Structuring contrasting forest stakeholders' views with the Strategic Options Development and Analysis (SODA) approach

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SUMMARY

The study reported here aimed at presenting the structuring of a complex problem that emerges from contrasting perspectives of different stakeholders on the use and conservation of native forests in a context where regulations restrict their management, as occurs in Santa Catarina State, Brazil. The methodology adopted in this work consisted both in the construction of a causal map, based on interviews with stakeholders of Santa Catarina native forests, and in the analysis of the map using techniques of the Strategic Options Development and Analysis (SODA) approach. The analyses carried out indicated that the economic valuation of forest resources as well as the monitoring of forest cover are key issues for the management of Santa Catarina's native forests. In addition, the information generated by the causal map analysis can assist not only the process of designing innovative and all-inclusive policies for the management of native forests, but also the modeling process based on Systems Dynamics in order to evaluate the impacts of policies on the dynamics that govern the conservation and use of the resources of native forests. The adopted SODA approach also proved to be effective in structuring the complex problem situation addressed in this study.

Keywords: Soft OR, SODA, Cognitive mapping, Atlantic Forest

Structurer les points de vue contrastants des intervenants de la forêt avec l'approche Développement et analyse des options stratégiques (SODA)

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L'étude dont un rapport est présenté ici visait à parvenir à structurer un problème complexe émanant des perspectives contrastées de tous les différents intervenants quant à l'usage et à la conservation des forêts d'origine, dans un contexte dans lequel les règles restreignent leur gestion, comme cela se passe dans l'état de Santa Catarina, au Brésil. La méthodologie adoptée dans ce travail consistait en la construction d'une carte des causes, basée sur des interviews auprès des intervenants des forêts d'origine de Santa Catarina, et en une analyse de cette carte, utilisant les techniques de l'approche Développement et analyse des options stratégiques (SODA). Les analyses effectuées indiquaient que l'évaluation économique des ressources forestières, ainsi que le contrôle du couvert forestier étaient des questions-clé pour la gestion des forêts d'origine de Santa Catarina. De plus, l'information générée par l'analyse de la carte des causes est à même d'aider, non seulement le processus de création des politiques d'inclusion générale et innovantes pour la gestion de ces forêts d'origine, mais aussi le processus de modelage basé sur les dynamiques des systèmes pour évaluer les impacts des politiques sur les dynamiques gouvernant la conservation et l'usage des ressources des forêts natives. L'approche SODA adoptée s'est aussi révélée être efficace dans la structuration de la situation problématique complexe qui fait l'objet de cette étude.

Estructuración de perspectivas contrastantes de actores forestales utilizando el método Strategic Options Development and Analysis (SODA)

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El estudio aquí reportado tiene como objetivo presentar la estructuración de una situación problemática compleja que surge de perspectivas contrastantes de diferentes actores sobre el uso y conservación de los bosques nativos en un contexto en el que las regulaciones restringen su manejo, como sucede en el Estado de Santa Catarina, Brasil. La metodología adoptada en este trabajo consistió tanto en la construcción de un mapa causal, basado en entrevistas con actores de los bosques nativos de Santa Catarina, como en el análisis de este mapa utilizando técnicas

de la metodología Strategic Options Development and Analysis (SODA). Los análisis realizados han indicado, entre otros resultados, que la valorización económica de los recursos forestales, así como el monitoreo de la cubierta forestal, son temas fundamentales para el manejo de los bosques nativos de Santa Catarina. Además, la información generada por el análisis del mapa causal puede ayudar no sólo en el proceso de diseño de políticas innovadoras e inclusivas para el manejo de los bosques nativos, sino también en el proceso de modelación basado en la Dinámica de Sistemas para evaluar los impactos de las políticas sobre la dinámica que rige la conservación y uso de los recursos de los bosques nativos. El enfoque SODA adoptado también demostró ser eficaz para estructurar la compleja situación problemática abordada en este estudio.

INTRODUCTION

Brazil is known for its forests and its biodiversity. One of its major biomes is the Atlantic Forest (AF), which originally encompassed 1.1M km^2 of forests (Brazilian Institute of Geography and Statistics – IBGE 2004) stretching along the Atlantic coast from 4° S to 32° S and from sea level to 2 900 m.a.s.l., incorporating various climatic zones and vegetation formations (Mantovani 2003). With a lush biodiversity, this region is considered one of the 35 global biodiversity hotspots (Conservation International 2016). The biome hosts more than 8 000 endemic species of vascular plants, amphibians, reptiles, birds, and mammals (Myers *et al.* 2000). However, the region is also home to approximately 70% of the Brazilian population (Brazilian Ministry of Environment 2013), which has historically been encroaching the forests with urban and agricultural growth.

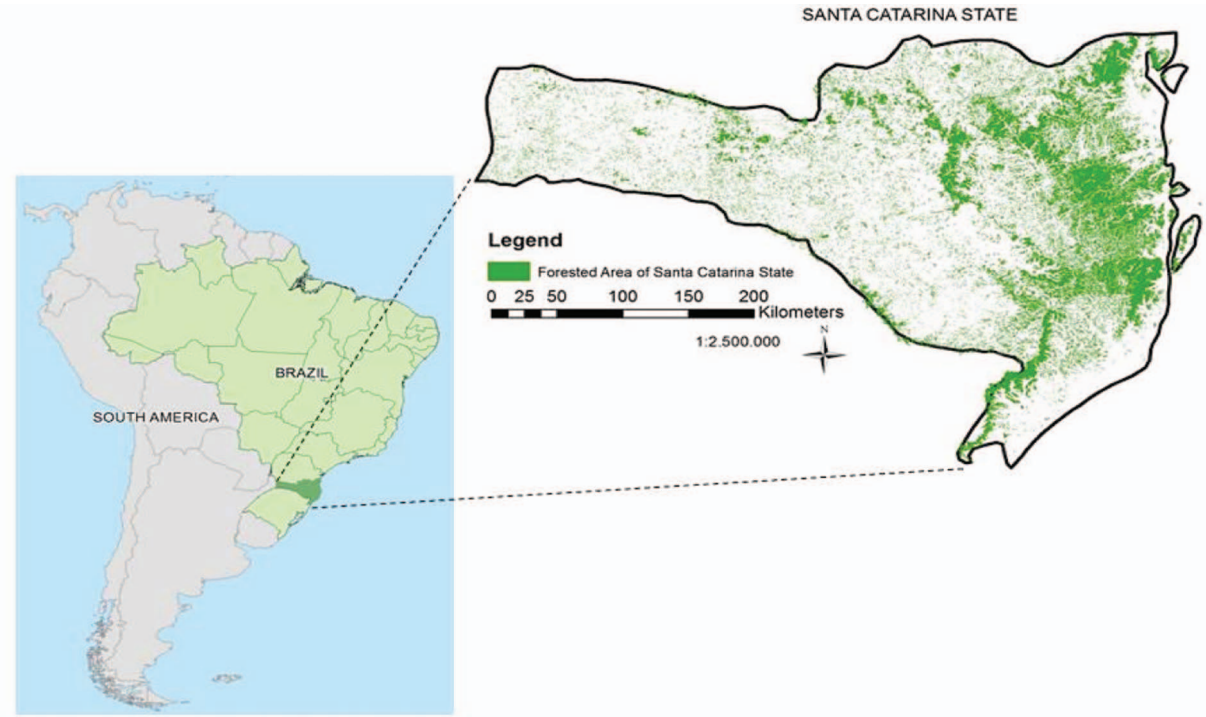
Contained within the Atlantic Forest biome is the state of Santa Catarina (SC) in Southern Brazil which has seven phytogeographical regions, three of which are covered with dense forests: Dense Ombrophylous Forest, Mixed Ombrophylous Forest and Decidual Seasonal Forest. These forests originally extended over 80 000 km^2 (Klein 1978) in the State, but only approximately 26 000 km^2 remins (Figure 1) (Vibrans *et al.* 2012), most of which is degraded to some extent.

As a result of the ecological complexity of these forests, stakeholders have manifested a wide and distinctive variety of interests and perspectives on the possibilities of managing the resources available in the forests, leading to the emergence of an extremely complex social-ecological situation.

