

can greatly assist in cartography teaching and in the easy access to updated information of many places. For example, it is possible to explore elements such as geographic coordinates, which helps the location on the planet, and the relief representation using three-dimensional models, which allows students to better understand topographic maps.

From a trip through the world of digital maps, students can observe a state, a county, and even their neighborhood on different scales. By means of digital maps, they can make many discoveries around the world, participate in environmental issues, and inform and contribute with more information in an interactive and participatory map. Educators and students can generate their own maps and represent different topics of interest. Tools such as GIS, GPS, and innovative initiatives in education like GEODEN and RiSO projects, can be used in schools today to help students go from map readers to mapmakers.

References

- Bauman Z.(2001) *Modernidade Líquida*. Rio de Janeiro:Jorge Zahar Ed
- Câmara G, Souza RCM, Freitas U, Garrido J (1996) SPRING: Integrating remote sensing and GIS by object-oriented data modeling. *Comput Graph* 20(3):395–403
- Delpupo LW (2014) *Caminhos e Descaminhos do Lixo: Educação e Tecnologia como Ferramentas de Apoio*. Relatório do Projeto PIBITI/UFF, 2012/2013. Map available in: <https://sites.google.com/site/risouff/coletaseletiva>
- Di Maio AC (2004) *Geotecnologias Digitais no Ensino Médio: Avaliação prática de seu potencial*. Thesis—Programa de Pós-Graduação em Geografia, Universidade Estadual Paulista, Instituto de Geociências e Ciências, Rio Claro, 188 p
- Di Maio AC (2007) GEODEN: geotecnologias digitais no ensino básico por meio da Internet. In: XIII Simpósio Brasileiro de Sensoriamento Remoto, Proceedings, Florianópolis, SC
- Di Maio AC, Francisco CN, Levy CH, Pinto CAL, Nunes EA, Carvalho MVA, Dornelas TS (2009) GEOIDEA—Geotecnologia como instrumento da inclusão digital e educação ambiental. In: XIV SBSR, Natal. Proceedings. São José dos Campos : INPE, vol 1, pp 2397–2404. <http://marte.sid.inpe.br/col/dpi.inpe.br/sbsr%4080/2008/11.02.18.51/doc/2397-2404.pdf>
- Duba VHC, Di Maio AC (2014) Geotecnologias e rede de informações: um mapa social para região metropolitana do Rio de Janeiro. *Revista Brasileira de Cartografia*, No 66/4: 783-801 ISSN: 1808-0936
- Mattos RA (2014) *De De Mercator ao Googlemaps: mapas colaborativos digitais no ensino e aprendizagem de Geografia*. Master Thesis, UERJ
- MEC (1999) *Parâmetros Curriculares Nacionais. História e Geografia (Ensino Fundamental)*, Ministério da Educação, vol 5, SEF
- Peixoto BM, Souza JM, Ribeiro RM, Di Maio AC (2014) Projeto GEOIDEA Saúde e Rural: geoinformação na educação básica, In: XXVI Congresso Brasileiro de Cartografia. http://www.cartografia.org.br/cbc/trabalhos/9/319/CT09-11_1403449171.pdf. Accessed 9 Aug 2014
- Santos GDS (2014) *(Geo)Cidadão Legal: Guia Eletrônico de Cidadania Ambiental Relatório do Projeto PIBIq/CNPq, 2013/2014 UFF*. Map available in: <https://sites.google.com/site/risouff/unidades-de-conservacao>
- Taylor DRF (2013) Challenges in mapping traditional knowledge in Canada's North. In: *International cartographic conference—ICC, Dresden*, p 27

Chapter 23

Geodesign for Landscape Connectivity Planning

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Abstract We observe, ever more astonished, a reduction or total destruction of natural habitats. In different parts of the globe, anthropic pressure on habitat and the species therein has been on an excessive scale. This causes the loss of linkage between habitats in the landscape and thus creates fragmented areas with less environmental regulation. Isolated management of protected areas is often not enough to guarantee biodiversity integrity, with the creation of management formats capable of integrating habitats being necessary. Methodological systematization provided by Geodesign for research, planning, and propositioning of solutions for a geographic area has great application potential in biodiversity protection and preservation strategies. This chapter's objective is to identify locations capable of making connectivity between protected areas possible and thus subsidizing an integrated management format for these areas. To meet the goal, we elaborated a script for an area's geographic representation, an analysis of the processes at play in space and time, and an evaluation of impacts the intended changes would cause in the study area so that we can indicate decision proposals aimed at integrated planning and management between protected areas. Geotechnologies supported the entire procedure using remote sensing and support of geographic information systems. Five suitable locations for establishing connectivity between habitats such as biodiversity corridors, stepping stones, and habitat mosaics were identified.

