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EDITED BY
Srimanti Duttagupta,
University of Georgia, United States

REVIEWED BY
Hadi Eskandari Damaneh,
University of Tehran, Iran
David Sidney Byrne,
Durham University, United Kingdom

*CORRESPONDENCE
Bruno M. Oliveira
oliveira@iiasa.ac.at

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How social-ecological systems resilience unfolds from distinct worldviews

Bruno M. Oliveira[1,2,3]*, Roelof Boumans[4], Brian D. Fath[2,5,6] and Joseph Harari[7]

[1]University of São Paulo, São Paulo, Brazil, [2]International Institute for Applied Systems Analysis, Laxenburg, Austria, [3]AZTI Foundation, Pasaia, Spain, [4]Accounting for Desirable Futures LLC, Charlotte, VT, United States, [5]Department of Biological Sciences, Towson University, Towson, MD, United States, [6]Department of Environmental Studies, Masaryk University, Brno, Czechia, [7]Oceanographic Institute of the University of São Paulo, São Paulo, Brazil

Resilience is a critically important factor to consider for sustainably managing natural resources and social-ecological systems (SESs). Each social system will, collectively, have its own goals for how resources are perceived and the principles that underpin their resilience, and, multiple actors, individually, will approach the question with different perspectives. Here, we represent these plural perspectives in terms of worldviews, using the typologies from cultural theory. We combined the underpinning resilience principles from a previously built SES model to assess the extent to which these worldviews influence the results. Resilience was measured using a prototype Dynamic Resilience Index (DRI) validated in a previous publication. The results show the resilience of our SESs will behave in three different ways depending on each worldview used. Free markets (individualists) start the simulation period with a higher resilience. Strong governance (hierarchy) will take a higher position around 2025 and maintain the best value to the end of the simulation in 2100. The precautionary principle (egalitarians) starts with the lowest values for the DRI but ends closer to the strong governance, and it is the only worldview that increased its resilience throughout the simulation. Each worldview couples better to a particular management approach, and the SES behavior responds accordingly. The relevance for the governance of the SES is great as each worldview brings flawed contributions to resilience and wellbeing. Our research also shows that a possible negotiated solution between these worldviews would locate resilience inside the "solution space," which is graphically determined and discussed. Adopting each worldview is then discussed in terms of contributions and problems they imply to the system's resilience.

KEYWORDS

social-ecological systems, resilience, system dynamics, governance, culture

1 Introduction

Worldviews are broadly understood as shared values and beliefs, cultural biases that act like the lens through which people understand and frame their relations with the environment and each other (Thompson et al., 1990). Recently, perspectives focusing on values have regained attention in several studies (e.g., Scharfbillig et al., 2021; Pascual et al., 2023), which have been promoted under the "no one left behind" motto (Breil et al., 2021). This approach calls attention to the necessity of broadening participation and inclusion toward the construction of a just and democratic society. This process implies a capacity to deal with plural perspectives of what the current problems are, how they will unfold in the future, and what are the just perspectives to deal with them (Sovacool et al., 2023). When applied to the management and resilience of social-ecological systems (SESs), plural worldviews not only are a democratic and participative way of understanding resilience but are also formative (Oliveira, 2022), and the appeal for embracing plurality in management has been gaining attention (Assoratgoon and Kantabutra, 2023) and relevance (Pahl-Wostl et al., 2008). As this article shows, worldviews shape the goals each part of society has for the SES, and as worldviews change, so does the resilience of the system. Understanding, therefore, how worldviews influence the resilience of SESs is timely, novel, and crucial in the context of plural risks humankind faces (Beck, 2014).

From the SES perspective, resilience can be simply understood as an emergent property of the interactions of society and nature. In the present case, we start from the framework proposed by Biggs et al. (2015), in which resilience is "the capacity of an SES to continue providing a desired set of ecosystem services in the face of unexpected shocks as well as more gradual ongoing change." From this theory, we highlight that the "desired set of ecosystem services" is a value-laden statement from society and therefore strongly influenced by culture. This is supported by many authors for whom resilience is socially built (e.g., Carpenter et al., 2001; Holling and Gunderson, 2002; Adger et al., 2009; Sundstrom and Allen, 2019).