Notwithstanding this plurality of points of view on the management options of existing forest resources, Siminsky (2009) draws attention to the restrictive approach of the policies ruling the use and management of local forests, particularly the forest regulations. He points out the necessity of creating more comprehensive policies that could allow a broader range of management options to accommodate the different viewpoints and interests regarding the fate of native forests resources.

According to Mendoza and Prabhu (2006), the formulation of comprehensive forest policies might be facilitated by the adoption of methodologies based on systems approaches applied to groups of stakeholders engaged in a given problem situation in the forest sector. Systems approaches help to capture and to structure the perceptions of different actors engaged in a given problem situation, making them effective

FIGURE 1 *Current native forest cover of Santa Catarina State based on IBGE (2016)*



instruments for achieving culturally acceptable solutions (Masys 2015). Mendoza and Prabhu (2006) have classified the systems approaches widely used for managing complexity in the forest sector into three groups: Qualitative System Dynamics, Fuzzy Cognitive Mapping and Cognitive Mapping. Among these groups, Cognitive Mapping is the most common and has been chosen for this study because it enables different stakeholders' views to be gathered and merged. With respect to the use of cognitive mapping in the forest context, the studies of Hjortsø (2004), Tikkanen *et al.* (2006), Tikkanen *et al.* (2016) and Laakkonen *et al.* (2018) are particularly relevant. These authors have addressed a range of issues using cognitive maps, from improving citizens' participation in strategic forest management, analysing forest owners' objectives, the improvement of regional forest programmes, to a comprehensive understanding of forest owners' attitudes towards climate change and forest management.

Eden and Ackermann (2004) explain that, through using causal mapping and analysis techniques, which form part of the consolidated soft operational research approach known as Strategic Options Development and Analysis (SODA), it is possible to structure a given problem situation and, consequently, to identify and explore potential policy options emerging from stakeholders' perceptions. Thus, the use of these techniques provides many benefits, such as the increase in public involvement in designing forest policies by including stakeholders' perceptions and obligations; a structuring of the planning context; communication of stakeholder perspectives; identification and management of encounters with stakeholders; formulation of a clear decision-making process; and enablement of accountability for final planned outcomes (HjorstØ 2004).

Likewise, this study aims to present how to structure the complex problem situation that emerges from contrasting perspectives of different stakeholders on the use and conservation of native forests in a context where regulations restrict their management, as is the case in Santa Catarina State. By integrating contrasting stakeholders' views into a single consensual model under the SODA approach, it is expected not only to identify relevant issues in the process of formulating a more inclusive and participative policy for managing native forests, but also, and perhaps more importantly, to gain a more comprehensive understanding of their management perspectives.

The remainder of the paper is structured as follows. The initial presentation of the general aspects of SODA including cognitive map analyses is followed by the description of the adopted methodological procedure focusing on stakeholder selection, cognitive mapping process, and data processing. The final part of the paper presents and discusses the results based on map analyses, along with a general conclusion.

STRATEGIC OPTIONS DEVELOPMENT AND ANALYSIS – SODA

General aspects

The Strategic Options Development and Analysis (SODA) was devised in the 1980s by Colin Eden and Fran Ackermann (Eden *et al.* 1983). Since its inception, SODA has been widely used to assist the process of formulating strategies by public and private organizations around the world (Ackermann and Eden 2010). SODA utilizes cognitive maps and causal maps to express thoughts and opinions of a group engaged in a given subject with the purpose of providing support for the establishment of strategies and/or recognition of a certain problem situation (Ackermann and Eden 2010, Eden and Ackermann 2001).

Cognitive maps, introduced by Kelly (1955), are a way of expressing how human thinking is structured and is based on the relationships among different constructs[1]. These maps are composed of several interconnected constructs, following a hierarchical cause-effect relationship. A link between two constructs is represented by an arrow: the rear end position of the arrow represents a cause while the arrowhead position points to an effect or a consequence. Within the map, the relative position of a construct, as well as its number of links, can reveal the importance of links in the entire context (Ackermann and Eden 2010).

When working with a group of stakeholders engaged in a given problem situation, SODA implementation entails various stages following a series of subsequent steps (Banxia Software Ltd 2017):

1. Individual interviews with each member of the group and the elaboration of individual cognitive maps: group members are interviewed individually by a facilitator, and each member presents the problem situation according to his/her perception. Afterwards, each interview is translated into an individual cognitive map;
2. Modelling and Analysis: the interviewer constructs a general map or causal map from each individual map. Through this causal map, it is possible to identify objectives, key issues, opinions, and actions undertaken by specific group members;
3. Group workshop: the causal map is discussed with as many group members as possible, when it is possibly modified for a restatement;
4. Group Decision Support Workshop: the causal map is displayed to all those involved in the problem situation to generate knowledge for the group and to expose other views on the problem situation. Another purpose of this workshop is to identify possible actions, based

[1] A construct is an assertive represented by a pair of antagonistic ideas separated by three points. From this polarization of ideas, it is possible to eliminate ambiguities and subjectivities, providing a higher clarification about the assertive under consideration (Ackermann and Eden 2010).

on a process of facilitated negotiations among the stakeholders;

5. Monitoring, control, and evaluation: the final causal map resulting from this process can be used to track and monitor the action plan progress.

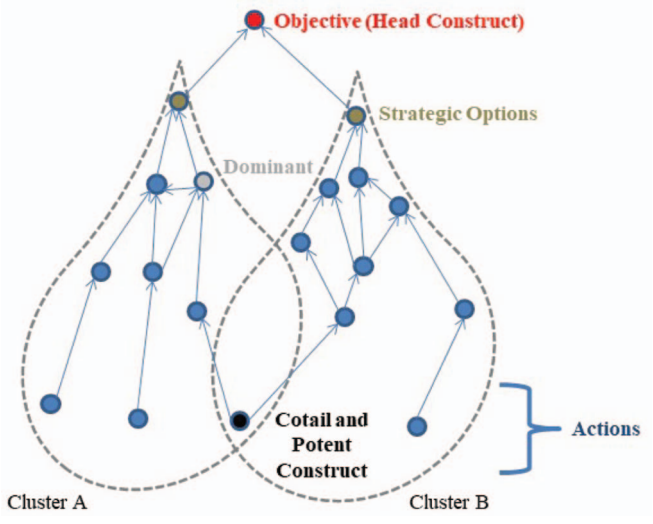
Although SODA has a standard methodological procedure, it is characterized as an extremely flexible methodology and it can present numerous variations depending on the problem situation, such as the client's objective, the availability of the interviewees, the infrastructure available for the interview, as well as the available technological apparatus (Ackermann and Eden 2010, Eden and Ackermann 2013). A clear illustration of adaptability can be observed in Hjortsø (2004), who performed steps 1 and 2 of the SODA and presented the results in the form of a catalog for the stakeholders involved in the problem situation. Bryson *et al.* (2004) have discussed the possibility of using a modified form of SODA to structure a problem situation according to the perception of only one stakeholder.

Map analyses

The realization of analysis in cognitive or causal maps is of quintessential importance in SODA studies. From these analyses it is possible to obtain information about the relevance of certain constructs in the context of a mapped problem situation. These analyses are based on the identification of constructs with privileged positions on the map or with many connections, as depicted in Figure 2, which presents the terminology of some constructs according to the number of connections and relative position in the causal map.

The layout of the causal map shows the hierarchy of constructs. At the top are constructs with long-term goals and objectives, while the lowest constructs represent short-term actions. The constructs at the top of the map are called head constructs, which are likely candidates for representing the objectives of the interviewee group. They receive links only from other constructs located at a lower level (Ackermann and Eden 2010, Eden and Ackermann 2001, Eden and Ackermann 2013). The constructs just below the objectives are called strategic options, i.e. commonly long-term facts which can provide the materialization of the objectives (Georgiou 2011, Georgiou 2012).

