

## **Incorporating biodiversity expert knowledge in landscape conservation planning: a case study involving the Pantanal**

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**Abstract.** We developed a framework to incorporate biodiversity information about target species based on expert knowledge into landscape metrics in order to subsidize conservation planning. Four steps make up our framework: 1) biodiversity expert consults, 2) processing and organizing the information, 3) validating the information and 4) incorporating biodiversity data into landscape metrics. As a case study, we applied this framework in the Upper Paraguai basin in the limits of Mato Grosso do Sul state. This is a part of an ongoing effort to incorporate biodiversity in the Zoneamento Ecológico Econômico of Mato Grosso do Sul state. Based on systematically collected data from biodiversity expert questionnaires, our results helped to fill species-level knowledge gaps concerning functional connectivity and matrix permeability at the landscape scale and provide clear target species parameters for the generation of conservation scenarios. This approach meets the need for spatially-explicit species based targets and recognize the importance for biodiversity for sustainable territorial planning.

**Key-words:** Expert knowledge, functional connectivity, matrix, permeability, target species, conservation planning, Ecological Economic Zoning.

**Resumo.** Desenvolvemos um arcabouço lógico para incorporar informações da biodiversidade em **métricas de paisagem a partir do conhecimento de especialistas no intuito de subsidiar planejamentos em conservação.** Quatro etapas compõem nosso arcabouço lógico: 1) consulta aos especialistas de biodiversidade, 2) processamento e organização da informação, 3) validação da informação e 4) incorporação de dados da biodiversidade em métricas de paisagem. Aplicamos este *framework* na Bacia hidrográfica do Alto Paraguai dentro dos limites do estado de Mato Grosso do Sul como nosso estudo de caso. Este é um desdobramento dos estudos de biodiversidade do Zoneamento Ecológico Econômico do estado de Mato Grosso do Sul. Baseados em coletas sistemáticas de dados de especialistas em biodiversidade, nossos resultados preenchem a lacuna de conhecimento de dados de espécies quanto à conectividade funcional e permeabilidade da matriz na paisagem, além de subsidiar parâmetros de espécies alvo para gerar cenários de conservação. Esta abordagem liga a necessidade de alvos espacialmente explícitos baseados em espécies alvo e aproxima a importância da biodiversidade a planejamentos territoriais sustentáveis.

**Palavras-chave:** Conhecimento de especialistas, conectividade funcional, matriz, permeabilidade, espécies alvo, planejamento de conservação, Zoneamento Ecológico Econômico.

## 1. Introduction

Biodiversity conservation planning at the landscape level is a major challenge in spatial strategies for conservation at regional and global scales. Surrogates extracted from remote sensing techniques, such as amount and configuration of natural vegetation, are among the usual indicators to define priority areas. However, these approaches and their assumptions may generate conflicting scenarios for biodiversity persistence, especially for threatened or rare species (Pettorelli et al. 2014). The use of a landscape scale approach underpinned by ecological functionality based on target species has been applied to calibrate models of landscape prioritization and invest conservation targets with a biological meaning (Margules & Pressey 2000).

Habitat loss in a landscape context is a crucial process in determining biodiversity and species persistence. The conversion of natural habitats for different land uses (e.g. pasture and agriculture) influences the species composition and consequently the environmental functionality (Bélisle 2005, Lindenmayer & Fischer 2007). In addition, matrix permeability dictates the ability of species to cross inter-habitat patches and directly influences the population viability of several species within the landscape (Ricketts 2001). Thus, there are clear motives for using information, such as the matrix permeability and the ability of species to cross unsuitable habitat patches, in supporting and delineating conservation targets (Fahrig 2003, Koen et al. 2014). However, basic information about species movements and behavior at the landscape scale are limited and scattered among many different sources, mostly within a context-specific or single-species (or taxonomic group) (Sutherland et al. 2004), which make its applicability difficult in wider contexts.

In this context, the use of expert opinion to set model parameters is one potential solution to fill the knowledge gap about species abilities to move in fragmented landscapes. Expert knowledge is being applied to support habitat management decisions, definition of action plans and selection of target conservation species (Drescher et al. 2013). Its principle is based on opinions generated by experts that have gained experience about the system through practice and training (Perera et al. 2012). Due to different degrees of expertise and the lack of systematic acquisition of expert opinions (Perera et al. 2012), rigorous methods are needed to validate opinions, which are considered of extreme importance for data poor regions at the landscape scale (Drescher et al. 2013). Providing evidence from expert knowledge can be key to acquiring information about various species in a landscape context, where data about biodiversity is limited, not formalized, or not easily mined from literature.

