to survive (Barlow et al. 2007; Gardner et al. 2007; Harris and Pimm 2004; Laurance 2007), secondary forests can sustain a significant amount of biodiversity (Develey and Martensen 2006). More than 50% of Atlantic Forest and most of the tropical regions are secondary or disturbed vegetation distributed on small fragments (Wright 2005) highlighting the necessity to include this size class on landscapes mapping. The present study filled gaps as presented in Ribeiro et al. (2009), in the underestimation of forest cover caused by the difficulty to correctly map the small fragments (<30 ha). The large number of small fragments (≤1 ha) founded here is an indicator that studies using larger scale mapping (≥ 30 ha) of the Atlantic Forest are missing an important feature of the landscape.

On the choice of indicators to access biodiversity, one must recognize that biodiversity is a multiple-scale concept (Vogt et al. 2007) influenced by spatial processes (Hou and Walz 2013) and the study must incorporate not only the large and well preserved fragments but also forest patches small fragments and corridors because of their contribution to the landscape connectivity and the value to biodiversity conservation theirself. Hedgerows are recognized as an easy option to improve connectivity in landscapes (Harvey et al. 2005) and small patches are also suggested as important components to improve landscape connectivity (Uezu et al. 2008). Disturbed areas containing small fragments ("stepping stones") (Boscolo et al. 2008; Castellón and Sieving 2005; Sekercioglu et al. 2006; Uezu et al. 2008) and hedgerows (Mesquita and Passamani 2012; Rocha et al. 2011) can facilitate animal movement. Small fragments and hedgerows, acting as habitat patches, can also be as stable source of seeds and individuals (Cerboncini et al. 2011; Mesquita and Passamani 2012; Ribeiro et al. 2009; Rocha et al. 2011). Because of the absence of information about most of threatened species distribution in tropical areas (Tobler et al. 2007), the fragmentation pattern and spatial distribution of forest patches can be used as an effective surrogate to conservation plans and management of the landscapes (Carvalho et al. 2009).

Besides vegetation mapping, it is important to indicate the land uses of the surrounding landscape, once they affect the fragments in diverse ways. Therefore, a clear differentiation among areas with diverse agricultural activities is important to define alternative conservation strategies (Fonseca et al. 2009; Pardini et al. 2009; Uezu et al. 2008; Umetsu et al. 2008; Umetsu and Pardini 2007). Beyond the matrix characteristics, fragments in landscapes affected by human activities requires structures that can promote make possible the permeability for species and, therefore, improve biodiversity conservation. The presence of hedgerows and small fragments contribute to landscape connectivity, but the degree of their roles will depend on the nature of the corridors, the nature of the matrix and the response of the organisms to both (Beier and Noss 1998; Rosenberg et al. 1997). Integration of hedgerows on farming systems contribute as a tool for conservation efforts because they occupy a small area and they do not interfer on farming activities.

The fragment size is fundamental for its species richness in highly isolated fragments of Brazilian Atlantic Forest (Christiansen and Pitter 1997; Ribon et al. 2003). However, studies have pointed out that connectivity can strongly diminish the negative effects of fragment-size reduction on species richness (Marsden et al. 2001). Therefore, small fragments and hedgerows can positively impact richness of fragmented landscapes. Although hedgerows might potentially favor the biotic flux on fragmented landscapes, their narrowness (maximum 15-meters width) and consequent extensive edge effect, enhance their vulnerability to the surrounding human activities and increase their risk of disappearance (Vogt et al. 2007).

While structural connection does not imply necessarily in functional connection, there is a large bulk of evidences that structural corridors are important for biodiversity conservation (Vogt et al. 2007). Certainly the large number of hedgerows found in the studied landscapes can contribute to increase structural connection of the landscapes. Besides , we showed that the hedgerows are present in the whole area of Minas Gerais 'Atlantic Forest, although, they are denser in the South of the state. It is also possible to find these hedgerows in other Brazilian's states (Paraná, São Paulo, Rio de Janeiro, Espírito Santo and Bahia) (personal observation). Nevertheless, studies of linear vegetation strips associated with land division in tropical regions of Central and South America are exclusively for live fence (Castro and van den Berg 2013). The diversity of fragments size linked to hedgerows suggests the importance of these elements to the majority landscapes. Because of the similarity between hedgerows and the fragments that they are associated with (Castro and van den Berg 2013) these elements are increasing the landscape connectivity for fragments of a variety of size or, at least, increasing the size of fragments in the landscapes.

Although the approach adopted in this study has clearly captured the distribution pattern of hedgerows for the Atlantic Forest in Minas Gerais, it did not entirely map all the landscapes on Atlantic Forest. The savannas' areas ("cerrado") were also not searched, although hedgerows exist there (personal observation). Therefore, we recommend a more extensive investigation looking of these hedgerows and investigating their holes as connectors.

5. Conclusion

This study applied an object-based approach to map, for the first time, the hedgerows and small fragments over a large scale region, the Atlantic Forest in Minas Gerais State. We incorporated all size range fragments and correlated them to different land uses. Other studies have been only focused on mapping the larger and preserved units but small fragments are also crucial for forest monitoring and conservation. The results present here can provides a basis for improving landscape management, through conciliation of structural pattern and ecological processes. The methods developed here can contribute to improve the detection of landscape elements in regular monitoring, to improving the accuracy of vegetation maps, making conservation and management decisions more precise and efficient.

We showed here that, at least for the Brazilian Atlantic Forest in Minas Gerais State, hedgerows are conspicuous structures, crossing extensive regions and possibly promoting biotic fluxes between forest patches. Besides of that, we showed that fragments smaller than 1 ha are also a predominant feature for that landscape and cannot be ignored on mapping procedures and conservation strategies. Mapping those structures with repeatable and accurate technique, like the ones we used here, can improve our understanding of landscape organization, and allow ecologists to better address the concept of corridors in biological conservation studies and policies (Vogt et al. 2007). Conservation activities needs to be include the hedgerows to legally protected these structures, once their existence is not recognized in the Brazilian environmental legislation (Castro and van den Berg 2013).