Understanding the processes between worldviews and the behavior of the system (i.e., the creation and development of institutions) is not trivial and escapes the scope of this article. Resilience, as modeled here, comes from the interactions of people (between themselves and with nature) that create and adapt institutions at multiple levels, according to their social and cultural arrangements (biased by worldviews). This interaction is described by Biggs et al. (2015) and modeled by Oliveira et al. (2022b). Usually, these institutions are politically supported by part of this society while at the same time contested by other parts (Ney and Thompson, 2000).

Building on Biggs et al.'s (2015) definition, resilience is supported by seven underpinning principles: (1) diversity, (2) connectivity, (3) the management of slow variables, (4) the understanding of the system as complex and adaptive, (5) learning, (6) participation, and (7) policentricity. In a previous study (Oliveira et al., 2022b), we showed a prototype model for a resilience index (namely, the Dynamic Resilience Index—DRI) in which we embraced these principles in a system dynamics model. The idea was to build a numerical simulation of resilience, based on Biggs et al. (2015), to explore how resilience would behave in the future, in a dynamics model, with several ecosystem services. To do that, we used *Homo economicus* as the determinant worldview as it is widely used in economic models. In the present article, we advance this analysis, embracing heuristics to understand plural worldviews from cultural anthropology (Douglas and Wildavsky, 1983; Thompson et al., 1990; Thompson, 1997; Douglas et al., 1998; Ney, 2009) that have a close history with ecology (e.g., Holling, 1986).

The relevance of worldview perspectives in SESs has a long history (e.g., Janssen and De Vries, 1998; Janssen and Carpenter, 1999) and has inspired scenarios of coupled SES models in many ways (e.g., Costanza and Folke, 1997; Costanza, 2000; Boumans et al., 2002; De Groot et al., 2002). The idea of embracing multiple worldviews was introduced in systems analysis by authors such as Churchman (1967), and it was explored in system dynamics by Checkland (1986, 1989), who produced a specific set of models based on plural worldviews, namely, "soft systems methodologies." The model used in this article builds on these authors' ideas and applies their knowledge to the simulation of coastal resilience of a specific SES. As the ecosystem services part is data-intensive (Oliveira et al., 2022a), it is understood as the hard part of the model. Furthermore, as the social sub-model brings the worldviews into the foundational concept, its experimental numerical simulation represents the soft part of the model. Briefly, the current approach has two sides: (1) from the ecosystem services provision side, the model is a data-based, "hard," numerical, calibrated, and validated system dynamics model and (2) from the resilience principles sub-model, it is a "soft," theory-based, and experimentally populated model. This dual character puts this article in a place between both soft and hard systems models.

Approaching resilience using the plural perspectives of worldviews comes from an understanding of science that points out that one solution for a complex wicked problem is poor and can only happen with severe restrictions of the plural perception and framing of these problems. Therefore, adopting worldviews in this article represents promising desired steps in at least two major theoretical realms: first, post-normal science (Funtowicz and Ravetz, 1993, 1997), which considers that "facts are uncertain, values are in dispute, stakes high, and decisions urgent," highlighting the role of the values in the definition of current facts, issues, and solutions, and, second, the construct of messy or wicked problems (Rittel and Webber, 1973; Ney, 2009), from which (a) any problem definition is uncertain and invariably contested and (b) solutions to these kinds of problems are not true or false but along a continuum of better or worse. Considering there are no absolute criteria to judge the solution, it will always depend on judgment and interpretation, value-laden actions that occur against a cultural background.

Finally, the objective of the present article is to simulate how resilience in our SES study unfolds according to different worldviews. We expect showing the relevance of multiple worldviews influencing the system's future will inspire future studies in which these social biases are explored and democratically discussed with stakeholders while informing robust decision-making processes.

1.1 The simulation background

This study complements two previous works, one in which the ecosystem services model was created, calibrated, and discussed (Oliveira et al., 2022a); and a second where the prototype of the resilience index (Oliveira et al., 2022b) was built and implemented using *Homo economicus* as the sole worldview (Figure 1). As all the model characteristics and limits were previously described and

