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Prioritization of Atlantic Forest remnants for biodiversity conservation: A patch index development

Desenvolvimento de um índice para priorização dos remanescentes da Mata Atlântica para a conservação da biodiversidade

Priorización de remanentes de Bosque Atlántico para la conservación de la biodiversidad: Desarrollo de un índice

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Abstract
Atlantic forest fragmentation is considered a serious threat to biodiversity since this biome is considered the hottest hotspot. Due to this reason, many environmental strategies are being developed in order to support its, one of them being the prioritization of forest remnants using landscape ecology metrics. Thus, the main objective of this study is the development of a patches prioritization index (PPI) in order to support conservation actions and research. Firstly, a diagnosis of forest remnants in the study area was performed using landscape ecology metrics. Secondly, by literature review and expert consulting, were selected the adequate landscape ecology metrics, next, their importance was determined for PPI composition. Selected landscape metrics (AREA, SHAPE, and NEARD) composed the PPI. Finally, using a rapid ecological assessment (BII) the PPI was validated in the field. The results showed that the study area has patches able to aid biodiversity maintenance in the landscape. Further, the selection and importance attributed to landscape ecology metrics were demonstrated to be adequate. Also, the index is accurate enough to identify priority patches, classes, and regions for biodiversity conservation. Finally, the validation of PPI in the field showed that PPI is effective to estimate patches integrity in the field. In conclusion, our results suggest that PPI could be used for the prioritization of Atlantic forest remnants in a landscape covered mainly by Atlantic forest remnants and agriculture.
Keywords: Landscape metrics; Landscape ecology; GIS; Atlantic Forest; Patches prioritization; Biodiversity conservation.

Resumo
A fragmentação da Mata Atlântica é considerada uma séria ameaça à biodiversidade, uma vez que este bioma é considerado um ‘hottest hotspot’. Por esse motivo, muitas estratégias ambientais estão sendo desenvolvidas para apoiá-lo, sendo uma delas a priorização de remanescentes florestais utilizando métricas de ecologia da paisagem. Assim, o objetivo principal deste estudo é o desenvolvimento de um índice de priorização de manchas (IPP) para subsidiar ações e pesquisas de conservação. Primeiramente, foi realizado um diagnóstico dos remanescentes florestais na área de estudo utilizando métricas de ecologia da paisagem. Em seguida, por meio de revisão de literatura e consultoria especializada, foram selecionadas as métricas adequadas de ecologia da paisagem e suas respectivas importâncias dentro do índice. Métricas de paisagem selecionadas (AREA, SHAPE e NEARD) compuseram o PPI. Finalmente, usando uma avaliação ecológica rápida (BII) o PPI foi validado em campo. Os resultados mostraram que a área de estudo possui manchas capazes de auxiliar na manutenção da biodiversidade na paisagem. Além disso, a seleção e a importância atribuída às métricas de ecologia da paisagem se mostraram adequadas. Ademais, o índice é preciso o suficiente para identificar manchas, classes e regiões prioritárias para a conservação da biodiversidade. Por fim, a validação do PPI em campo mostrou que o PPI é eficaz para estimar a integridade das manchas em campo. Em conclusão, nossos resultados sugerem que o PPI pode ser usado para a priorização de remanescentes de Mata Atlântica em uma paisagem coberta principalmente por remanescentes de Mata Atlântica e agricultura.

Palavras-chave: Métricas da paisagem; Ecologia da paisagem; SIG, Mata Atlântica; Priorização de fragmentos, Conservação da biodiversidade.

Resumen

La fragmentación del Bosque Atlántico se considera una grave amenaza para la biodiversidad, ya que este bioma se considera un 'punto caliente'. Por esta razón, se están desarrollando muchas estrategias ambientales para apoyarlo, una de las cuales es priorizar los remanentes de bosque utilizando métricas de ecología del paisaje. Por lo tanto, el objetivo principal de este estudio es el desarrollo de un índice de priorización de puntos (IPP) para apoyar las acciones de conservación e investigación. Primero, se realizó un diagnóstico de los remanentes de bosque en el área de estudio utilizando métricas de ecología del paisaje. Luego, a través de una revisión de la literatura y el asesoramiento de expertos, se seleccionaron las métricas de ecología del paisaje apropiadas y su respectiva importancia dentro del índice. Las métricas de paisaje seleccionadas (AREA, SHAPE y NEARD) formaron el PPI. Finalmente, mediante una evaluación ecológica rápida (BII) se validó el PPI en el campo. Los resultados mostraron que el área de estudio cuenta con parches capaces de ayudar a mantener la biodiversidad en el paisaje. Además, la selección e importancia atribuida a las métricas de ecología del paisaje resultó adecuada. Además, el índice es lo suficientemente preciso para identificar lugares, clases y regiones prioritarias para la conservación de la biodiversidad. Finalmente, la validación del PPI en campo mostró que el PPI es efectivo para estimar la integridad de los parches en campo. En conclusión, nuestros resultados sugieren que el PPI se puede utilizar para priorizar los remanentes de Bosque Atlántico en un paisaje cubierto principalmente por remanentes de Bosque Atlántico y agricultura.
Palabras clave: Métricas del paisaje; Ecología del paisaje; SIG; Bosque Atlántico; Conservación de la biodiversidad.