Gathering and analyzing this information is crucial in the context of territorial ordination

and sustainable planning. Zoneamento Ecológico Econômico, one of the tools in the National environmental policy (Brasil 1981), calls for the incorporation of biodiversity conservation priorities in the generation of sustainable development scenarios. Motivated by this challenge, we developed a framework to incorporate biodiversity data in landscape metrics. The framework leverages knowledge of regional biodiversity experts to support conservation planning in line with species requirements and conservation targets.

## 2. Objective

Our goal was to develop a framework to incorporate target species parameters in landscape characterization and conservation planning based on regional biodiversity expert. We used the Upper Paraguay basin as a case study and compared different scenarios based on functional connectivity and matrix permeability in the lowland and plateau areas of the basin in the state of Mato Grosso do Sul.

## 3. Methods

### Study area and classification of land use and vegetation

The study area comprises the Upper Paraguay Basin (BAP – acronym in portuguese) in the state of Mato Grosso do Sul (MS), which covers an area of 100,953.84 km<sup>2</sup> and includes the southern portion of the Paraguay river. The surrounding plateau is part of the Brazilian savanna biome, the Cerrado. The plateau is strongly linked to the lowland floodplain of the Pantanal because it contains many of its headwaters rivers. Despite the importance to the Pantanal, only 15.9% of original forested vegetation and 20.2% of native Cerrado phytophysionomies remains, while in the lowlands, a greater proportion of natural vegetation cover is unaltered (CI et al. 2012).

Within the plateau-lowland limits, we established six main vegetation and land use classes: i) forested areas, ii) Cerrado formations (including native open areas), iii) pasture, iv) planted forest, v) agriculture and vi) urban areas. These categories were synthesized from the main classes of land use and vegetation coverage, obtained from the 2010 vector map of the Upper Paraguay basin, which uses official classes of land use and vegetation in Brazil (for general descriptions of categories, see CI et al. 2012 and IBGE 2012).

### Framework steps

#### i. Biodiversity expert consults

Expert knowledge data was collected by adopting the principles of the Delphi method, such as anonymity of experts and the replication of questionnaires (**Figure 1**). Recently, the use of Delphi techniques to provide a more rigorous analysis of the information provided by expert has been applied to solve complex problems in situations where information is limited (Edwards et al. 2011, Scolozzi et al. 2012).

We invited a large sample of biodiversity experts (researchers, professors, graduate students, NGO members and environmental consultants) from MS with experience in ecology and natural history of diverse taxonomic groups in MS state (plants, fishes, reptiles, amphibians, birds, cave fauna, bats and mammals) to contribute their knowledge and experience during this exercise. In a first step, we sent digital forms to each expert and asked them to select and provide information on at least five main species that they considered target for conservation in the context of regional conservation planning based on criteria, such as: threatened species status,

level of endemism or rarity. Digital forms guaranteed independence of data contributions as experts had the possibility to express their opinion individually.

After this process, we asked experts to assess the permeability of different matrices (planted forest, urban, pasture and agriculture) for the selected species, and estimate movement distances of species in areas with different land uses. For the permeability metrics, the experts indicated values between 1 to 10 for a given target species in each land use category, where 10 represented no impediment for target species to move (high permeability) and zero represented an impermeable matrix. For species movement data, experts reported the distance between two habitat patches that each target species would be able to cross in different matrix categories (pasture, planted forest, agriculture and urban areas). To do this, biodiversity experts chose one of the following distance classes for each target species: i) up to 50 meters, ii) up to 100 meters, iii) up to 500 meters, iv) up to 1000 meters or v) more than 2000 meters. Plants, fishes and fauna associated to caves were not included in the questionnaires of landscape permeability and functional connectivity because of their biological and habitat use peculiarities.

## **ii. Processing and organizing the information**

We received all forms independently and summarized their contents by ranking potential target species based on the frequency the species were cited by specialists, and by calculating average values of permeability and movement for each target species. The results were organized, presented and supplied to experts at a workshop, where a final selection of target species for planning and conservation of regional biodiversity was completed. This working meeting was promoted by the Estudos de Biodiversidade team from Zoneamento Ecológico Econômico de Mato Grosso do Sul.