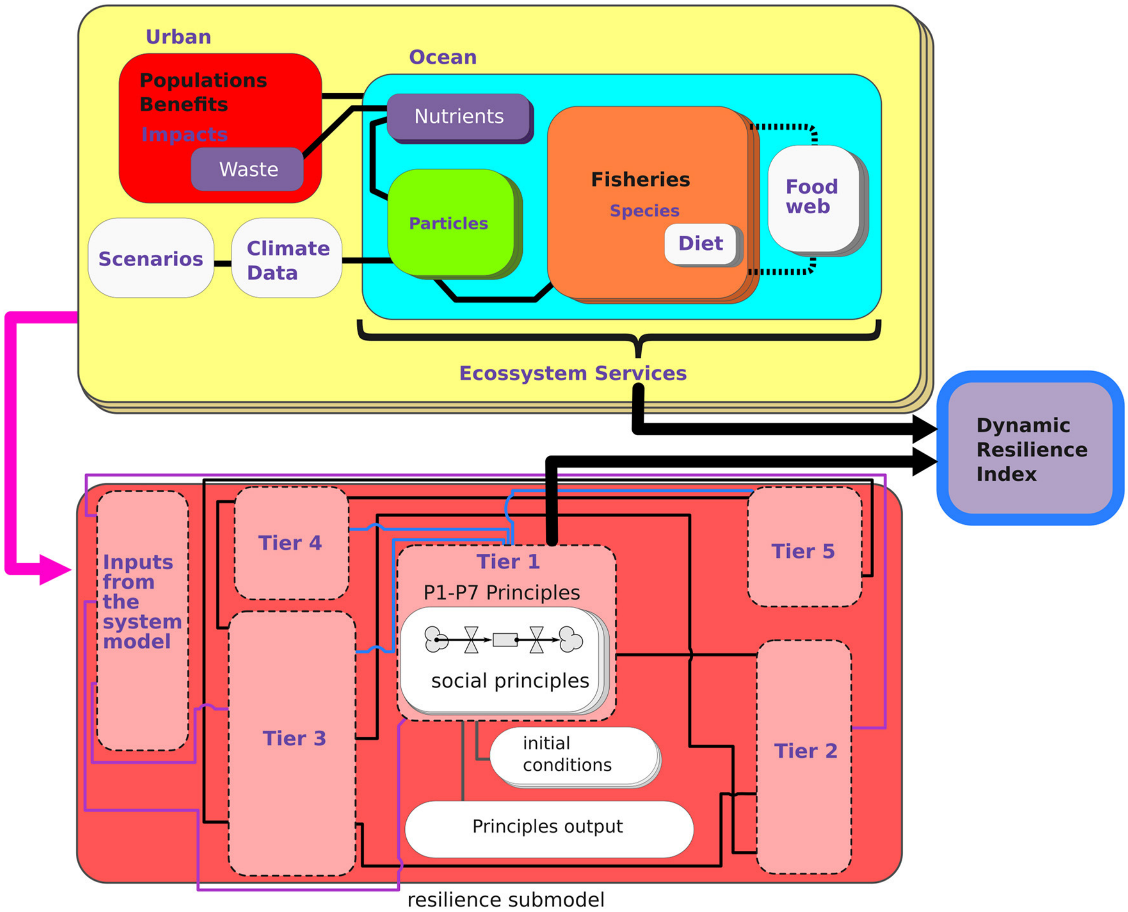

FIGURE 1
The coastal system simulation, showing the ecological sub-model and the social sub-model interacting to form the Dynamical Resilience Index. Source: Oliveira et al. (2022b). Behind every resilience principle (P1–P7) there are many variables, described in the work of Biggs et al. (2015), that were experimentally simulated in the previous work. These variables were organized into levels of influence (tiers) toward resilience. All the descriptions and methods can be verified in the source paper.

discussed in these papers, we provide just a small description of the approach to help the reader with context. For additional information, refer to the original papers.

Our case study was applied in the Brazilian coastal city of Ubatuba, which experiences strong pressure from tourism. This was simulated by the high number of visitors during summer and additionally a seasonal pattern in the ecosystem services provision. The simulation time span (2010–2100) presents the results of the ecological and social sub-models dynamically coupled within the system dynamics model. The ecological model resulted in daily values for 10 ecosystem services (Table 2), while the social sub-model provides values for the seven principles underpinning resilience provided by Biggs et al. (2015) while simulated with a causal model described in the prototype paper (Oliveira et al., 2022b).

Additionally, as simulated by the DRI, resilience (Figure 2) shows a downward behavior throughout the simulation, which allowed some insights regarding (a) the stage the adaptive cycle the system might be operating, (b) the general and specific resilience character of this index, (c) the possibility of a system trap, and (d) a distinct strength of some principles (connectivity and diversity) over the others, as revealed by a sensitivity analysis (Oliveira et al., 2022b).

