Indicators of Ecosystem Services in an Atlantic Forest, Pernambuco - Brazil

Abstract

The use of Ecosystem Services (ES) indicators may help when designing, implementing and monitoring public environmental policies. In addition, using ES assessment and communication may support decision-making processes and improve the involvement of stakeholders. Moreover, the process of selecting and identifying these indicators may be used as a management support tool for natural protected areas. Quantifying ecosystem services and developing related indicators need a great deal of data and information, which are sometimes neither easily accessible nor available. Similarly, there are many obstacles which may prevent the analysis and use of environmental services data. This can include a lack of ecological and social knowledge on how these services are shaped and used and how they vary in time and space. The main aim of this research study is to identify environmental service indicators for Atlantic forests, using a participatory approach with different types of stakeholders. A case study is made of an Atlantic Forest area in the Northeast of Brazil, under the jurisdiction of the Brazilian Army. To accomplish this aim, a questionnaire survey was sent to a group of stakeholders in order to evaluate an initial set of proposed 44 indicators for several forest ES. Supported by the participatory process, 26 ES indicators for Atlantic forests were obtained, for which stakeholders’s perceptions and views were weighted. Some of the indicators identified were specifically tailored for the military forest context, thus showing an approach that balanced common and site-specific aspects of ES. Having a good understanding of ecosystem indicators can support managers in decision-making processes on environmental issues.

Key words: ecosystems services; forests; indicators; stakeholder engagement.

1. Introduction

The concept of Ecosystem Services (ES) emerged with the need to demonstrate that natural areas fulfil essential functions in the processes of maintaining life, as opposed to the false idea that preserved or intact ecosystems are unproductive or represent obstacles to economic development [1]. This means that every ecosystem produces a series of benefits, such as water, wood, food, landscaping, climate regulation and air purification, all of which man takes possession of. ES can be defined as flows of materials, energy, and information from stocks of natural capital which are combined with both manufactured and human capital services to produce human welfare [2]

ES are fundamental for human survival and for social and economic development. These services are generated by all ecosystems at different scales. These ecosystems can be cultivated, urban, polar, marine or coastal land, inland waters, forests and woodlands, dry lands, islands or mountains [3]. Forests provide several intangible benefits such as they regulate local and global climate, protect watersheds protection, prevent soil erosion, and cycle nutrients [4].

Forest ecosystem services have been analyzed in different research studies [5] [2] [6] [7] [8] [4], some of which focused on marine, biodiversity, cultural and forest ecosystem service. Several other authors [4] [9] [10] [11] [12] [13] [14] [15] explored the identification and valuation of forest ecosystems services, including the role of indicators [16] [8] [17] [18] [19] to assess and report the state of and pressures on ES. Most studies focused on the concept of ecological indicators, including provisioning services, regulating services, cultural services as well as supporting services and their importance in the decision-making process.

In a more extensive approach, [20] presented a group of environmental services specifically available in forests. The authors gathered the mentioned services into groups that were broader than the ones detailed below (Fig. 1).
Indicators are special signs that convey “value added messages” in a simplified and useful manner to the different stakeholders. An indicator can be derived from a single variable to reflect some attribute or from an aggregation of several variables (indices) [21] [22]. As synthetized by [23] indicators are variables which provide aggregated information on certain phenomena. They are also used by organizations to monitor, evaluate and report if a process, activity, product or service was able to either fulfil its goals or reach its minimal performance level [24]. In the context of ES assessment they may have similar meanings and understandings: (i) ES can be used as indicators in in human-environmental systems, as stated by [18]; and (ii) indicators can be used to assess and report ES attributes [25].

An ecological indicator is defined as a measure, an index of measures, or a model that characterizes an ecosystem or one of its critical components. An indicator may reflect biological, chemical or physical attributes of an ecological condition [26]. The primary uses of an indicator are to characterize current status...
and to track or predict significant changes. With the foundation of diagnostic research, an ecological indicator may also be used to identify major ecosystem stresses [27]. These indicators must provide information relevant to specific assessment questions, which are developed to focus monitoring data on environmental management issues [26]. Other authors, such as [28] state that any measuring system must go beyond the simple creation of indicators. Thus, it must enable different dimensions of effort and result, with different weights, to be created. Moreover, it should also allow the attribution of a grade to every indicator that expresses a relative measure, which represents a weighted and aggregated measurement that enables a measure to be created that synthesizes performance, this being a global grade that carries within itself the result of the evaluation.