FIGURE 2 *Nomenclature of some constructs according to the number of connections and relative position in the causal map, based on Eden and Ackermann (2013)*



Constructs grouped together with one particular strategic option are called a cluster. This arrangement is often in the shape of a tear drop (see Figure 2). It is possible to find more than one cluster on the causal map. The splitting of a map into clusters is known as cluster segmentation (Ackermann and Eden 2010, Eden and Ackermann 2001, Eden and Ackermann 2013). If a construct is part of more than one cluster, it is referred to as a 'potent construct', as it implies its contribution to more than one strategic option. A potent construct is usually found near or at the bottom of the causal map. A construct that is part of a cluster and contains more than one outbound link is referred to as a 'co-tail construct'. This, too, tends to be located near or at the bottom of the map. If a construct has both the status of being potent and co-tail, it necessarily has a higher potential to achieve the construct which represents the objective (Ackermann and Eden 2010, Eden and Ackermann 2001, Eden and Ackermann 2013).

One construct that has many links, either inbound or outbound, is known as a 'dominant construct' and represents key issues in the problem situation (Ackermann and Eden 2010, Eden and Ackermann 2001, Eden and Ackermann 2013).

A causal map may also display a circular or dynamic structure between two or more constructs, showing the presence of a feedback loop (Ackermann and Eden 2010, Eden and Ackermann 2001, Eden and Ackermann 2013). In short, the visual aspects of causal maps assist in providing a quick understanding of complex problem situations.

METHODS

Methodologically, an adaptation of the procedure to apply SODA, tested in a similar problem situation by Hjortsø (2004), was carried out with a group of selected stakeholders. In this study, only steps 1 and 2 of the traditional SODA application (Figure 3) were carried out due to the impracticality of bringing together all interviewed stakeholders in one workshop.

Selecting and inviting stakeholders

Although there is not merely one single manner to select the stakeholders who should participate in a SODA based study, Ackermann and Eden (2011) proposed a stakeholder power-interest grid (figure 4) that can help in this task.

The stakeholder power-interest grid is a classification method of stakeholders of a given problem situation, taking into consideration the relationship expressed by the variables of power and interest: the power to trigger changes in the problem situation and the interest in relation to the problem situation. In accordance with this classification method, stakeholders can be classified into four categories: Crowd,

FIGURE 3 *Overview of the adopted methodological procedure*

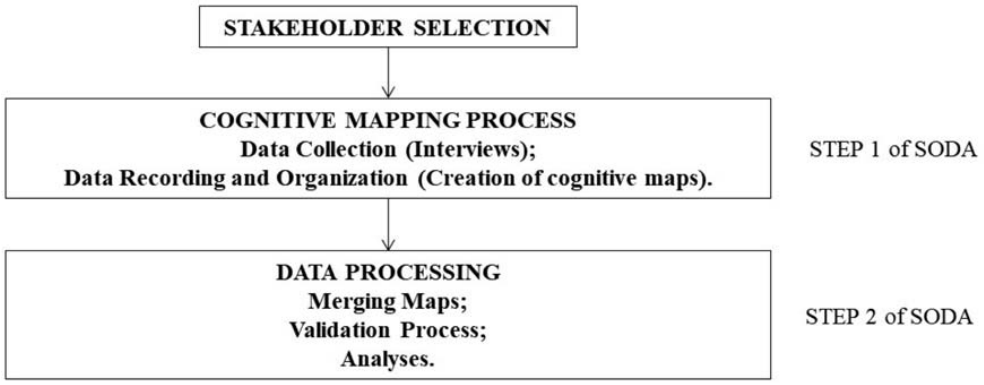
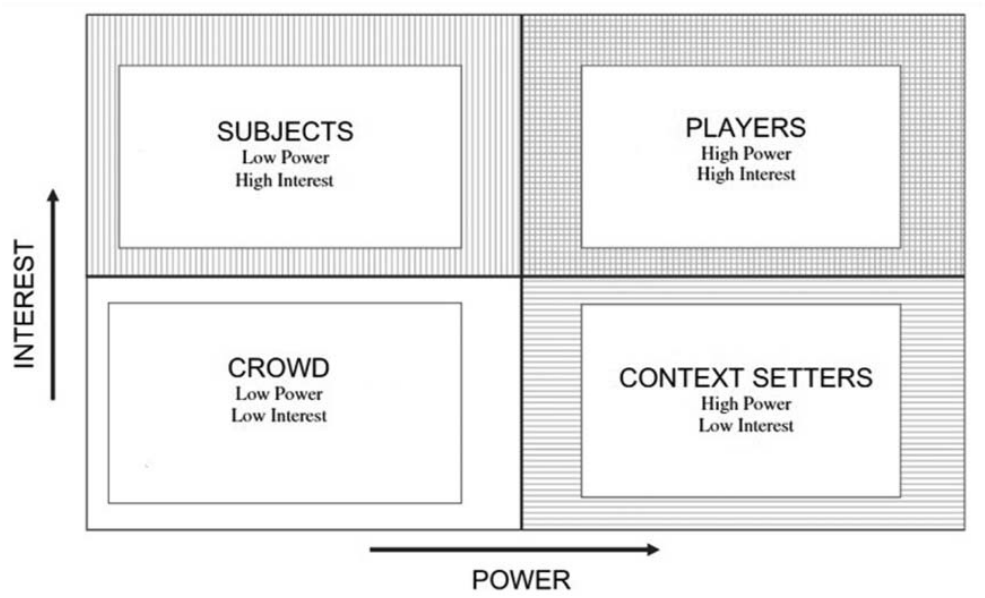


FIGURE 4 *Outline of the stakeholder power-interest grid, adapted from Ackermann and Eden (2011)*



Context Setters, Subjects and Players. The Crowd represent stakeholders who have no interest in the problem situation, nor any power to influence it. The Context Setters refer to disinterested stakeholders, who, otherwise, would have power to influence the situation. The Subjects and The Players refer to stakeholders with interest in the problem situation either without and with the power of influence, respectively (Ackermann and Eden 2011).

According to Ackermann and Eden (2011) stakeholders with more power and interest are those who have a higher potential of contributing to the improvement of a given problem situation. In this sense, those Stakeholders, who are identified as Players, should be prioritized to participate in a study when adopting SODA[2]. Other ways of identifying possible stakeholders to participate in similar assessments can be found in Robertson (2000).

The selection of stakeholders to be interviewed took into consideration two criteria: to ensure the presence of different values and knowledge about forest management in the selected group, and to account for the power-interest of stakeholders as proposed by Ackermann and Eden (2011) in Figure 4. Thus, based on expert knowledge, a list of 20 "Players" was generated, which afterwards were invited to participate in the research through a formal invitation sent by e-mail.

Cognitive mapping process

Data Collection (interviews)

Each interview was conducted at the interviewee's office in order to make the respondent feel as comfortable as possible (Eden and Ackermann 2013). The conversation put the interviewee and the researcher face-to-face for the interview

[2] Evidently, those stakeholders classified according to the power-interest grid as "subject" could also have important views on the problem situation. However, by definition, they do not have the power to influence it. Moreover, if "subjects" were selected, the study could lose its influencing potential, since the feedback occurring in the validation process of the causal map would be on stakeholders who do not have the power to influence the problem situation.

duration of 60 to 90 minutes. Beforehand, a preliminary explanation of the cognitive mapping process was provided. The interviewer collected information about perspectives and goals regarding the utilization of forest resources as well as about measures and actions necessary to achieve these goals.

The first question asked dealt with the stakeholders' views on possible purposes for forest resources in Santa Catarina state. Depending on the interviewee's answer, the subsequent question could contain two possible follow-ups: a "why" or a "how" question. This absence of pre-formulated questions ensured a free-flowing rather than formulaic conversation. However, the interviewer always made sure that the main aspects were covered, namely the objectives of the stakeholders when using forest resources, and the necessary actions to achieve them.

The answers were immediately transcribed as written records, which were also visible and accessible to the interviewee. In case some confusion or doubt emerged on the part of the participant, clarification could be offered instantly. The answers provided during the interview represented the raw data in the data collection process.

Data Recording and Organization (Creation of Cognitive Maps)

All the data collected from the interviews were organized using a mapping capability within the Decision Explorer[3] software. The responses from each interview were systematically organized in an individual cognitive map constructed during the interview, making it visible and accessible for the respondent, and therefore enabling the interviewer to share the given information, as well as providing a sense of ownership to the interviewee. This validation process verified that the answers were correct, and the respondents had a greater sense of active involvement in the study.