1.2 A broader rationale

Cultural theory (CT) is a well-developed social and anthropological approach created over decades to represent the plural perspectives of society (Douglas and Wildavsky, 1983; Schwarz and Thompson, 1990; Thompson, 1997; Chuang et al., 2020). This theory presents five worldviews along group–grid axes that can be used as heuristics to understand cultural bias in resilience and the management of natural resources. However, when applying it to modeling and environmental management, scholars have typically only used three of these five, the active worldviews known as egalitarian, hierarchist, and individualist. The fatalist and the hermit are passive voices that respond but do not act, and therefore, they are usually discarded from the studies in this field (e.g., Linnerooth-Bayer et al., 2016; Chuang et al., 2020). We understand *Homo economicus* as being equivalent to

TABLE 1 Profiling of each solidarity's goal for resilience principles.

N	Principles	Individualist	Hierarchist	Egalitarian
P1	Response diversity and functional redundancy	Virtually zero (0.01)	High but limited (0.9)	Intermediate limits (0.6)
P2	Connectivity	Higher the better (1)	High but limited (0.9)	Intermediate limits (0.6)
P3	Management of slow variables	Higher the better (1)	High but limited (0.9)	Intermediate limits (0.6)
P4	SES as CAsK	Virtually Zero (0.01)	Virtually Zero (0.01)	Higher the better (1)
P5	Learning	Narrow limits (0.4)	High but limited (0.9)	Higher the better (1)
P6	Broaden participation	Intermediate limits (0.6)	Narrow limits (0.4)	Higher the better (1)
P7	Policentricity	Intermediate limits (0.6)	Narrow limits (0.4)	Higher the better (1)

TABLE 2 Weights for each principle and ecosystem service according to each solidarity.

		Individualist	Hierarchy	Egalitarians
Resilience principles	P1—Diversity	0.01	0.07	0.02
	P2—Connectivity	0.1	0.07	0.02
	P3—Slow variables	0.1	0.07	0.02
	P4—SES as CAsK	−0.01	−0.01	0.07
	P5—Learning	0.05	0.07	0.07
	P6—Participation	0.01	−0.01	0.05
	P7—Policentricity	−0.01	−0.01	0.05
	Subtotal	0.25	0.25	0.3
Ecosystem services	ES1—Crustaceans production	0.1	0.1	0.07
	ES2—Mollusks production	0.1	0.1	0.07
	ES3—Cartilaginous fish production	0.1	0.1	0.07
	ES4—Bonefish production	0.1	0.1	0.07
	ES5—Carbon sequestration	−0.01	0.05	0.07
	ES6—Sewage depuration	0.1	0.1	0.07
	ES7—Nutrient cycling	0.1	0.01	0.07
	ES8—Oxygen production	−0.01	0.05	0.07
	ES9—Mineralization	0.07	0.04	0.07
	ES10—Water quality	0.1	0.1	0.07
	Subtotal	0.75	0.75	0.7
	Total	1	1	1

the individualist. The description of these types presented here is based mostly on Thompson and Verweij (2004), Ney (2009)), and Linnerooth-Bayer et al. (2016). In the following, we draw our characterizations from the literature, highlighting the most salient and stereotypical features of each worldview. The language is intentionally leading and florid, which does not undermine the historical and scientific basis for the theory.

1.2.1 Profligacy, an egalitarian tale

According to this frame, most environmental problems come from the disparities presented by societies concerning consumption. Justice understands that historical imbalances must be acknowledged and compensated to proportionate equality. Egalitarians consider the world as a highly intricate place where everything is connected to everything else, an eco-centric world in which environmental degradation is not just environmental but also a reflex to the asymmetries of power and richness of society as a whole. Framing and managing problems involve holistic and naturalistic approaches.

The inequities of fractured societies and faceless global markets are the villains, pushing society to desire unsustainable products that are empty of what matters to humans (living in harmony with nature and others); the heroes are those institutions or people who have managed to see through the veil of progress and technology to understand that to stop environmental degradation, a social transformation to equality in an eco-centric perspective is mandatory. Justice for this group means parity, meaning equal