1. Introduction

Brazilian Atlantic forest is one of the biomes with the highest concentration of biodiversity and endemism in the world, which is considered a hotspot having about 11% of its original cover (Mittermier et al., 2011; Ribeiro et al., 2009). Scientists have already highlighted its importance for fauna, flora, and ecosystem services (Mittemier, 2005; Myers et al., 2000, Paviolo et al., 2016), as well as the consequences of its degradation (SPECHT et al., 2015).

Despite that, the Atlantic forest is under the constant pressure of cropland expansion, pasture, and urbanization, especially because more than 60% of the Brazilian population lives near Atlantic forest remnants (Pinto, 2012; Martinelli et al., 2013). In this context, prompt strategies for Biome preservation are needed, which should be considered as a priority for biodiversity conservation (Joly et al., 2014).

Brazil has reasonably well-defined strategies to preserve the largest Atlantic forest areas, since they commonly become protected areas, such as National Parks and National Forests. Thus, the Atlantic Forest is probably the biome with the higher number of protected areas in Latin America, with having Brazil approximately 698 Protected areas (Tabarelli et al., 2005).

Nevertheless, this number of protected areas cover less than 2% of the biome, which is composed mainly of forest patches smaller than 50 ha, frequently unprotected by law (Ribeiro et al., 2009, 2011; Gascon et al., 2000; WWF 2018). The majority of these forest patches are immersed in rural or urbanized landscapes, under constant anthropic pressure (Ribeiro et al., 2009). Due to their size and location, those Atlantic forest remnants tend to be converted into cropland, pasture, or urbanized areas (De Lima et al., 2016). However, they are fundamental to the biodiversity maintenance of those landscapes (MELO et al., 2013).

Considering this scenario, we can say that the forest patches are the main responsible for biodiversity conservation (Magnano et al., 2015), supporting the endemic and threatened species (Toledo-Aceves et al., 2014). Furthermore, they can work as a refuge for native species from degraded areas, which tend to come live on them (Schelhas and Greenberg, 1996). In addition, forest remnants can support ecological corridors, helping fauna maintenance (Uezu et al., 2008).

Furthermore, Polensek and Pirnat (2018) also affirmed that the small patches of a landscape can support the species crossing amongst forest areas. In this way, they contribute to avoiding the reduction of gene flow at landscapes, assuring the genetic variability of fauna and flora, on the landscapes (Jousimo et al., 2014).

Further, Atlantic forest remnants contribute to the maintenance of the landscape water resources (De Mello et al., 2017).

Fernandes et al. (2013) demonstrated that water quality improves according to the rate of forest cover. Therefore, in addition to the fauna and flora conservation, forest patches support different ecosystem services. Hence, considering the configuration of the Atlantic Forest remnants and their importance for biodiversity, we can say that it is necessary to develop conservation strategies for forest patches conservation. Especially, because among forest remnants, there are those that can be classified as more relevant for biodiversity conservation (Iezzi et al, 2022).

Thus, environmental planning has been a tendency worldwide and, consequently, the definition of priority areas for conservation becomes a strategy broadly adopted (Dickson et al., 2014; Jones et al., 2016). Frequently, the definition of priority areas uses landscape metrics as the main method, since they can indicate the largest, most roundish, and the most connected patches. According to Shrestha et al. (2021) the definition of priority areas can support governmental and non-governmental actions for conservation, driving land-use planning, future research, investments, and supporting the conservation areas establishment.

Although prioritization strategies are valuable tools, they are usually not validated in the field, due to high costs, logistical questions, and lack of time, causing a decrease in their accuracy (Fan & Myint, 2014; Liu & Yang, 2015).

In this context, the main objective of this study was the development of a forest patch index, based on landscape ecology metrics, to prioritize Atlantic Forest remnants, for biodiversity conservation. The index was developed for a preserved Atlantic Forest landscape, containing forest patches surrounded mainly by agriculture. In order to compose the index, a new metric was generated to estimate connectivity, considering the landscape permeability. Furthermore, the index field validation is presented as well, in order to demonstrate its efficiency and fill the gap on prioritization strategies. This way, we can say that this paper presents an index methodology and its validation, attempting to support the decision-making process of selection areas for conservation purposes.

2. Methodology

Study Area

The study area was a southern portion of the Atlantic Forest in Brazil, between the protected areas Jurupará State Park (north) and Itupararanga Environmental Protection Area (southwest). Having approximately 9427 ha, locally it is named Pirapora headstreams (Figure 1), which was already declared as a priority for environmental conservation by Brazilian environmental agency and by the Biota/FAPESP project, one of the biggest biodiversity research projects developed in Brazil (MMA, 2018; Rodrigues et al., 2008). Also, according to Sayuri (2013), the study area could be considered as having a high/very high priority level to biodiversity conservation.