Considering their extensive presence on the analyzed landscape, further research focused on conservation must include small fragments and hedgerows as well as legal background must be providing to protect them.

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ARTIGO 2

THE RULE OF SMALL FOREST PATCHES AND HEDGEROWS ON BIODIVERSITY PARAMETER AT LANDSCAPE SCALE

Artigo estruturado nas normas da revista "Biological conservation"

The rule of small forest patches and hedgerows on biodiversity parameter at landscape scale

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Abstract

Landscape structure and biodiversity are strongly dependent on available area, isolation and connectivity among remnants. Small fragments and connectors are now common features in most of the landscapes related to human activities. However, little importance is given to those elements and their relationship to the area where they are inserted. In order to evaluate landscape characteristics and their association to vegetation remnants, matrix, hedgerows, landscape isolation and connectivity, we carried out analyses in 49 landscapes distributed over the entire Atlantic Forest included in the Minas Gerais state, Brazil, with a variety of vegetation cover and forest patches size. We considered sub-regions, distance to anthropogenic activities, relief and abiotic factors as likely important variables. Statistical analyses, based on selection model by AICCc value, revealed influence of physical structural, relief and political division on the remnant vegetation, isolation and hedgerows length. Small fragments (<100 ha) and narrow connectors (width ≤ 15 m) appeared as key elements to promote connectivity within the landscapes. Based on our results, we emphasize the necessity to take into account small fragments and connectors in landscape management and biodiversity conservation, even and mainly in areas where most of the natural habitat has already been converted to anthropogenic areas.
Keywords: landscape ecology; Atlantic Forest; fragment size; isolation; connectivity

1. Introduction

Biodiversity effective conservation is positively related to the amount of remain habitat and inversely related to habitat fragmentation (Fischer and Lindenmayer 2007; Martensen et al. 2008; Wilcox and Murphy 1985). Those findings are justified by the impact in biotic and abiotic relationships and ecological processes caused by landscape modifications (Bierregaard Jr. et al. 1992; Pardini 2004). Removal of fragments, reduction in size and increase of remnants isolation are considered main factors of global species extinction in the present time (Fahrig 2001), mainly resultant from the expansion of anthropogenic activities into natural areas.

Size and distribution of vegetation remnants and their relation to the surrounding landscape are fundamental issues on landscape planning and management with focus on species conservation, once spatial arrangement of landscape has fundamental relationships with ecological processes (Neel et al. 2004; Turner 1989). Larger area generally offers more resources and more environmental variation to harbor more individuals, allowing opportunities for niche specialization (Hodgson et al. 2009).

Agriculture and cattle raising result in landscapes dominated by small and isolated fragments inserted in agricultural mosaics (Fahrig 2003; Neel et al. 2004; Tabarelli et al. 2010), negatively affecting population and community diversity. Because remaining forest is directly influenced by nearby land use, the fragments and the surrounding matrix are of particular interest for one who is trying to establish conservation strategies in this context. The type and permeability of the surrounding matrix influence on the species flux through landscapes elements (Uezu et al. 2008; Umetsu et al. 2008). Landscape mosaics include different kind of land uses, such as urban areas, roads, water courses, agriculture and pastures associated with patches of natural vegetation with heterogeneous structure and variable conditions for species occupancy (Carvalho et al. 2009; Vandermeer and Perfecto 2007).

Some landscape traits and elements can provide connectivity among fragments, allowing biological fluxes in fragmented landscapes. The connectivity is a key factor in species persistence (Fahrig and Merriam 1985; Fischer and Lindenmayer 2007), afforded by structural or functional connectivity between fragments (Tischendorf and Fahrig 2000; With and King 1997). Structural connectivity enables the biological fluxes between patches through physical linkages (Forman and Collinge 1997) and functional connectivity are dependent of species behavior demands on a particular landscape, considering their capacity to cross the matrix (Tischendorf and Fahrig 2000). At many scales, landscape connectivity is important for species, individuals and populations moving among patches (Minor and Urban 2007), increasing the species survival chances (Boitani et al. 2007).

Considered as a main landscape element that enhances the connectivity between patches, vegetation corridors (Beier and Noss 1998; Pardini et al. 2005; Uezu et al. 2008) are recognized as narrow, continuous strips of habitat that structurally connect two otherwise non-contiguous habitat patches (Saunders et al. 2001; Tischendorf 2001) and gives the opportunity for individuals to use different fragments, reducing the influence of fragment size (Martensen et al. 2008).

In Brazil, the hedgerows generated by natural colonization of land plot boundaries ditches are a prominent landscape feature (Castro and van den Berg 2013). These hedgerows exhibit high plant diversity inside a three meters wide ditches (Castro and van den Berg 2013) creating a maximum 15 meters of canopy cover, working as well as a fragments connectors or habitat for mammals (Castro and van den Berg 2013; Mesquita and Passamani 2012; Rocha et al. 2011). Besides increasing connectivity, the hedgerows in agricultural landscapes are recognized globally for providing habitat, shelter and resources for some plant and animal species (León and Harvey 2006). Because these elements can determine the probability of colonization between patches (Baum et al. 2004; Fischer and Lindenmayer 2007), they can also have a larger-scale influence, on the total diversity of a landscape (Uezu et al. 2008).

Therefore, the understanding of the consequences of fragmentation and habitat loss to the structural distribution of patches, their area and connectivity is an important tool to infer about species persistence (Antongiovanni and Metzger 2005; Beier and Noss 1998; Carvalho et al. 2009; Metzger and De´camps 1997).