Quantifying ecosystem services as well as developing their indicators need a great deal of information which is sometimes neither easily accessible nor available [29]. Similarly, there are many obstacles which may prevent the analysis and use of the ecosystem services data. This includes a lack of ecological and social knowledge on how these services are formed and put to use and how they vary in time and space. Moreover, standardized quantification and mapping of the main components in environmental servicing may be absent [31] [12] [29] [30].

The selection of ES indicators may help when designing public environmental policies. Similarly, the communication of ES may support the decision-making process and improve communication with stakeholders [24]. Moreover, identifying these indicators may contribute as an administrative tool towards managing and conserving natural areas [13]. Thus, by balancing the demands of government policy and regulations with private initiatives, developing and protecting natural resources has become the greatest challenge in environmental management. Also, instead of simply protecting the ecosystem from any potential harmful impact, an environmental approach may be considered as a form of investing in the sustainable management of ecosystems [32]. All definitions and classifications of indicators, as well as of ecosystem services, depend strongly on the characteristics of the investigated ecosystem and the context of the decision in which they are being applied [17]. Consequently, service indicators are policy-relevant representations that identify gaps and communicate trends and information on the sustainable use of these services and the benefits derived from maintaining them for future generations [33].

For an effective development and use of ecosystem indicators, quality as well as acceptance is very important and the inclusion of stakeholder perspectives can be an important contribution to both [16]. Several authors have stressed the need to integrate 'technical' and 'participative' approaches when selecting indicators and development processes [22] [21] [34] [35].

Overall, and despite the above-mentioned studies on ES indicators, there is a lack of research on how to select and use ES indicators in practice in order to improve and facilitate data collection for indicators, processing, analysis and reporting. Also, participatory approaches are becoming well covered by research initiatives on general sustainability indicators but are still poorly explored for ES indicators. Therefore, ES indicator approaches, frameworks and case studies should be further investigated to analyse if they can introduce added-value in the process of assessing ES services and communicating, understanding and exploring their potential weaknesses and strengths.

In this context, the main aim of this study was to identify and select a set of indicators of ecosystem services for forest areas, through a participatory process. The proposed approach was tested in a fragment of Atlantic Forest in the Northeast of Brazil, under the jurisdiction of the Brazilian Army.

2. Methods

2.1 Study Area: fragment of Atlantic forest located in the CIMNC (Marshal Newton Cavalcante Instruction Camp)

The Brazilian Army is directly responsible for around 22,352 km² of Brazilian territory, which represent about 0.71 % of the national territory, an area bigger than countries such as Israel and El Salvador. Included
in these are the most different biomes, such as Atlantic Forest, Caatinga, Amazon Forest, Brazilian Cerrado and Pantanal [36].

The study area is a forest located inside the Marshal Newton Cavalcante Instruction Camp of the Brazilian Army which was created in the 1940s. It is located in the Northeast Region of Brazil (Fig. 2). Originally, the area consisted of ten sugarcane plantations, the vegetation of which mostly comprised sugarcane plants and pasture, and also included twenty small fragments of Atlantic Forest. Currently these woods of the CIMNC have undergone a process of natural or involuntary regeneration.

The selection of this forest area was supported by the following main criteria: (i) it is the largest fragment of Atlantic forest located in the northeast of Brazil [36] (ii) is an isolated forest fragment in a region close to large urban concentrations; (iii) is an area with exceptional concentrations of endemic species and experiencing exceptional loss of habitat [37].

The expression ‘Atlantic Forest’ (Mata Atlântica, in Portuguese) was first proposed in 1884 by J. E. Wappaeus who defined it as a coastal forest of evergreen trees, which may or may not be located on hills, mostly at low altitudes and even a little above sea level [36]. The Atlantic Forest ranks among the top five biodiversity hotspots in the world, yet it is also one of the rainforests most adversely affected by man [37]. The Atlantic Forest and its related ecosystems originally covered an area corresponding to 15% of Brazilian territory. Currently, it only represents about 1.2% [38] [39].

