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Addressing ecosystem services from plan to project to further tiering in impact assessment: Lessons from highway planning in São Paulo, Brazil

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ABSTRACT

Tiering in impact assessment has been advocated for mainstreaming environmental goals into different levels of planning. Likewise, the ecosystem services concept has been receiving increased attention for its potential contribution to the difficult mission of integrating the fragmented views of society's dependence on nature when taking decisions about development proposals and public policies. Using the tiered planning of transportation infrastructure in São Paulo, Brazil, this paper examines the use of the ecosystem services concept as a thread to tiering in impact assessment from the strategic to the project level. By exploring a particular case in the transportation infrastructure sector, we aim at advancing knowledge and drawing lessons about the contribution of ecosystem services as an integrative tool to knit the analysis of impacts at successive levels of planning. The highway affects forest lands and watersheds that provide invaluable services for a large population. By analyzing strategic and project environmental assessments, we found that although ecosystem services underpin three out of five key strategic issues, they were addressed mostly implicitly, both at the strategic and at the project levels, missing an opportunity to integrate societal concerns into the assessment. The explicit and upfront consideration of ecosystem services is necessary to support an integrated assessment and the structured consideration of socio-ecological systems in decision-making and to reveal trade-offs that are usually hidden in piecemeal assessments.

1. Introduction

Mainstreaming environmental strategic goals into decision-making at different levels of planning remains a challenge for impact assessment (IA) practice (Carvalho et al., 2017; Banhalmi-Zakar et al., 2018; Siqueira-Gay and Sánchez, 2019). A coordinated and integrated sequential environmental assessment from policy to plan, to program, and to project level is known as tiering. Tiering can be carried out in three ways: (i) policy or plan or program to projects (vertical tiering), (ii) plan to plan across sectoral plans at the same level (horizontal tiering) and (iii) a combination of vertical and horizontal planning (diagonal tiering) (Arts et al., 2011). In practice, tiering seems to flow downwards most commonly from Strategic Environmental Assessment (SEA) to Environmental Impact Assessment (EIA) (Thérivel and González, 2021). Vertical tiering from policies to projects is rare, with an example being the provisions under the United Nations Convention on

the Law of the Sea for undertaking EIA (Hassanali, 2021). An example of horizontal tiering is the use of river basin management plans as instruments for linking water resources planning with other sectoral planning in Brazil (Santos et al., 2020). In terms of diagonal tiering, Rehhausen et al. (2018) show connections between marine spatial planning and different systems (transportation, transmission grid) through SEA.

Tiering is considered as an important approach to facilitate mainstreaming of environmental considerations in decision-making in sectors such as transportation (Fischer, 2004; Malvestio et al., 2018), waste management (Desmond, 2009; Vieira et al., 2019), energy (Phylyp-Jones and Fischer, 2015) and land use planning (Bond and Cherp, 2000; Marull et al., 2007). Tiering in IA is a way to ensure information is transferred through different levels of planning and assessment tiers by using a combination of science-based data gathering and analysis (Bond et al., 2018) as well citizen perspectives (Thérivel and González, 2021).

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Coutinho et al. (2019) highlighted the scarcity of studies on tiering in IA literature in recent years, and that mostly disappointing results are reported in different jurisdictions. For Thérivel and González (2021, p.9), tiering remains as a “particularly weak aspect of environmental assessment processes”.

Gaps in the linkages between SEA and project EIA are reported in Canada (Noble, 2009), and in the United Kingdom, where Fidler and Noble (2012) found a weak influence of SEA on EIA. Phylip-Jones and Fischer (2015) found similar results from studying SEA-EIA tiering in planning wind energy development in Germany and United Kingdom. In Brazil, key shortcomings in a SEA of highway planning include the narrow scope of strategic issues (Sánchez and Silva-Sánchez, 2008) and limited consideration of these strategic issues in the EIA reports (Turco and Gallardo, 2018). Thérivel and González (2021) also observe weaker tiering requirements in the European IA directives than in the US regulations. On the other hand, Carvalho et al. (2017) verified the influence of SEA in the planning process of three high-speed train projects in Europe and concluded that SEA can be beneficial if developed before project decision-making.

One approach to mainstream strategic environmental goals related to the value of nature in planning processes is applying the ecosystem services (ES) concept (Geneletti, 2015). The value of applying ES has been discussed in many decision-making processes, such as EIA (Rosa and Sánchez, 2015), spatial planning (Barral and Oscar, 2012); urban planning (Cortinovis and Geneletti, 2018), SEA (Partidário and Gomes, 2013); land rehabilitation planning (Rosa et al., 2020) and mine closure planning (Rosa et al., 2018). Particularly, Grêt-Regamey et al. (2017) discuss the advantages of a tiered approach guided by the ES concept, such as ensuring proper information on relevant variables to be considered at different levels of decision.

For Geneletti (2015, p. 21) “SEA has considerable potential for helping to achieve a better inclusion of concerns about ES and their beneficiaries into strategic decisions”. Partidário and Gomes (2013) demonstrated that SEA can drive development opportunities focusing on environmental and sustainability priorities that include ES. The ES concept can provide a means to translate unattended and unintended consequences of policy implementation into human well-being to define the SEA scope to deal with environmental and social issues in an integrated manner (Kumar et al., 2013). Studying practice in Chile, Rozas-Vásquez et al. (2017) emphasize the need of providing institutional guidelines and methodological support for moving forward to integrate ES in SEA in Chile. Gutierrez et al. (2021), finding limited integration of ES in SEA reports in Australia, see wasted opportunities to obtain more substantial benefits from planning and advocate the urgency to evaluate the SEA process with the lens of ES concept.

Applying ES to impact assessment is a relatively recent innovation (Costanzo and Sánchez, 2019) inline with its growing application in other planning contexts. Several advantages were observed in applying ES into EIA, such as improving stakeholder engagement, including the perspective of affected communities in determining impact significance and designing mitigation measures; and identifying impacts on livelihoods that may otherwise be overlooked (Rosa and Sánchez, 2016); adding value to the assessment process by avoiding trade-offs in achieving benefits from ES (Karjalainen et al., 2013); and facilitating an integrated analysis of social and biophysical impacts (Slootweg et al., 2010).

From this background, we found a gap in the literature that is exploring the application of the ES concept from planning to project. We aim to simultaneously contribute to furthering the discussion of tiering and the use of ES in IA practice. This paper examines the use of the ES concept as a thread to tiering in impact assessment from the strategic to the project level. By exploring a particular case in the transportation infrastructure sector, we aim at advancing knowledge and drawing lessons about the contribution of ES as an integrative tool to knit the analysis of impacts at successive levels of planning. To gather empirical evidence to illustrate the inquiry, we study the successive assessments of

a major highway in São Paulo, Brazil, which affects important ecosystems that provide services to several beneficiaries.

2. The reviewed case: from planning to projects

A major project to improve transportation in Brazil's largest metropolitan area, São Paulo, comprehends a peripheral highway, approximately 175 km long, with the purpose of reducing congestion and air pollutant emissions due to the high volume of freight traffic in urban districts. Named *Rodoanel*, it was planned to be sequentially implemented in four sections (respectively West, South, East, and North) along several years (Fig. 1).

Although initially conceived as a single project, a SEA report for the so-called *Rodoanel* program was prepared to better understand its region-wide impacts and to provide structured environmental guidance for route selection. Separate EIA reports were prepared for each section (Gallardo et al., 2015; Gallardo et al., 2016). The construction of the West section was completed in 2002, the South section was concluded in 2010, the East section in 2014, while the North section is still under construction in 2021. The assessment of individual projects is guided by terms of reference tailored to their context (Borioni et al., 2017). In this case, the preparation of terms of reference for each EIA was informed by recommendations from the SEA.

Construction works required vegetation clearing and significant volumes of earthmoving near protected areas and water reservoirs, affecting ES supply. Furthermore, the highway was expected to contribute to urban sprawl (Sánchez and Silva-Sánchez, 2008), threatening the integrity of these areas and the flow of their services in the long run. *Rodoanel* affects catchments providing water supply to the metropolitan region, as well as remnants of native Atlantic Forest and protected areas in the São Paulo City Green Belt Biosphere Reserve (GBBR), a 24 thousand km² area considered as the largest biosphere reserve in an urban context. A recent review of ES in the GBBR showed that relevant provision, regulation, cultural and support ES are provided in this area that contains 17.4% of the total area with native vegetation in the state of São Paulo (São Paulo, 2020). Although awareness of these pressures was presented in the public discussion of the *Rodoanel* Program (Sánchez and Silva-Sánchez, 2008), they were not framed in terms of ES.

The relevance of ES in this context is reinforced by evidence from public hearings, both of the program and the projects. Water flow and quality and conservation of forests were major concerns raised by the public and considered in the review conducted by the environmental agency. This is in line with the recent discourse on ES-informed decision-making stimulated by the publication of the GBBR plan (São Paulo, 2020) and the growing importance of new legal requirements of payment for environmental services.

3. Review methods

This exploratory research was based on document review and conducted at two levels of analysis:

- 1) we analyzed how ES were considered in the SEA and the EIA reports;
- 2) we drew on the literature to devise the use of the ES concept as a thread to tiering to identify opportunities to add value to tiering for IA practice.