Assessing effects of habitat loss and fragmentation is feasible by the application of landscape structure metrics on satellite images classifications (Neel et al. 2004; Stehman and Wickham 2011; With and King 1997). Those tools are useful surrogates for biodiversity assessments and can be used in different steps of conservation planning (Fischer and Lindenmayer 2007). Specially in broad-scale landscapes, landscape structural analyses are desirable, mainly where species inventories and biodiversity distribution patterns are still unavailable (Fairbanks et al. 2001), which is the case for most of tropical area (Ribeiro et al. 2009).

The Atlantic Forest it was considered one of the largest rainforests of the Americas, originally covering around 150 million ha, distributed in highly heterogeneous environmental conditions. Habitat loss and fragmentation process reduced the Atlantic Forest to landscapes dominated by small fragments (<100 ha; (Ranta et al. 1998) isolated from each other (Metzger 2000; Metzger et al. 2009) corresponding to less than 12% of the original vegetation, although it still supports one of the highest degrees of species richness and rates of endemism in the planet (Myers et al. 2000).

In this study we aimed to evaluate the structural distribution of fragments and hedgerows and their relationship with anthropogenic and natural characteristics in landscapes for the Atlantic Forest in the Minas Gerais state. We calculated the amount of remain vegetation, isolation and connectivity of landscape and analyzed the relation between the fragments and ecological parameters.

2. Methodology

2.1 Study area

Most of the Atlantic Forest was originally located in Brazil (92%) (Huang et al. 2007) covering 17.4% of the country territory and distributed over distinct topographic and climate conditions, presenting a high variety of forest physiognomies and compositions (Metzger et al. 2009). This highly heterogeneous forests harbor a high number of species (1 to 8% of species in the world) and is considered a biodiversity hotspot (Metzger et al. 2009; Myers et al. 2000) and one of the most highly threatened tropical forests, with 70% of the Brazilian population occupying its territory. The vegetation has been reduced to fragments with less than 50 ha, surrounded by anthrogenic areas (Metzger et al. 2009).

Historically, deforestation of the Atlantic Forest has been related to economic exploitation, resulting in highly fragmented landscapes and a large number of threatened species (Metzger et al. 2009). Minas Gerais State possess a highly diversified landscape. Possibly, it is related to historical occupation, vegetation composition, climate differences and relief complexities. The Brazilian Institute of Geography and Statistics (IBGE), based on these attributes, created 12 mesoregions in Minas Gerais state, as a subsidy to administrative, economic, social and tributary activities, contributing to planning activities. Therefore, it is also possible that the different patterns of fragmentation and distribution of fragments in the state relate indirectly to these mesoregions.

2.2 Methods

We evaluated 49 landscapes each one with 12 ×12 km, randomly distributed at Atlantic forest biome, Minas Gerais state, southeast Brazil (Figure 1). Sample sites were randomly selected according to the following restrictions: (1) The areas had to be completely included inside the domain (Atlantic Forest). All randomly selected samples touching the domain edges were excluded; (2) The areas could not share boundaries.

For every sample site, one high spatial resolution land cover classification is available (first chapter), resultant from imagery extracts composed of a RapidEye image acquired in 2011, with five meters of spatial resolution. This resolution enables us to include a large range of fragment sizes and connectivity conditions.

Land cover information was obtained by using a multilevel object-oriented semi-automatic approach based on image segmentation using scale, color and shape as parameters to identify landscape elements. The classification resulted on land cover maps of all fragments size, agriculture, urban areas, water, pasture (native and non-native) and hedgerows. Agriculture class was subdivided in permanent agriculture, for perennial plantations like coffee and eucalyptus and temporary agriculture, including frequently modified plantations. The agriculture areas can influence in different ways the species persistence offering different type of permeability in the landscape.

We used the Nearest Neighborhood (NN) algorithm, trained by image samples in each class, for definition of the classes. With same spectral characteristics of vegetation, the hedgerows were detected by structural and contextual rules. We used ancillary data of rivers, roads and conservation units to superpose on the land cover maps and calculate the distance to fragments. Elevation Model was used to calculate the altitude and slope of landscapes.

2.3 Map validation

We used independent data source, randomly located within each class and equitably distributed over the 49 scenes for the accuracy assessment. User's accuracy, producer's accuracy and overall accuracy were computed and analyzed. The accuracy assessment also reported overall kappa statistics for each class (Concheddaa et al. 2008). All kappa measures, overall accuracy and object validation showed a high level of agreement and confirmed the accuracy of this classification. The overall accuracy of more than 80% and the kappa coefficient greater than 0.76 for vegetation and hedgerows pointed out to a an reliable result (Fielding and Bell 1997).