Data processing

Merging Maps

The next stage was to merge all individual cognitive maps, thus creating a single causal map. This process, which uses some commands of the Decision Explorer software, consisted of the following steps (Eden and Ackermann 2013):

1. Creation of a new blank Decision Explorer file;
2. Renumbering the constructs of all existing cognitive maps in order to avoid duplicate numbers for different constructs (using the *ren* command);
3. Copying all cognitive maps and pasting them into the previously created file;
4. Locating constructs with the same meanings (using the *find* command) and combining them (through the *merge* command), hence generating a new construct with connections between the original ones;
5. Identifying constructs with no connections, and verifying possible connections (using the *orphan* command);
6. Identifying, correcting and eliminating redundant connections (i.e. two distinct lines of argument with the same meaning).

The resulting causal map brought together and integrated the different perceptions of all stakeholders who participated in this study.

Validation Process

After the merging process, the causal map was sent by email to all interviewees, who were invited to provide feedback in the form of suggestions, criticisms and changes. After having incorporated all feedback comments, a revised causal map was produced. The integration of the received feedback, therefore, served as the validation process of the ultimate and definitive version of the map.

Analyses

To obtain relevant information about objectives common to the stakeholders as well as about the actions leading to their objectives, some analyses in the causal map were carried out with the analysis tools[4] of the Decision Explorer software. In the present study, the following analyses were carried out: head construct, strategic options, dominant constructs, segmentation of clusters in the form of teardrops, potent constructs, co-tails, and feedback loops.

The head, dominant, potent, and co-tails constructs analyses as well as feedback loops analysis were performed through the following commands of the Decision Explorer software: LH, DOMT, POTENT, COTAIL and LOOP, respectively. Whereas strategic options constructs were determined without the aid of software commands since these types of constructs are connected immediately below the head constructs.

Once the strategic options constructs have been determined it is possible to group the constructs that lead to them. This can be done using the HIESET command of the Decision Explorer software, which groups all hierarchically inferior constructs in clearly subordinated positions to each strategic option, thus creating clusters.

RESULTS AND DISCUSSION

This section is divided into three parts. It offers an initial discussion on the methods adopted in the study, followed by

[3] Developed by the British company Banxia Software, Decision Explorer is widely used for managing "soft" issues – the qualitative information that surrounds messy problems. This software allows capturing in detail thoughts and ideas, exploring them to gain new understanding and insight. More specifically, the software enables the construction and aggregation of cognitive maps, allowing their analysis based on graph theory algorithms.

[4] The analysis tools of the Decision Explorer software are largely based on Graph Theory Algorithms. For more information see Eden and Ackermann (2013).

a discussion on aspects related to both the choice of stakeholders and the size of the causal map. The final section presents the results and discussions about the analyses carried out on the causal map.

Discussions on the method

Regarding the creation of individual cognitive maps, the adoption of the SODA approach was extremely successful and was even praised by the interviewees. During the construction of these maps, the stakeholders were very curious about the interview approach, raising several questions about the method. One of the interviewees even asked specific questions about the operation of the software claiming that he was considering replicating the method in a problem situation experienced in his own organization. Besides the interest in knowing about the method, the stakeholders interacted extensively with the computer screen, manifesting their sense of ownership of the map, which is a desirable feature according to Eden and Ackermann (2013).

The process of aggregating the individual cognitive maps did not require much effort, thanks to the tools available in the Decision Explorer software. However, it is noteworthy that the validation of the causal map was somewhat slow and difficult, since the communication with the stakeholders by email is slower, and, generally, less effective than a face-to-face conversation. Additionally, the fact that the causal map has been presented to the stakeholders by email might have made learning more difficult. In the traditional application of the SODA method the causal map is presented and discussed with the stakeholders in person, leading to more interaction among them and, possibly, to a greater learning outcome. Nevertheless, it can be said that the SODA method proved to be suitable for capturing and aggregating the different perspectives of the stakeholders interviewed in the study, since both the individual cognitive maps and the (aggregated) causal map were duly validated by them.

Number of selected stakeholders and map size

Eight of the twenty stakeholders invited to participate in the interview accepted the invitation and were interviewed, representing a range of institutions: three researchers from the Universidade Federal de Santa Catarina – UFSC (Federal University of Santa Catarina); one researcher from the Universidade Regional de Blumenau – FURB (Regional University of Blumenau); one employee from the Fundação de Amparo à Tecnologia e ao Meio Ambiente – FATMA, currently denominated Instituto de Meio Ambiente de Santa Catarina - IMA (Institute for the Environment of Santa Catarina State); one employee from the Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina – Epagri (Agricultural Research and Rural Extensive Service of Santa Catarina State); one employee from the Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis – IBAMA (Brazilian Institute of Environment and Renewable Natural Resources); and one employee from the Assembléia Legislativa do Estado de Santa Catarina (Legislative Assembly of Santa Catarina State).

According to Eden and Ackermann (2013) there is no correct or exact number of stakeholders to build a group suitable for applying SODA. This lack of reference is the result of the different degrees of contribution that diverse interviewees might provide. Hence, one specific interview could be more helpful than ten interviews together (Eden and Ackermann 2013). Despite not having a precise method to establish the necessary number of interviewees in investigations similar to the one being reported here, eight interviewees can be considered a satisfactory number (Eden and Ackermann 2013). This number is within a range in which it is possible to obtain information without getting lost in the complexity resulting from the amount of acquired data.

The causal map validated by the stakeholders presented 37 constructs and 51 connections (appendix A). Given its size, the causal map is presented here segmented in order to facilitate its interpretation and subsequent discussions about its structure. The head constructs are presented first, followed by the connected strategic options. Subsequently, the dominant constructs are presented, i.e. those with a large number of connections. Next, the clusters resulting from the three strategic options are presented, as well as the constructs that are simultaneously co-tail and potent. Finally, the map also presents the constructs that are connected and form a feedback loop.

Map analyses

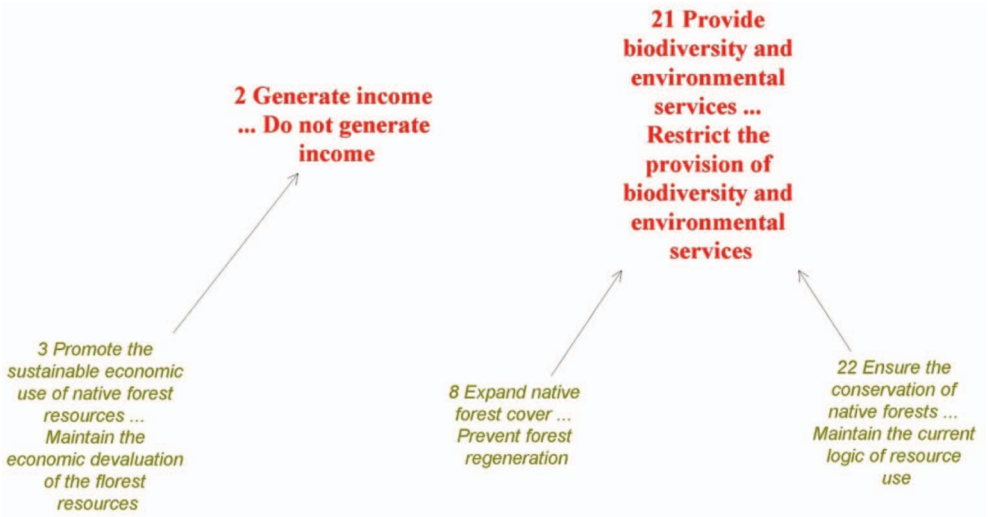
Head constructs and strategic options

The partial causal map depicted in Figure 5 presents the head constructs and the strategic options. The head analysis of the causal map points to two constructs: "Generate income. . .Do not generate income", and "Provide biodiversity and environmental service. . .Restrict the provision of biodiversity and environmental services". The first construct reveals an economic dimension associated with forests, i.e. the fact that they can be seen as a financial resource. The second concerns the major importance of the forest to achieve an ecological balance. On the other hand, the three strategic options represented by the constructs 3, 8 and 22 indicate the main long-term actions that can assure that the head constructs will be implemented.

The generation of income from the economic utilization of forest resources and the provision of biodiversity and environmental services through the conservation and/or expansion of native forest seem to be, at first impression, contradictory activities, and, as such, the result of a dualism (i.e. two different ideas viewed as opposites). However, according to a conservationist line of argumentation, the relationship between these two apparently opposing activities are complementary and, as such, not necessarily incompatible (Milner-Gulland and Rowcliffe 2007).