Documents reviewed are the *Rodoanel* Program SEA report (São Paulo, 2004), the three EIA reports for the South (Fundação Escola de Sociologia e Política de São Paulo – FESPSP, 2004), East (São Paulo, 2009), the North (São Paulo, 2010) sections of the highway and their respective technical opinions prepared by the State EIA Division of the Environment Department.

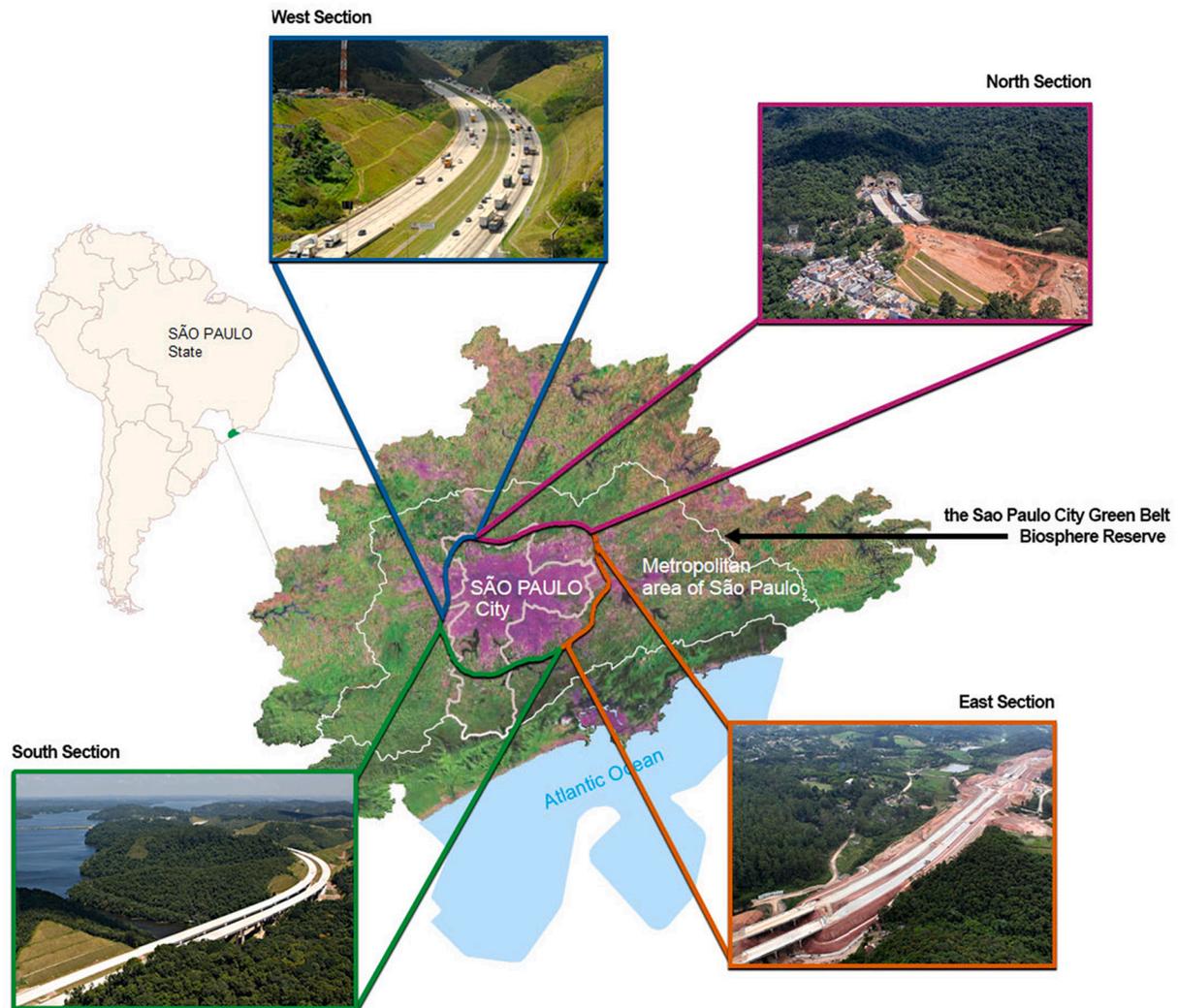


Fig. 1. Rodoanel highway and its four sections.
Source: The map is modified from [São Paulo \(2020\)](#).

3.1. Analyzing the ecosystem services contents in the SEA and EIA reports

Guidance about integrating ES into IA, such as [IFC - International Finance Corporation \(2012\)](#) and [Landsberg et al. \(2013\)](#), recommendations from the literature, including [Slootweg et al. \(2006\)](#); [Rounsevell et al. \(2010\)](#); [Burkhard et al. \(2012\)](#); [Honrado et al. \(2013\)](#); [Partidário and Gomes \(2013\)](#), [Rosa and Sánchez \(2016\)](#) and general guidance from sources such as [Ranganathan et al. \(2008\)](#) provide advice on how best to incorporate ES into planning. To choose an analytical approach to review the case, we considered those described and previously tested for integrating ES in IA at different planning levels. The framework developed by [Honrado et al. \(2013\)](#) for evaluating ES in EIA and SEA reports was used as the key reference, while the Millennium Ecosystem Assessment ([MEA - Millennium Ecosystem Assessment, 2005](#)) classification of ES (provision, regulation, cultural, and support) was applied. The SEA and EIA reports were reviewed to identify if ES were considered and how - explicitly or implicitly, as proposed by [Honrado et al. \(2013\)](#) ([Fig. 2](#)).

3.1.1. Analyzing the ecosystem services contents in the strategic environmental assessment report

The Rodoanel Program SEA ([São Paulo, 2004](#)) presents the results of its environmental viability assessment, as well as the strategic issues associated with its gradual implementation, over sections, in a fifteen-

year horizon, defining the guidelines for individual environmental studies.

To extract ES-related contents from the SEA report ([São Paulo, 2004](#)), two chapters were used: (i) strategic issues and (ii) guidance for the subsequent analysis of routing alternatives in each EIA report of the three planned sections of the highway. Qualitative content analysis was used to analyze the five major strategic issues presented in this report - namely “transportation, circulation and metropolitan logistics”; “use and occupation of metropolitan territory”; “use and consumption of natural resources and protection and conservation policy”; “protection of freshwater resources and water supply”; “air quality and climate conditions in the metropolitan territory” - plus the strategic guidelines for the development of the three sections (South, East, and North, the West section was built before the SEA).

We used guidance from [Honrado et al. \(2013\)](#) to evaluate explicit and implicit consideration of ES in the report. The criteria for ES explicit analysis ([Fig. 2](#)) comprises, according to [Honrado et al. \(2013\)](#), six levels: (1) ecosystem - identifying the ecosystems affected by the development can reveal relevant ES to different stakeholders; (2) ES identification - mentions to terms and concepts that can be associated with any of the ES established by [MEA - Millennium Ecosystem Assessment \(2005\)](#); (3) stakeholders - identification of groups of people that can be affected by the supply or demand of ES; (4) drivers of change that directly or indirectly affect the ecosystems; (5) benefits -