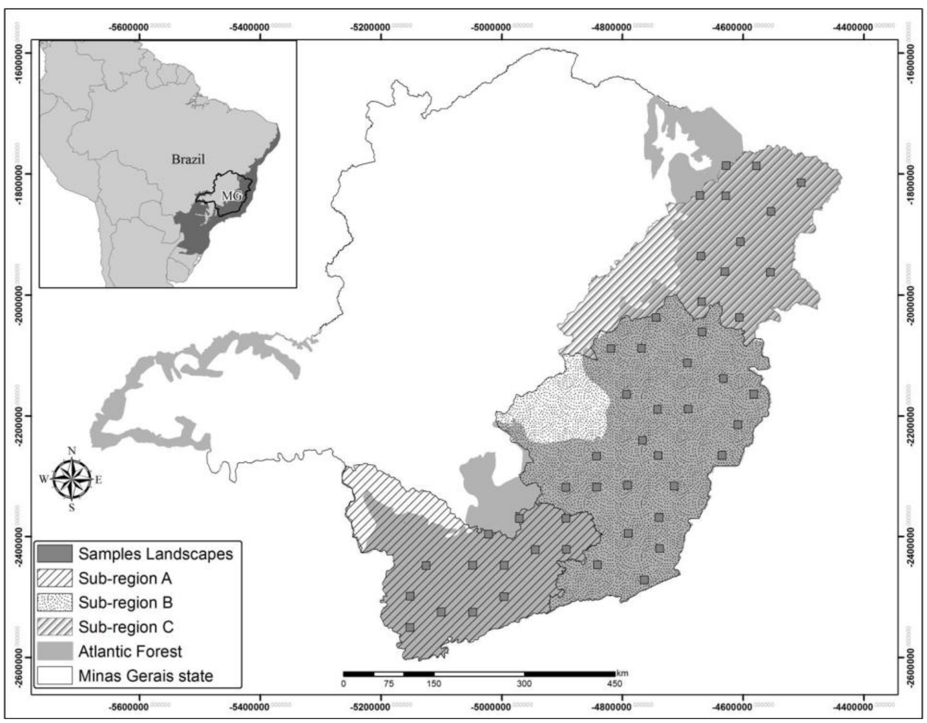

Figure 1. Location of the study sites. Atlantic Forest domain inside Minas Gerais (MG) state and sub-regions distributions. Gray squares indicates the sample sites used on this study.

2.4 Landscape component indices

We selected isolation, matrix data, remained vegetation, connectivity and hedgerows length as landscape descriptors. Our choice was based on their relevance to forest and ecological conservation.

Landscapes configuration was measured by the number and area of remnants, length of hedgerows, mean slope and mean altitude of each landscape. We used fragments area to create, for each landscape, two classes of variables: fragments larger than 100ha and fragments up to 99ha. We computed the mean size of these two fragments for each sub-region. Land cover classes were also used to access the mean distance of agricultural areas and pastures to each fragment and hedgerow as well as mean distance to conservation units, roads, rivers and urban areas, provided by ancillary data. We calculate the density of rivers in each landscape dividing the total extension of rivers by the area of landscape. Sub-regions were used in the analysis as variables, with 13, 12 and 24 landscapes for sub-region A, B and C, respectively.

Remaining vegetation is a predictor of habitat available to species and a measure of conservation degree of landscapes (Fahrig 2003). Based on the size of all fragments, we calculate the percentage of remaining vegetation for all sample sites. Afterwards, we evaluated the relation between the percentage of remain vegetation and structural variables.

We calculated the connectivity indices using the graph theory, defining clusters of fragments functionally connected (Urban and Keitt 2001) in a multi scale approach. Graph Theory employs the species capacity to cross different size of matrix to reach another fragment (Minor and Urban 2007; Urban and Keitt 2001) based on different species perception of landscape structure. Distance between fragments was used as the measure of capacity to cross the matrix (Awade and Metzger 2008; Martensen et al. 2008) and the clusters show the available area to species depending on landscape structure perception by the groups (Urban 2005). Therefore, the connectivity index is the sum of fragments inside of the species potential home range boundaries; it is the vegetation available area for a certain functional distance. Connectivity maps were built for functional distance classes and the mean cluster was calculated for each landscape.

Supposing that small fragments are a very common element in fragmented landscapes, mainly in the Atlantic Forest, and that those small fragments can modify the structure and influence species distribution, we evaluated the importance of small fragments to the landscape isolation by removing the small fragments in successively larger maximum sizes classes of fragments and calculating the mean isolation. Isolation was calculate based on Ribeiro et al (2009), adapted from Fortin and Dale (2005), measuring the distance between random points to the nearest fragment in the landscape. For each landscape, we randomized 100 points and then the isolation was measured to each process of fragment size class removal. The mean isolation with all fragments was calculate for each landscape and sub-region and used to evaluate the relationship to landscape configuration metrics.

Structural changes and their magnitude in forest remnants is influenced by the surrounding areas (Mesquita et al. 1999). In order to evaluate the influence of matrix on the fragments, we assess the relation between temporary and permanent agriculture with the number of fragments and total area of vegetation in landscapes.

As a component of landscapes, hedgerows can be influenced by various structural and physical characteristics. We tested these relationships measuring the length and amount of hedgerows in each landscape in relation to the number and area of fragments, mean slope and mean altitude, mean distance of pasture, temporary and permanent agriculture, mean distance to conservation units, roads, rivers and urban areas.

2.5 Data analysis

For remaining vegetation, number and area of fragments; hedgerows number, length and length sum we examined the distribution and tested the difference between the mean and median. For variables with normal distribution we used analysis of variance (ANOVA). Followed by Tukey test in the case of significant differences. To those variables with non-normal distribution, we analysis was performed using a Man-Whitney test.

In order to identify the variables that better predict remaining vegetation, isolation and hedgerows size in landscapes, we conducted a model selection using multiple regressions and Generalized Linear Model (GLM).

We used as previous analysis, a Spearman test to build a correlation matrix to explore the degree of association among the 15 variables: fragment area, number of fragments, mean area of fragments above 100 ha, mean area of fragments between 1 and 99 ha, number of hedgerows, distance to rivers, distance to roads and distance to conservation units, sub-regions, mean slope and altitude; distance to urban area, to pasture and to permanent and temporary agriculture. For the subsequent model development, and in order to minimize autocorrelation among independent variables, we only included the variables not correlated to each other, discarding the variables which correlations were significant ($p<0.05$). Five variables were removed using this criteria: fragment area, number of hedgerows, distance to rivers, to roads and to conservation units. We kept 10 variables: number of fragments, mean area of fragments above 100ha, mean area of fragments between 1 and 99ha, sub-regions, mean slope and altitude; distance to urban area, to pasture and to permanent and temporary agriculture.