Fig. 2. Location of CIMNC in the Northeast of Brazil.
The processes of deforestation suffered by the Atlantic Forest since the late 19th century has restricted this biome to only dispersed fragments in its original area. Such fragmentation introduced a series of new factors into the evolutionary history of natural populations of plants and animals. These changes affected in different forms the demographic parameters of mortality and birth-rate of the existing species, thereby affecting the structure and dynamics of the ecosystem as a whole [9].

The remnants of Atlantic Forest in metropolitan areas have major relevance, since they are under potential or real pressure of urbanization due to new roads being constructed, the setting up of industrial plants, creating new construction lots and housing areas and to informal urban occupation, factors which are very typical in the so-called peri-urban perimeters. Most of its original areas have been transformed into residential neighborhoods or, in rare exceptions, into urban forests, such as isles of native vegetation [40].

The fragments of Atlantic Forest inside the CIMNC are evergreen woods with a canopy up to 50 m high, and emerging trees up to 40 m tall. They also possess dense shrubby vegetation comprising ferns, arborescent trees, bromeliads and palm trees. This composition is due to high temperatures (average 25° C) and high rainfall, which is well distributed throughout the year. The dry season varies from 0 to 60 days. The predominant soil is dystroferric red latosol (Oxisol Haplutox) and, exceptionally, eutrophic red latosol (purple eutrutox), originating from granite and gneiss, as well as sandstone with volcanic spills from various geological periods [36].

The annual average insolation in the CIMNC is 2,556.4 hours. Catucá is the most important headwater in the area. After it runs through the area of the MNCIC it is dammed upstream, thus forming the Botafogo Dam (The Botafogo System is a part of the Water Production System in the state of Pernambuco). This dam has an area of 1.79 km², a capacity of 27,600,000 m³ and an average outflow of 1.2 m³/s. The area of the basin of the Catucá stream is 88 km² mostly located inside the CIMNC [36].

2.2 Survey questionnaire

A questionnaire survey was designed and administered by the research team to obtain an evaluation of a proposal of forest ES indicators for the selected study area (questionnaire in appendix) by a selected group of stakeholders. The method was implemented over several steps, as described below (Figure 3).

The first stage of this survey approach was to select ES related to forest areas. In order to do so, the profile of services presented by the [41] [20] [2] [3] [14] was observed. The ES proposed by these studies were inventoried and then divided using the classification suggested by[20], due to their extensive division and subdivision of specific ecosystem forest services (Fig 3). After this selection step, intermediate services were discarded in order to eliminate services that did not create direct benefits, thus avoiding the double count of any particular service, as suggested by [42].

Afterwards, a second stage was conducted. Supported by the literature review on ES indicators and an expert qualitative analysis conducted by the research team, indicators were identified and selected which relate to different forest ES. These indicators were mostly derived from the structure (measurement/state) of the basic elements in an ecosystem or from either the supply or use of the services [43]. It is worth noticing that for some selected services more than one indicator was selected in order to use different forms of measurement, and cover the wide scope and complexity of certain services. During the process of analysing and selecting the set of indicators, several criteria were observed. The criteria suggested by [32] among other authors (e.g. [44]) were adopted. Beyond the scientific robustness and related aspects of credibility, the practical usefulness and the capacity to support decision-making processes were two of the main drivers for this stage, so that they could be more useful and practical for the design, implementation, operation and follow-up of policies, plans, programmes and projects. The set of indicators obtained comprises 44 forest ES indicators.

In a third stage, a survey questionnaire was developed with the list of ES and their respective indicators. It contained both multiple choice and open-ended questions. A pre-test to the questionnaire with a set of selected environmental researchers was conducted. The pre-test was performed to assess the quality of the
draft questionnaire and integrate the necessary adjustments in the identified questions, as recommended by [45].

A group of stakeholders was selected to evaluate the proposed set of forest ES indicators, using a scoring procedure developed for the questionnaire. The following took part in this process: 21 stakeholders from academia, business, local, regional/state and national administration, local community and no-governmental organisations; environmental managers in the Instruction Camp, and of military units of the Brazilian Army which deal with environmental issues in both local and national levels, and also of the surrounding community which included a rural settlement, as well as a sugarcane plant, and a public company which collects water from the hydrographic basin located inside the study area.

