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Different ecological indicators applied to the quality of forest restoration in the Atlantic Forest in Brazil

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Abstract

Ecological indicators can help in identifying the way the targets set in a restoration project. Being quantitative or qualitative, they can be measured or evaluated subjectively. In this sense, the present study had the objective of comparing two different methodologies aiming to evaluate the quality of the reforestation through ecological indicators. The study was carried out along the Yellow Trail of the Guapiaçu Ecological Reserve, Cachoreiras de Macacu, RJ. Different methodologies were selected and a plot of 20 x 10 meters was demarcated to evaluate the quality of the reforestation. We also performed variance analysis and Tukey test to evaluate some ecological indicators. The closed area was the one that presented greater density of arboreal individuals as well as a greater coverage than canopy. In the INEA score, the closed area presented a final concept superior to the open area. However, in the second methodology, both areas presented the same final grade. In none of the areas were exotic or endangered species found. A Shannon index of 3.9 and 3.91 was recorded respectively for the closed and open area. Natural regeneration can be noted in both areas as well as planting ordinance. The low values of richness and zoocoric individuals in the areas can be justified by the method of implantation of the reforestation in which in areas of poor site quality, more robust and fast growing species such as legumes are commonly used. Although INEA's methodology used a smaller number of indicators to evaluate the quality of the reforestation, it was in it that a difference of the scores between the evaluated areas can be noticed. This implies that there is no need to use a high amount of indicators for evaluation, since it will only require time and cost for the developer. It was concluded that the methodologies are efficient to evaluate the quality of reforestation.

Key words: forest restoration, reforestation, INEA, ecological parameters

INTRODUCTION

In a simplified way, indicators are methodological resources that seek to express some aspect of reality so that we can observe or measure it (Dale and Beyeler, 2001). For Howell et al. (2012), monitoring the recovery of degraded areas is a systematic process by which we periodically check, describe and evaluate the status of a project. It is fundamental to evaluate the effectiveness of conservation efforts, and the methods of evaluation and monitoring of environmental processes are based on the use of indicators that are parameters that allow the evaluation of attributes of areas or processes, allowing monitoring trends of environmental changes (Dajoz, 1973) or diagnose causes of an environmental problem (Dale and Beyeler, 2001).

Indicators can be quantitative or qualitative. Sánchez-Fernandez (2009) describes quantitative (or objective) indicators as measurable and can be measured directly or indirectly as qualitative (or subjective) indicators refer to information based on subjective perceptions of reality becoming difficult to quantify. For Brancalion et al. (2012), qualitative indicators are obtained in an unmeasurable way, based on the observation and judgment of the observer. Such indicators are normally used in an abstract and subjective way without there being a set of data for which a certain indicator is included in each quality category. For example, occurrence of erosive processes can be categorized as high, medium or low intensity from visual observation.

Melo and Durigan (2007) point out that it is important to choose indicators that facilitate the execution of the evaluation, either in obtaining the data or in its interpretation, suggesting canopy cover as an indicator of the structural development of restoration forests. Whatever the parameters selected as indicators of restoration, they should be chosen based on criteria that reflect the viability and stability of the ecosystem in the long term (Mummey et al., 2002).

Ecological indicators can also assist in identifying how the goals established in a restoration project, such as the reproduction of a certain level of structure or floristic composition, are related to natural succession processes (Hobbs and Harris, 2001).

Much used for the evaluation of environmental conditions, the use of ecological indicators represents a scientific analysis, with numerical or descriptive categorization of environmental data, and is often based on partial information that reflects the status of extensive ecosystems (Van Straalen, 1998; Manoliadis, 2002). The selected indicator should represent a synthesis of four types of characteristics: (i) the 'pressure' indicator, which describes the cause of the problem or impact; (ii) the 'state', which describes some physical and measurable environmental characteristics that result from the pressure; (iii) 'impact', similar to the 'pressure' indicator, which should monitor long-term results; and (iv) the 'response' indicator, represented by policies, actions or investments that are defined to solve the problem (Manoliadis, 2002). Monitoring can be divided according to Brancalion et al. (2012) in three moments. During the implementation phase of the project, from the first to the twelfth month, where in the first three months after planting, the evaluations should be carried out monthly, as it is a critical phase, while in the next phase the evaluations can be more spaced every three months. Post-implantation phase, from the first to the third year. In this phase, when the planting is in the middle stage of development, the evaluations should be semester. Phase of vegetation formed, from the fourth year. In this phase, indicators that indicate the success or otherwise of the restoration are prioritized and that support a decision on the definitive abandonment of the restored areas or the recommendation of additional actions.