We evaluate the candidate models by Akaike´s Information Criterion (AICc) (Burnham and Anderson 2002) and calculated the estimation of the relative quality of the statistical model (AICc); the relative difference of AICc value for every model in relation to the smallest value of AICc among all models (Δi AIC); the chance for the model to be select, which varies from 0 to 1 (wAICc); relative fraction of the value of wAICc for every model with the higher value of wAICc among all models (evidence ratio). We used the 'dredge' function from 'MuMIn' package to test models defined by all possible variable combinations and ranked them by their AICc-based model weight (Burnham and Anderson 2002).

In order to estimate the relative importance of every variable included in any of the six best models, we calculated the sum of Akaike weights of the models where these variables were included (Burnham and Anderson 2002). We considered the models which presented values of (Δi) AIC below two, the most likely to be selected. All analyses were conducted in R version 2.9.1 (R Development Core Team 2009).

3. Results

3.1 Vegetation and hedgerows distribution

The distribution of remain vegetation in Minas Gerais varies expressively among the analyzed landscapes in the Atlantic Forest domain, with mean percentages of cover ranging from 4 to 70%, and for sub-regions ranging from 25 to 40% (Table 1). Most of landscapes have lost more than 60% of their original cover. The total vegetation covers only 30% of the territory analyzed (705,600 ha).

Atlantic Forest is highly fragmented (Table 1), highlighting the sub-region A that has the highest number of fragments and hedgerows compared to the others sub-regions. For the whole region, we found few fragments with more than 100ha, but most of them are smaller than 1ha (80% of fragments in the landscapes).

Table 1. Fragments and Hedgerows of Atlantic Forest distribution over sub-regions at Minas Gerais state. Mean values are for normal distributions, median for non-normal. Superscript letters indicates the statistical difference.

	Sub-region								
	A			**B**			**C**		
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.
Remain Vegetation (ha)	3610.59^{a}		729.30	4084.11^{a}		1849.27	5789.53^{c}		2126.16
Number of fragments	2306.20^{a}		743.62	2065.52^{a}		901.96	2105.46^{a}		418.48
Fragments area (ha)		1.80^{a}	0.55		1.83^{a}	3.25		2.63^{a}	1.61
Number of hedgerows		174^{a}	11.28		26.00^{b}	23.75		3.00^{c}	12.03
Mean Hedgerow length (m)		219.65^{a}	19.20		205.72^{a}	91.48		208.20^{a}	117.13
Sum of hedgerows length (m)		38808.88^{a}	27186.22		5348.68^{b}	4506.77		1238.50^{c}	2440.00

Number of hedgerows and the sum of hedgerows length was statistically different for all sub-regions, but the mean extension of hedgerows was similar.

The sub-region A had the smallest percentage of area covered by vegetation (25.1%) (Table1), distributed on small and isolated fragments, with 26.582m of isolation. The fragmentation level was less pronounced on the sub-region B (28.2% of vegetation), with a mean isolation of 30.22m. Sub-region C hold the most preserved landscape, and had 40.2% covered by vegetation and isolation of 29.117m.

Model selection pointed out that the influence of fragments larger than 100 ha, density of rivers and sub-regions were the most relevant variables to explain the percentage of remain vegetation in landscapes (Table 2). We observed a positive relationship for these variables, showing an increasing of vegetation percentage with the presence of more rivers and fragments larger than 100ha in the landscapes. The smaller AICc value for model1 suggests that is the best model to explain the remain vegetation (wAiCc 0.436). The variable fragments larger than 100ha was especially important, once it was present in all of the top ranked models, having the higher relative importance in model selection (0.738) together with sub-regions.

Table 2. Model selection based on Generalized Linear Model (GLM) and first six AiCc-based model selected by (i) percentage of remain vegetation, (ii) landscape isolation, (iii) hedgerows length. A100 - Fragments larger than 100ha; RD - Density of rivers in landscape; M- sub-regions; A99 - Fragments up to 99 ha; AL -altitude; N -number of fragments; S - slope; D - distance to permanent agriculture. Signal inside parentheses indicate the effect of each variable

Model ranks						
Vegetation Percentage	**Model**	**K**	**AICc**	**Delta (Δ)**	**Weight**	**Cumulative weight**
1	(+)A100+(+)RD+M	5	367	0.00	0.436	0.436
2	(+)A100+M	4	368	0.73	0.302	0.738
3	(+)A100+(+)RD+M+(+)A99	6	369	2.43	0.129	0.867
4	(+)A100+M+(+)A99	5	370	3.18	0.089	0.956
5	(+)A100	3	373	6.15	0.020	0.976
6	(+)A100+(+)RD	4	374	6.95	0.014	0.99
Landscape Isolation						
1	(-)AL+(-)RD+(-)N	5	340.1	0.00	0.450	0.450
2	(-)AL+(-)RD+(+)A99	5	341.3	1.17	0.251	0.701
3	(-)AL+(-)RD+(-)N+(+)A99	6	341.6	1.53	0.210	0.911
4	(-)AL+(-)RD	4	345.0	4.88	0.039	0.950
5	(-)RD+(+)A99	4	346.9	6.77	0.015	0.965
6	(-)RD+(-)N	4	347.5	7.37	0.011	0.976
Hedgerows Length						
1	(-)S+M	4	1092.2	0.00	0.56	0.560
2	(-)S+M+(-)A99	5	1094.3	2.16	0.19	0.750
3	(-)S+(+)D+M	5	1094.6	2.39	0.169	0.919
4	(-)S+(+)D+M+(-)A99	6	1096.9	4.71	0.053	0.972
5	M	3	1099.5	7.27	0.015	0.987
6	M+(-)A99	4	1101.5	9.30	0.005	0.992

3.2 Landscape isolation

The regression selection procedure provided a set of three equivalent models (Δ less than two) to explain the relationship of isolation with explanatory variables. However, the first model is considered the best one, exhibiting the lowest AICc value. Density of rivers was included in the first six models, suggesting that this variable is important to the isolation of fragments in landscapes. All variables had a negative relationship with landscape isolation. The highest weight was provided by model 1, with 45% of probability that this model is the best model in the set.