Stakeholders were asked to evaluate each indicator using three main dimensions: (i) Comprehensibility – how clear is the indicator to illustrate the intended ES and to support good communication; (ii) Relevancy – how important is the indicator to represent the ES and underpin decision-making; (iii) Feasibility – what potential does the indicator have for use in practice. A scale of 1 to 5 was used for scoring each indicator in each dimension 1 (very low performance) to 5 (very high performance). Missing cases (blank responses) and ‘don’t know’ responses were dealt with as non-responses. Also, stakeholders could propose new or adapted indicators, and for those cases the same scoring scheme was used. The indicator evaluation followed the approaches conducted by [46] [47].

The survey questionnaire was sent by email or hand delivered during June 2014. The use of questionnaires was a very appropriate choice because of the number of interviewees and their great dispersion. Therefore, this process was conducted over a more extensive target zone, and demanded less time and cost, as suggested by [48]. When necessary or requested to clarify important doubts, a Skype or in-person meeting with the stakeholders was held, to clarify the goal, scope or scoring procedure.

During the selection process, an analysis was made of surveyed data, the arithmetic mean of each scoring dimension (C – comprehensibility, R – relevancy, F – feasibility) was calculated for each evaluated indicator, and this was followed by calculating the mean of the three aggregated dimensions, in accordance with the following equations:

\[ C = \frac{20}{n} \sum_{i=1}^{n} C_i \quad R = \frac{20}{n} \sum_{i=1}^{n} R_i \quad F = \frac{20}{n} \sum_{i=1}^{n} F_i \quad G = (C + R + F)/3 \]

Where C is the degree of acceptance of the indicator i for the attribute Comprehensibility; R is the degree of acceptance of the indicator i for the attribute Relevancy; F = degree of acceptance of the indicator i for the attribute Feasibility; G is the degree of general acceptance (converted into a percentage scale - assuming that 5 is equal to 100%, the score was multiplied by 20) and n is the total number of stakeholders’ evaluations by indicator i.

After calculating the general degree of acceptance for each indicator, only those with an upper value of 70% were considered. The adopted cut-off threshold was supported by the assumption that the high rated indicators in the three dimensions were the most consensual and representative among stakeholders, as suggested by other authors, e.g. [49] [50]. From the 44 indicators initially proposed in the questionnaire, only 26 were selected by the arithmetic procedure.

In a final stage, based upon the general index of acceptance, the indicators were ranked from the highest to the lowest scores. The research team conducted a final post-scoring evaluation, supported by a qualitative analysis of the set of final indicators selected. At the same time, the suggestions presented by the
Interviewees were evaluated, resulting in either keeping the indicator as it was, or modifying or discarding it. In the process of discarding an indicator, factors such as the level of difficulty for measuring it, its appropriateness to the respective ES and its resemblance with other indicators were taken into consideration.

![Flowchart of the method used in selecting the indicators.](image)

**Fig. 3. Flowchart of the method used in selecting the indicators.**

### 3. Results and Discussion

#### 3.1 Stakeholders’ Scoring of the Indicators

All the invited stakeholders answered the indicator scoring survey. Although stakeholders were allowed not to evaluate some of the indicators, the vast majority evaluated all of them. This was possible due to the stakeholders involved having extensive knowledge of and interest in the concepts of ecosystem services and/or in the study. Also, an initial process of making personal to explain the aim and scope of the research was conducted to ensure effective engagement with the survey.

The participatory scoring also led to the respondents making several suggestions, thereby allowing a more detailed analysis of the weaknesses and strengths of the indicators proposed. In addition to the scores given to the indicators, qualitative contributions were of substantial help in evaluating and selecting the indicators.
It is also worth emphasizing that, as a result of the comments and suggestions made by stakeholders, some adjustments could be made when drafting the initial indicators proposed which led to their being more comprehensive.