The objective of this study was to compare two different methodologies to evaluate the quality of reforestation through ecological indicators. In this context, the following hypothesis was given: (1) the methodologies are efficient when evaluating the quality of the reforestation.

2. LITERATURA REVIEW

Habitat loss is considered the greatest threat to biodiversity (SCDB, 2010). In Brazil, this threat is even greater in the Atlantic Forest due to the greater loss of original cover, high fragmentation and reduced size of forest remnants (Ribeiro et al., 2009). The major challenge today is to obtain indicators that effectively characterize the state of an ecological system and are simple to be measured and interpreted without difficulty by decision makers (Dale and Beyeler, 2001). The increase in the density of individuals and the percentage of cover by native vegetation, in a given time interval, can be important tools for the evaluation of the success of ecological restoration experiments (Rodrigues et al., 2009). The catalytic effect of the plantations is due to microclimatic changes, favoring the germination and establishment of seedlings, the development of a layer of litter and humus and the improvement in soil fertility. These factors favor the initial establishment and future growth of the individuals, by increasing the structural complexity of the habitat, the attraction of the fauna, the greater entrance of propagules, the suppression of weeds (grasses) and the exclusion of fire, in the speed and continuity of the succession (Engel and Parrotta, 2008). Thus, the need to rethink in the restoration, which makes the monitoring one of the essential stages of the entire process of ecological restoration, since in addition to the reflection, it also allows to analyze, continuously, the way the area is reacting to the treatments (Brancalion et al., 2010).

Vallauri et al. (2005) recommend that monitoring and evaluation actions are not tasks performed only at the end of a project, rather they should be a critical and essential part throughout the recovery project. According to some authors (Dau and Beyeler, 2001; Doren et al., 2009; Durigan, 2011), ecological indicators should meet some desirable characteristics such as being easily measurable: being able to express something through values (quantitative or qualitative), such as percentage of degraded areas in a landscape or river basin; to be sensitive to system stress: to have a known response to disturbances, anthropogenic stresses and changes over time, revealing the different stages of change in response to the implementation of the recovery project on a scale applicable to the whole system or a significant part of it ; be predictable: indicate imminent changes in the main characteristics of the ecological system, so that they can be avoided by management actions; be integrative: to assemble a set of parameters to provide a measure of coverage of key gradients in ecological systems (eg through soil gradients, vegetation types, temperature, space, time, etc.) and be reliable: demonstrate the characteristics being monitored (such as ecological functions, structure and forest composition); as well as presenting low variation in response and being scientifically defensible.

In the state of Rio de Janeiro, Brazil, the resolution of the State Environmental Institute (INEA) No. 89, dated June 3, 2014, states that the monitoring steps must be carried out over four years or until its full establishment. The same institute proposed a "restorative" calculator, which allows the reformer to evaluate the quality of its population (Table 1). In the state of São Paulo - Brazil, SMA Resolution 08/2007 is in force. Brancalion et al. (2012) based on this resolution also established a scoring standard in order to qualify the state of a reforestation (Table 2). According to the author, this final note can be compared to the hypothetically obtained score for an ideal project, which obtained maximum score in all parameters. Based on this, the environmental agency or a contractor of a forest restoration service could, based on this model, set a minimum grade for the restored area to accept, reject, or require improvements in a particular ecological restoration project or program.

3. MATERIAL AND METHODS

3.1 Study area

The Guapiaçú Ecological Reserve - REGUA (22 ° 24'S, 42 ° 44'W) is located in Cachoeiras de Macacu, RJ, Brazil (Figure 1). Part of REGUA territory overlaps with the Três Picos State Park, which corresponds to 58,790 ha contiguous forest in the Serra do Mar (Braz et al. 2014), the climate is characterized by two distinct seasons: a dry and cold period from May to October and a hot and rainy season, between November and April, temperatures vary daily from 14º to 37º C and average annual rainfall is 26000 mm.

Two areas (open and closed) of reforestation along the Yellow Trail of REGUA (Figure 2) were selected and one plot was plotted in each area of 20 x 10 m proportion, and all the ecological indicators present in both methodologies were quantified (Table 1 and 2).