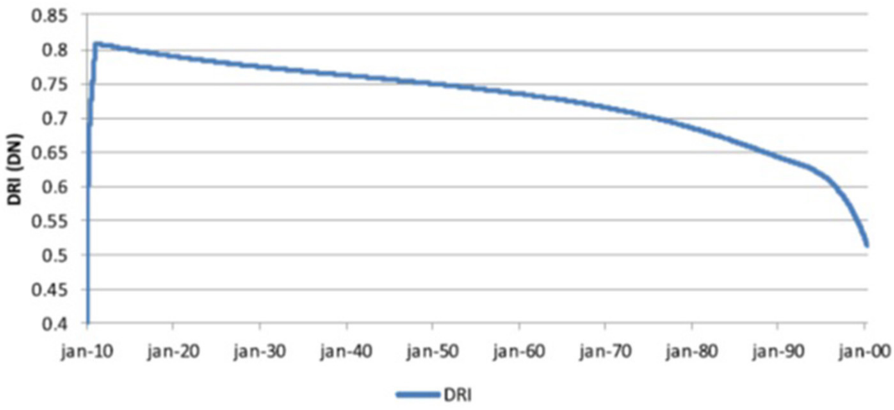

FIGURE 2
Dynamic Resilience Index showing the behavior of the resilience of Ubatuba with the *Homo economicus* rationale. Source: Oliveira et al. (2022b).

shares to all claimants (Rayner et al., 1999). Using the precautionary principle and spreading the decision-making power are ways to achieve an egalitarian goal.

1.2.2 Prices, an individualist story

In this frame, environmental problems come from the misuse of prices of environmental resources, which are historically distorted and do not reflect their scarcity, which allows overconsumption and thus degradation. There is no need to appeal to complexities and social justice claims when dealing with social problems once markets can make the most efficient allocation of resources. Environmental degradation is just a technical issue for which a technical answer can be given. Justice here comes from the priority of distributing the outcomes of successful competition, presumably by first in time, first in right (Rayner et al., 1999).

Economic growth and markets are not the sources of the problems but the solutions to eventual problems once all management, including managing the environment, is cost-intensive, and through economic growth, the bill of a technical solution can be paid. Misguided economic policies, barriers to international trade, and subsidies for inefficient sectors are the villains in this story. Management amounts to deregulation and freedom to innovate and take risks as a way toward solutions.

The heroes of this tale are those institutions who reinforce the market solution for problems, and there is no need for revolution since the economic institutions are already in place: they just need to put the right prices on products and services like carbon taxes and tradable emission permits. Laissez-faire is the goal of the individualist.

1.2.3 Proportion, a hierarchical tale

Here, environmental problems come from the disproportionate growth of society due to a lack of control. In the global South, rapid and uncontrolled population growth leads to environmental pressure, increasing resource demands and degradation. In the global North, unregulated markets lead to environmentally imbalanced societies. Hierarchists say that "wise guidance" and expert planning are the solutions. Justice here is procedural and must be allocated according to an administrative determination of rank, contribution, or need (Rayner et al., 1999).

The villain for this frame is the lack of control, and thus, the heroes are those institutions with technical and managerial capacity who take the "right" responsibility. Environmental problems, on every scale, should be left to the appropriate expert institutions with the power and resources to take the appropriate answer.

1.3 Summary

These CT perspectives (or values, solidarities, typologies, worldviews, frames, etc.) vary across two axes: group (meaning the degree to which one individual choice is bounded by the group) and grid (Thompson et al., 1990; Figure 3; the degree to which an individual life is circumscribed by externally imposed prescription and thus the degree to which is open to individual negotiation). The exhibition of an egalitarian worldview indicates strong group boundaries and weak prescriptive (grid) values. To this group, the theory attributes the "ephemeral myth of nature," meaning that egalitarians understand nature as fragile, something that needs attention and caution when treated. Any mistake can lead the system to an undesired state or collapse (Thompson, 1997; Holling et al., 2002).

Individualists' worldview is less bounded by group or grid. They are virtually free from control from others. To this group, the theory attributes the "myth of nature as being benign," meaning that all boundaries are flexible and that nature can always take care of itself, independent of human use or abuse.

Hierarchists' behavior has strong group boundaries and grid prescriptions, resulting in hierarchical relations. For this group, nature can be "perverse yet tolerant" depending on thresholds that must be managed properly by qualified personnel.