Keywords Geodesign · Connectivity · Landscape · Geotechnologies

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1 Introduction

Preservation of natural areas is the most primary form of biological diversity conservation. There are throughout the planet areas set aside for preservation due to their singularity, beauty, threat level, among other parameters that characterize the need for effective management and sustainable handling of the natural resources in them. Often, these protected areas are created or may become isolated fragments in areas that have already succumbed to anthropic pressure. In a more realistic scenario, biodiversity preservation's success hinges on biotas' survival capacity in landscapes fragmented by human intervention (Bennett 2003). According to Noss et al. (1987), efficient planning models that try to conciliate human occupation and continuity of natural communities should be elaborated for areas in advanced stages of fragmentation.

According to Noss (1992), connectivity expresses, in many ways, the opposite of fragmentation. Landscape connectivity is made evident from the spatial arrangement of habitat fragments (Forman and Baudry 1984). In this way, it demonstrates landscapes' capacity to make biological flows and the intensity of organisms' movements among habitats easier. Lang and Blaschke (2009) affirm that a landscape's structural characteristics are observable, describable, and quantifiable and also indicative of processes that contributed to how the landscape is. Structural analysis of a landscape relates to the study of the landscape mosaic that appears as a pattern and specific spatial ordering of landscape units in a determined research section. Generally, evaluating landscape connectivity consists of identifying and characterizing aspects that make a connection between the different elements in the landscape easier or more difficult. Increasingly, this kind of analysis has been used in environmental planning and implementation of biodiversity conservation policies.

According to the systematization proposed by Steinitz (2012), Geodesign's scope permits investigation into the habitat fragmentation process. It also has the potential to point to the propositioning and development of strategies to maintain biodiversity in modified landscapes through the restoration of connectivity between habitats. Following a characteristic script in Geodesign projects, the goal of this paper is to geographically represent a study area and analyze dynamic processes at the landscape level, thus making an area's evaluation possible regarding habitat fragmentation processes and also providing support for identification of locations and propositioning of feasible forms to set up structural connectivity among habitats.

The area under analysis is the mosaic of protected areas of the "Espinhaço Alto Jequitinhonha–Serra do Cabral", located in the southern portion of the mountain range called "Serra do Espinhaço." It is considered a heritage site by UNESCO called the "Serra do Espinhaço Biosphere Reserve." This mosaic of protected areas was instituted in 2010 and encompasses 19 protected areas within its limits. In Brazil, they are called conservation units (UC's) and can be of two types:

full protection (more restrictive regulations, impeding some forms of anthropic activities) and sustainable use (joining conservation and a wider range of anthropic activities).

2 Performing a Geodesign

Geodesign is based on and shaped by a set of questions and methods necessary to solve large, complicated and significant design problems, often at geographic scales ranging from a landscape region or river basin. The development of a methodological routine for geodesign landscape linkages was based on the six models proposed by Steinitz (2012); representation models, process models, evaluation models, change models, impact models, and decision models, as described in the following sections.

2.1 Representation

The starting point for the area's representation was the creation of the "Espinhaço" Protected Areas Mosaic's limits. In this way, reading the November 26, 2010 Regulation 444 (which established the Mosaic), conservation units surrounded by the mosaic and that should be included in it were identified.

Initial mapping, done with the intention of defining the mosaic's official boundaries and that would later be taken for discussion in the mosaic's consultative council, was done taking the physical environment's aspects into consideration and the river basin was considered a planning unit. In this opportunity, a workshop to discuss the proposed limits was held. The workshop brought together conservation unit managers, environmental bodies' servants, municipal representatives, professors, researchers, companies' and third sector representatives. The methodological script for the mosaic limits' mapping was published in a specific event of the area (Ribas and Gontijo 2014a). We can see the referred mapping in Fig. 1.

After defining the mosaic's topological limits, land use and land cover thematic mappings for two different time periods were done. For the year of 1984, LANDSAT 5 satellite's multispectral images captured by the Thematic Mapper (TM) sensor were utilized. For 2013, LANDSAT 8 satellite images were used. These are the most recent of the LANDSAT mission and are part of the "The LANDSAT Data Continuity Mission" (LDCM) project. The methodological script for the LANDSAT image processing was published in a specific journal of the area (Ribas and Gontijo 2014b).