Small fragments are important elements in the landscapes, mainly to sub-regions that holds less amount of vegetation like A and B (Figure 2). The removal of fragments with successively larger maximum sizes increased the isolation for all size classes in the sub-regions A and B, although this effect was stronger for smaller fragments (<100 ha) (Figure 2). The increase of isolation in the sub-region C was more gradual. We found for sub-region C that the removal of fragments with minimum size larger than 600ha almost did not change the mean isolation.

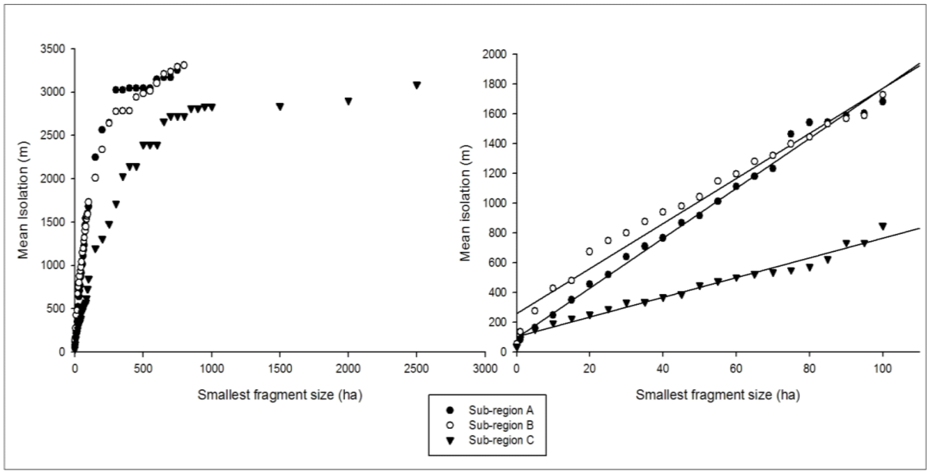

Figure 2. Landscapes isolation (m) for different sub-regions resulted from successive removal of small fragments (ha) for all class of size (i) and for fragments up to 100ha (ii). Fragment size 0 (ha) indicates no exclusion of any fragments in the landscape.

3.3 Landscape Connectivity

The area functionally connected can be use to demonstrate the available area for species depending upon their capacity to cross open areas. Sub-region A, where the fragments are smaller but also the isolation is smaller compared to sub-region B, had the lower cluster size available, but the changes on the size of the cluster of fragments increased faster when compared to sub-region B. In the sub-region C, where there is larger vegetation cover and larger fragments than in the other sub-regions, the size of the cluster for the same functional distances is larger and the cluster size increases faster. For all sub-regions the available cluster area changes dramatically in the functional distance between 100 and 150.

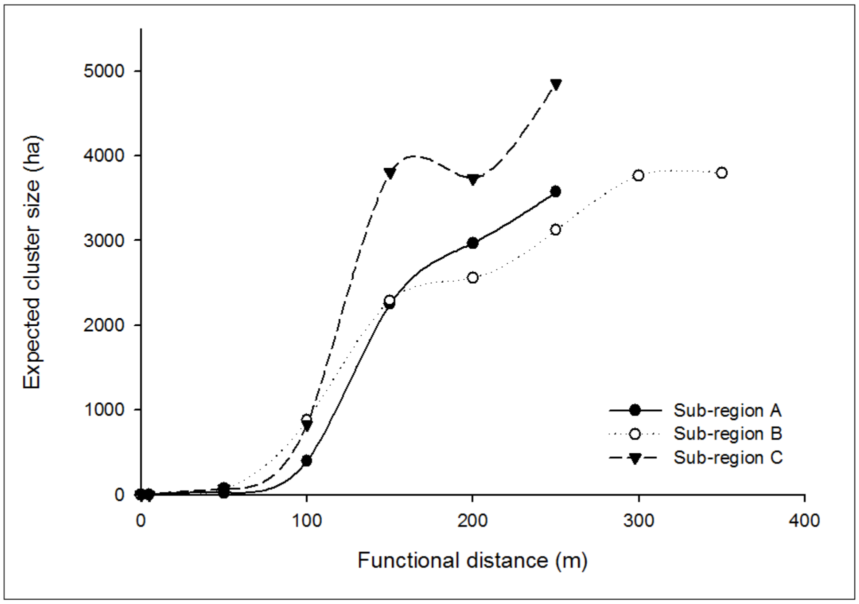

Figure 3. Functional distance (cluster size) according to the expect capacity of species to cross the matrix.

Hedgerows were significantly denser in sub-region A and the sub-region C presented just a few hedgerows (Table 1). Longer hedgerows are present mainly in the sub-region A, but the sub-region B also had long hedgerows (with more than 1000m length), although the mean length was very similar between sub-regions.

Just one model (Model 1) can be considered plausible according to delta value ($\Delta<2$) (Table 2). There was a significant negative relationship between length of hedgerows and slope, the sub-region also affected the length of hedgerows.

The variables distance to urban area, to pasture and to temporary agriculture did not show any relation with isolation, once they were not included on none of the six first models for remain vegetation, isolation and hedgerows length

3.4 Agricultural matrix

There is a distinction between fragments and remaining habitats in the two different agricultural matrix. Landscapes with permanent agriculture had more landscapes with temporary agriculture. Variation is also higher in fragments associated to permanent agriculture, compared to temporary agriculture (Figure 4).