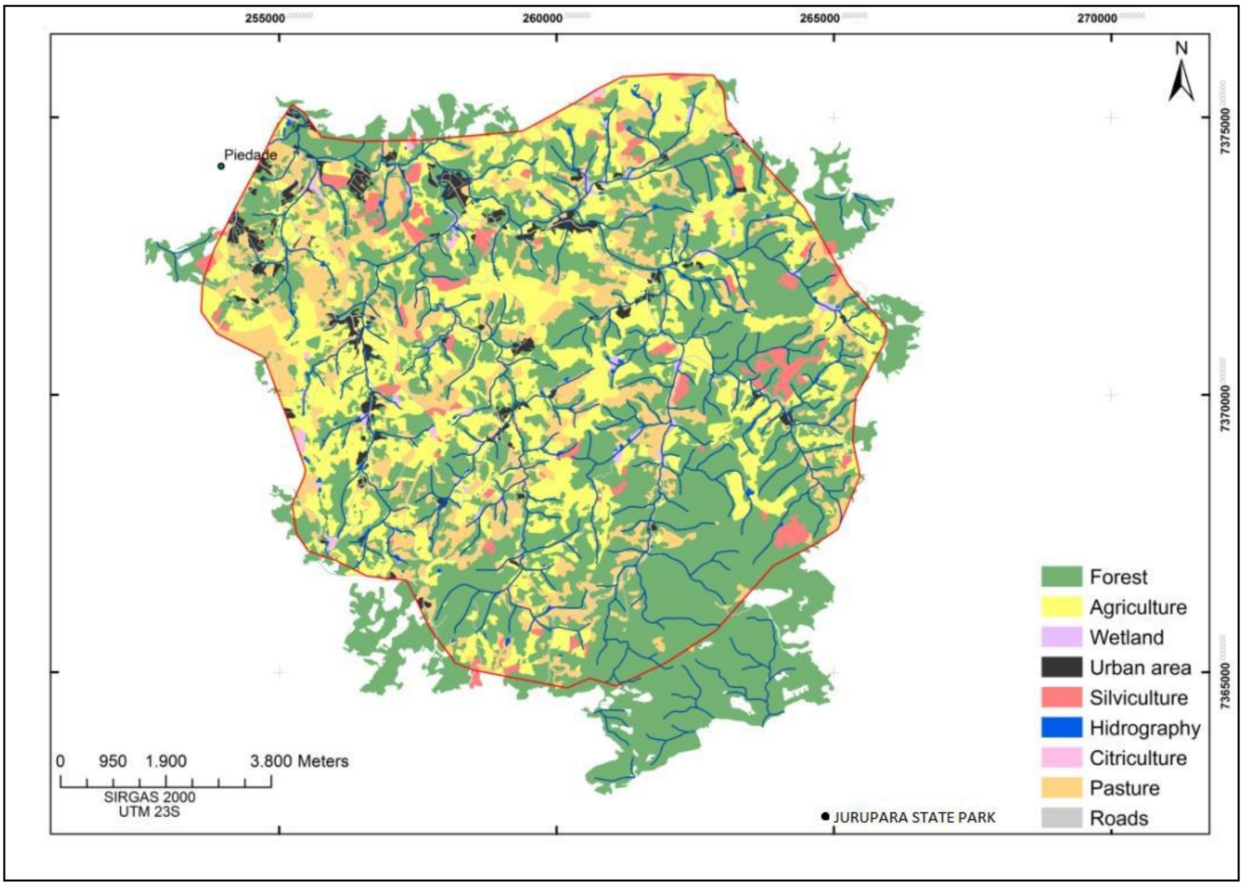
Pirapora river is one of the main rivers of the Tiete River basin, located in the São Paulo State, southeastern Brazil (Figure 1), and it supplies three cities and towns, providing water for domestic, agricultural, and other purposes (Silva et al., 2017). The watershed was originally covered by Atlantic Forest, where Dense Ombrophilous Forest is the predominant forest type (Oliveira-FILHO and Fontes, 2000).

This region acquired especial importance a few years ago, when Brazil faced a severe water crisis, that was not related to the meteorological condition, but according to Mello and Randhir (2018) it was a consequence of the basin management. The authors highlighted the importance of native forest conservation to support ecosystem services related to water.

Nowadays Pirapora headstreams are covered in 55.08% by forest remnants, that are scattered in an agriculture matrix composed of cropland, pastures, and planted forest, which occupy 24.32%, 14.15%, and 2.87 %, respectively. Pirapora headstreams have also urban areas, that are amount to 2,15% of the landscape (Figure 1). Forest remnants are composed of 527 forest patches, however, for conservations purposes, as suggested by Graciano-Silva (2017), we selected only the bigger than five ha, remaining 97 forest remnants (Figure 4).

The regional climate is classified as Cwa (humid, temperate, and dry winters), having an average temperature of 25,7°C in hot seasons and 13,5°C in cold seasons, moreover, the average annual precipitation is 1354,7 mm (CEPAGRI, 2014).