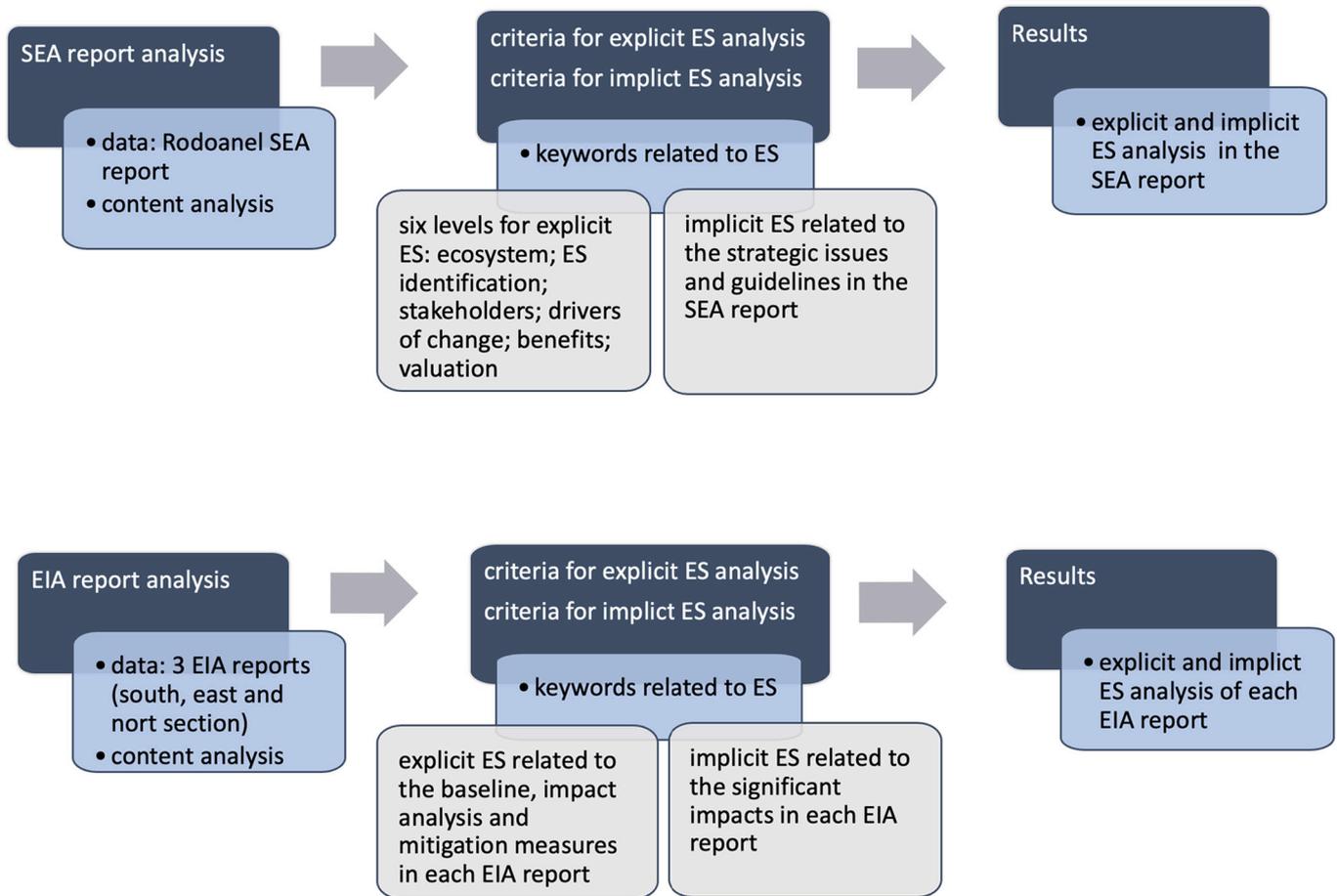


Fig. 2. Roadmap for analyzing ES in SEA and EIA reports.

recognition of the benefits that people can obtain from the identified ES; (6) valuation – how to manage valuation and its management, therefore, consider the effects of different pressures and also for promoting discussion among the different stakeholders.

For the analysis of the five major strategic issues and the strategic guidelines sections of the SEA report, we performed a qualitative content analysis using keywords associated with ES as record units or units of analysis. Then a semantic analysis was carried out to study the meaning of the record units, considering their content and context, to verify if the context in which the keyword was used is consistent with inferences of any of the six levels of the criteria for ES analysis. After unitizing, we sampled the collection of units of analysis that represent explicit ES-related to the six levels of analysis of [Honrado et al. \(2013\)](#). To capture implicit ES we used the same procedure in order to infer ES related content. The product of this analysis was tabled and related to either explicit or implicit ES in the reviewed documents.

3.1.2. Analyzing the ecosystem services contents in the environmental impact statements

Two approaches were used for extracting and analyzing data from the three EIA reports ([FESPSP, 2004](#); [São Paulo, 2009, 2010](#)) ([Fig. 2](#)). Firstly, to explore the explicit consideration of ES, we reviewed the baseline, impact description, and mitigation chapters of each EIA report, searching for terms and concepts that can be associated with ES. For the first scan, we used expressions and keywords related to ES and the categories or subcategories presented in [MEA - Millennium Ecosystem Assessment \(2005\)](#). After identifying explicit ES, to understand information potentially allowing the estimation of impacts on ES, a qualitative content analysis ([Creswell, 2014](#)) was performed. We considered

each ES identified as the unit of analysis. For each text selected containing the unit of analysis (identified explicit ES) additional aspects were explored, such as description, spatialization, and quantification of ES, as recommended by [Honrado et al. \(2013\)](#). The product of this analysis is presented in a table that also provides the number of explicit ES mentions, with examples of its description.

Secondly, to explore implicit mentions to ES, we focused on significant impacts identified in each EIA report. Impacts classified as of “medium” or “high” significance (regardless of whether positive or negative) were considered and those classified as of “low” significance were discarded, assuming that their relationship with potential ES would be negligible. For each impact selected, a search was made for keywords related to each category of ES as established by [MEA - Millennium Ecosystem Assessment \(2005\)](#), classified as the units of analysis, by quantitative and qualitative content analysis ([Creswell, 2014](#)). The products of this analysis are presented in two tables: one shows the number of associations between impacts and implicit ES; the other summarizes the analysis of implicit ES according to the categories and sub-categories of [MEA - Millennium Ecosystem Assessment \(2005\)](#).

3.2. Exploring ES integration within SEA and EIA reports as a way of promoting tiering in IA

[Honrado et al. \(2013\)](#) proposed a framework named Ecosystem Services in Environmental Assessment framework – ESEA to infer ES in SEA and EIA reports. This framework is expected to allow a systematic consideration of ES to promote better practice in SEA and EIA. However, the authors did not apply the framework for their evaluated sample of EIA and SEA reports and did not propose its use for studying tiering.

Here we use the ESEA framework alongside insights from the literature (Arts and van Lamoen, 2005; Arts et al., 2011; Coutinho et al., 2019; Thérivel and González, 2021; Slootweg, 2021) for exploring ES integration within SEA and EIA as a way to promote tiering in IA (Fig. 3).

For Honrado et al. (2013), the three main components of the ESEA framework – integration, evaluation, and quantification - may allow for considering the relation between the ecosystem’s capacity to supply services and the society demand as well as drivers of changes. From Fig. 3, we applied the five-stage framework to analyze:

- the SEA report, to explore the status of ES in the strategic approach to planning;
- the set of EIA reports, to verify if either explicit or implicit consideration of ES contains relevant information for evaluating ES and for supporting assessment, monitoring, and mitigation of impacts on ES supply.

Finally, we jointly apply the 5 stage-framework for the SEA report and the set of EIA reports in search of evidence of tiering and to explore how this integration could be fostered by the ES concept. Supported by our results and some insights from the literature, we discuss insights on how tiering could be embedded using the ES concept to SEA followed by EIA.

4. Results

The results are presented in this section, following the research steps depicted in Fig. 2.

4.1. Analyzing ecosystem services in the Rodoanel program SEA report

The findings of the analysis of the explicit and implicit ES contents in the SEA report are presented in Table 1.

In accordance with the categories for the analysis of ES explicit consideration of ES in SEA (Honrado et al., 2013) two-out six criteria were not met (Table 1). “ES identification” and “Valuation” are entirely absent, while “Ecosystems”, “Stakeholders”, “Drivers of change” and “Benefits” are mentioned. For the strategic issues analyzed, ecosystems were identified, but stakeholders were generically described without identification of interest groups that could be affected by a possible decrease of ES supply. The drivers of change were not explained in any detail, being generically presented as “highway building”. Although it is

undoubtedly the main driving force, it can trigger other not described driving forces that can affect ecosystems and their supply of services, such as urban sprawl. Benefits are relevant, but they were identified in a generic way, without linkage with their respective beneficiaries.

Some ES could be implicitly inferred for three out of five strategic issues (regulating and provisioning services) and for the three sections (regulating, provisioning, and cultural services). The spatial accuracy of the alternatives may be responsible for more detailed coverage of the ES when compared to the scope of the strategic issues.

Although ES that could be affected were implicitly identified, they were neither integrated in the strategic planning nor into the SEA recommendations for further consideration of these services in lower tiers of planning. There is no prioritization of ES and stakeholders were grouped in the generic all-encompassing category “population”; therefore, its involvement failed to be discussed.

As a result, SEA did not transfer any structured guidance to develop alternative routes for highway sections that could safeguard the provision of ES.

4.2. Analyzing ecosystem services in the environmental impact assessment reports

Table 2 summarizes the findings of the analysis of the consideration of explicit ES in the three EIA reports.

Despite the absence of guidance, two services – freshwater and pollination – were explicitly considered. Freshwater was examined under impacts on land use and water resources, while pollination was discussed within biodiversity issues. Specific mitigation measures were proposed only for impacts on freshwater. Freshwater was better featured, in terms of spatialization and quantification, in the most recent reports – East (São Paulo, 2009) and North (São Paulo, 2010) sections. However, water resources in the South section present the greatest vulnerability, as the highway affects two of the main water reservoirs of São Paulo city. Regarding pollination, the EIA report of the North section (FESPSP, 2004) presented a less detailed description, but it is exactly the section that affects an Atlantic Forest State Park.

Table 3 summarizes the findings of the analysis of the consideration of implicit ES in the three EIA reports.

It was found that 61 out of 94 impacts described in the EIA reports have no association with any type of ES; 18 have more than one association and 15 only one association. The impacts associated with ES are mainly on the physical environment (17 impacts with 29 associations)

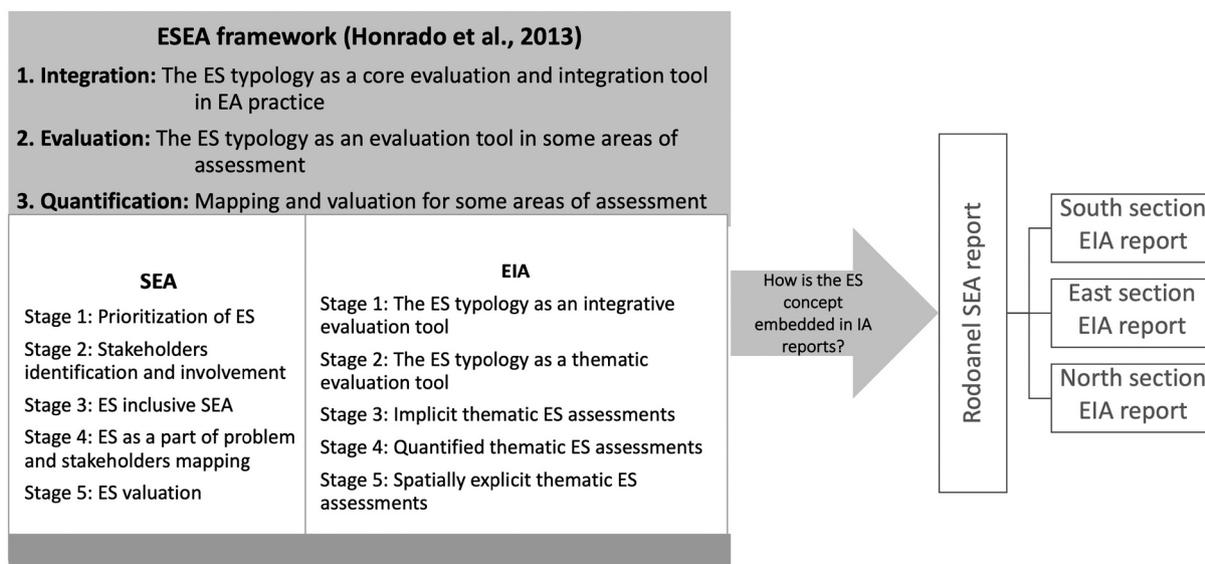


Fig. 3. Roadmap for analyzing the status of ES integration within SEA and EIA reports and supporting the discussion of IA tiering embedded in the ES concept.