Besides the results emerging from the head analyses, Siminski (2009) and Fantini *et al.* (2016) also draw attention to the necessity of a conservationist forest management approach in Santa Catarina. Within the main allegations of these authors, the idea can be deduced that the conservation of the existing native forests may, in fact, generate income

FIGURE 5 *Head constructs (in red) and strategic options (in brown) of the problem situation*



through their use, because it enhances life quality of rural populations and, consequently, reduces the migration of youths to the urban centres.

Dominant constructs

The dominant analysis pointed out two key issues represented by the following constructs: "Encourage the economic valuation of native forest resources. . .Maintain preservationist approach" and "Promote adequate monitoring. . .Maintain insufficient monitoring". These two constructs (represented in figure 6 in grey letters) can be interpreted - due to the great number of connections around them - as the central issues about forest management in Santa Catarina. The structure of the causal map suggests that the appropriate economic valuation of Atlantic Forest resources and the monitoring of the forest cover area are influenced by a variety of factors. In the causal map, these factors are represented by all the inbound links connected to these two constructs, as shown in figure 6.

For the context of native forests in Santa Catarina, Siminski (2002, 2004, 2009), Siminski *et al.* (2004), Siminski and Fantini (2007), and Fantini *et al.* (2016), also have discussed the issue of economic valuation of native forest resources as a central theme for forest management. They affirm that farmers have traditionally used resources of the Atlantic Forest as an integral part of their agricultural activities. However, more recent regulations have imposed severe restrictions on the exploitation of forest products, especially timber. Landowners have argued that such restrictions turned their forests valueless. Seeking alternatives to the lost income, landowners have responded to regulations by changing land use from native forests to pastures and exotic tree plantations, which are unregulated activities in the region.

It is noteworthy that prohibiting the harvesting of timber from late secondary forests reduces the possibility of generating income. Secondary forests compose up to 95% of the 12 000 km^2 of forests in the Dense Ombrophylous Forest region in Santa Catarina (Vibrans *et al.* 2012). Fantini *et al.* (2016) estimated the volume of timber stocked in these forests as valued at approximately US$ 3.63 billion. The stock value grows to US$ 7.87 billion if such an estimate is scaled up to the whole forest cover of the State (26 000 km^2). Under a scenario of a sustainable forest management with a harvesting cycle of 20 years, the annual income resulting from the considered activity would be approximately US$ 390 million. Besides economic gains, according to Chazdon (2014), the appropriate economic value of native forest resources can also contribute to the maintenance and growth of native forest areas, encouraging the process of forest regeneration as well as the maintenance of forest cover through sustainable forest management practices.

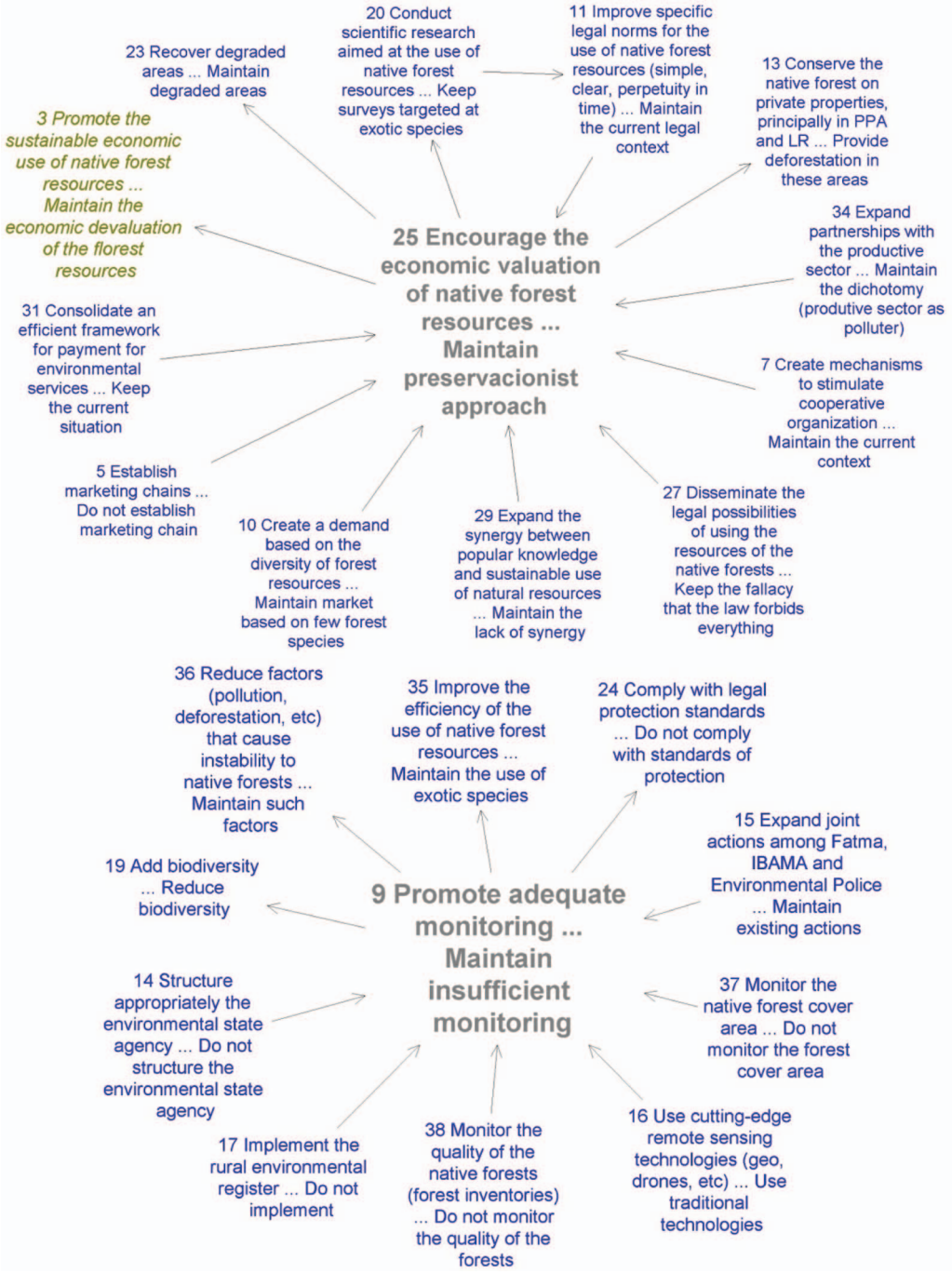
Another key issue illustrated by the dominant analysis in the causal map is the necessity of implementing the monitoring of forest cover (Figure 6). This issue has also been discussed in Arraes *et al.* (2012), who studied the main causes of deforestation in Brazil and its projection in the global context, based on a discrete multinomial ordered model. According to these authors, proper monitoring of forest cover is extremely important for the reduction of deforestation, and consequently for proper forest management. For example, the simulation of the presence of control authorities in each municipality of the Legal Amazon region indicates a significant reduction in deforestation, whose levels have remained close to those found in more developed countries. Schweizer *et al.* (2018) also suggest the control and the monitoring of forest cover as a key issue for the restoration of the forest of Latin American countries.

Clusters segmentation

Based on cluster segmentation (see item 2.2), it is possible to distinguish the most relevant actions to achieve the strategic options identified previously and, consequently, the predetermined objectives. These actions are represented by constructs located at the bottom of the causal map and, more significantly, they appear in all the clusters as co-tail constructs. The three clusters of constructs referring to the strategic options are depicted in the figures 7, 8 and 9.

The assertives identified by the constructs 6, 10, 17, 37 and 38 represent the short-term actions most relevant to the

FIGURE 6 *Key issues identified in the problem situation by the dominant analysis*



achievement of the strategic options and, consequently, also of the pre-established objectives (Figures 7, 8 and 9). These actions, besides influencing simultaneously the three strategic options (long-term assertives), have more than one output connection, thus representing also a cause that may influence a large number of constructs of the causal map. Among all of the most relevant actions, those represented by constructs 17, 37 and 38 already have somehow been incorporated into the management process of native forests in Santa Catarina.