Figure 1. Location and land-use/land-cover of the Pirapora headstreams, Piedade municipality, and Jurupara state park in the São Paulo state, Brazil.



Source: Authors.

Prioritization index for biodiversity conservation (PPI)

The Patches Prioritization Index was based on the AREA, SHAPE e NEARD metrics. The first and second were calculated as proposed by Mcgarigal and Marks (2015), using the VLATE (Tiete) extension on the GIS environment (ARCGis). The NEARD metric represents connectivity among forest patches, considering that forest remnants are surrounded by different land-use/land-cover with different resistance levels for fauna individuals pass through. Thinking to obtain NEARD map, firstly we attributed values for land-cover/land-use resistance, accordingly their capacity to facilitate an organism movement through the landscape. Those values were obtained from the literature review and 12 specialists (biologists, ecologists, and forest engineers), consulting by questionnaires, containing closed and open questions. The low resistance represents ease of movement for individuals and a high resistance represents a barrier (Newbold et al., 2015; Azhar et al., 2013; Boron et al., 2019; Billeter et al., 2018).

Secondly, a Euclidean distance amongst forest patches was generated, and the two maps were normalized to a common scale varying from 0 to 1, using a linearly decreasing function, since lower distance and resistance mean better connectivity characteristics. Thus, overlaying the distance and resistance maps, we obtained the intermediated map, having values that consider the Euclidean distance plus the land-use use/land-cover resistance. Those values were also normalized (i.e. 0 to 1), using a linearly decreasing function.

Finally, we generated lines, representing the edge-to-edge Euclidean nearest neighbor (ENN) for each forest patch. Overlaying the ENN map and the intermediated map, we obtained the map with the NEARD value for each patch.

In the same way, AREA, and SHAPE were normalized to the common scale, using the linear increasing function and a linear decreasing, respectively. Since high area values are associated with better forest conservation conditions, low SHAPE values represent more regular forest patches.

Performing the Spearman test, using R software, we evaluated the correlation among the metrics, verifying previously the normality hypothesis of the metrics through the Shapiro-Wilks test (Racine, 2012).

The last step was the metrics importance definition, which was obtained by the pairwise comparison between metrics, following the literature review and experts opinion as previously described. The metrics importance varied from 0% to 100%, in order to compose the Patches Priority Index (PPI) as presented in equation 1.

$$IPP = I_1 \times metric_1 + I_2 \times metric_2 + I_n \times metric_n \qquad (1)$$

Where: I, metric importance value; and metric, selected metric.

PPI also was normalized to the common scale, where forest patches associated with values near to 1, representing the most important for biodiversity conservation (i.e. with the largest areas, more connected, and the most regular shapes). This way, we rank the forest patches, considering their importance for biodiversity conservation.

Likewise, the closer is PPI from 0, the lower is the forest patch priority for biodiversity conservation (smaller area, less connected, and irregular shape). In this context, PPI was calculated for forest patches in the study area. From PPI values it was generated a map containing the priority forest patches for biodiversity conservation.

PPI validation

We employed a Biotic Integrity Index (BII), which was developed by Medeiros and Torrezan (2013). The method considers a rapid ecological assessment, based on vegetation characteristics observation, that is estimated according to the biotic integrity of the forest patch.

We adapted BII for the local vegetation characteristics (i.e. forest patches of Atlantic Forest, where Dense Ombrophilous Forest is the predominant type), having a range from 11 to 55 (Table 1), where 11 represents the lowest integrity and 55 the highest. Through the stratified sampling, we selected a statistically relevant number of forest patches to apply the BII, considering also these patches distribution through the landscape as well as the significant range of PPI value.

The sample results in nine forest patches distributed over the study area, where three plots of 100 square meters were established, totalizing 27 sampling plots. Each sampled plot received a BII score, composed by the mean BII value of its plots scores, as proposed by Graciano-Silva (2017).

We also calculated the correlation between PPI (Prioritization index) values and BII (Biotic integrity index), using Spearman's correlation test, which requires no normality on data.

Table 1. Biotic integrity index (BII) parameters and ordinal integrity scale, applied in the Pirapora headstreams, SP state, Brazil**.**