Table 1
Analysis of explicit and implicit consideration of ES related to the main issues and the strategic approach to the road route alternatives presented in the SEA report.

Key sections of the SEA report		Explicit consideration of ecosystem services in the SEA report						ES implicitly considered in SEA
		Ecosystem	ES identification	Stakeholders	Drivers of changes	Benefits	Valuation	
(i) Strategic issues	Transport, circulation and metropolitan logistics	Not considered	Not considered	Not considered	Not considered	Not considered	Not considered	Not considered
	Use and occupation of metropolitan territory	Not considered	Not considered	Not considered	Not considered	Not considered	Not considered	Not considered
	Use and consumption of natural resources and protection and conservation policy	Forests, protected areas	Not considered	Population	Highway building	Not considered	Not considered	Water quality regulation, erosion control
	Protection of freshwater resources and water supply	Forests, freshwater, wetlands	Not considered	Population	Highway building	Drinking water supply	Not considered	Freshwater provision; water quality regulation
	Air quality and climate conditions in the metropolitan territory	Forests, protected areas	Not considered	Population	Highway building	Decrease of heat islands and air quality	Not considered	Air quality regulation; climate regulation
(ii) Strategic guidelines for the development of the three sections	South Section	Forests, protected areas, floodplain, wetlands	Not considered	Population	Highway building	Protection of springs	Not considered	Freshwater provision, water quality regulation; erosion control; recreation and ecotourism; cultural diversity; spiritual and religious values
	East Section	Forests, protected areas, floodplain, wetlands	Not considered	Population	Highway building	Flood cushioning and sediment containment	Not considered	Freshwater provision; water quality regulation; erosion control
	North Section	Forests, protected areas, Atlantic Forest Park, floodplain, wetlands	Not considered	Population	Highway building	Urban recovery and environmental protection	Not considered	Freshwater provision; genetic resources provision; water quality regulation and erosion control

Notes: data from [São Paulo \(2004\)](#), categories for analysis of explicit consideration of ES from [Honrado et al. \(2013\)](#).

and the biotic components (11 impacts with 22 associations). The socio-economic impacts (66) are the least associated with ES (only 8 associations), possibly because these impacts are generally related to economic issues or to social impacts not directly linked to changes in the biophysical environment.

The EIA report of the East section presents the largest number of impacts associated with ES (25 associations), mainly the biotic impacts (16); followed by the EIA of the North section, with 19 impacts associated to ES and the South section with 15 impacts. In the EIA report of the South section, only provisioning and regulation services could be associated to impacts, while the EIA report of the North section also encompassed supporting services; finally, the EIA report of the East section covered the four categories.

The baseline and the description of impacts on the biotic components were presented in more detail for the East section, resulting in more associations (12 for the East section, 6 for the South section and 4 for the North section). The characterization of physical impact is very similar in the three reports. However, the greater number of associations for the East and North sections results from the more detailed description of baseline and impacts assessment. [Table 4](#) presents a description of some examples of implicit references to ES from the list of impacts identified in each EIA report.

According to [Table 4](#) regarding the categories of ES, 19 associations were found for provisioning services, 29 associations to regulating, 1 association to cultural and 10 associations to supporting. Freshwater is the most cited service in the three EIA reports followed by erosion control and water regulation. Nevertheless, the latter is more evident in the EIA report of the South section that crosses a water reservoir. Habitat

is an ES implicitly mentioned in two of the three EIA reports; it is absent in the EIA report of the South Section. The East Section EIA report presents the best distribution of ES implicitly considered compared to the other EIA reports. It is the only one that considers one cultural service and one supporting service. Although these ES can be inferred by implicit analysis, their description does not allow performing a valuation. The information found in the EIA report did not sufficiently detail the quantification or spatialization of these services.

4.3. Exploring ecosystem services integration within SEA and EIA reports and its potential role in tiering

Implicit consideration of ES was observed from the program to the project level. Provisioning and regulation services are most frequently cited in the reports. Provision of freshwater is the service most frequently considered in the SEA report and analyzed in more detail in the three EIA reports, either explicitly or implicitly, including mitigation and monitoring measures. Considering only provision of freshwater, evidence of tiering includes it being mentioned in two out of five strategic issues, in the guidelines for developing terms of reference for the EIA reports and in their uptake by those reports, receiving not only implicit but also explicit consideration.

In addition, six other ES (regulation of water quality; erosion control; regulation of air quality; genetic resources; regulation of climate; recreation and ecotourism) were implicitly considered both in SEA and EIA, showing that these issues were tiered down. Moreover, four ES (habitat; biological raw materials; regulation of pests and diseases; nutrient cycling) were implicitly considered only in EIA reports.

Table 2
Examples of results of explicit association of ES in the EIA reports.

EIA report	Explicit ES/number of explicit considerations (1)	Example of the explicit consideration of ES in the EIA reports (2)
South section	Freshwater (23)	Pressures on the fresh surface and underground water are described, highlighting the situations of greatest risk and vulnerability and with the spatialization of some of the most susceptible and environmental components that can be affected, such as aquatic fauna.
	Pollination (3)	The fragmentation of vegetation affects the reproductive capacity of many species (i.e., pollination and spread of propagules) and interferes with the natural process of succession. The location of the remaining fragments that may have this service affected is presented, as well as the most vulnerable species.
East section	Freshwater (36)	The characterization of the ES is described in detail in terms of surface and underground resources, potential impacts on springs, bodies of water for both human activities, and aquatic and related fauna. Some aspects are spatialized, and the quantification of services is discussed for the future details of the executive project.
	Pollination (3)	The fragmentation of vegetation affects the reproductive capacity of many species (i.e., pollination and spread of propagules) and interferes with the natural process of succession. The location of the remaining fragments that may have this service affected is presented, as well as the most vulnerable species.
North section	Freshwater (34)	The characterization of the ES is described in detail in terms of surface and underground resources, potential impacts on springs, bodies of water, and reservoirs for both human activities and aquatic and related fauna. Some aspects are spatialized, and the quantification of services is discussed for the future details of the executive project.
	Pollination (1)	Some sections of the highway will be close to their forests, which may cause the frightening of the fauna mainly during the works and, potentially, in the operation of the highway, due to the noises originated. Given the close relationship between fauna and vegetation, regarding pollination and dispersion of plant species, the potential scare away of fauna may cause changes in the structure and diversity of these forests in the long run. There is no spatial definition of where these ES will be affected, or about species.

Notes: (1) – the number in brackets represents the number of times the ES is explicitly featured as a regulation service or a provision service in the text of each EIA report. (2) – direct quotations from the EIA reports.

The results of the analysis of the integration of ES by applying the ESEA framework (Fig. 3) are presented in Table 5 for the SEA report and in Table 6 for the set of EIA reports.

Table 5 synthesizes how far the ES concept is from having a prominent position in strategic planning decisions of the Rodoanel Program. Since stages 1 and 2 of integration, ES have not been included in the planning process, as confirmed by the absence of a careful definition of affected groups of people without distinction for drivers of change or stakeholders and with little detail about benefits. Hence, stages 3 and 4

of evaluation were impaired and there is no evidence that decision-makers were aware of the importance of impacts on ES. The quantification stage has thus not been reached, as necessarily stems from the previous states. Monetary values of ES, considered by Honrado et al. (2013) as important to attract the attention of decision makers are not mentioned.

The results presented in Table 6 show how far is the ES concept from being integrated into the EIA reports. ES are expected to be explicitly considered to support the integrated assessment of impacts, conflicts, and trade-offs for addressing mitigation measures. In the East Section conflicts about water uses, affecting other categories of services (conflicts with irrigation activities, recreational fish farming) and trade-offs (interferences with springs and water pollution affecting fauna diversity) could be identified. In the North Section, trade-offs were identified in terms of interferences with the availability of water for forests formations, aquatic communities, and springs due to possible disturbances in groundwater, but conflicts were not discussed. The EIA report of the South Section only mentions that there will be no conflict between water quality and urban supply.