It was identified that there was an uneven distribution of the indicators as to the types of environmental services suggested. It was found that there was a higher concentration of indicators relating to hydric services, there being a total of seven of these; while services for biodiversity conservation; tourism leisure, sports and nautical activities; and education and culture had four indicators each; erosion control services, climate service and carbon retention and resilience services had two indicators each and services on scenic beauty that did not show indicators with attributes above 70%.

3.2 Specific features of the set of selected indicators

The three selected indicators with highest scores were the I(1), I(11) and I(14) (Table 01). These indicators came from the same type of ecosystem service (the hydrological ES suggested by [20]. This result supports the relevant role that a forest has in the process of the cycling of water, which was reflected in stakeholder’s inputs to the survey inputs. Note also the occurrence in this group of indicators, the indicator I(14) that expresses the cost avoided on purifying water within the CIMNC. This type of indicator is relatively easy to measure and, consequently can be part of a database which may give support to decision-making and management systems [51]. In addition to these first three indicators, there are I(2), I(17), I(10) and I(19) which are also derived from the ES. This type of service had the highest number of indicators, which highlights its relevance in the context of the study area. This observation is reinforced by [36] [52] [20] when they argued for the aspects of the benefits generated by forest fragments and the possibility of measuring easily them.

Table 1. Set of forest ES indicators ranked by decreasing order of acceptance

<table>
<thead>
<tr>
<th>Indicator code</th>
<th>Selected indicators</th>
<th>Types of Environmental Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>I(1)</td>
<td>Volume of water captured by the public water system in Catucá Basin [m3]</td>
<td>X</td>
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<tr>
<td>I(11)</td>
<td>Outflow of Catucá Stream during the dry season [m3/s]</td>
<td>X</td>
</tr>
<tr>
<td>I(14)</td>
<td>Cost avoided on treating water for consumption [RS/m³]</td>
<td>X</td>
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<td>-------</td>
<td>------------------------------------------------------</td>
<td>---</td>
</tr>
<tr>
<td>I(13)</td>
<td>Average Temperature Variation inside and outside the study area [°C]</td>
<td>X</td>
</tr>
<tr>
<td>I(33)</td>
<td>Number of academic research studies in forest habitats [Number of related studies per year]</td>
<td>X</td>
</tr>
<tr>
<td>I(26)</td>
<td>Number of endangered native species of the Brazilian Atlantic Forest found at the MNCIC. [Units]</td>
<td>X</td>
</tr>
<tr>
<td>I(41)</td>
<td>Number of people participating in Environmental Education events inside the woods [people/year]</td>
<td>X</td>
</tr>
<tr>
<td>I(27)</td>
<td>Number of native species from the Brazilian Atlantic Forest found at MNCIC. [Units]</td>
<td>X</td>
</tr>
<tr>
<td>I(6)</td>
<td>Number of plant species per hectare found in the woods [Units/ha]</td>
<td>X</td>
</tr>
<tr>
<td>I(35)</td>
<td>Area of Atlantic Forest existent in the limits of the MNCIC [Atlantic Forest area (km²)/area of the Instruction Camp (km²)]</td>
<td>X</td>
</tr>
<tr>
<td>I(8)</td>
<td>Existing plant biomass [t/area(km²)]</td>
<td>X</td>
</tr>
<tr>
<td>I(2)</td>
<td>Amount of water in Catucá Basin used for irrigation [m³]</td>
<td>X</td>
</tr>
<tr>
<td>I(40)</td>
<td>Number of people who engage in ecotourism in the MNCIC area [Units/year]</td>
<td>X</td>
</tr>
<tr>
<td>I(17)</td>
<td>Average volume of rainfall intercepted by the forest [mm.ha]</td>
<td>X</td>
</tr>
<tr>
<td>I(10)</td>
<td>Ratio between hydric response of the basin studied and another basin with similar physiographical characteristics, but without vegetal coverage [Adimensional value]</td>
<td>X</td>
</tr>
<tr>
<td>I(31)</td>
<td>Number of military exercises in forest habitats [Units/year]</td>
<td>X</td>
</tr>
<tr>
<td>I(24)</td>
<td>Extension of headwater sections in Catucá Basin in the process of degradation [km]</td>
<td>X</td>
</tr>
<tr>
<td>I(29)</td>
<td>Accidents due to any military training activity with people from outside the MNCIC [people who suffered any accident/ year]</td>
<td>X</td>
</tr>
<tr>
<td>I(19)</td>
<td>Percentage of water bodies with parameters adequate to their respective classes [%]</td>
<td>X</td>
</tr>
<tr>
<td>I(44)</td>
<td>Number of people who participated in sports activities which take place in green areas or open spaces [People/year]</td>
<td>X</td>
</tr>
<tr>
<td>I(5)</td>
<td>Quantity of seeds collected for seed banks [t or kg]</td>
<td>X</td>
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<tr>
<td>I(25)</td>
<td>Fragment area of the forest forming ecological corridors [km²]</td>
<td></td>
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<tr>
<td>I(43)</td>
<td>Number of people who participate in activities based on observing species in the wild [Units/year]</td>
<td>X</td>
</tr>
<tr>
<td>I(24)</td>
<td>Number of people who use the headwaters in the MNCIC for recreation, bathing and leisure [Units/year]</td>
<td>X</td>
</tr>
<tr>
<td>I(21)</td>
<td>Forest area protecting hillsides thus preventing landslides [km²]</td>
<td>X</td>
</tr>
<tr>
<td>I(39)</td>
<td>Number of people engaging in nautical sports in the area of the Catucá Basin [Units/year]</td>
<td>X</td>
</tr>
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</table>