The construct 17 "Implement the rural environmental register. . .Do not implement" refers to the Rural Environmental Register (CAR), created by the Law 12.651, issued in 2012. The article 29 of such law states its goal as "*integrating the environmental information of the rural properties and possessions, composing a data base for the control, monitoring, environmental and economic planning and combat of the deforestation*". CAR can then be considered a supporting tool for managing the resources of native forests. By February 2018, 83% of the rural properties in Santa Catarina were already registered, according to SCrural (2018).

Regarding the actions represented by the constructs 37 and 38, these are linked, to a certain extent, to the "Inventário Florístico Florestal" (Forest Floristic Inventory) of the state of Santa Catarina (Vibrans *et al.* 2013), since one of the

FIGURE 7 *Cluster and the most relevant actions (underlined constructs) referring to the strategic option "Promote the sustainable use of native forest resources. . .Maintain the economic devaluation of the forest resources"*

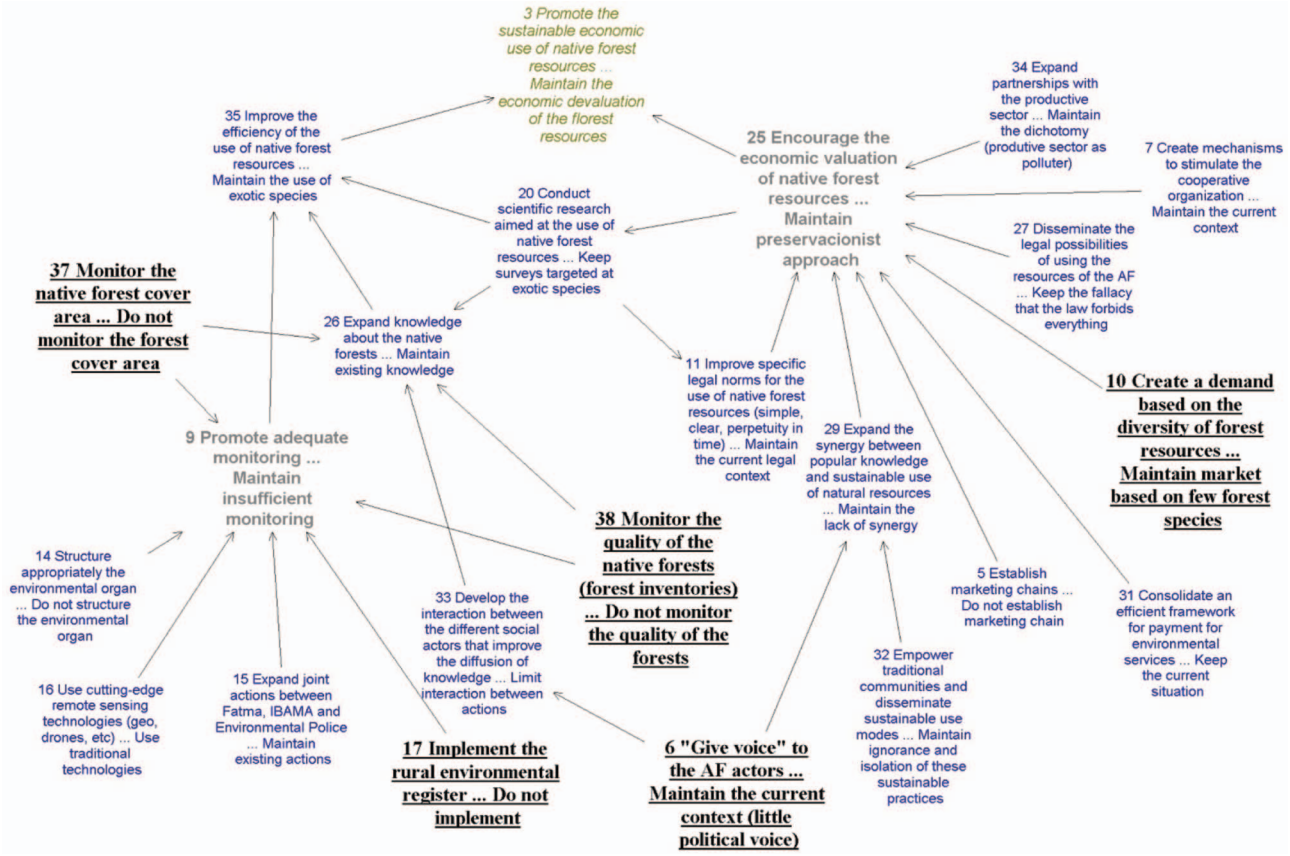


FIGURE 8 *Cluster and the most relevant actions (underlined constructs) referring to the strategic option "Expand native forest cover. . .Prevent forest regeneration"*