According to Honrado et al. (2013), even if ES are implicitly considered in EIA, they can still play a relevant role in decision-making. Six ES were implicitly considered in the SEA report and associated with the impact analysis of the three EIA reports, but their presence did not result in a more in-depth assessment of these impacts. The application of ES as a concept that integrates the biophysical and socioeconomic valued components and processes was not properly found here. None of the analyzed EIA reports present quantified and spatially explicit assessments of the affected ES (stages 4 and 5 – Table 6).

According to the public and environmental agency concerns about the pressures on ES by the highway program and projects, the recent and wide-ranging baseline of ES of the São Paulo metropolitan region (São Paulo, 2020) and the implicit references to the ES concept in some strategic issues of the SEA report, the results of Table 5 and Table 6 are jointly analyzed as an attempt to identify evidence of tiering in this cycle of highway planning.

Considering the key aspects of the ESEA framework and the roadmap (Fig. 3), as a proxy to explore IA tiering by the ES concept, we highlight:

1. Integration: Little evidence of the influence of the most implicit consideration of ES in tiered planning was found. Although several ES were either implicit or – to a limited extend – explicit in the reports, little evidence was found of possible influence on the project decisions. There is a poor connection of information from the highest level of planning to the project level. In terms of a potential role for tiering, ES should be considered as an integrative tool in the planning cycle, by identifying the ES that could be affected by the program, prioritizing them for assessment in the subsequent EIAs, appropriately identifying the key stakeholders affected by strategic planning in the SEA report, and hence better identifying the groups and their socio-ecological systems that could be affected at the project level;
2. Evaluation: The drivers of change and the stakeholders were generically approached both in the SEA and the EIA. Although some benefits provided by ecosystems were highlighted, they were diluted in the contents of reports, because the beneficiaries and their spatial and temporal distribution were not mapped. ES did not fit as part of a problem and did not come from a proper stakeholder mapping. Decision-makers and stakeholders could not become aware of the importance of ES in the area by reading the reports. Albeit present to varying degrees in the three EIA reports, the concept was disconnected from the assessment methodology. To define how the supply and demand of ES would be affected and considered in tiering decision-making from the strategic level to individual projects, the drivers of change, priorities, sensitiveness, and benefits between stakeholders and ES should have been identified in the SEA report and detailed or updated in the EIA. Hence, mitigation and compensation measures could have been properly defined at the project

Table 3
Summary of results of implicit association of ES in the EIA reports.

EIS	Number of impacts	Number of implicit associations with ES categories (Table 4)					Number of impacts associated to ES		
		Provisioning	Regulation	Cultural	Support	Total	association to ES		
							more than one	only one	Without
South Section	Physical	5	2	5	0	7	2	3	0
	Biotic	2	3	3	0	6	2	0	0
	Socioeconomic	21	1	1	0	2	1	0	20
	Subtotal	30	6	9	0	15	5	3	20
East Section	Physical	6	3	6	1	11	3	3	0
	Biotic	6	5	3	0	12	5	0	1
	Socioeconomic	21	0	1	0	2	0	2	19
	Subtotal	33	8	10	1	25	8	5	20
North Section	Physical	6	4	6	0	11	4	2	0
	Biotic	3	1	1	0	4	1	1	1
	Socioeconomic	24	0	3	0	4	0	4	20
	Subtotal	31	5	10	0	19	5	7	21
	Total	94	19	29	1	10	59	18	15

Note: the division of physical, biotic, and socioeconomic valued components follows the usual IA practice. One example: environmental impact: “Reducing water concentration times and increasing the basin areas of some streams and rivers” was associated with ES provisioning in the 3 EIA reports.

level, immersed in the socio-ecological system, and fed by the ES vision at a strategic level;

3. Quantification: ES quantification and valuation are not found in the reports. ES are presented descriptively in such a way that does not allow for displaying their value in a pragmatic and operational mode. Arguably, ES can hardly be evaluated if not explicitly considered. There was no tiering regarding the aspects of quantification for ES, but we cannot say that this absence from the program report has led to the lack of this consideration at the project level reports. However, the lack of provision hinders the discussion of the value of these ES at the level of strategic planning for later valuation (monetary or non-monetary) and spatial definition of the ES affected at the project level, not allowing appropriate mitigation, and offset.

5. Discussion: some lessons learned and insights for using ecosystem services in impact assessment tiering

The lack of provision to frame the strategic issues in terms of benefits to society provided by ecosystems, resulted in a largely implicit consideration of ES, because matters such as “protection of freshwater resources and water supply” and “use and consumption of natural resources and protection and conservation policy” (Table 1), that had to be addressed in the SEA at a level that is commensurate with its importance in the São Paulo metropolitan region, are directly related to the conservation and use of ecosystems.

If not explicitly incorporated into decision-making, such issues are likely to assume a secondary or marginal role, subject to eventual goodwill or even magnifying glass from those who will use technical information in SEA to read between the lines.

Although ES were formally absent in the tiered assessment, not only they were present implicitly, but they played a growing role in the

Table 4
Description of implicit ES identified in the EIA reports.

Number of implicit associations with ES categories	Implicit ES subcategories	South Section	East Section	North Section	Examples of references of ES from the description of environmental impacts presented in the EIA reports
Provision (19)	Biological raw materials	1	1	–	Interference with the structure and distribution of plant species communities
	Genetic resources	–	3	1	Fragmentation of natural forest that may eventually interrupt corridors, linear elements that join isolated fragments particularly important in fragmented landscapes for species whose pollination and/or dispersion depend on animals that are strictly forest dwellers or that avoid non-forest environments
	Freshwater	5	4	4	Reducing water concentration times and increasing the watershed of some streams and rivers
Regulation (29)	Air quality regulation	1	2	3	Deterioration of air quality in the highway area due to the attraction of trips that would otherwise continue to use the preexisting road system
	Climate regulation	–	–	1	GHGs emissions would decrease based as the average distance traveled in one day would be reduced
	Water quality regulation	3	2	1	Localized changes in river morphology leading to drainage obstruction with impact on riverside vegetation
	Erosion control	4	3	3	Erosion processes are intensified
	Water purification and waste treatment	1	2	1	Destabilization of margins or increased risk of flooding
	Regulation of pests and diseases	–	1	1	Enabling the transmission of diseases and the spread of predators and exotic species that compromise the dynamics of the metapopulation
Cultural (1)	Recreation and ecotourism	–	1	–	Affecting water channels that have small dams used for water intake, for irrigation or for breeding fish for recreational purposes
Support (10)	Habitat (biodiversity)	–	5	4	Possible interferences with wildlife corridors or forest continuums that guarantee genetic diversity among wild populations, as they allow the displacement of wild fauna
	Nutrient cycling	–	1	–	Occasional problems may occur, such as destabilizing margins or the increased risk of flooding

Table 5
The Ecosystem Services in Environmental Assessment (ESEA) framework analysis to infer ES in the SEA of the Rodoanel Program.

ESEA framework	Stages and questions	Key findings on ES at the Rodoanel Program SEA report
1 Integration	<p>Stage 1: Prioritization of ES <i>Have ES been identified in their relevance to the strategic decision context?</i></p> <p>Stage 2: Stakeholders' identification and involvement <i>Have stakeholders been adequately identified and engaged?</i></p> <p>Stage 3: ES inclusive SEA <i>Are ES in the SEA agenda in terms of critical decision factors, assessment criteria or indicators, and included in trend analysis?</i></p> <p>Stage 4: ES as a part of problem and stakeholders mapping <i>Have ES and stakeholders been related in relation to priorities, sensitivities, and benefits?</i></p> <p>Stage 5: ES valuation <i>Can ES be valued in a pragmatic and operational way?</i></p>	<p>ES that may be affected by the Program were only implicitly identified, but no criterion for prioritization was presented.</p> <p>Stakeholders were defined generically as "population", there was no evidence of the involvement of stakeholders during the assessment.</p> <p>Considering the results presented in Table 1, only a few criteria for including ES in the SEA report have been implicitly captured. This does not allow observing whether ES represent any value for the decision-makers.</p> <p>Data related to priorities, sensitivities or benefits between stakeholders and ES are not presented.</p> <p>The way ES are presented does not allow recognizing the value of ES in a pragmatic and operational way. There is no mention of monetary values of ES.</p>
3 Quantification		

Source: stages and questions of the framework from [Honrado et al. \(2013\)](#), data from [São Paulo \(2004\)](#) and its analysis presented in [Table 1](#).

Table 6
Ecosystem Services in the Environmental Assessment (ESEA) framework analysis to infer ecosystem services in the Rodoanel EIA reports.