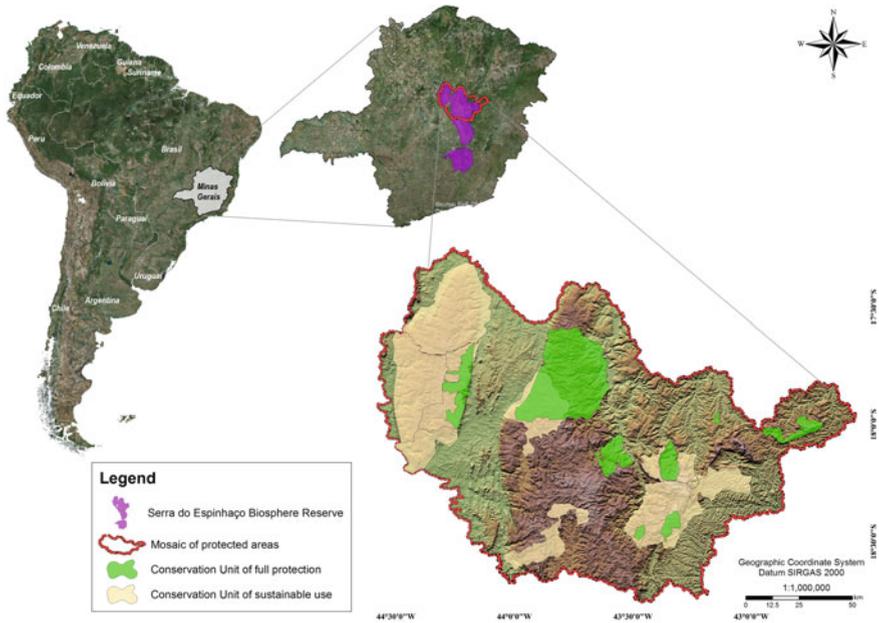


Fig. 1 Location map

2.2 Process

The totals by typology for temporal dynamics and landscape structure's spatial patterns analyses in 1984 and 2013 were calculated. Landscape structure quantification by landscape metrics calculated by the Fragstats computer program (McGarigal et al. 2012) was also done. Fragstats is a freeware directed at categories that represent a landscape structural model in a landscaping mosaic. Input categories in Fragstats were extracted for the vegetation cover and land use mapping done in the previous step for 1984 and 2013. For landscape temporal dynamics in this study, metrics at the level of determined landscape classes in 1984 and 2013 were calculated. The following classes were selected as relevant for this study: dense vegetation, herbaceous vegetation, rupestrian vegetation, and eucalyptus. Evaluated metrics have the potential to indicate fragmentation processes' tendencies and as multitemporal scenarios will be analyzed, a landscape fragmentation interpretation tendency could be realized.

2.3 Evaluation

Through the results obtained in the spatial dynamics processes evaluation, we observed a fragmentation tendency in the protected area's mosaic landscape in the

period analyzed that made the loss of structural connectivity in the landscape between 1984 and 2013 evident.

To evaluate factors affecting landscape connectivity in the study area, a multi-criteria evaluation using the “Multicriteria Evaluation for Discrete Set of Options” toolbox of Professor Piotr Jankowski of San Diego State University (Ligmann-Zielinska and Jankowski 2012; Ligmann-Zielinska et al. 2012) was done in the study area’s landscape connectivity. In this decision-problem structuring phase, groups and their constituent factors that will influence the decision were identified. Selected criteria were split into three groups: a biotic factors group, another with physical environment components, and, finally, a group with criteria related to anthropic pressures. Criteria utilized in this study, as presented in Fig. 2 were selected based on studies by the main author of this text as well as by indications given by a multidisciplinary group of specialists.

In this study, normalization was done via a linear function because it assumes a linear impact relationship in the value scale attributed to criteria. The variation interval for criteria value variation was defined on a 0 to 1 scale. To normalize data, it was also necessary to define variables’ cost or benefit values. Benefit values occur when the variables’ higher values are the more positive and, in return, cost values occur when the variables’ lower values are the more positive. Within the criteria used in this study (Fig. 2), only the distance between roads and urban areas were defined as cost.