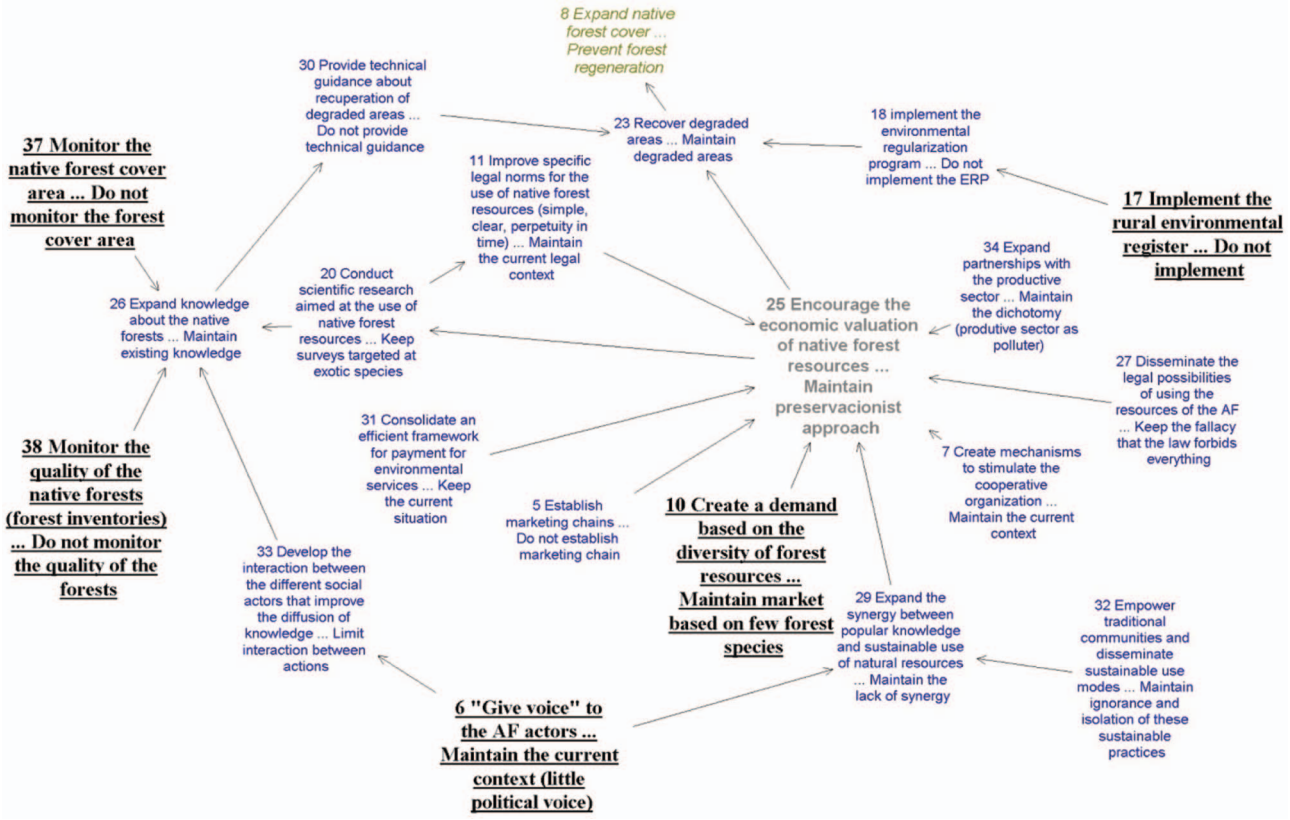
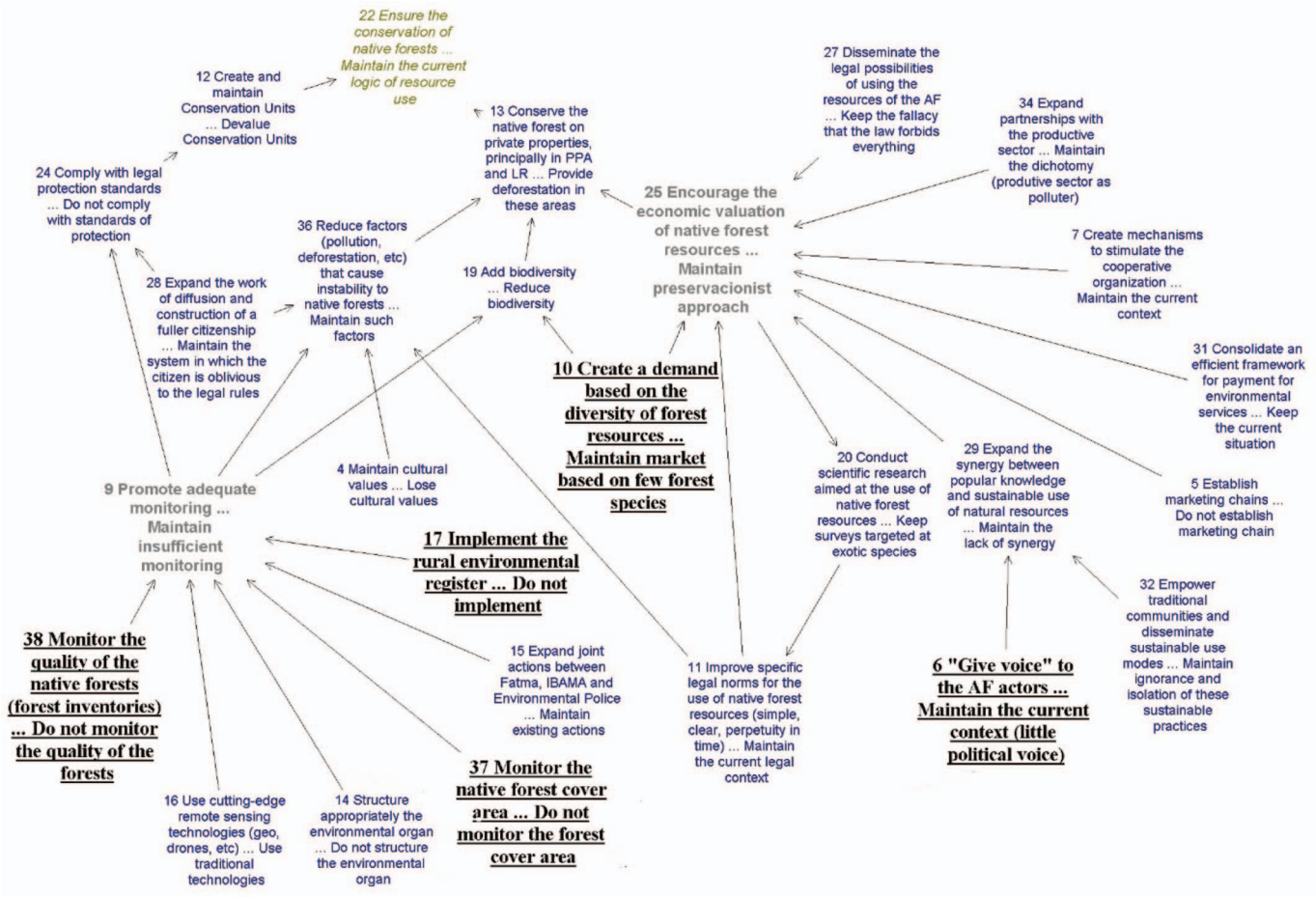


FIGURE 9 *Cluster and the most relevant actions (underlined constructs) referring to the strategic option "Ensure the conservation of native forests. . .Maintain the current logic of resource use"*



objectives of this Inventory is to provide information for monitoring quantitative and qualitative aspects of the native forests of the state. Another aspect common to the causal map and the Inventory refers to the similarity between the goal attributed to the information generated by the Inventory and the meaning of the strategic options. According to these authors, the Inventory aims to provide "*subsidies for the formulation of public policies directed to the conservation of the forests of Santa Catarina and for the adoption of concrete measures of sustainable use of forests resources*" (Vibrans *et al.* 2013). The stated goal includes a conservationist view resulting from the three strategic options, that is, to ensure the conservation and expansion of native forests, as well as to promote the sustainable use of its resources.

The similarity found between the strategic options and the goal attributed to the information resulting from the Forest Floristic Inventory may be explained by the fact that some interviewed stakeholders are affiliated to the organizations that have carried out this inventory. In the authors' view, this similarity gives credibility to the methodology adopted in this study, since it underscores that the stakeholders' perceptions were collected and interpreted in a consistent manner.

Regarding construct 6, "Give voice to the AF (Atlantic Forest) actors... Maintain the current context (little political voice)", Rodrigues (2001) discusses the possible gains related to the participation of traditional communities of the Atlantic Forest in the formulation of comprehensive policies for its management, considering the (practical) knowledge of landowners about the dynamics of use and conservation of forest resources. Their participation may ensure further achievement of their interests, which will contribute to the maintenance of their traditional management practices.

Construct 10 "Create a demand based on the diversity of forest resources. . .Maintain market based on few forest species" refers directly to increasing biodiversity (since there will be an incentive for the establishment of species other than the exotic *Pinus* spp. and *Eucalyptus* spp.). Rico-Gray *et al.* (1990) and Bennett and Robinson (2000) claim that market demand is selective, and consequently, can negatively influence the conservation of the biodiversity of a given forest that provides natural resources. Such an argument builds upon the fact that the market can instigate rampant and, thus, unchecked exploitation of some species (in a scenario of no monitoring), contributing therefore to the ecological imbalance and consequently to the biodiversity loss. Homma (1992) describes the recurrent dynamics of the establishment and growth of the demand of a given forest resource, however, with a slightly different emphasis. Initially, he claims, the profits associated with the harvesting of a forest product increase, hence severely reducing its quantity and quality. As

a consequence, the given resource becomes scarce and its price increases, stimulating the "domestication" of this resource, that is, the cultivation of the species to scale up production.

The above-mentioned domestication process of forest resources – if adapted to the context of the native forests of Santa Catarina in the case of a possible use of its timber resources – could contribute, in the long term, to an increase of the diversification of species of the forest plantations in the state. In this way, other arboreal species beyond Pinus and Eucalyptus would become a viable and attractive option for the establishment of homogeneous forests.

Feedback loop

The feedback loop analysis has pointed to the presence of one circular arrangement, composed of three constructs: construct 11 "*Improve specific legal norms for the use of forest resources (simple, clear, perpetuity in time) . . . Maintain the current legal context*"; construct 20 *"Conduct scientific research aimed at the use of AF resources. . .Keep surveys targeted at exotic species*", and construct 25 "*Encourage the adequate economic valuation of native forest resources. . .Maintain preservationist approach*" (Figure 10).

Siminski (2009) mentions such feedback relationships in his study of secondary forests of Santa Catarina, albeit not presenting them as a circular structure. A feedback loop detected in the causal map might be characterized as a vicious or virtuous cycle, also known as positive or self-reinforcing feedback loop because it amplifies deviations, generates growth, and reinforces change (Sterman 2000). The feedback loop (Figure 10) suggests a dynamic according to which scientific research projects aimed at the use of native forest resources provide the basis to improve regulations for resource use which, in turn, fosters the economic valuation of these resources. As a result, this creates the demand for more scientific research aimed at the use of native forest resources, and so on.