ESEA framework	Stages and questions	Key findings on ES in EIA reports of highway sections
1 Integration	<p>Stage 1: The ES typology as an integrative evaluation tool <i>Have ES been explicitly used as a central evaluation tool across the IA process?</i></p> <p>Stage 2: The ES typology as a thematic evaluation tool <i>Have ES been explicitly evaluated in any of the thematic IA evaluations?</i></p> <p>Stage 3: Implicit thematic ES assessments <i>Have ES been implicitly evaluated in any of the thematic IA evaluations?</i></p> <p>Stage 4: Quantified thematic ES assessments <i>Do data and results from thematic/sectoral assessments allow a quantified evaluation of ES?</i></p> <p>Stage 5: Spatially explicit thematic ES assessments <i>Do data and results from thematic/sectoral assessments allow a spatially explicit evaluation of ES?</i></p>	<p>Only two ES were explicitly, and 12 others are implicitly identified. There is no evidence that the ES concept was used as an evaluation tool across the EIA.</p> <p>Regarding two ES explicitly evaluated, only provision of freshwater shows direct evidence for specific mitigation and monitoring measures.</p> <p>Twelve ES were implicit identified, but the ES dimension of one or more components of socio-ecological systems was poorly distributed.</p> <p>Little evidence that quantitative evaluations may result from the way ES were explicitly and implicitly mentioned in these EIA reports.</p> <p>Little evidence of spatialization and quantification only for freshwater, denoting potential impacts on water supply, but with few elements to support the spatial-explicit design or monitoring programs and mitigation measures.</p>
2 Evaluation		
3 Quantification		

Source: stages and questions of the framework from [Honrado et al. \(2013\)](#), data from [FESPESP \(2004\)](#) and [São Paulo \(2009, 2010\)](#) and their analysis presented in [Tables 2-4](#).

Table 7
 Actions to embed ES into a tiered assessment from SEA to project EIA and their potential contribution.

Key stages of SEA	Actions to embed the ecosystem services concept in SEA	Key stages of EIA	Actions to embed the ecosystem services concept in project EIA	Contributions of the ecosystem services concept as an integrative tool	Source*
Context, objectives, and scoping	Identifying the main ES potentially affected by the policy, program or plan, the stakeholders to be engaged, the multi-actor arrangements and the main drives of changes induced or boosted by the planning.	Scoping	From the list of ES identified in SEA that can be affected by individual projects, prioritizing ES in the context of each project by engaging stakeholders, in particular local beneficiaries.	Maintain the focus of assessments on priority ES, as defined by stakeholders' engagement in both SEA and EIA. State that one or more ES may be considered to achieve different environmental and planning objectives. Lower the probability of missing important issues.	Landsberg et al., 2011; Landsberg et al., 2013; Barral and Oscar (2012); Baker et al. (2013); Partidário and Gomes (2013); Geneletti (2015); Mascarenhas et al. (2015); Rosa and Sánchez (2015); Tardieu et al. (2015); Rozas-Vásquez et al. (2017); Rozas-Vásquez et al. (2018).
Baseline	Mapping supply and demand of ES by the beneficiaries related to the policy, program, or plan.	Baseline	Developing the baseline guided by the integration of socio-ecological systems to quantify and describe the supply of priority ES, benefits, and characterize their beneficiaries.	Provide a more integrated and focused baseline at ecosystem level. Reveal delivering bundles of benefits from nature.	Landsberg et al. (2011); (Landsberg et al., 2013); Karjalainen et al. (2013); Kumar et al. (2013); Rosa and Sánchez (2016); Grêt-Regamey et al. (2017); Burgos-Ayala et al. (2020).
Evaluation of strategic options/ alternatives	Discussing how ES and stakeholders can be affected in different planning scenarios and alternatives.	Impact analysis	Predicting the changes on priority ES over the life of the project. Identifying and assessing impacts on priority ES. Determining impact magnitude on the service benefit. Determining vulnerability of receptor by engaging stakeholders.	Demonstrate the social consequences of biophysical impacts and thus reducing potential conflicts between environmental and economic arguments.	Landsberg et al. (2011); Landsberg et al., 2013; Baker et al. (2013); Geneletti (2013); Partidário and Gomes (2013); Honrado et al. (2013); Rosa and Sánchez (2016); Slootweg (2021).
Planning guidelines	Providing guidelines for incorporating, quantifying, valuing, and evaluating ES (demand and supply) in terms of planning.	Mitigation Measures	Developing alternatives for avoiding, minimizing, restoring, and compensating impacts on ES, aiming to improve or at least maintain affected beneficiaries' well-being.	Deliver mitigation measures tailored by the ES affected and enhance positive features from restoring and maintaining the ES supply. Make explicit for decision makers the value and human dependence on nature.	Landsberg et al. (2011); Landsberg et al., 2013; Baker et al. (2013); Karjalainen et al. (2013); Burgos-Ayala et al. (2020); Slootweg (2021).

Note: * - Works that explore the theme of ecosystem services in different stages of SEA and EIA.

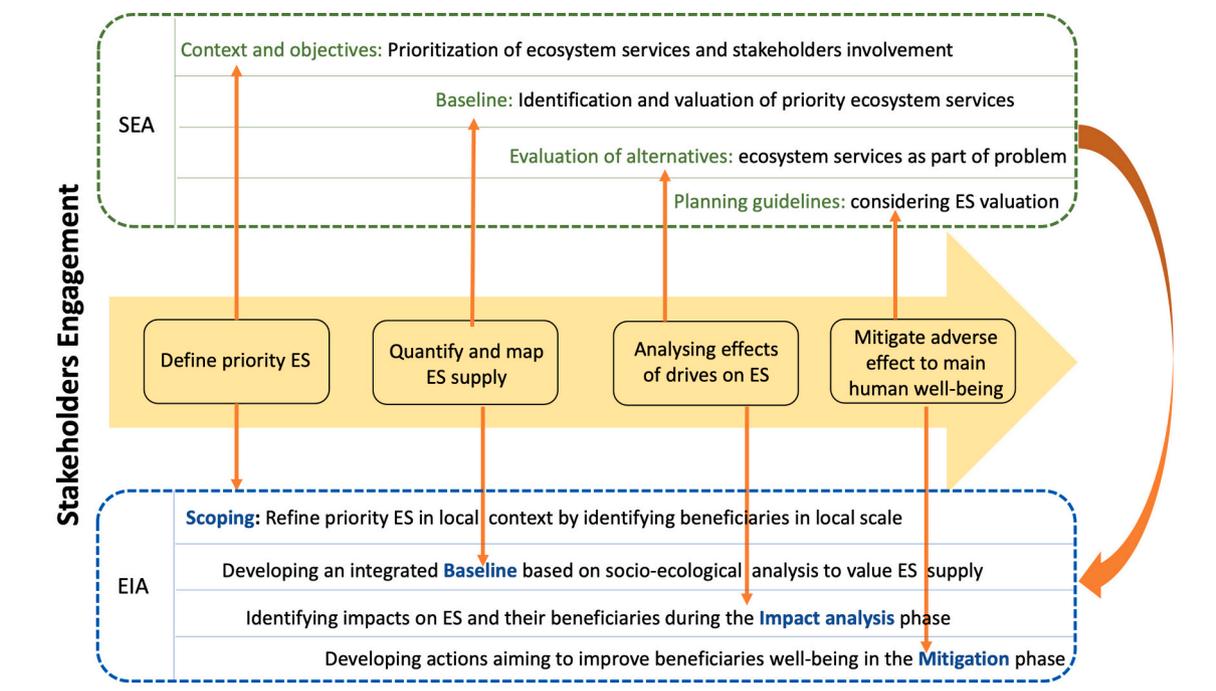


Fig. 4. Ecosystem services embedded in a tiered impact assessment process from SEA to EIA.

speeches of citizens' organizations in public hearings and in recent planning documents of the Biosphere Reserve. However, for tiered assessments to address ES, clear guidance for project-level evaluation must come from SEA (Fidler and Noble, 2012; Thérivel and González, 2021, among others). Limitations, such as those mentioned by Baker et al. (2013), must be also acknowledged, including the complexity of ES concept and weaknesses of the legal framework in many jurisdictions to enable the application of the concept within the existing decision-making formal procedures.

These empirical findings are useful to draw lessons that could be applied for future tiered assessments to fulfill the potential benefits of employing ES as an integrative concept and thread for tiering. We believe that the ES concept can add value to each stage of vertical SEA-EIA tiering. Actions for promoting the potential contribution of ES as an integrative tool to strengthen the whole cycle of IA planning processes by making explicit to decision-makers and stakeholders the value of and human's dependence on nature are drafted in Table 7.

The actions summarized in Table 3 are depicted in Fig. 4 in terms of four major tasks in applying ES to IA, with stakeholder engagement taking place all over the process. Major tasks in SEA are informed by the ES assessment and in turn are carried on to the EIA, providing room for a continuous process (Arts et al., 2011).

Tiering bears potential benefits, such as the coverage of different types of impacts, "funneling effect" (refining the scope of impacts and alternatives, Coutinho et al., 2019), focusing on sustainability priorities and dealing with environmental and social issues at the project level (Geneletti, 2015; Partidário and Gomes, 2013; Kumar et al., 2013). However, tiered approaches can be poorly implemented or overlooked by decision-makers, lessons learned not considered and timeframes not coordinated (Coutinho et al., 2019), or the projects associated with a particular policy, plan, or program materialize only many years after SEA, when policy assumptions may be outdated (Thérivel and González, 2021).

Such shortcomings can be lessened if the ES concept is used as a thread for tiering. When higher-level assessments are spatially defined, issues identified and data collected at this level can set the scope for more targeted lower-level assessments and public participation can be enhanced, to the extent that ES "language", i.e., benefits to people, are easy to understand.

6. Conclusions and future paths

In this paper, we examined the use of the ecosystem services concept as a thread to tiering in impact assessment from the strategic to the project level, a topic not explored in the previous literature.