Weighing of criteria is a procedure that can be reached through the knowledge level of specialists in a determined area or concept or can be derived by approximation using statistical methods. The Delphi method was applied to define weight given to criteria that will be used in the decision process. According to Bonham-Carter (1994), this way of defining weights is called knowledge-driven evaluation. Formation of a multidisciplinary group of 15 specialists to apply a questionnaire related to the objective was the procedure adopted. The mentioned group was made up by conservation units in the mosaic region’s managers, researchers whose line of research involves biodiversity in the focused region, spatial

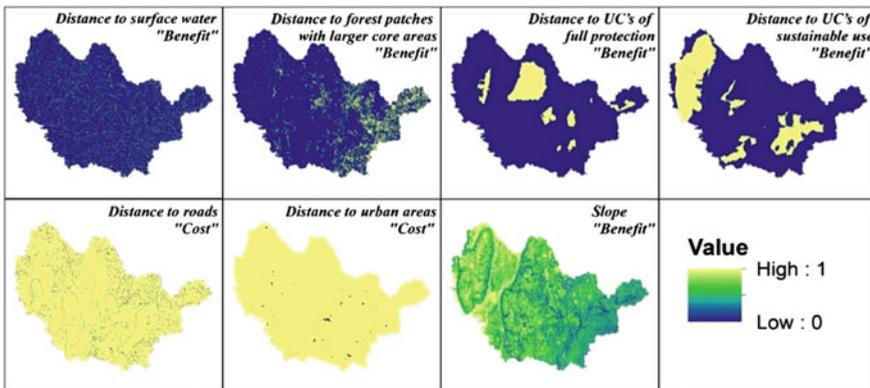


Fig. 2 Criteria and values used

Table 1 Weight used for each criteria

Criteria	AW	SD	PDF	Analysis interval
Distance to surface water	0.25	0.028	1 × SD	0.222–0.278
Distance to UC's of full protection	0.20	0.047	1 × SD	0.153–0.247
Distance to UC's of sustainable use	0.05	0.020	2 × SD	0.010–0.090
Distance to forest patches with larger core areas	0.20	0.023	2 × SD	0.153–0.247
Distance to roads	0.05	0.009	1 × SD	0.041–0.059
Distance to urban areas	0.10	0.009	1 × SD	0.091–0.109
Slope	0.15	0.016	2 × SD	0.118–0.182

analysis specialists in multicriteria methods, and researchers focused on geomorphologic studies.

To generate a sustainability map of connectivity, a multicriteria evaluation using the “Multicriteria Evaluation for Discrete Set of Options” toolbox of Professor Piotr Jankowski of San Diego State University (Ligmann-Zielinska and Jankowski 2012; Ligmann-Zielinska et al. 2012) was carried out. The “Weighted Sum for Feature Class” tool carries out a multicriteria evaluation through points’ vector archives. Observing this characteristic of the tool, a vector points grid was created with the same dimensions of columns and lines of normalized layers in raster format. Thus, value extraction for each raster layer pixel for vector points was done. Weights used are shown in Table 1 for each criterion in the present multicriteria evaluation, corresponding to the average (AW) extracted from the ponderings of the 15 interviewed specialists.

The result of the multicriteria evaluation provided by the “Multicriteria Evaluation for Discrete Set of Options” tool in a vector archive was converted into raster and permits creation of a connectivity suitability map (Fig. 3).

For analysis of the uncertainties inherent to a multicriteria evaluation procedure and a reading of the robustness of the evaluation model in case of changes in variables combination, the “Multicriteria Evaluation for Discrete Set of Options” toolbox of Professor Piotr Jankowski of San Diego State University was also used through the process named “Sensitivity Analysis to Land Suitability Evaluation” (Ligmann-Zielinska and Jankowski 2012; Ligmann-Zielinska et al. 2012).

The Monte Carlo statistical method was applied using the “Monte Carlo Weighted Sum” tool. The analysis is based on building possible results by attributing different intervals of maximum and minimum values in relation to the average value attributed to each criterion. Intervals are groups of random values generated by a probability density function (PDF) and are defined using the standard deviation (STD) regarding the average. This is a symmetrical distribution and values closer to average will present a higher occurrence probability.