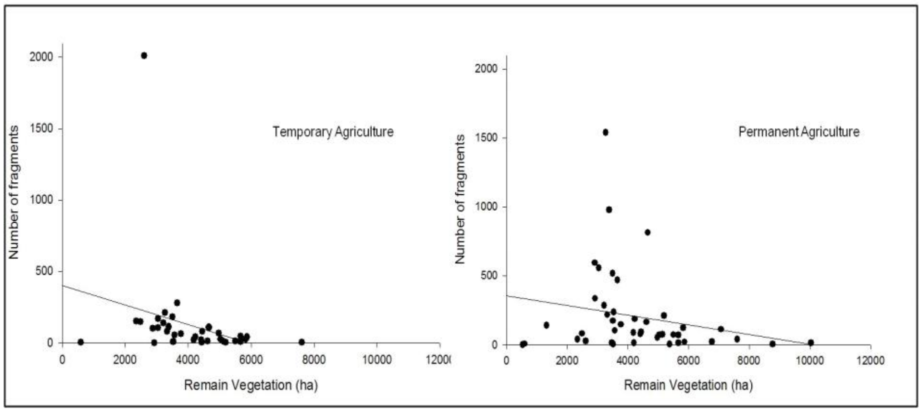

Figure 4. Relation between remain vegetation in the landscape and number of fragments inserted in a temporary (left) and permanent (right) agricultural matrix

4. Discussion

The importance of small fragments for reducing landscape isolation and improving the connectivity increased with the level of fragmentation in Atlantic Forests in Minas Gerais. Remaining vegetation distribution is an indicator of the landscapes conservation and recuperation exigencies.

Moreover, secondary forests can sustain a significant amount of biodiversity (Develey and Martensen 2006; Viana and Tabanez 1996) and needs to be considered in conservation, being of particular importance for biodiversity conservation as their coverage is rapidly expanding in the tropics (Barlow et al. 2007). For more than half of the analyzed landscapes, the spatial distribution of fragments, isolation and connectivity are crucial elements for biodiversity conservation once for areas with habitat cover below of 30%, habitat configuration becomes particularly relevant (Fahrig 2003; Radford et al. 2005).

Our results demonstrated that political divisions, physical and structural characteristics play a substantial role on determining patterns of remain vegetation, isolation and hedgerows distribution for the Atlantic Forest domain in Minas Gerais state. The mean size of fragments larger than 100 ha was one of the strongest predictors of remain vegetation, as well as the density of rivers and sub-regions. The absence of relationship of others variables with remain vegetation in the landscape can be explained by the fact that these landscapes have a long history of human occupation and deforestation, with land use varying over time. The real drivers of deforestation then were the historical socio-economic and political conditions that provide demand for agricultural, mineral and forest products. The association with this historical context is highlight by the positive correlation between sub-regions and the amount of remaining vegetation. Land use activities nowadays have little influence on the remain vegetation, since the most of actual activities are not the same when the vegetation was suppressed. The influence of sub-regions on remain vegetation can be explained by these historical difference in resources uses defined by political decisions and frontiers.

Other alternative hypothesis can be suggested to explain the absence of relationship between remain vegetation, isolation and hedgerows with agricultural and pastures areas. These independent variables may have influenced locally, dissipating the effects when analyzed at landscape scale.

Density of rivers were related to vegetation remain because riparian vegetation is protected since the Brazilian Forest Code created at 1965 (30 to 500 width, varying according to the river width). This legal protection resulted in larger amount of remain vegetation in landscapes with higher density of rivers in Minas Gerais.

Although larger forest cover in areas of rougher relief is quite evident for the whole Atlantic Forest (Cabral et al. 2007; Silva et al. 2007), this pattern wasn't evident for Minas Gerais state. The possible reason for that is that the sub-regions with rougher relieve in state (A and B) are also the ones with lower amount of forest cover, probably because of older anthropogenic occupation.

The results indicated a meaning difference in percentage of remain vegetation between sub-regions A (25%) and C (40%), but at the same time sub-region C had a higher isolation value (29). By comparing these two sub-regions we can see an indicative of absence of correlation between the increase of remain vegetation with landscape isolation.

Some variables are not direct drivers of landscapes isolation, but they act as a guide to land modification. Economic land use is easier on less declivous areas and at lower altitude, leading to a more drastic reduction in forest cover in these situations (Silva et al. 2007). Therefore, higher altitudes areas suffer less human interference and, consequently, lower disturbances, retaining larger amount and less fragmented vegetation, consequently, have lower isolation.

High density of rivers in landscape means more protected and connected vegetation around them and less isolation. In Atlantic Forest region, forest was commonly found on steep slopes and near streams, where it is difficult to grow crops and accessibility was limited or the forests are protected (Freitas et al. 2010). Tropical forests are in most cases located in sites where access is difficult (Cabral et al. 2007; Freitas et al. 2010; Silva et al. 2007).

We found a higher isolation than Riberio et al (2009), when we removed fragments with similar maximum sizes. The removal of fragments small than 500 ha in Ribeiro´s study resulted on 1400m of isolation. On the other hand, in our analysis this class of fragment removal resulted in a 3000 m of isolation (for A and B region). We believe these differences can be explained by the inclusion of others states and regions in the analyses, with higher amount of forest cover.

The same reasoning used to explain the absence of correlation between remaining vegetation and land use can be used to explain the influence of these variables on landscape isolation. The actual land use activities were not the same when the landscapes suffer a high deforestation and increasing on remaining fragments isolation.

Traditionally it is believed that biodiversity conservation depends strongly on large fragments maintenance (Pardini et al. 2009; Uezu et al. 2008; Umetsu et al. 2008). On the other hand, we showed here that small fragments can be key features on the landscape when habitat isolation is considered, mainly for species able to cross small open or agricultural areas. The influence of small fragments on landscape isolation highlights the necessity of protecting small fragments and hedgerows, reducing the isolation and increasing the connectivity. The small fragments are especially important in the sub-regions A and B, where they respond for most of forested areas. In landscapes where small fragments dominate, but with low isolation level, it is expected that patch size would have a minor importance (Marini and Garcia 2005). Also, the hedgerows present abundantly in the sub-regions A and B are already recognized as habitats for animals and plants and connectors among fragments (Castro and van den Berg 2013; Mesquita and Passamani 2012; Rocha et al. 2011). Considering the actual level of forest fragmentation and the small size of most remnants in the Brazilian Atlantic Forest, stronger efforts must be direct to investigate the ecological relevance and sustainability of these small fragments and hedgerows and their role for connectivity between the larger ones (Ribeiro et al. 2009). Therefore, although is unquestionable the importance of large fragments for conservation of biodiversity (Ribeiro et al. 2009), conservation strategies must consider the small ones and hedgerows not only as step stones or connectors among large fragments, but also as habitats per se.