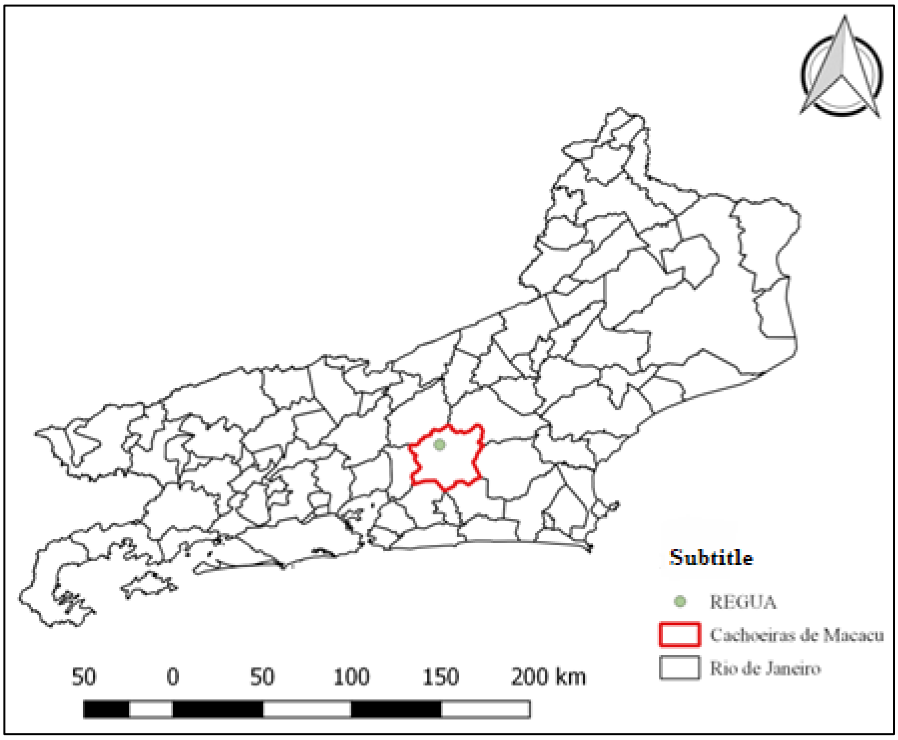

Figure 1. Location of the study area, Guapiaçu Ecological Reserve - REGUA, located in the municipality of Cachoeiras de Macacu, RJ, Brazil.