A Monte Carlo simulation with a greater number of iterations will have a more reliable answer but will demand higher computational resources. In this study, 100 iterations between indicated weight intervals were done. The interval of minimum

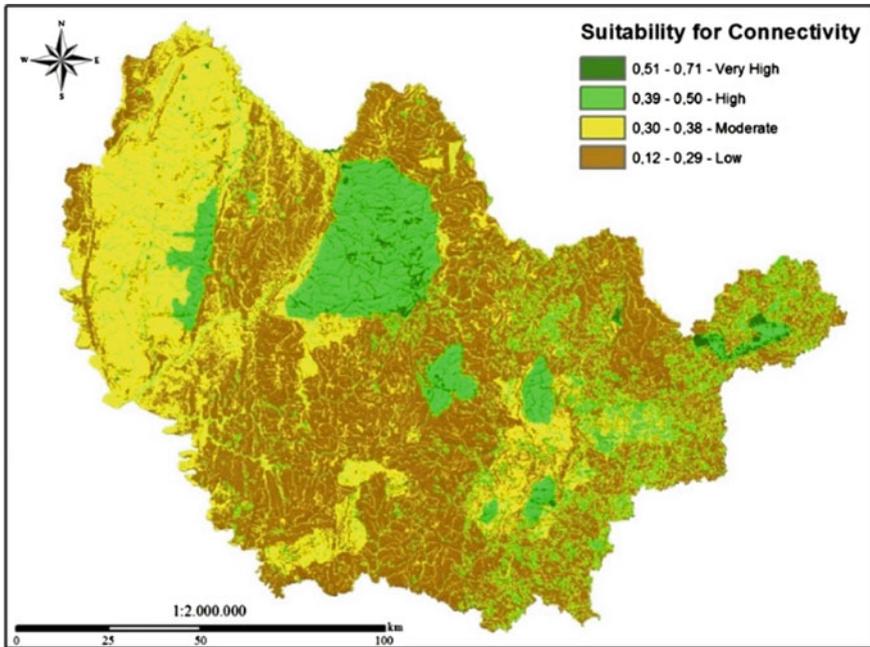


Fig. 3 Connectivity suitability map

and maximum weights attributed to each criterion varied due to weights attributed by the specialists, as shown in Table 1. As proposed by Moura et al. (2014), we can observe the difference between the lowest and highest value among the specialists, being that, if opinion variation on criterion is low, it is feasible to opt for 1 STD for each side of the average value. However, if there is great variation in specialists' opinions regarding a determined criterion, STD is used twice for each side of the average value because a broader range will be analyzed for criteria that generated more doubts.

Uncertainty analysis through the Monte Carlo method produces a result indicating a ranking of average classified values (Rank AVG) and a ranking obtained from the standard deviation (Rank STD). The higher values are those that have first positions in the ranking. According to Ligmann-Zielinska and Jankowski (2012), these results allow carrying out an analysis on the area's aptitude level as well as the uncertainty related to this aptitude; a combination of rules is possible for than exploratory analysis of the result.

Striving for a better analysis of results, a results combination in a thematic map (Fig. 4) demonstrates simulated possibilities of connectivity suitability. Areas presenting better suitability for connectivity among protected areas are those that have a low ranking position for the standard deviation "low uncertainty" and a high ranking position for the average "high suitability." Such areas correspond to 19.82 % of the mosaic's total area. Highly suitable areas, however, also have high