In a regulatory context in which Strategic Environmental Assessment is voluntary and project Environmental Impact Assessment practice is well developed, we studied a case of SEA followed by EIA of individual projects affecting an area where society's dependence on ES is increasingly acknowledged (São Paulo, 2020). Public hearings conducted as part of the EIA process revealed that ES supply was a major social concern. Explicit consideration of ES was not expected to be found in these studies, because it is not required by official guidance. However, we found that the concept was implicitly contained both in the SEA and the EIA reports. Its widespread presence – and, in relation to water resources – prominence, raises the point that it could have been used to organize a conscious and explicit transfer of information from the SEA level to its explicit reception at the project level (Thérivel and González, 2021).

Our findings do not imply that ES should be considered in every impact assessment, but that in scoping for SEA if an analysis of the context can identify issues or critical decision factors that can be framed in terms of ES, the concept can be transferred to lower planning tiers and used to integrate the assessment of biophysical and social impacts.

We are aware that more integrated assessments can be achieved without the ES conceptual basis and that the literature does not

necessarily calls for tiering by using this concept. As other best practice recommendations, we believe that these should be tailored to specific planning contexts, but can also be replicated in similar situations, namely when ES can provide an adequate framing to conceptualize the impacts of development on socioecological systems. We do not call for further burdening the sparse use of tiering in impact assessment by adding ES to a list of issues, but we do invite both practitioners and researchers to reflect upon its potentially facilitating role in the transfer of information among planning levels.

In our view, the main opportunities to add value to tiering lie in explicitly considering ES at each stage of a vertical SEA-EIA connection. As ES represent a link between nature and society, this approach paves a path to further the integration of environmental matters into successive planning cycles and raises awareness about the societal benefits provided by ecosystems to influence decision-making. This approach can also strengthen public participation by calling attention to priority services provided by ecosystems and to engage different stakeholders, thus contributing to maintaining the focus and scope of tiered assessments.

Author statement

This article is unpublished and is not submitted to any other periodical for evaluation.

Declaration of Competing Interest

There is no conflict of interest.

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References

- Arts, J., van Lamoen, F., 2005. Before EIA: defining the scope of infrastructure projects in the Netherlands. *J. Environ. Assessm. Pol. Manag.* 7 (1), 51–80. <https://doi.org/10.1142/S146433320500189X>.
- Arts, J., Tomlinson, P., Voogd, H., 2011. Planning in Tiers? Tiering as a way of linking SEA and EIA. In: Sadler, B., et al. (Eds.), *Handbook of Strategic Environmental Assessment*. Earthscan, London, Washington, DC, pp. 415–433.
- Baker, J., Sheate, W.R., Phillips, P., Eales, R., 2013. Ecosystem services in environmental assessment—help or hindrance? *Environ. Impact Assess. Rev.* 40, 3–13. <https://doi.org/10.1016/j.eiar.2012.11.004>.
- Banhalmi-Zakar, Z., Gronow, C., Wilkinson, L., Jenkins, B., Pope, J., Squires, G., Witt, K., Williams, G., Womersley, J., 2018. Evolution or revolution: where next for impact assessment? *Impact Assessm. Project Appr.* 36 (6), 506–515. <https://doi.org/10.1080/14615517.2018.1516846>.
- Barral, M.P., Oscar, M.N., 2012. Land-use planning based on ecosystem service assessment: a case study in the southeast pampas of Argentina. *Agric. Ecosyst. Environ.* 154, 34–43. <https://doi.org/10.1016/j.agee.2011.07.010>.
- Bond, A., Pope, J., Retief, F., Morrison-Saunders, A., 2018. On legitimacy in impact assessment: an epistemologically based conceptualization. *Environ. Impact Assess. Rev.* 69, 16–23. <https://doi.org/10.1016/j.eiar.2017.11.006>.
- Bond, J., Cherp, A., 2000. Quality review package for strategic environmental assessments of land-use plans. *Impact Assessm. Project Appr.* 18 (2), 99–110. <https://doi.org/10.3152/147154600781767529>.
- Borioni, R., Gallardo, A.L.C., Sánchez, L.E., 2017. Advancing scoping practice in environmental impact assessment: an examination of the Brazilian federal system. *Impact Assessm. Project Appr.* 35 (3), 200–213. <https://doi.org/10.1080/14615517.2016.1271535>.
- Burgos-Ayala, A., Jiménez-Aceituno, A., Rozas-Vásquez, D., 2020. Integrating ecosystem services in nature conservation for Colombia. *Environ. Manag.* 66, 149–161. <https://doi.org/10.1007/s00267-020-01301-9>.
- Burkhard, B., Kroll, F., Nedkov, S., Müller, F., 2012. Mapping ecosystem service supply, demand and budgets. *Ecol. Indic.* 21, 17–29. <https://doi.org/10.1016/j.ecolind.2011.06.019>.
- Carvalho, S., Partidário, M., Sheate, W., 2017. High speed rail comparative strategic assessments in EU member states. *Environ. Impact Assess. Rev.* 66, 1–13. <https://doi.org/10.1016/j.eiar.2017.05.006>.
- Cortinovis, C., Geneletti, D., 2018. Ecosystem services in urban plans: what is there, and what is still needed for better decisions. *Land Use Policy* 70, 298–312. <https://doi.org/10.1016/j.landusepol.2017.10.017>.