## **iii. Validating the information**

The specialists were gathered in taxon-based working groups during the one day workshop, where the lists with ranked potential target species were evaluated. Within each working group, experts debated results and elected five target species after a consensus was reached. Permeability and distance values were also re-evaluated during the meeting, to refine and validate the information (values were not estimated for plants, fish and cave fauna).

## **iv. Incorporating biodiversity data in the landscape metrics**

Based on target species parameters, we characterized the area encompassed by the BAP within the MS. We separated the BAP into by lowland and plateau regions, and we conducted the analysis within a grid of 10,000 ha hexagons, which comprised our landscape units. All analysis were performed in Arcgis 9.3 and Fragstats (McGarigal et al., 2002, ESRI INC 2008). Cerrado (including native open areas) and forested areas were joined in one native vegetation class. Both categories were selected and first corrected by the function Multipart to Singlepart, so polygons could be definitely separated, followed by the operation Repair Geometry, which allowed us to correct all polygons if any error was present. The file was converted to raster and exported as the format “.grid”.

We calculated the matrix permeability metric as follows:

$$\text{Matrix permeability} = \sum_{i=m}^n (\text{Matrix}_i \times \text{Permeability}_i)$$

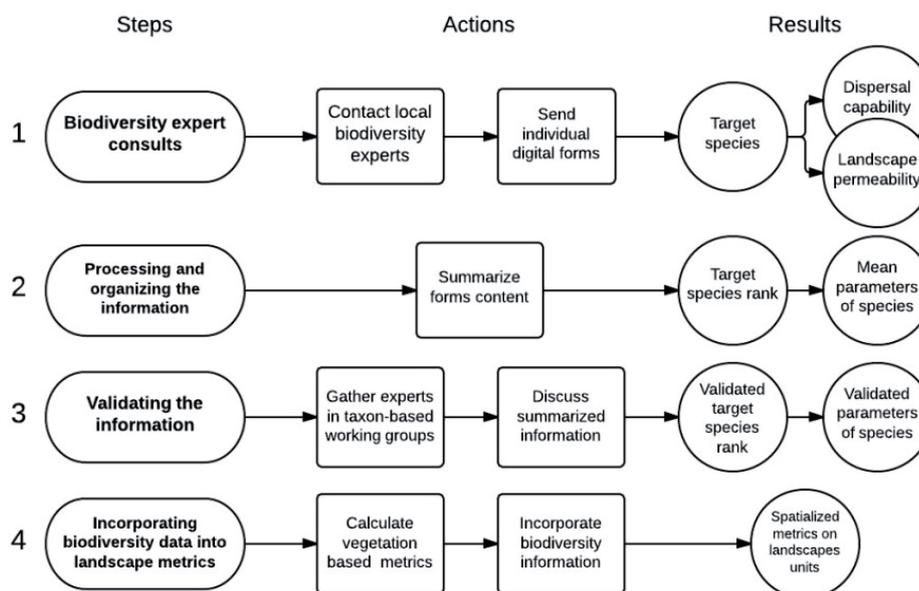
where  $i$  represents agriculture, pasture, planted forest and urban area;  $Matrix_i$  is the percentage of area of each matrix in a landscape unit and  $Permeability_i$  is the averaged permeability of all target species in the  $i^{th}$  Matrix category.

As a measure of functional connectivity, we proposed a metric that represents the percentage of species that would be maintained in a landscape based on the distance between habitat patches (native vegetation). To obtain this metric, we used workshop data and calculated the percentage of species that would cross each of the determined distance classes (i) up to 50 meters, ii) up to 100 meters, iii) up to 500 meters, iv) up to 1000 meters or iv) more than 2000 meters) for each matrix class. Then, using the BAP map, we calculated the average Euclidean distance between remaining vegetation patches in each landscape unit. This average distance was matched with the respective percentage of target species maintained within the distance classes of the dominant matrix category in each landscape unit.

Therefore, our metric represented the percentage of target species that could cross the mean distance among natural habitat fragments in a given landscape unit.

Landscape units (hexagon cells) that overlapped with areas surrounding the BAP and had low quantities of mapped classes were excluded to avoid bias from the absence of vegetation or land use information.