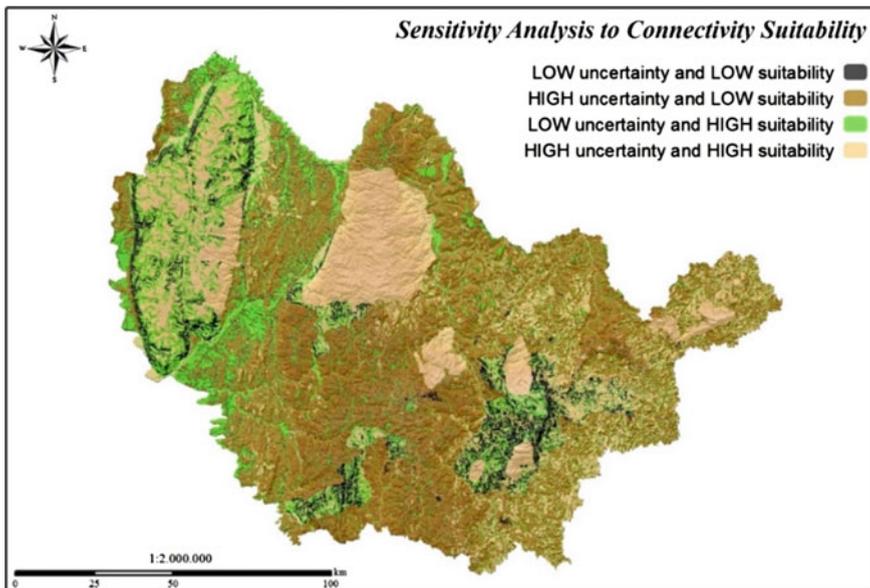


Fig. 4 Map of sensitivity analysis to connectivity suitability

uncertainty and can also be considered important to foster connectivity although they need a more detailed analysis of associated uncertainties. These areas correspond to 28.73 % of the mosaic's total area. Areas that present low suitability but have high associated uncertainty are the landscape's matrix, with 43.48 % of the mosaic's total area. In these areas, there are different land use typologies and, consequently, coexisting habitats. More research on these habitats and their respective species is needed in these areas, striving for a deeper analysis of fragments' real functionality to serve as connectors in the landscape.

It is interesting to note that even integrally protected areas have high uncertainty linked to their connective capacity and thus demonstrate that some agents involved in the multicriteria analysis may harbor doubts on these areas' roles. It is also indicative of little consensus among specialists valuing criteria under analysis. Taking areas with higher suitability into consideration, or that have low ranking position for standard deviation (low uncertainty) and a high ranking position for the average (high suitability), five principal locations that have patterns capable of allowing connectivity between protected areas were identified.

In area 1, located in the mosaic's northwestern portion, there are dense patches of vegetation in the landscape. It presents a stepping stone pattern that may come to allow connectivity between the northern region of the "Serra do Cabral" and the main face of the "Serra do Espinhaço" near "Sempre Vivas" National Park. Area 2, in the mosaic's western section, is shaped to potentially permit connectivity via a typical biodiversity corridor formed by the Curimataí River's riparian vegetation. It allows connection between the southern region of the "Serra do

Cabral” and the main face of the “Serra do Espinhaço” near “Sempre Vivas” National Park. Areas 3, 4 and 5 present a landscape mosaic pattern in which the differently shaped habitat fragments have the potential to permit connectivity in the landscape. Within the methodology presented here, these areas must be the object of a more detailed evaluation to implement environmental management policies, striving to preserve biodiversity through the establishment of connectivity among habitats.

2.4 Change

Land use and land cover mapping at different times (September 2010 and 2012), using Rapideye satellite high-resolution spatial images, were used to analyze changes in the area. Red-Edge band provides the vegetation’s photosynthetic activity monitoring and is thus very indicated for map vegetation cover. Classes selected for this classification were roads, water, dense vegetation, rupestrian vegetation, and matrix (including understory vegetation, pastures, among other typologies of this nature). Spatial dynamics analysis and modeling was supported by the IDRISI Selva software (Eastman 2011). After identifying and analyzing changes, a 2014 landscape simulation was done. Analysis and spatial simulation procedures were implemented through Markov Chain and Cellular Automata algorithms. In this section, we present results for the evaluation model’s previously identified area 1.

The transition matrix of the area generated by Markov chain algorithms will be the rule used to guide changes in the state of cellular automata. Two iterations in the cellular automata model were done and a 5×5 filter was applied to neighborhood analysis. Four catalyzing variables for the landscape transformation process were introduced into the model: distance from roads, distance from fires, the region’s pedological characteristics, and proximity to the eucalyptus monoculture already present in the area.

It can be perceived that the eucalyptus and dense vegetation classes were the only ones that managed a positive balance in the period. A fact that may be related to this trend is the approval of State Act 18,365 in 2009, which defined as a goal reduction in consumption of charcoal made from native vegetation, up to a maximum limit of 5 % of yearly global consumption starting in 2019; this created an expectation of eucalyptus plantation growth to meet demand. Therefore, native species conservation could already be starting as an compensation measure by companies in the segment. The probability matrix presented in Table 2 was the result obtained by applying the Markov chain in land use and land cover maps in 2010 and 2012. This matrix represents the probability of a class changing into another.