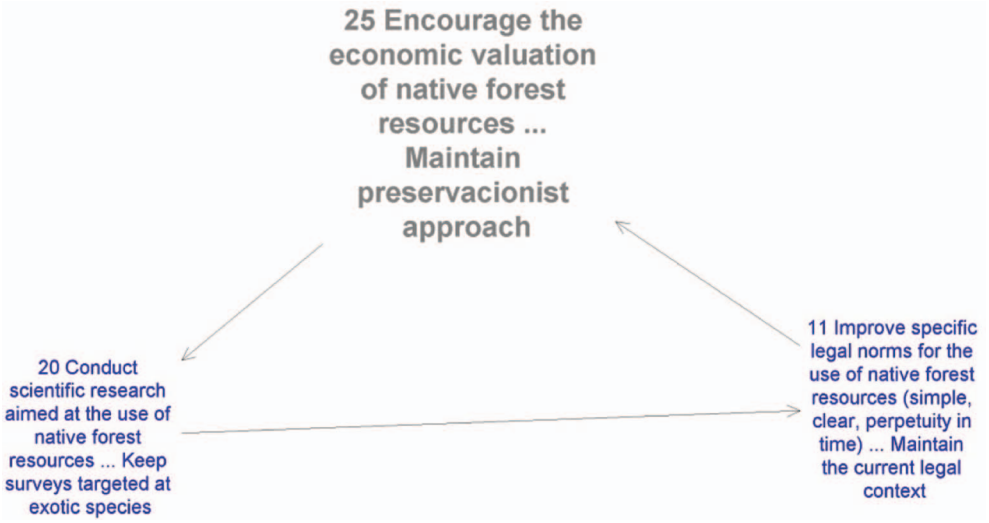
Such a reinforcing cycle (or positive feedback) could stimulate the planting and regeneration of native species, since an economic value will be attributed to them. This, in turn, mitigates the undesired consequences of valueless native forests, as mentioned by Siminski (2002, 2004, 2009), Siminski *et al.* (2004), and Siminski and Fantini (2007).

CONCLUSIONS

The SODA approach adopted in this research and the resulting causal map have allowed the structuring of the complex, wicked problem situation that emerges from the different stakeholder views on the use and conservation of native forest resources in Santa Catarina State. In addition, the analyses carried out on the causal map facilitated the identification of relevant issues to be considered in the design of a more inclusive and participative forest policy based on the conservation of the native forests of Santa Catarina through the use of their resources.

According to the stakeholders interviewed in this project, the native forests of Santa Catarina could not only provide biodiversity and ecosystems services, but also generate substantial income. Thus, it is recommended that the management of these forests should ensure their long-term conservation and expansion as well as the sustainable use of their resources as shown as the strategic options of the causal map. Additionally, it is advisable that the management of the forest resources should focus on their economic valuation and on the monitoring of its remnants (the key issues of the causal map). Among the main short-term actions identified with the analysis of the causal map, it is vital to make the case for the monitoring of the forest cover, the implementation of the Rural Environmental Register (CAR) and the engagement of the stakeholders in the management of native forests (the potent actions of the causal map). In summary, the analysis of the causal map conducted in this study has allowed the

FIGURE 10 *Feedback loop identified in the consensual causal map*



identification of a range of issues and measures that might be taken into consideration in the process of designing policies that are systemically desirable and culturally feasible for the management of the resources of native forests in Santa Catarina.

Although participatory approaches based exclusively on the qualitative interpretation of causal maps may support forest policy-making, such a process is limited in terms of providing a deeper understanding of a given problem situation of interest. Nevertheless, such an interest can be achieved by adopting a systems dynamic modelling approach. Systems Dynamics (SD) is an effective methodology to support the process of policy making in highly dynamic and complex contexts, and its implementation has experienced a growing and increasingly prominent role and acceptance since its creation in the mid-1950s (Sterman 2000). The SD modelling process can build upon and be facilitated by the analysis of a causal map and by the information it generates, as mentioned by Willians *et al.* (1995), Vennix (1996) and Howick *et al.* (2008). A subsequent step in this process would be the development of an SD model aiming to understand how the dynamics that govern the conservation and use of the resources of native forests will be influenced by the wide range of management options made possible by the policy making process. It is recommended that such development is researched and implemented in the near future for the badly needed benefit of forest management.

FUNDING

This work was supported by the Brazilian Federal Agency for Support and Evaluation of Graduate Education – CAPES [grant number 88881.133850/2016-0].

ACKNOWLEDGEMENTS

The authors would like to express their thanks to Liet Hellwig for providing language support and to the referees for their valuable advice.

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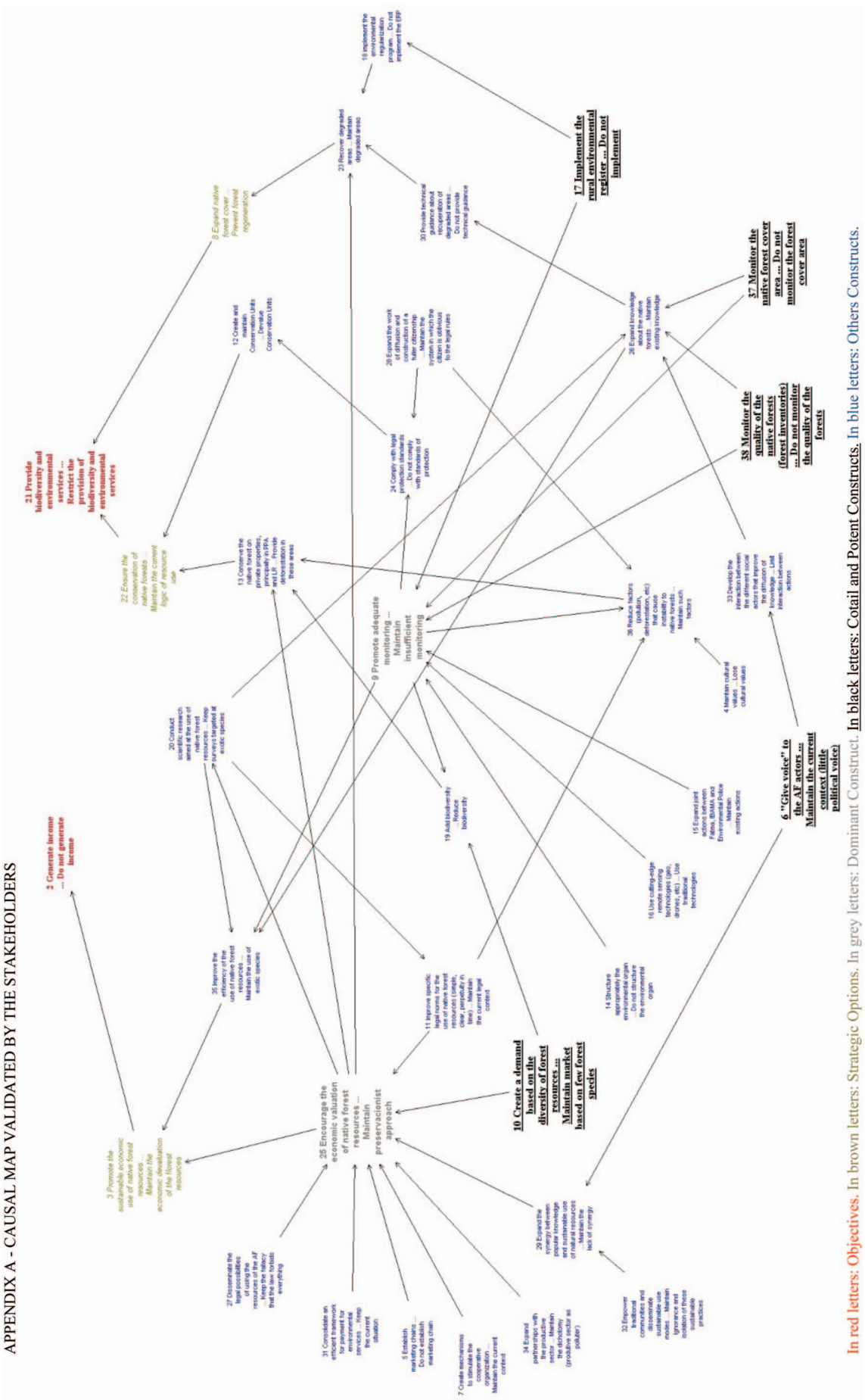
APPENDIX A - CAUSAL MAP VALIDATED BY THE STAKEHOLDERS



In red letters: Objectives. In brown letters: Strategic Options. In grey letters: Dominant Construct. In black letters: Cotail and Potent Constructs. In blue letters: Others Constructs.

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