The sub-region C, with higher remain vegetation and larger fragments preserved, is also the one with more available areas for species capable to cross gaps among the remnants larger than. Nevertheless, the cluster areas available for both sub-regions before100m of crossing capacity its almost the same.

High level of fragmentation can explain low cluster sizes for species able to cross less than 100 m. The reduction in size and the increase in isolation of fragments affect mainly the species with large life area and those with low capacity to cross open areas. Functional connectivity is the estimation of actual potential of immigration on landscapes (Tischendorf and Fahrig 2000), but it's necessary to consider attributes of the species, as well as consider the interaction between the species and the landscape (Hodgson et al. 2009).

In landscapes characterized by low percentage of forest cover distributed among small fragments and high isolation, recreating or improving connectivity is essential to preserve species and functional diversity (Martensen et al. 2008).

The enhance in the area functionally connected is beneficial to all functional groups and should be accounted for conservation priority (Hodgson et al. 2009; Martensen et al. 2008; Moilanen and Nieminen 2002). Landscape connectivity may also provide connectivity for several ecological processes (Bennet 1990; Noss 1987).

The size of hedgerows is indirectly affect by altitude, justify by the distribution of agricultural land use in areas of low slope, since hedgerows were associated to land boundaries ditches. The sub-region influence on hedgerows length demonstrate on model 1 can be explained by the economical and political differences across the state and their influence on agricultural land use. The conservation of hedgerows would represent and excellent opportunity to extend the overall coverage of vegetation remain, particularly in low to intermediate elevations; to reduce the isolation of landscapes; to improve the connectivity of landscapes facilitating species to cross the matrix (Castro and van den Berg 2013; Mesquita and Passamani 2012).

In landscapes already fragmented, as the majority analyzed here, some sort of connectivity among elements and processes is the best alternative to reduce the negative impacts of fragmentation and of the small sizes of remain patches (Crooks and Sanjayan 2006).

The activities and land modification around hedgerows doesn´t influenced in the size of hedgerows, once they are located on ditches and/or land boundaries, being relatively permanent elements on the landscapes. Hedgerows are also elements with low negative economic impact on agribusiness, and, because of that, they suffer little pressure in terms of deforestation. Because they are a common feature of many managed landscapes, mainly in sub-region A, research should include them in biodiversity studies, justified by a low cost-effective and politically acceptable conservation strategy in landscapes with high level of modification (Barlow et al. 2010).

Although most of Atlantic forest at Minas Gerais state already disappeared or is reduced to small remnants, further removal of small remnants as showed here or vegetation fragmentation can bring new impacts and negative consequences on the environment. The maintenance of corridors like hedgerows can be an important factor to increase the connectivity and decrease the isolation in landscapes. Beyond the necessity of protecting large fragments, networks of small fragments, corridors and stepping-stones are effective for conservation and are probably the last alternatives to stop or reduce biodiversity loss in high fragmented and occupied landscapes (Martensen et al. 2008).

Corridors and stepping stones (small vegetation patches scattered through a landscape) always contribute to landscape connectivity (Beier and

Noss 1998), but they are not universally efficient for all the species. They are probably inefficient for species that do not cross no-forested matrix or avoid forest edges. Eventually they also can facilitate the spread of invasive species (Simberloff et al. 1992). Nevertheless, increase in landscape connectivity is usually more likely to have desirable effects on native species and ecological processes than undesirable effects (Haila 2002; Levey et al. 2005).

In our study we didn't found an influence of land use activities on structural parameters but agricultural activities may have strong effects on many forest ecological processes (Pardini et al. 2010; Uezu et al. 2008; Umetsu et al. 2008) and must to be analyzed together with species evaluation. In regions with old human occupation, territorial land use must be considered.

5. Conclusion

In our analysis, it was possible to understand landscape heterogeneity and the influence of structural characteristics. As the sub-regions are used as guides for public policies development, the differences presented in this study can be used to direct how and where to act, depending of the landscape location.

Considering the lack of distribution information for many threatened species, especially in tropical areas (Tobler et al. 2007), remaining vegetation, isolation and hedgerows distribution and their relationships with structural landscapes factors are a cost-effective surrogate for evaluation of species persistence and may be useful tool to plan and manage land-use strategies in respect to biodiversity conservation.

Considering the current level of fragmentation and level of urban and farmland occupation, sub-regions A and B should be considered as priority areas for the preservation or the increase on size of corridors, with the intention to enable the connectivity among remnants. Larger fragments, more present in the sub-region C, are specially important on biodiversity preservation.

In order to avoid species extinction in the Atlantic Forest, some measures focused on conservation of corridors and increase of the size of fragments must be implemented in Minas Gerais. Extinction processes are particularly likely to occur in landscapes with low native vegetation cover, low landscape connectivity, degraded native vegetation and intensive and use in modified areas. Almost all landscapes analyzed currently gathers desirable characteristic that can promote the extinction of vegetation and species. Most threatened fragments appeared to be related to interfluvial areas with smoother relief characteristics. These regions have an attractive social conditions in terms of employment

Effective conservation and restoration planning should to consider how fragments and hedgerows are distributed on landscapes. The spatial differences in remaining habitat, isolation and connection of fragments needs to be considered for management activities.

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