PARAMETER	**ORDINAL INTEGRITY SCALE FROM 1 TO 5**				
	1	**2**	**3**	**4**	**5**
1-Litter cover	0 - 10%	10 - 25%	26 - 50%	51 - 75%	76 - 100%
2-Clearings	More than 50%	26 - 50%	11 - 25%	1-10%	Absent
3- Presence of *Euterpe edulis* higher than 1 m of height	Absent	1 - 3	4 - 6	7 - 9	10 or more
4- Vascular ephypites	Absent	1 – 2 (1 sp)	3-6 (1 - 2sp)	6-9 (2 - 3 sp)	10 or more (4 or more sp)
5-Standing dead trees	4 or more	3	2	1	0
6-Vines	Only slim, 4 more tangles	Only slim, 2 or 3 tangles	Only slim, 1 tangle	Thick (more than 4cm) and a few slim (tangle)	Only thick (more than 4cm of diameter)
7- Canopy height	0 – 9 m	10 - 14,9 m	15 - 19,9 m	20 - 24,9 m	25 or more
8- Diameter of canopy individuals	Less than 9 cm	9,1 - 17 cm	17,1 – 25 cm	25,1 – 33 cm	More than 33 cm
9- Other exotic species[1]	4 or more	3	2	1	Absent
10 – Individuals of late-stage species in canopy [3] -	Absent	1 (1sp)	2 (1 - 2sp)	3 (2 - 3sp)	4 or more (3,4 or more sp)
11 – Understory species [2]-	Absent	1-2 (1sp)	3-5 (1 - 2 sp)	6-9 (2 - 3sp)	10 or more (3,4 or more sp)
[1] Individuals of species *Eucaliptus, Pinnus, Leucena* (frutíferas- Citrus, Mangifera, Coffea, ...)					
[2] Individuals of Rubiaceae, Myrtaceae, Meliaceae (*Trichillia* sp) and Arecaceae (*Euterpe edulis) families*					
3 CANELAS (= Ocotea sp, Nectarndra, Cryptocarya), JEQUITIBÁ (*Cariniana estrellensis* Kuntze), FUMÃO = *Bathysa australis* (K.Schum);					

Source: Adapted from Medeiros and Torezan (2013)

3. Results and Discussion

Pirapora headstreams forest patches presented a range of values, varying from 5 to 1848 ha for AREA metric; 1.323 to 6.644 for SHAPE index; and 0.0019 to 0.1685 for NEARD metric.

Normalized values for landscape resistances (i.e. related to NEARD) are illustrated in Figure 2 (A). Further, Figure 2 (B) illustrated normalized values for Euclidean distance amongst forest patches higher than 5 ha. Finally, Figure 2 (C) shows NEARD values, which consider resistance and Euclidean distances.

According to the literature review and experts, the forest was classified as less resistant/null resistant, followed by water/wetland; planted forest; citriculture; pasture; agriculture; and urban areas/roads. The normalized resistance values for forest conservation was 0.001 for forest; 0.17 for water/wetlands; 0.33 for planted forest; 0.5 for citriculture; 0.67 for pasture; 0.83 for agriculture; and 1 to urban areas/roads.

Spearman's correlation test demonstrated that there is no correlation amongst the selected metric, thus all the three metrics were considered (equation 2). In terms of metrics importance, the consensus was AREA assuming 60%, NEARD 30%, SHAPE 10% (equation 2), resulting in PPI values ranging from 0 to 1.

$$IPP = 0.6AREA + 0.3NEARD + 0.1SHAPE \quad (2)$$

Where: AREA, normalized patch area; NEARD, the normalized value of the distance between nearest patch considering landscape resistance; SHAPE, normalized patch shape.

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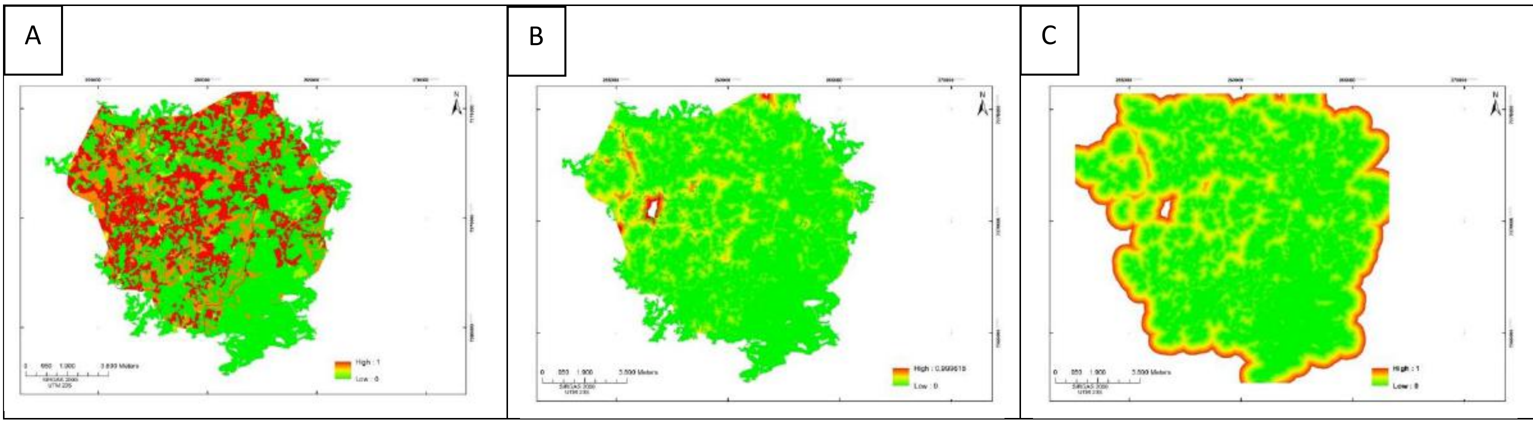
The correlation analysis among metrics and PPI demonstrated that AREA had a Spearman correlation of 0.7566 (Figure 2-A); NEARD 0.6217 (Figure 2-B); and SHAPE -0.3969 (Figure 2-C). In this context, we verified a positive correlation between PPI with the metrics AREA and NEARD, on the other hand, there is a negative correlation between PPI metric and SHAPE.