For the application of this framework to characterization of the BAP based on target species information, we incorporated values of both permeability and percentage (of target species that can cross the mean distance among fragments in a given landscape unit) from expert knowledge with the percentage of natural vegetation coverage. This allowed us to contextualize a the scenario for the BAP and compare the lowland and plateau results.



**Figure 1.** Fours steps for the development of the framework to incorporate target species parameters in landscape characterization based on regional expert opinion of biodiversity.

#### 4. Results and Discussion

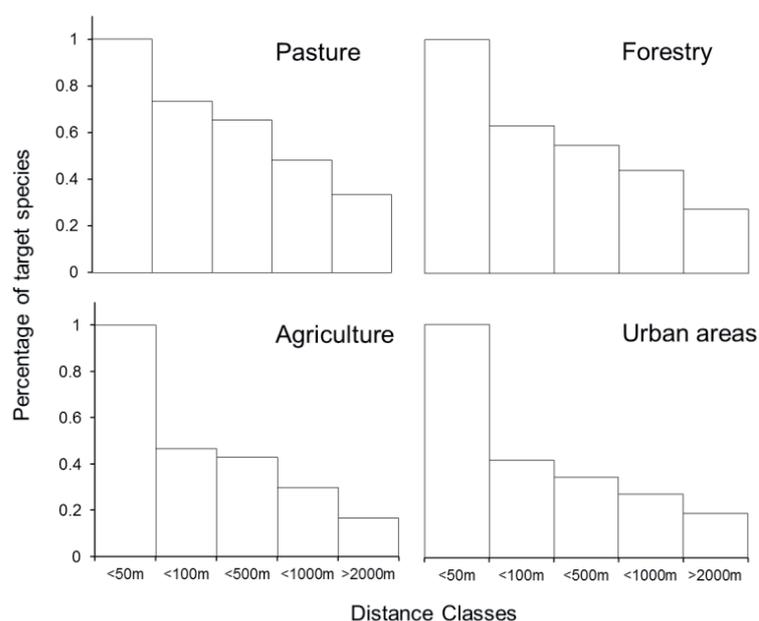
##### Target species results based on expert knowledge

We received 43 forms from 39 specialists that comprised 250 records and 151 potential target species. The most prevalent group in terms of number of indicated species was birds, fol-

lowed by reptiles, fish, anuran, bats, mammals, plants, invertebrates and cave fauna. During the workshop, the ranks of target species and their average parameters values (permeability and movement distances) were refined and validated based on consensus decisions by all specialists within each taxon work group. For additional analyses, we eliminated target species for which there was inadequate information on their response to land use and vegetation classes, leaving a total of 84 species for incorporation in landscape metrics. Plants, fishes and cave fauna were excluded because the peculiarity of their habitat use could not be represented in this exercise. Other criteria for determining target species in all taxonomic groups were dependency on natural areas, value as bioindicator of habitat quality and threatened species status.

Considering mean values for all target species, pasture was the most permeable matrix indicated by specialists, with a mean permeability value of  $3.56 (\pm 2.76 \text{ SD})$ . Planted forest ( $2.27 \pm 1.89 \text{ SD}$ ), agriculture ( $2.19 \pm 1.98 \text{ SD}$ ) and urban areas ( $1.95 \pm 2.01 \text{ SD}$ ) obtained respectively lower values.

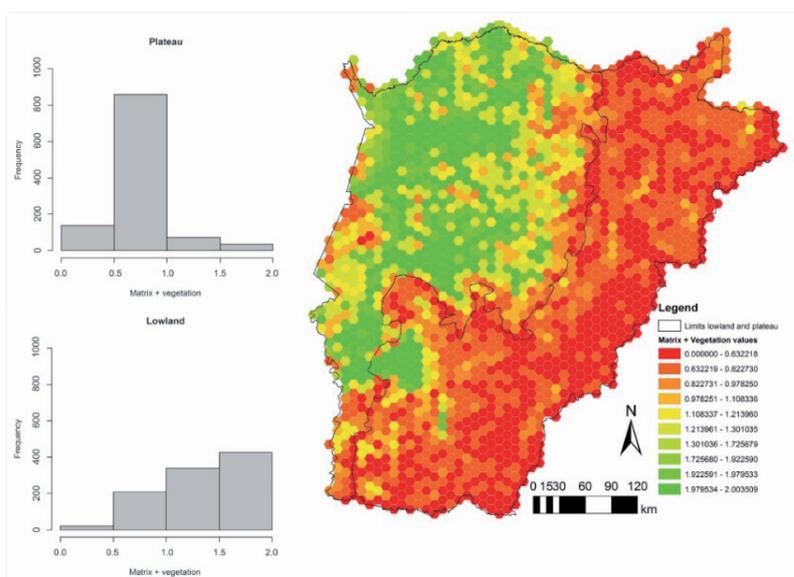
The pattern of reduction of species maintained in a landscape with increasing distance between natural habitat patches was different for each matrix type (**Figure 2**). One hundred percent of the target species from all matrix categories were reported as having the ability to cross distances of  $\leq 50$  meters. Only 33.3% of encountering pasture, 27.4% planted forest, 16.6% agriculture and 19.1% urban areas were reported to have the ability to cross distances  $>2000$  meters between natural habitat patches. Overall, pasture was the most permeable matrix category, retaining at the highest percentage of target species with increasing distances among natural vegetation fragments, while the urban area class was the most restrictive matrix in terms of species movements.