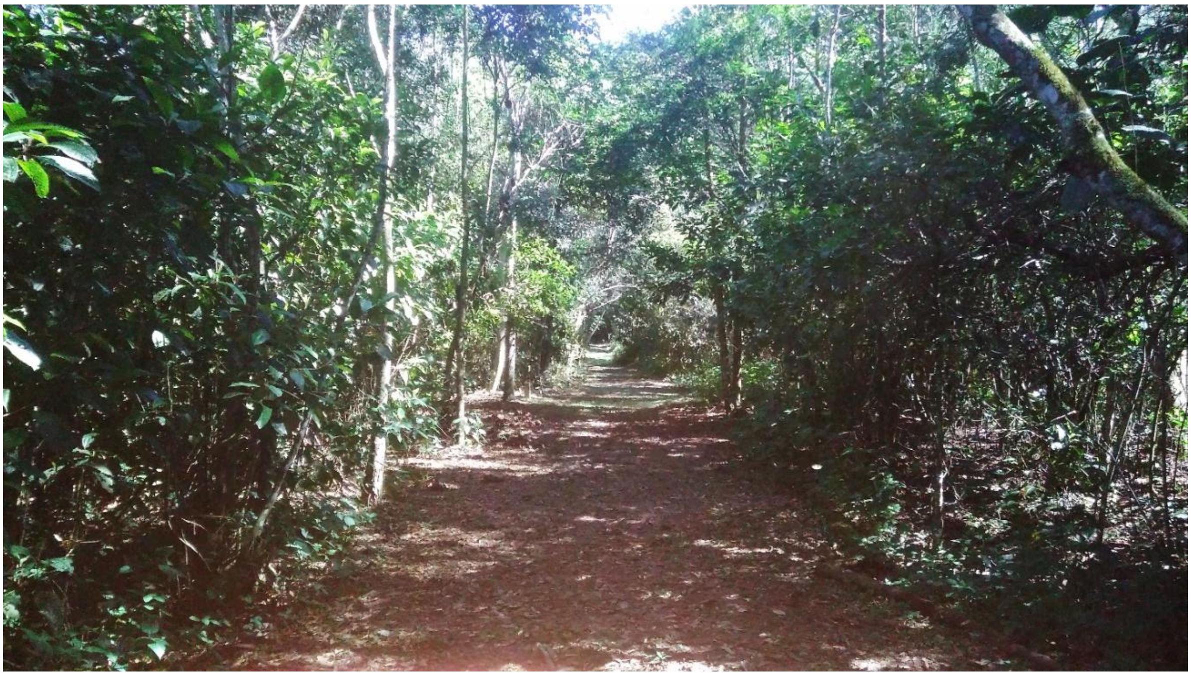

Figure 2. Characterization of reforestation in the Yellow Track in which the plots were allocated in the Guapiaçu Ecological Reserve.

3.2 Methodology

Two different methodologies were selected to evaluate the quality of reforestation. The first one (Table 1) is used by the State Environmental Institute (INEA) based on Resolution No. 89, dated June 3, 2014, and the second one (Table 2) was proposed by Brancalion et al. (2012), which established criteria based on SMA Resolution No. 08/2007 in São Paulo.

Table 1. Restorative calculator used by the State Environmental Institute (INEA-RJ) based on Resolution No. 89, dated June 3, 2014.

Indicators parameters	**Reference table**		
	Critical=0	**Minimum=0,65**	**Suitable=1**
Density (n° ind/ha)	<1111	≥ 1111< 1250	≥ 1250
Zoocoric ind (%)	<40	≥ 40 < 60	≥ 60
Cup coverage (%)	<50	≥ 50 < 70	≥ 70
Equity - J'	<0.6	≥ 0.6 < 0.8	≥ 0.8
Diversity - H'	<1.5	≥ 1.5 < 2.5	≥ 2.5
Average Height (meters)	<2	≥ 2 < 3	≥ 3
Grass infestation (%) *	≥ 30	≥ 20 < 30	≤ 20
Final Concept*			

*Final concept >8,0= satisfactory;<8,0= insufficient

Table 2. Possible scores of each parameter evaluated, based on criteria established by SMA Resolution 08/2007 in force and recommended for restored areas.

Indicator	Standard	Score	Weight
Wealth of tree species	< 30 sp	0	3
	From 30 to 59 sp	1	
	From 60 to 79 sp	2	
	> 80 sp	3	
Diversity (H’)	Below 1.0	0	3
	Between 1.1 and 2.0	1	
	Between 2.1 and 3.0	2	
	> 3.0	3	
Presence of exotic invasive species	Presence	0	3
	Absence	3	
Presence of exotic	Presence	0	2
	Absence	3	
Presence of endangered species	Presence	0	1
	Absence	3	
Average height of planted seedlings	<0.5 meters	0	2
	Between 0.6 and 1.0 meters	1	
	Between 1.1 and 1.5 meters	2	
	> 1.5 meters	3	
Natural Regeneration	Absence	0	3

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	Presence	3	
Cup Coverage	< 20%	0	3
	Entre 20 e 50 %	1	
	Entre 50 e 80 %	2	
	> 80 %	3	
Invasive Grass Coverage	≥ 30%	0	3
	Entre 20 e 30 %	1	
	Entre 10 e 19 %	2	
	< 10 %	3	
Orderly distribution of planting seedlings	Houve	3	3
	Não houve	0	
Full mark	-	78 (100%)	

3.3 Data analysis

To calculate Shannon diversity and Pielou equitability, the equations "$H = \sum_{i=1}^{r} \text{Pi} \times \log_e Pi$" e "$e = H/\log R$" were respectively used, where $pi = ni/N$; ni = density of each group, N = density of all groups; R = wealth. In addition, the canopy cover was calculated: $Ci = \pi \times (\frac{L1+L2}{4})^2$, where L1 and L2 are the longitudinal and perpendicular rays of the canopy and Ci = the canopy cover.

Grass cover was estimated visually without the aid of an apparatus or mathematical formula. The height was determined by means of a hypsometer. The ANOVA and the Tukey test were used to evaluate the difference between some indicators in the open and closed area with the aid of *software R*.