Figure 2. Normalized resistance values (A), distance values (B), and NEARD values (C), in Pirapora headstreams, SP state, Brazil.



Source: Authors.

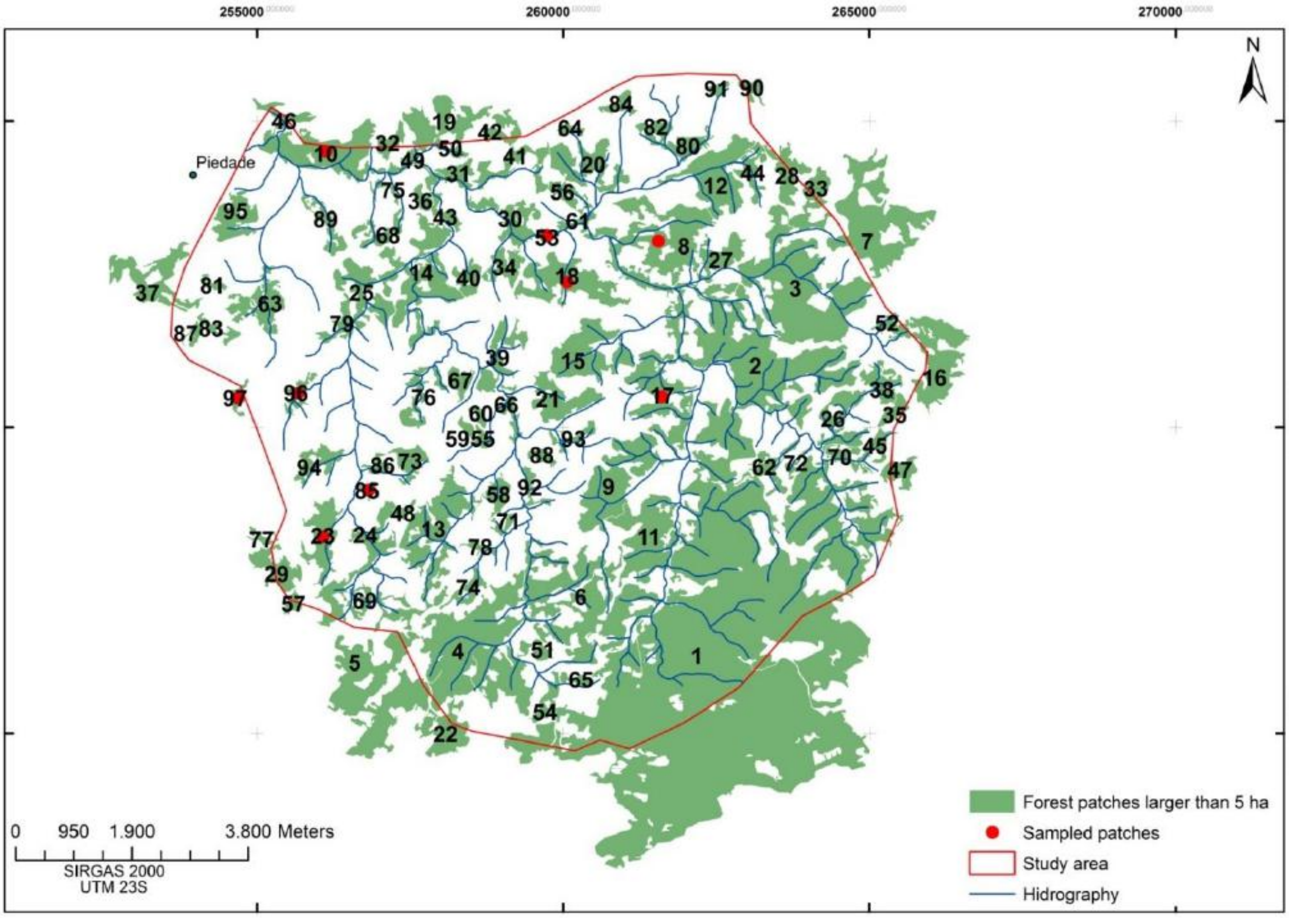
Moreover, in Figure 3, it is possible to observe the forest patches labeled according to their respective position in the PPI ranking. The majority of forest patches classified as the most priority ones are located in the southwest portion of the study area (Figure 3), which are the larger and connected forest patches. On the other hand, smaller and more isolated forest patches received lower values of PPI. Most of them, are located in the northwest portion of the study area.

Further, observing the PPI values, it is feasible to find decreasing values in the same direction as the fragmentation process (Figure 3). PPI supports the prioritization of the forest patches that are the most connected, highlighting the ones labeled 477 and 460, that presented low NEARD values (NEARD =0.0073; 0.0067), meaning they are closer to other patches and their distance have non/low resistant uses. Also, those forest patches have the highest values for AREA in the landscape (AREA = 1848.60 ha; 260.3 ha), since they are well connected and large, they received the maximum values of PPI.