The indicator I(13), which is the second most relevant indicator, is related to the variation of temperature inside and outside the study area (Table 1). It is noticeable that the indicators related to climate environmental services in forest areas are of particular importance, since they need to represent and monitor fundamental phenomena such as the control of local climate, where extreme weather events are mitigated by the forest. These services and related indicators may also have an impact on the urban morphology, since mapping and understanding of local climate phenomena provide better conditions for managing urban spaces [6]. Together with I(13), the indicator I(8), which expresses the existing plant biomass, is also a member of the group of indicators which are related to environmental services arising from climate and carbon retention. This type of indicator is highly relevant for the sustainable management of vegetation, since forests represent important carbon drainage areas [11].

![Fig. 4 – Degree of acceptance of indicators per attribute.](image)

The indicator I(33) represents the number of academic research studies in forest habitats. This is an indicator related to the environmental services of education and culture. These services are still a little unknown because they have intangible characteristics. Also, their value is difficult to assess both monetarily and biophysically. They are interrelated with other services, and there are few indicators to monitor their non-tangible effects on – or direct contributions to – social systems [5] [7]. It is evident that the cultural services indicators reviewed are generally lacking in terms of conscious conceptualization of the subject to be measured, which may lead to confusing results [53], most specifically about the object of study it is possible to find several works that describe environmental aspects of CIMNC.

The indicators I(41), I(31) and I(43) are also derived from the environmental services of education and culture, which account for the second largest number of indicators per type of service. I(31) has an
innovative characteristic since it is only directed to forest areas which are also used by the Armed Forces for military training. However, this specificity does not mean that the indicator cannot be applied in other types of biomes, such as military training areas in other regions in the world. Indicators derived from cultural services are still incipient, unlike the indicators of other types of services. One reason for this is that transdisciplinarity is required to address non-tangible issues, since by definition cultural services (encompassing physical, intellectual and spiritual interactions with biota) need to be analyzed from multiple perspectives, such as ecological, social and behavioural ones. A second reason is the lack of data for large-scale assessments, as detailed surveys are a main source of information [8].

The indicators I(26), I(27), I(6) and I(5) are related to the environmental services of biodiversity conservation. They are mainly associated with quantitative aspects of the fauna and flora found in the study area and with the existence of endangered species. I(26) specifically addresses the number of native endangered species in the Brazilian Atlantic Forest, like the ones found inside the study area. This indicator was also identified by the interviewees as the one with highest Relevancy thus presenting a degree of almost 100% importance in this attribute (Fig. 4). As to the indicators related to sustainability, most of them are related to the quantifying species, rather than to identifying them [10]. In a study on drawing up appropriate biodiversity indicators for monitoring sustainability on a local level, [54] affirmed that the data derived from such a system would be instrumental in supporting the work of policy- and decision-makers as well as stakeholders.