- Costanzo, B.P., Sánchez, L.E., 2019. Innovation in impact assessment theory and practice: how is it captured in the literature? *Environ. Impact Assess. Rev.* 79, 106289. <https://doi.org/10.1016/j.eiar.2019.106289>.
- Coutinho, M., Bynoe, M., Pires, S.M., Leão, F., Bento, S., Borrego, C., 2019. Impact assessment: tiering approaches for sustainable development planning and decision-making of a large infrastructure project. *Impact Assessm. Project Appr.* 37 (6), 460–470. <https://doi.org/10.1080/14615517.2019.1578481>.
- Creswell, J.W., 2014. *A Concise Introduction to Mixed Methods Research*. SAGE Publications, Los Angeles.
- Desmond, M., 2009. Identification and development of waste management alternatives for strategic environmental assessment (SEA). *Environ. Impact Assess. Rev.* 29 (1), 51–59. <https://doi.org/10.1016/j.eiar.2008.05.003>.
- Fidler, C., Noble, B., 2012. Advancing strategic environmental assessment in the offshore oil and gas sector: lessons from Norway, Canada, and the United Kingdom. *Environ. Impact Assess. Rev.* 34, 12–21. <https://doi.org/10.1016/j.eiar.2011.11.004>.
- Fischer, T.B., 2004. Transport policy making and SEA in Liverpool, Amsterdam and Berlin—1997 and 2002. *Environ. Impact Assess. Rev.* 24 (3), 319–336. <https://doi.org/10.1016/j.eiar.2003.10.017>.
- Fundação Escola de Sociologia e Política de São Paulo – FESPSP, 2004. *Estudo de Impacto Ambiental – EIA – Programa Rodoanel Mário Covas – Trecho Sul modificado*. FESPSP, São Paulo.
- Gallardo, A.L.C.F., Cavalhieri, C.P., Camos, S.J.A.M., Bitar, O.Y., 2015. Improving effectiveness of mitigation measures in EIA follow-up. *Manag. Environ. Qual.* 26, 518–537. <https://doi.org/10.1108/MEQ-04-2014-0052>.
- Gallardo, A.L.C.F., Aguiar, A.O., Sánchez, L.E., 2016. Linking environmental assessment and management of highway construction in southeastern Brazil. *J. Environ. Assessm. Pol. Manag.* 18, 23–35. <https://doi.org/10.1142/S1464333216500022>.
- Geneletti, D., 2013. Assessing the impact of alternative land-use zoning policies on future ecosystem services. *Environ. Impact Assess. Rev.* 40, 25–35. <https://doi.org/10.1016/j.eiar.2012.12.003>.
- Geneletti, D., 2015. A conceptual approach to promote the integration of ecosystem services in strategic environmental assessment. *J. Environ. Assessm. Pol. Manag.* 17 (04), e1550035 <https://doi.org/10.1142/S1464333215500350>.
- Grêt-Regamey, A., Altwegg, J., Sirén, E.A., Van Strien, M.J., Weibel, B., 2017. Integrating ecosystem services into spatial planning—a spatial decision support tool. *Landsch. Urban Plan.* 165, 206–219. <https://doi.org/10.1016/j.landurbplan.2016.05.003>.
- Gutiérrez, M., Bekessy, S.A., Gordon, A., 2021. Biodiversity and ecosystem services in strategic environmental assessment: an evaluation of six Australian cases. *Environ. Impact Assess. Rev.* 87, 106552. <https://doi.org/10.1016/j.eiar.2021.106552>.
- Hassanali, K., 2021. Internationalization of EIA in a new marine biodiversity agreement under the law of the sea convention: a proposal for a tiered approach to review and decision-making. *Environ. Impact Assess. Rev.* 87, 106554. <https://doi.org/10.1016/j.eiar.2021.106554>.
- Honrado, J.P., Vieira, C., Soares, C., Monteiro, M.B., Marcos, B., Pereira, H.M., Partidário, M.R., 2013. Can we infer about ecosystem services from EIA and SEA practice? A framework for analysis and examples from Portugal. *Environ. Impact Assess. Rev.* 40, 14–24. <https://doi.org/10.1016/j.eiar.2012.12.002>.
- IFC - International Finance Corporation, 2012. *International Finance Corporation's Performance Standards on Environmental and Social Sustainability*. IFC, Washington, DC.
- Karjalainen, T.P., Marttunen, M., Sarkki, S., Rytönen, A.M., 2013. Integrating ecosystem services into environmental impact assessment: an analytic-deliberative approach. *Environ. Impact Assess. Rev.* 40, 54–64. <https://doi.org/10.1016/j.eiar.2012.12.001>.
- Kumar, P., Esen, S.E., Yashiro, M., 2013. Linking ecosystem services to strategic environmental assessment in development policies. *Environ. Impact Assess. Rev.* 40, 75–81. <https://doi.org/10.1016/j.eiar.2013.01.002>.
- Landsberg, F., et al., 2011. Ecosystem services review for impact assessment. World Resources Institute, Washington, DC. Available at: https://www.wri.org/sites/default/files/ecosystem_services_review_for_impact_assessment_introduction_and_guide_to_scoping.pdf. Accessed June, v. 10, p. 2016.
- Landsberg, F., Treweek, J., Stickler, M.M., Henninger, N., Venn, O., 2013. *Weaving Ecosystem Services into Impact Assessment: A Step-by-Step Method. Abbreviated Version 1.0*. World Resources Institute, Washington.
- Malvestio, A.C., Fischer, T.B., Montaña, M., 2018. The consideration of environmental and social issues in transport policy, plan and programme making in Brazil: a systems analysis. *J. Clean. Prod.* 179, 674–689. <https://doi.org/10.1016/j.jclepro.2017.11.152>.
- Marull, J., Pino, J., Mallarach, J.M., Cordobilla, M.J., 2007. A land suitability index for strategic environmental assessment in metropolitan areas. *Landsch. Urban Plan.* 81 (3), 200–212. <https://doi.org/10.1016/j.landurbplan.2006.11.005>.
- Mascarenhas, A., Ramos, T.B., Haase, D., Santos, R., 2015. Ecosystem services in spatial planning and strategic environmental assessment—a European and Portuguese profile. *Land Use Policy* 48, 158–169. <https://doi.org/10.1016/j.landusepol.2015.05.012>.
- MEA - Millennium Ecosystem Assessment, 2005. *Ecosystems and Human Well-Being: Our Human Planet — Summary for Decision Makers*. Island Press, Washington, DC.
- Noble, B.F., 2009. Promise and dismay: the state of strategic environmental assessment systems and practices in Canada. *Environ. Impact Assess. Rev.* 29 (1), 66–75. <https://doi.org/10.1016/j.eiar.2008.05.004>.
- Partidário, M.R., Gomes, R.C., 2013. Ecosystem services inclusive strategic environmental assessment. *Environ. Impact Assess. Rev.* 40, 36–46. <https://doi.org/10.1016/j.eiar.2013.01.001>.
- Phylip-Jones, J., Fischer, T.B., 2015. Strategic environmental assessment (SEA) for wind energy planning: lessons from the United Kingdom and Germany. *Environ. Impact Assess. Rev.* 50, 203–212. <https://doi.org/10.1016/j.eiar.2014.09.013>.
- Ranganathan, J., Bennett, K., Raudsepp-Hearne, C., Lucas, N., Irwin, F., Zurek, M., Ash, N., West, P., 2008. *Ecosystem Services — A Guide for Decision Makers*. World Resources Institute.
- Rehhausen, A., Köppel, J., Scholles, F., Stemmer, B., Syrbe, R.U., Magel, I., Geißler, G., Wende, W., 2018. Quality of federal level strategic environmental assessment—a case study analysis for transport, transmission grid and maritime spatial planning in Germany. *Environ. Impact Assess. Rev.* 73, 41–59. <https://doi.org/10.1016/j.eiar.2018.07.002>.
- Rosa, J.C.S., Sánchez, L.E., 2015. Is the ecosystem service concept improving impact assessment? Evidence from recent international practice. *Environ. Impact Assess. Rev.* 50, 134–142. <https://doi.org/10.1016/j.eiar.2014.09.006>.
- Rosa, J.C.S., Sánchez, L.E., 2016. Advances and challenges of incorporating ecosystem services into impact assessment. *J. Environ. Manag.* 180, 485–492. <https://doi.org/10.1016/j.jenvman.2016.05.079>.
- Rosa, J.C.S., Sánchez, L.E., Morrison-Saunders, A., 2018. Getting to 'agreed' post-mining land use - an ecosystem services approach. *Impact Assessm. Project Appr.* 36, 220–229. <https://doi.org/10.1080/14615517.2018.1445175>.
- Rosa, J.C.S., Morrison-Saunders, A., Hughes, M., Sánchez, L.E., 2020. Planning mine restoration through ecosystem services to enhance community engagement and deliver social benefits. *Restor. Ecol.* 28, 937–946. <https://doi.org/10.1111/rec.13162>.
- Rounsevell, M.D.A., Dawson, T.P., Harrison, P.A., 2010. A conceptual framework to assess the effects of environmental change on ecosystem services. *Biodivers. Conserv.* 19 (10), 2823–2842.
- Rozas-Vásquez, D., Fürst, C., Geneletti, D., Muñoz, F., 2017. Multi-actor involvement for integrating ecosystem services in strategic environmental assessment of spatial plans. *Environ. Impact Assess. Rev.* 62, 135–146. <https://doi.org/10.1016/j.eiar.2016.09.001>.
- Rozas-Vásquez, D., Fürst, C., Geneletti, D., Almendra, O., 2018. Integration of ecosystem services in strategic environmental assessment across spatial planning scales. *Land Use Policy* 71, 303–310. <https://doi.org/10.1016/j.landusepol.2017.12.015>.
- Sánchez, L.E., Silva-Sánchez, S.S., 2008. Tiering strategic environmental assessment and project environmental impact assessment in highway planning in São Paulo, Brazil. *Environ. Impact Assess. Rev.* 28 (7), 515–522. <https://doi.org/10.1016/j.eiar.2008.02.001>.
- Santos, S.M., Souza, M., Bircol, G.A.C., Ueno, H., 2020. River basin management plans and their challenges: the case of the alto-Tietê river basin-state of São Paulo, Brazil. *Ambiente Sociedade*. 23, e02342 <https://doi.org/10.1590/1809-4422asoc20170234r2v2020L1AO>.
- São Paulo, Estado, 2004. *Desenvolvimento Rodoviário. Avaliação Ambiental Estratégica*. DERSA, São Paulo.
- São Paulo, Estado, 2009. *Estudo de Impacto Ambiental – EIA – Programa Rodoanel Mário Covas – Trecho Leste*. Secretaria dos Transportes de São Paulo, São Paulo.
- São Paulo, Estado, 2010. *Estudo de Impacto Ambiental – EIA – Programa Rodoanel Mário Covas – Trecho Norte*. Secretaria dos Transportes de São Paulo, São Paulo.
- São Paulo, Estado, 2020. *Serviços Ecosistêmicos e Bem-Estar Humano na Reserva da Biosfera do Cinturão verde da Cidade de São Paulo*. Rodrigues, E.A. et al. (Eds.). Instituto Florestal, São Paulo. <https://www.infraestruturameioambiente.sp.gov.br/institutoflorestal/2020/12/servicos-ecossisticos-e-bem-estar-humano-na-rbcv/>.
- Siqueira-Gay, J., Sánchez, L.E., 2019. Mainstreaming environmental issues into housing plans: the approach of strategic environmental assessment. *Environ. Impact Assess. Rev.* 77, 145–153. <https://doi.org/10.1016/j.eiar.2018.12.005>.
- Slootweg, R., 2021. Ecosystem services in strategic environmental assessment: An integrating concept in a world of silos. In: Fisher, T.B., González, A. (Eds.), *Handbook of Strategic Environmental Assessment*. Edward Elgar, Cheltenham, pp. 266–282.
- Slootweg, R., Kolhoff, A., Verheem, R., Hof, R., 2006. Biodiversity in EIA and SEA — Background Document to CBD Decision VIII/28: Guidelines on Biodiversity-Inclusive Impact Assessment. Commission for Environmental Assessment, The Netherlands.
- Slootweg, R., Rajvanshi, A., Mathur, V.B., Kolhoff, A., 2010. Biodiversity in Environmental Assessment: Enhancing Ecosystem Services for Human Well-Being. Cambridge University Press.
- Tardieu, L., Roussel, S., Thompson, J.D., Labarraque, D., Salles, J.M., 2015. Combining direct and indirect impacts to assess ecosystem service loss due to infrastructure construction. *J. Environ. Manag.* 152, 145–157. <https://doi.org/10.1016/j.jenvman.2015.01.034>.
- Thérivel, R., González, A., 2021. Ripe for decision: Tiering in environmental assessment. *Environ. Impact Assess. Rev.* 87, 106520. <https://doi.org/10.1016/j.eiar.2020.106520>.
- Turco, L.E.G., Gallardo, A.L.C.F., 2018. Avaliação de impacto ambiental e avaliação ambiental estratégica: há evidências de tiering no planejamento de transportes paulista? *Gestão Regionalidade* 34, 40–55. <https://doi.org/10.13037/gr.vol34n101.3878>.
- Vieira, M.C.M., Gallardo, A.L.C.F., Aguiar, A.D.O., Gaudereto, G.L., 2019. Plano de gestão integrada de resíduos sólidos de São Paulo na perspectiva da avaliação ambiental estratégica. *Urbe. Revista Brasileira de Gestão Urbana*. 11, 1–16. <https://doi.org/10.1590/2175-3369.011.e20180155>.