However, PPI also emphasizes NEARD and SHAPE, as could be seen, for samples, in forest patches 352 and 529. Patch 352 (third highest value) has a lower area (207 ha) than patch 529 (220.5 ha). Nonetheless, it has better connectivity and a more regular shape. The same pattern could be noticed, for sample, between patches 335 and 454, 335 is lower than 454, but it is more connected and has a regular shape. Thus, higher PPI values are not only related to larger areas but still to more connected forest patches and with regular shapes. Larger forest patches tend to lose biodiversity if they are isolated and/or have quite irregular shapes. Then, it is possible to argue that despite the higher importance attributed to area metric, PPI is also sensitive to connectivity and forest patches shape.

Differently, PPI attributed the lowest values for small forest patches (AREA < 20 ha), that are isolated or surrounded by use, which could be considered a barrier for fauna individuals passing. There are exceptions for the AREA metric of lowest PPI values, patches 475 and 391 are larger than other patches, with low PPI values. This is mainly due to their high value of NEARD, meaning that despite their size, they are isolated, or the path to the nearest forest patch has a use/cover, which is a barrier for organisms passing (Zheng et al., 2009). PPI presented a lower level of priority for isolated forest patches, like that on labeled as 391, 443, and 147, which were associated with the lowest value of PPI in the landscape.

Figure 3. Forest patches labeled by ranking position accordingly to Patches Prioritization Index and, sampled patches for field validation, in Pirapora headstreams, Sao Paulo state, Brazil.



Source: Authors.

Figure 3 also indicates the forest patches where BII was performed for PPI validation. Those BII values are presented in Table 2, which shows that sampled forest patches with the three highest values of PPI also demonstrated the three highest values of Biotic Integrity in the field. Likewise, with one exception, the lowest PPI values received the lowest BII scores as well.

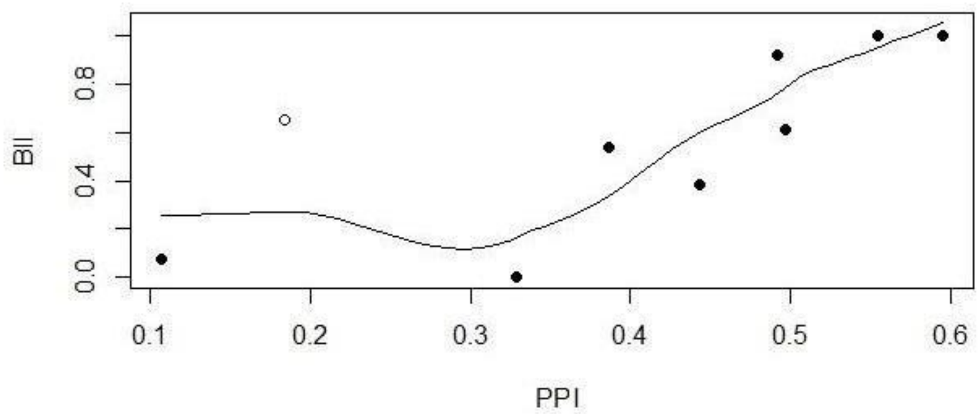
Table 2. PPI value, BII mean score, and normalized BII values for sampled forest patches at Pirapora headstreams, São Paulo, Brazil.

PPI value	BII mean score	BII normalized
0.594	39	1
0.554	39	1
0.496	34	0.615
0.491	38	0.923
0.443	31	0.384
0.386	33	0.538
0.328	26	0
0.125	38	0.653
0.107	27	0.077

Source: Authors.

Further, the Spearman correlation value between PPI and BII for sampled forest patches was 0.776, the correlation graph is shown in Figure 4. In this graph, it is possible to notice that the Biotic integrity is mostly explained by PPI values, which could indicate the accuracy of PPI to predict biotic integrity of forest patches in the field. Thus, PPI is indicating preserved forest patches as priority ones for biodiversity conservation.

Figure 4. Correlation amongst Biotic Integrity index and Patches prioritization index values for Pirapora headstreams, Sao Paulo state, Brazil.



Source: Authors.

4. Discussion

From the results obtained by forest patches diagnosis, it is possible to notice that the landscape has a large range of forest patch configurations. It means that as patches have different structures, they possibly play different roles for biodiversity conservation (Nicasio-Arzeta et al, 2021; Bruscagin et al., 2017). Moreover, there is a gradient of fragmentation from northwest to southeast (Figure 3), since there are increasing values of the area, as well as decreasing NEARD values in the same way. Area decreases and increases of patch isolation are indications of forest fragmentation in landscapes. Thus, since the forest patches have a heterogeneous configuration, and their diagnosis suggests that they are currently threatened by fragmentation, environmental planning for biodiversity conservation in this landscape could be quite useful. In this context, Brodie et al. (2016) suggest that the decision-making process for biodiversity conservation could be guided by a diagnosis of forest patches.