The indicators I(35) and I(25) were specifically designed to address spatial analysis of the resilience of the forest. Besides that, if associated with other indicators, such as those derived from services of biodiversity conservation, they strengthen the generation of information and provide better conditions for the decision-making process, as stressed by [55]. The indicator I(35), which refers to the area covered by Atlantic Forest inside the study area, was considered the indicator with the highest degree of Feasibility (Fig. 4). [55] mentions that indicators related to resilience are useful for evaluating whether an ecosystem has the ability to keep its function despite the environmental variability.

Despite not being among the priorities of the activities undertaken in military training fields, leisure and tourism activities inside military areas may occur [15]. These activities are directed to the public from both inside and outside the barracks. I(40), I(44), I(24) and I(39) were suggested based on activities which take place inside the study area. Sustainable tourism is currently being consolidated at the international level as an approach which must be used in promoting other types of tourism since it is beneficial environmentally, socially, and economically [19]. A common practice in forest areas is the use of an indicator system for both conceiving and applying a sustainable tourism model, as explored by [36] [19] [20]. Therefore, these kinds of indicators will also have an important role for the study area, since tourist activities take place in the CIMNC [36].

The dynamics of the erosive process is influenced by variations in climate, geomorphology, soil and hydrology of the area, and also by land use and its vegetal cover. Thus, forest environmental protection services against degradation and erosion of rivers are often mentioned by many authors [56] [57] [58] [59]. In this context, the indicators I(24) and I(21) were initially proposed because they measure the extent to which the Catucá Basin is being degraded and forest areas used to prevent landslides from the hillsides, respectively. Surveyed stakeholders confirm they accept these indicators, which they score with high values for Relevancy (Figure 4), and as highlighted by [59] [56] [57] there is a series of techniques and methods used to study erosive processes. These techniques depend on many factors such as the objective of the study, the human and financial resources available, climate conditions, types of soil and environmental conditions. This are probably some of the reasons that many of the interviewees score I(24) as the most difficult to implement.

Finally, the indicator I(29) is related to accidents that occur due to some military training activity with people from outside the MNCIC, and is specific to military forest areas. Stakeholders considered it the easiest to understand among all the selected indicators. It is also important to observe that I(29) has no association with any of the environmental services suggested by [20] (Fig. 03).
4. Conclusions

The development of ES indicators for forest areas, using a participatory process, enables the main services provided with the integration of stakeholders’ views and values to be recognized. This tool could support decision-making about and the management processes of forest areas, and facilitate assessing the state of the ecosystem and reporting mechanisms. In Brazil, as in other countries, large areas of forest are under the jurisdiction of the Armed Forces and are used for military training. Therefore, the ES indicators proposed for the forest case study of a forest, an area under the guardianship of the Brazilian Army, may indicate that their potential use and results could be adapted and applied in other similar areas, at national and international levels.

The set of 26 ES indicators obtained for Atlantic forests reflects the results of a participatory approach in which stakeholders’ perceptions and views were integrated. Some of the indicators identified were specifically tailored for the context of a military forest, and showed an approach that balanced common and tailor-made aspects. Some of these indicators integrated innovative aspects, since they reflect particular features related to nature conservation areas within a military operation and management context, such as the occurrence of accidents, as a result of military activities, to people from outside the study area. This is a similar service to those related to biodiversity protection or hydrologic resources, since all of them also reinforce the physical integrity of humans.

Despite there being a relevant amount of research on ES indicators, studies on their integration and use in the environmental management of natural forest areas is still scarce, since few studies have explored practical applications of data from the indicators, such as the role of stakeholders to support the design, implementation and operation of this tool.

The ES have grown in importance due to the increasingly perceived need to conserve natural resources. ES indicators may be of great use as tools to policy-making in areas where these resources have special value. However, further research should seek to include other forest areas, with different institutional management systems, distinctive legal frameworks, and covering different geographical and socio-economic contexts. Also, approaches on how best to engage stakeholders could be used after the indicators have been selected and identified to explore how to implement and operationalize ES indicators, with a view to obtaining effective and useful outcomes for the management of forest ecosystems that face several pressures from humans.

References