Analyzing information contained in Table 2, in the main diagonal, we see the existing probability of classes not undergoing changes. We can observe thus that the dense vegetation class has the least probability of not suffering changes

Table 2 Probability matrix

	Water	Rupestrian	Dense	Eucalyptus	Road	Matrix
Water	0.8500	0.0000	0.1500	0.0000	0.0000	0.0000
Rupestrian	0.0000	0.6132	0.3816	0.0000	0.0000	0.0052
Dense	0.0000	0.0289	0.5875	0.0098	0.0000	0.3738
Eucalyptus	0.0000	0.0000	0.0285	0.8492	0.0000	0.1223
Road	0.0000	0.0000	0.0000	0.0000	0.8500	0.0000
Matrix	0.0000	0.0000	0.0135	0.2747	0.0000	0.7117

(approximately 59 %). The class with the greatest probability of becoming dense vegetation is the matrix class, which has a 37 % chance. This finding is totally pertinent to reality—happening not only in the study area, but also in different parts of the country, where native vegetation is substituted by pastures and cultures, among other typologies related to anthropic uses. The rupestrian vegetation class has an approximately 61 % chance of not changing; it is interesting to note that the dense vegetation class is responsible for around 38 % of this chance for change. This situation can be explained by the trend of riparian vegetation growth on the banks of the drainages that cut rupestrian fields. The matrix class has a high probability of not undergoing change; however, in its areas where there is a transformation chance, the greatest probability is of becoming eucalyptus. This situation can be sustained due to the better pedological condition for this monoculture’s development in the matrix’s cambissoils and also due to the presence of a better road network.

The image coming from the 2014 simulation was visually compared to the maps and through comparison of quantitative values of area by class in 2012 and 2014.

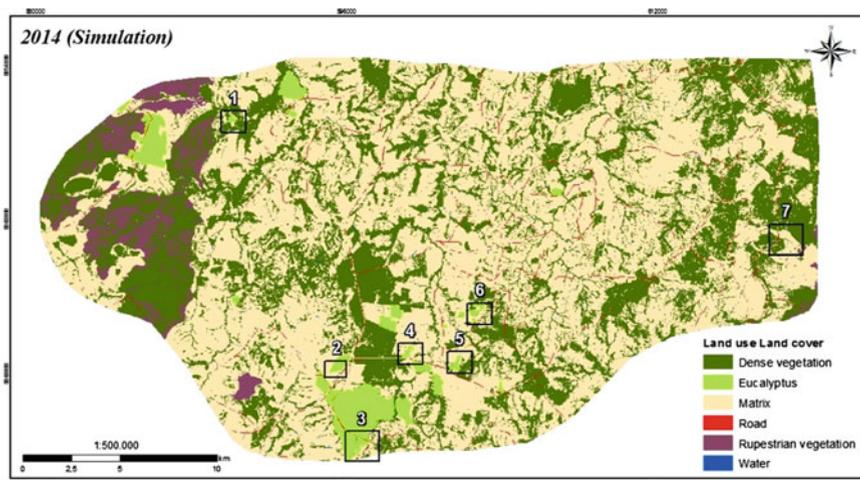


Fig. 5 2014 simulation map

More expressive augmentation in the matrix and eucalyptus classes of respectively 203.97 and 196.69 ha was observed. More discreetly, a possible rise in the number of roads was verified. Rupestrian vegetation and dense vegetation classes had a decrease in quantity in the period analyzed, with losses of 107.86 and 295.95 ha, respectively. Among these analyses, we perceive that the eucalyptus and rupestrian vegetation classes maintained the tendency mapped in 2010 and 2012, from which the transition probability matrix was extracted; eucalyptus gained area while rupestrian vegetation lost area.

Besides comparing the 2012 mapping and the 2014 simulation, a verification of the real land use and vegetation cover situation was done in 2014 as well. This *in loco* verification was done in November 2014 and was carried out in areas where possible alterations pointed out in the simulation were detected, as shown in Fig. 5.

2.5 Impact

Analyzing the change dynamics of land use in area 1 pointed to matrix and eucalyptus classes' growth; they are typically anthropic. The rupestrian and dense vegetation classes diminished; they are natural typologies. We understand the impact of these dynamics is prejudicial to biodiversity conservation and may bring great difficulties for good natural resource management.

Eucalyptus monoculture and other activities going on in the matrix, such as cattle raising, large-scale plantations, mining projects, among others, may cause negative impacts on the region from an environmental point of view, such as biodiversity reduction in flora and fauna, land exhaustion and degradation, and a compromise of superficial and subterranean water sources. From a social and economic viewpoint, this may cause economic dependency on market variations of monoculture, cattle industry and mining byproducts, and potentially affect the whole production chain as well as labor. Moreover, there is the possibility of plague and disease dissemination due to changes in the natural environment with the introduction of exotic species.