Fatalists' worldview indicates that people are strongly bound by grid prescriptions but exhibit weak group participation. To these people, nature cannot be managed or controlled, and thus,

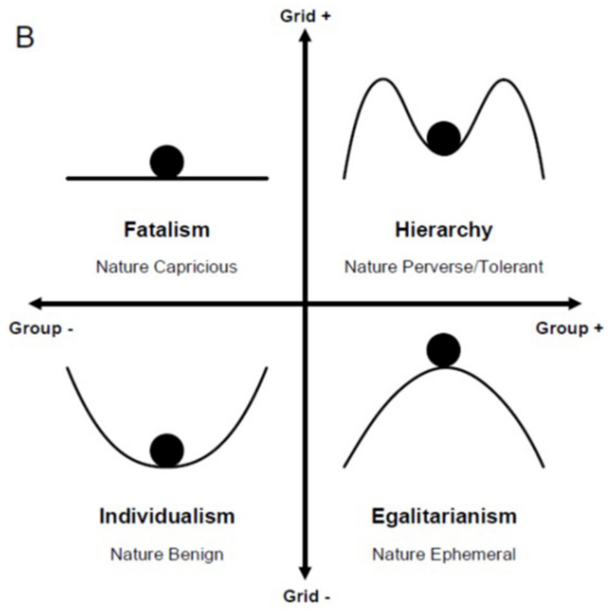

FIGURE 3
A metaphor about culture theory's worldviews behave in terms of stability domains, the surface where the ball (system) might behave. Source: Chuang et al. (2020).

the "myth of nature capricious" is attributed to them. They cope with nature, and institutions do not learn or adapt. We note and appreciate the underutilized and understudied role of the fatalist as an important research gap but will address that in future work.

The last worldview would be the hermit (autonomy), which is not controlled by the grid or group and leaves the participation in any decision. Fatalists and hermits are not active frames because they are not actively participating in decision-making, one by choice and the other by a lack of opportunity; therefore, they are not included in the present analysis (and are absent in most CT-related case studies).

As the question this research tries to answer (how resilience unfolds according to different worldviews) and the theory supporting the simulation have been described, we structure the rest of the article into three sections. The Methods section describes the numeric simulation assumptions, including the Cobb–Douglas-like equation and the weights and values for the equation. Limits and caveats are also presented in this section. In the Results and Discussion section, the "solution space" is graphically delimited and discussed with the assumptions of the theory. Finally, in the Conclusion, we summarize our results.

2 Methods

The system dynamics model used in the simulation is called MIMES, the Multiscale Integrated Model of Ecosystem Services (Boumans et al., 2015). This section describes the assumptions made in the theory to obtain the quantitative parameters necessary to run the numerical simulation.

2.1 Numerical simulation

Because MIMES runs a numerical simulation, these value-dependent goals for resilience (*worldviews*) were numerically represented (Table 1). This kind of profiling of solidarities is similar to that done by Janssen and De Vries (1998), Janssen and Carpenter (1999), Janssen (2002), and Oliveira et al. (2022a). We acknowledge other methods for translating qualitative statements into quantitative data (e.g., Kok, 2009), but as a different set of values was required here, we decided to follow the previous experiences with CT and populate the storylines with weighted preferences for each worldview. Therefore, the translation of each resilience principle's goal with a worldview was internally validated by a group of specialists. A scale of values for goals was used to translate the storylines to numbers; it ranges from virtually zero (0.01; while the value is extremely low, it cannot be *literally* zero because the model needs something different from zero to run), narrow limits (0.4), intermediate limit (0.6), high but limited (0.9), and higher the better (1).

The individualist storyline and its numerical representations are that there is no need for response diversity and redundancy (P1 = virtually zero) and that the market is the answer to solving environmental problems. Thus, the market must stay connected to every possible point in the system (P2 = higher the better), and slow variables, such as long economic cycles, must be managed properly (P3 = higher the better) to avoid surprises or dissonances in the market equilibrium. The resource bases of the economic system are not complex (P4 = virtually zero) and can be managed by rational economic beings, who know the ways of the market, and their preferences, and with a little more learning (P5 = narrow limits) about the right prices, the management will be appropriate. There is no need for others to participate unless it is necessary to maintain good competition in the markets (P6 = intermediate limits), and there is no need to spread the government when small groups using centralized solutions can leave the markets free to work (P7 = intermediate limits).

Hierarchists understand the value of diversity and redundancy but limit them to a somewhat controllable fashion (P1 = high but limited); the same happens with connectivity among this diversity (P2 = high but limited). Slow variables, such as economic development or tax rates, must be managed in high but controlled standards (P3 = high but limited). Understanding the system as a complex entity only muddies the clear view experts have about the complicated, but not complex, nature of things: there is no need for such uncertainty (P4 = virtually zero). Learning is high because being a management expert requires technical development and governance maturity: they know how to put things in order (P5 = high but limited). Participation is tolerated under a controlled situation (P6 = narrow limits), and policentricity is almost unnecessary (P7 = narrow limits).