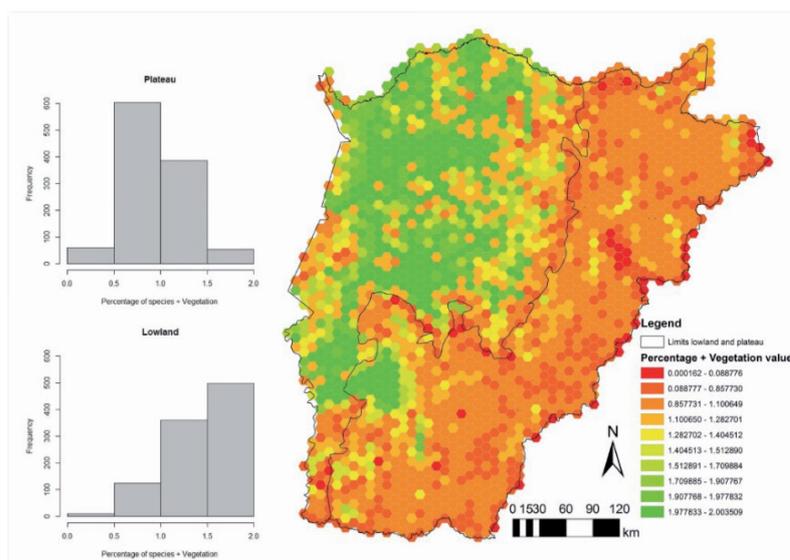
**Figure 2.** Percentage of target species maintained with increasing distance between natural habitat patches for 4 matrix categories, based on movement distance values estimated by biodiversity experts during a workshop coordinated by the Estudos de Biodiversidade team of the Zoneamento Ecológico Econômico of Mato Grosso do Sul state.

Matrix permeability was lowest on the plateau. Areas of high permeability were restricted to continuous forest habitat in protected areas, mainly the Kadiwéu indigenous reserve and the

Serra da Bodoquena National Park. However, overall, low values were dominant because most natural vegetation has been converted to other land uses. For the target species, the lowland area was comparatively the most permeable portion of the BAP, with high permeability values predominating and widely distributed throughout the area (**Figure 3**). Similar trends and differences between the plateau and lowlands were found for the percentage of target species able to cross the mean distance among fragments in landscape units (**Figure 4**).



**Figure 3.** Histograms of matrix values combined with vegetation coverage on the plateau and in the lowlands, and a map showing the spatial distribution of values within the of Mato Grosso do Sul state.



**Figure 4.** Histograms of percentage of species combined with vegetation coverage on the plateau and in the lowlands, and a map showing the spatial distribution of values within the BAP of Mato Grosso do Sul state.

## **Framework Discussion**

As shown by this study, the use of biodiversity as a component of landscape models may enhance regional planning efforts for conservation and sustainable regional planning. This information may not necessarily be obtained from environmental structural surrogates based solely on remote sensing techniques, because species can respond differently to landscape change. So, there is a need to convert local biodiversity information into large scale data assessments.