2.6 Decision

Observing fragmentation trends and thinking of a more realistic scenario, we understand that for more effective biodiversity conservation to exist in the study area, it is necessary that integrated management models be created through legal means. They should strive for a better understanding among the aspirations of the local population, government, the third and private sectors, and in this way find better ways for biodiversity conservation. The "Espinhaço" Protected Areas Mosaic is an example of this model, as is the "Espinhaço" Biosphere Reserve. However, the scale for analysis is much more encompassing and oftentimes does not allow a more

detailed landscape analysis, be it through remote sensing and geoprocessing techniques or field incursions into reality.

In this context, a decision model formulated after analysis using Geodesign models will, besides conciliating natural communities' survival possibilities in fragmented landscapes with human intervention, have to have the capacity to direct strategies on a larger scale—or in other words, with greater attention to details. The proposition is that legal instruments be created. They should follow concepts within the scope of landscape ecology, which was initially proposed by Forman and Godron (1986). In it, landscape has a three-element structure: matrix, patch, and corridor. Starting from this landscape ecology concept, management models based on landscape's structural elements can be created minding greater biodiversity conservation efficiency. In landscape mosaics in places with a typical matrix pattern, areas in which there is a habitat typology intertwining, such as pasture lands, native forests, monocultures and others, it would be necessary to create policies making economic growth and biodiversity conservation compatible. To do this, it would be crucial to develop matrix permeability studies that contemplate endemic species and their transit capacity in the matrix. In places with a stepping-stone pattern, in which connectivity is reached through short movements among habitat patches dispersed within the matrix, a decision-making model would be to carry out metapopulation research, including degree of patches' isolation studies, efficiency of patches' core areas, verification of patches' real functioning as habitats, how species coexist in the habitat, and others. In locations with an ecological corridor pattern, which can be understood as great avenues on which biodiversity moves through habitats, creation and verification of the real functionality of existing policies on riparian vegetation conservation as water networks with preserved riparian vegetation is an efficient ecological corridor. Besides this, constant analyses on possible interconnection locations among habitats must be checked with the help of orbital images and field teams.

3 Conclusion

The Protected Areas Mosaic of the Espinhaço corresponds to an area of regional dimensions, and that leads to complicated situations regarding territorial management—be it due to lack of technical knowledge or because of the territory itself. We conclude that the methodology presented herein was very satisfactory as it allowed identification of areas with great suitability for this theme, which was habitat connectivity in the landscape. Geodesign permits sequential procedures' systematization and makes landscape analysis focused on identifying suitable places for habitat connectivity possible in a satisfying way. When going through the Geodesign process, it was possible to transition between scales and focus on areas of interest starting from a great cutout in the landscape. Moreover, besides identification, Geodesign showed itself to be a methodology capable of directing intervention in a study area via impact and decision models.

One of the characteristics of the multicriteria analysis method is to take into consideration decision makers' opinions and be expressed through criteria and their weighting. However, we observed that in the course of the criteria and weighting definition process, some uncertainties were identified. This situation was satisfactorily resolved in this study through applying sensibility analysis using the Monte Carlo method. This analysis lends robustness to the methodology because it permits analysis of the relationship between weighting, criteria, and their propositioning method. We conclude that the advantage of applying landscape dynamics research models is the capacity to go between various temporal scenarios. We understand that the benefit of a simulation model occurs when it is conjugated with a good in loco focal area analysis so that an immersion into current reality is able to instigate a deepening in knowledge on the gears that make the space dynamic. This permits the production of good research on the present supported by the way started in the past and productive proposals to follow the trend up in a possible future scenario. IDRISI Selva software through the CA-MARKOV module proved itself a useful tool to develop a landscape dynamics analysis. It has good performance in working with raster data. The result obtained in scenario forecasting using the Markov Chain and Cellular Automaton was quite coherent with field reality and can thus be considered a robust methodology for understanding and forecasting land use and occupation tendencies.

Keeping in mind the entire methodological procedures' integration capacity in a GIS environment and the possibility of different scale analyses, we believe this method can add to protected areas' management by taking into consideration definition of apt or vulnerable areas for determined activities and helping in the search for solutions to increase biodiversity conservation. We hope that, from this study, new protected area integrated management modes can be effectuated so that biodiversity conservation gains more possibilities, taking into account the great threats to natural resources.

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References

- Bennett AF (2003) Linkages in the landscape: the role of corridors and connectivity in wildlife conservation, vol 2. The World Conservation Union (IUCN) Forest Conservation Programme, Gland, Cambridge, p 262
- Bonham-carter G (1994) Geographic information systems for geoscientists; modelling with GIS. Pergamon, Ottawa