Egalitarians use the precautionary principle when nature is at stake, so diversity (P1 = intermediate limits) and its connectivity (P2 = intermediate limits) must be managed with caution. Slow variables, such as the economy, must be controlled (P3 = intermediate limits) because they know it is part of an infinitely interconnected and complex non-linear system (P4 = higher the better) that requires a lot of scientific development and understanding (P5 = higher the better). To manage this highly complex system, participation by all is required (P6 = higher the better), and the most decentralized form of decision-making is best (P7 = higher the better).

With goals in hand, the numerical indicator (DRI) was constructed using a Cobb–Douglas-like function (Equation 1), and all the feedback identified in the causal loop diagram (Oliveira et al., 2022a) were embodied in the stock-and-flow simulation to provide the results in DRI (Figure 1).

Equation 1: Cobb–Douglas-like function for the DRI.

$$DRI = \prod_{i=1}^{7} P_i^{\gamma i} \prod_{j=8}^{17} ES_j^{\gamma j} \qquad (1)$$

Equation (1) (Oliveira et al., 2022a) shows the integration of the seven resilience principles (P) with the 10 ecosystem services (ES) simulated for the case study. The value for each variable is described in Table 1, and the weights are detailed in Table 2.

2.2 Weighting the Cobb–Douglas equation

The method used for aggregation of ecosystem services and resilience attributes (Equation 1) as a Cobb–Douglas-like function, demands dealing with exponents (γ^{1-17}). Those exponents represent the weight every variable has on the overall index (production, in their case). Boumans et al. (2002, 2015) claim that the weighting values are intrinsically unknown and reflect aggregated individual preferences. Therefore, the CT profiling was replicated to cover the weights each frame gives to the set of Ecosystem Services (ES) and resilience goals (Table 2).

The weights represent the grades of approval/disapproval for each variable in the function of each worldview and assumed values ranging from an undesired situation (−0.01) to positive weights, such as undesired (−0.01), very low (0.01), low (0.02), medium (0.05), high (0.07), and very high (0.1). Those values represent variations around the medium value of 0.058 for each of the 17 components of DRI, which totals 1.

The storylines (numerically represented in Table 2) are complementary to those in Table 1 and coherent with the worldview's description in the Introduction. For individualists, there is no need for diversity in the response (P1 = very low); the market is the answer to solving environmental problems. Thus, the market must stay connected to every possible point in the system (P2 = very high), and slow variables (e.g., economic cycles) must be managed properly (P3 = very high) to avoid surprises or dissonances in the market equilibrium and avoid losing the source of economic income. The resource bases of the economic system are not complex, and the understanding of it as complex is undesired (P4 = undesired); resource bases can be managed by rational economic beings, who know and learn about their preferences (P5 = medium). There is no need for the participation of others unless it is necessary to maintain good competition in the markets (P6 = very low), and there is no need to spread the government when centralized solutions can leave the markets free to work (P7 = undesired).

Individualists focus their efforts on ecosystem services that provide an immediate economic yield, maximizing the bottom line. Thus, high value is given to production (ES1–ES4 = very high) and to water quality and sewage depuration (ES6, ES10 = very high) because they matter to tourism frequency. Nutrient cycling (ES7 = very high) and mineralization (ES9 = high) are bonuses from nature that can help ensure better water quality and thus tourism. Carbon sequestration and oxygen production are global problems that could lead stakeholders to choose a different management system for the environment, against the one provided by markets, and so they are not welcome (undesired).

The storyline for hierarchists reflects their understanding of the value of diversity and the limits they skillfully put on this value (P1 = high); the same happens with connectivity (P2 = high). Slow variables (e.g., economic development, tax rates) must be managed to high standards (P3 = high) due to their relevance to society and the government's bottom line. Understanding the system as a complex thing would bring confusion and uncertainty (P4 = undesired). Learning is high but still limited once complexities must be avoided (P5 = high). Participation and polycentricity preferably should be avoided because they make decision-making slow and reduce the efficiency of the governance system (P6 and P7 = undesired).