Our framework constitutes a democratic exercise to collect and spatialize biodiversity data from expert opinion using a landscape ecology approach to support exercises in systematic conservation planning. Four steps made up our framework: 1) biodiversity expert consults, 2) processing and organizing the information, 3) validating the information and 4) incorporating biodiversity data into landscape metrics. This process was a useful way to gather information about potential target species from independent sources with a wide range of individual field experiences and knowledge about MS environments (step 1). Data about matrix permeability and functional connectivity are commonly scarce in the literature, usually species' specific, and the methods used are time consuming (Pettorelli et al. 2014). In this context, the possibility of involving local biodiversity experts and convert their field experiences and knowledge into quantitative landscape-level data appears to be a cost effective alternative to expensive species-level studies, especially when information is not available. Different methods, such as the Delphi techniques, have been developed to manage uncertainty in these data (Edwards et al. 2011, Eycotta et al. 2011, Scolozzi et al. 2012). In our case, multiple independent opinions about species-specific parameters and a large number of target species provided enough data to calibrate and generate average values, which represented the convergence of knowledge from diverse field experiences and taxonomic groups (step 2).

In addition, for our case study of the BAP, target species of plants, fishes and fauna associated with caves were excluded from the estimates of landscape permeability and functional connectivity due to their biological and habitat use peculiarities. Certainly, developing metrics that can represent such taxonomic groups will be a future challenge for our framework.

Finally, we believe that the workshop, which gathered together a pool of experts, offered a final opportunity to reach consensus on the landscape metrics and their mean parameter values (step 3). Groups did not necessarily species' rank and their respective parameter values. They could opt to maintain the results generated by summarizing independent opinions or they could choose to change the results based on work group discussions. In our case, specialists from all of the different taxonomic work groups altered species' ranks, usually based on the ecological importance of target species in regional conservation. Regardless of group decisions, it was essential to ensure the participation of numerous experts distributed among the working groups to validate the data obtained previously via online consultations.

### **Permeability and functional connectivity on BAP: lowland vs. plateau**

We collected expert opinion data on a large sample of target species (84 in total) specifically associated with the Cerrado and Pantanal biomes in MS. Metrics represented: i) the permeability of a given matrix type to animal movements and ii) the ability of target species to move between natural habitat patches in a given matrix category. Although data were based solely on the experiences of local biodiversity experts, the information was easily incorporated into landscape-based metrics, which were used to produce a highly plausible characterization of landscapes in the BAP. Using our framework, the permeability metric based on target species may be combined with representative classes of matrix in landscape units to generate a spatially-explicit matrix permeability index. The percentage of target species that are able to cross a given

distance through classes of matrix may also be associated with the mean distance of fragments within landscape units, resulting in a functional metric of connectivity at the landscape scale.

Both permeability and functional connectivity metrics confirmed the striking differences in the conservation status of the plateau and lowland regions of BAP. The conversions of native forest and Cerrado phytophysionomies into agricultural and grazing areas are the main drivers of permeability and functional connectivity loss on the plateau. In contrast, the high proportion of native vegetation in the lowlands indicates a suitable opportunity for long term conservation of the Pantanal. However, it is crucial to consider the importance of the surrounding plateau to protect the hydrological cycle and integrity on the lowland environments. All of the rivers on the plateau drain onto the lowlands and regulate the complex seasonal dynamics of floodplain habitats. This flood pulse is the major ecological force modulating plant and animal populations in the Pantanal. Our results corroborate those based on vegetation coverage approaches that emphasize the importance of conservation efforts on the plateau to long-term persistence of the Pantanal.

## 5. Conclusions and suggestions

Our framework reveals that expert knowledge can be a useful tool to incorporate biodiversity data into landscape conservation planning. However, it is important to acknowledge that expert opinion approaches have certain constraints. The amount and accuracy of information are dependent on the presence of local biodiversity experts and the diversity of their research interests. In addition, data about species movements and matrix permeability are difficult and costly to obtain and analyze in wide-scale approaches. This may lead to concerns by local experts about the destination, citation and use of their data. These concerns are justified and, so throughout completion of the framework steps, we promoted a model of collaborative contribution and construction in an integrative way, e.g., by producing collaborative products, such as this paper. Furthermore, our framework is adaptable for any approach and developments in remote sensing of environment for applicability in a conservation context. It can be extended to incorporate expert opinion of different social agents for diverse conservation targets, from fine to large scale approaches. Readjustments on the four steps rely on the definition of the prioritizing goal, which necessarily must be assessed with an existing mapped source. Finally, our framework provides an effective way to obtain a final index of landscape prioritization based on biodiversity information, an outcome that is specified in the objectives for the Zoneamento Ecológico Econômico for the state of Mato Grosso do Sul.

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