4. RESULTS

The closed area was the one that presented greater density of arboreal individuals as well as a greater coverage than canopy (Table 3). On the other hand, the open area presented greater equity. However, in both areas a low percentage of zoocoric individuals can be observed, besides not presenting infestation of grasses. The values of wealth were lower than those recommended by the methodologies and all the species presented a height superior to three meters.
In none of the areas were exotic or endangered species found (Table 4). A Shannon index of 3.9 and 3.91 was recorded respectively for the closed and open area. Natural regeneration can be noted in both areas as well as planting ordinance.

Table 3. Score obtained by the restorative calculator of the State Environmental Institute (INEA-RJ) based on Resolution No. 89, dated June 3, 2014.

Indicators parameters	Open	Closed
Density (n° ind/ha)	2200 b	2850 a
Zoocoric ind (%)	<40%	<40%
Cup coverage (%)	88% b	94% a
Equity - J'	0.94	0.90
Diversity - H'	18 a	20 a
Average Height (meters)	> 3	> 3
Grass infestation (%) *	0%	0%
Final Concept*	**80.7**	**85.7**

Comparing the methodologies, it can be noted that there was a difference in the results. In the INEA score, the closed area presented a final concept superior to the open area. However, in the methodology of Brancalion et al. (2012), both areas presented the same final grade.

Table 4. Scoring obtained by the methodology recommended by Brancalion et al. (2012).

Indicators	Open	Closed
Wealth of tree species	0	0
Diversity (H ')	9	9
Presence of exotic invasive species	9	9
Presence of exotic	6	6
Presence of endangered species	3	3
Average height of planted seedlings	6	6
Natural Regeneration	9	9
Cup Coverage	9	9
Invasive Grass Coverage	9	9
Orderly distribution of planting seedlings	9	9
Note (%)	**88.46**	**88.46**

5. DISCUSSION

The greater number of individuals in the closed area can be explained by the better consolidation of the species in the system. In which the pioneer species gave space to new species allowing a greater coverage of canopy. However, these areas can progress or retreat into structural and floristic diversity according to internal disturbances such as opening of clearings (Whitmore, 1978; Pillar, 1994).

The low values of richness and zoocoric individuals in the areas can be justified by the method of implantation of the reforestation in which in areas of poor site quality, more robust and fast growing species such as legumes are commonly used. Species that mostly do not present zoocoric dispersion. Pereira and Rodrigues (2011) affirm that in revegetation, mainly with leguminous species, it is an extremely necessary measure for the recompositing of the soil surface horizon.

Although INEA's methodology used a smaller number of indicators to evaluate the quality of the reforestation, it was in it that a difference of the scores between the evaluated areas can be noticed. This implies that there is no need to use a high amount of indicators for evaluation, since it will only require time and cost for the developer. However, in both methodologies the final result was satisfactory (note above 80%), which allows to say that they are efficient to evaluate the reforestation.

There are a number of parameters that can be used as indicators, but the great challenge is to develop or adapt valid criteria to monitor and evaluate the functionality of the area as well as to discriminate indicators that provide the desired information accurately and at acceptable costs. It is also necessary to look for other specific indicators for each situation and each environment to be recovered, and it is unlikely that only universal indicators can be developed (Rodrigues and

Gandolfi, 2001). The development of indicators is a critical area of research in forest ecology, since, although the rationale for their selection is reasonably well established, the greatest remaining task is to test and validate them (Noss, 1999). For Eiswert and Haney (2001), the reliability of the indicators depends on attributes such as sensitivity, specificity and predictability.

6. CONCLUSION

Based on the results obtained during the present study, it can be concluded that:The main parameters evaluated in this study were the density of individuals and the cover of the crown, indicating that they are fundamental parameters for the evaluation of the quality of a reforestation. Closed environments tend to have higher density of individuals since they present edaphoclimatic conditions more conducive to natural regeneration. Although zoocore species are fundamental to the success of ecological succession, in areas of poor site quality it is recommended to use more robust species such as legumes. It is fundamental to choose efficient parameters to evaluate the quality of a reforestation, since the measurement of these parameters demands time and cost. In this sense, the choice of these should take into account the age of the reforestation as well as the difficulty of access to the area and the purpose of the reforestation. There is a need for the elaboration of more methodologies for the evaluation of reforestation quality since Brazil is a continental country presenting multiple biomes. Both methodologies evaluated in this study were efficient to evaluate the quality of the reforestation, although INEA methodology was able to distinguish the study environments.

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