Additionally, it was possible to observe that NEARD values represented a significant approach to estimate connectivity since it estimated connectivity amongst forest patches considering land-cover/land-use. Carvalho et al. (2016), strongly recommend that land-cover/land-use be considered for biodiversity conservation purposes, such as made in NEARD values. Besides, NEARD methodology offers the possibility of changing its weights, thus, the metric could be adapted for different landscapes. This flexibility could be considered relevant for Atlantic Forest patches since they are commonly surrounded by heterogeneous matrices (Porto et al., 2017). Furthermore, it is important to notice that NEARD could be considered as an effortless method, since was completely developed in GIS environment with commonly used tools, thus increasing its range of application.

Furthermore, Figure 2 illustrated that NEARD is sensitive to urban/roads areas, which are classified as damages to connectivity (Threlfall et al., 2012; Edwards et al., 2017). This supports connectivity studies that argue that larges distances in a permeable path are more desirable for biodiversity conservation than small distances with an impermeable route (Pierik et al., 2016; Baldwin et al, 2021). Besides, NEARD keeps using the ENN metric, which is one of the most used metrics to measure connectivity (Mcgarigal, 2002). Thus, it is possible to argue that the estimation of connectivity in PPI is adequate and contributed positively to PPI results. Further, evaluating PPI results, it is possible to notice that the index determined as priority forest patches those ones with the larger areas in the landscape, however, PPI also considered their isolation level. This indicates that the index is driven by two main conditions, area and connectivity, that are essential for biodiversity conservation (Hodgson et al., 2010; Banks-Leite et al., 2011, Philips et al., 2018). Thus, this forest patch configuration is considered adequate for the majority of fauna and flora species as effective for biodiversity conservation by many studies including (Hodgson et al., 2009).

However, as could be seen in the results, PPI also highlighted connected areas with regular shapes. According to Hanski and Ovaskainen (2000), for biodiversity conservation, it is fundamental to have connected areas. Moreover, the weight attributed for the SHAPE metric in PPI, assured that if you are not prioritizing one of the larger forest areas in the landscape, at least, you are prioritizing connected areas with a more regular shape. This configuration also supports biodiversity conservation (Carroll et al., 2010; Schindler et al., 2015; Magioli et al., 2016; Herrera et al., 2017). In addition, if there are two forest patches with similar areas and connectivity, the one with a better shape will be a priority since shape matters mainly to avoid edge effects and preserve biodiversity in forest patches (Ewers & Didam, 2006). In this context, it could be seen that PPI is offering options of priority forest patches with many different structures, this expands its applicability.

On the other hand, PPI indicated as fewer priority ones isolated and small forest patches. Those patches are mainly surrounded by urban areas, roads, agriculture, and pasture, which are considered barriers to patches connectivity (Pinto & Keitt, 2009; Sánchez-de-jesús et al., 2016). In this context, the result suggests that NEARD values are accurate to indicate connectivity considering landscape permeability. Moreover, it means that PPI reproduces terrestrial reality and is according to literature since indicates small and isolated forest patches as less priority for biodiversity conservation (Brudvig et al., 2017). Furthermore, it is possible to argue that the results obtained for BII were adequate to validate PPI results. The results demonstrated that PPI is highlighted correlated with forest patches biotic integrity. The evaluation of forest patches with varied PPI values demonstrated that PPI has satisfactory performance from high to low preserved patches.

Finally, as PPI and BII presented a high value of correlation, it is possible to support PPI as an effective predictor of forest patches biotic integrity. According to Burke et al. (2016), a field survey increases the confidence level of prioritization studies, expanding its possibilities of application. Moreover, it is important to notice that field validation is one of the higher gaps in landscape metrics studies (Medeiros & Torezan, 2013). Since PPI has a high correlation with BII values, it could be used for determining forest patches level of priority even when those presented heterogeneous configurations.

5. Conclusion

Considering that agricultural landscape is an extremely common scenario for Atlantic Forest remnants, we developed an index for prioritization of those remnants for forest conservation. According to the results, PPI has adequate accuracy to be broadly applied for the forest patches, that belong to this Biome.

According to the Index, large patches, connected and characterized by regular shapes, are the priority for biodiversity conservation. On the other hand, patches with an irregular shape, isolated and small, received a low level of priority for biodiversity conservation. In this context, we concluded that the PPI index is adequate for patches prioritization aiming at biodiversity conservation.

In the same way, the importance, that we attributed to landscape metrics demonstrated to be efficient since the index supports the patches prioritization, having a higher capacity to support biodiversity conservation.

Finally, from PPI and BII results, it was possible to verify that the index can predict the biotic integrity of forest patches. In this manner, PPI fills one gap related to patches prioritization using landscape metrics. Thus, PPI could be used for the decision-making process in the prioritization of patches and regions for biodiversity conservation. As a further step, we suggest PPI application in different study areas, to analyze analyzing PPI accuracy for landscapes with diverse configurations.

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