Regarding ecosystem services, hierarchists value all kinds of fisheries production (ES1–ES4 = very high), and water quality and sewage depuration must be very high (ES6, ES10 = very high), reflecting the wise governance of basic environmental needs because those are relevant variables for the proper management of the coastal area while ensuring the revenue for city development. Carbon sequestration and oxygen production (ES5, ES8 = medium) are relevant in a secondary position once a higher governance hierarchy is supposed to take care of climate change. Mineralization (ES9 = medium) and nutrient cycling (ES7 = very low) are important, but they are already included when fish production and water quality are monitored and satisfactorily managed.

Egalitarians cherish management with precaution and thus diversity (P1 = low), connectivity (P2 = low), and slow variables (P3 = slow) must be managed with caution, preferably allowing the precautionary principle and non-interference to make their part. Considering the system is infinitely interconnected and non-linear (P4 = high), learning (P5 = high) must also be enhanced. Considering that all have something to say about governance, participation (P6 = medium) and policentricity (P7 = medium) can be useful strategies. Egalitarians would like to weigh learning, Complex Adaptive system Knowledge (CAsK), participation, and polycentricity more, but their understanding that nature is the best guide for itself limits the amount of governance this solidarity must have.

Thus, for ecosystem services, egalitarians give the same value to each of them (high), with no advantage for those with an economic return once all aspects of nature are equally relevant and are treated with the same caution and respect.

2.3 Limits and caveats

The current study has several limitations, but we believe the results compensate for the flaws. The numerical translation of social goals and perspectives has not only technical limitations but also the meanings of social agency get muddy with this transformation (Kok, 2009). How social processes from worldviews apply to institutional development represents a central topic in sociology and has been studied from several perspectives, which escapes the scope of the article. In terms of SES modeling, the use of typologies for social behavior, perspectives, and values is a beneficial tool that has been widely employed. Understanding society in terms of typologies is as difficult as it is reductionist. Yet embracing the full diversity of the social realm in terms of knowledge, culture, and behavior in simple categories seems to be a valid exercise for the sake of scientific development, despite all its caveats. This reductionist approach has been used in different sciences (psychology, sociology, anthropology, economics, etc.). Specifically for ecological or economic models, it has been used as a standard for individual behavior, from which the use of the term *rational actor* (considered equal to *Homo economicus*) emerged (Gintis, 2000). Nevertheless, there is a whole body of knowledge describing the limitations of this individualist actor model (Siebenhüner, 2000; Van den Bergh et al., 2000), its rationality (Gintis, 2000), and the usefulness of its considerations about society (Cobb and Daly, 1994) and scientific development is changing in favor of a more inclusive and plural rationalities approach (Lundquist et al., 2017; Lempert and Turner, 2021; Pascual et al., 2023).

3 Results and discussion

The main result of this simulation (Figure 4) shows that resilience will behave in three different ways, varying according to the worldviews. Each principle of resilience presents a different behavior (Appendix), determined in the model by the value of the goal and the weights (Tables 1, 2).

3.1 The definition of the solution space for resilience

The result of simulating DRI for each worldview (Figure 4) happens at the SES level, in our case, the coastal city of Ubatuba, where the data for the study came from. Three possible curves for resilience are presented, formed by the integrated behavior of the 10 ecosystem services, plus the seven underpinning resilience principles framed by each worldview.

When simulated in an integrative and dynamic form as used here, the numerical possibilities of resilience to occur, *ceteris paribus*, is bounded by the worldview applied to the SES. This means that the structure described by Biggs et al. (2015) for the SES resilience and modeled by Oliveira et al. (2022b) for the *Homo economicus* can present different behaviors for the resilience of the same set of ecosystem services, according to each worldview as described by their storylines and numerically simulated.

The meanings of this numerical simulation to each variable are difficult to pinpoint as the translation of the storylines to numbers plus the Cobb–Douglas function merged all the variables, making the process of translating back from the numbers (in DRI) into storylines a difficult path. Nonetheless, this result shows that resilience at the beginning of our simulation was higher for the individualist and lower for the egalitarian. By the end of the century, the situation was diametrically the opposite, with the individualist presenting more than 10% less resilience than the hierarchist, the best case by that time.

Only the egalitarian view presented an increase in resilience over time, despite being very modest. In that case, the egalitarian management perspective, guided by the precautionary principle, always desires operating in the expected safe zone, lowering the risk of passing some unknown tipping point or creating an event with undesired cascading effects. As this SES is operating in mature K-stage (Oliveira et al., 2022b), the ecosystem provides a steady stream of ecosystem services, with growth being constrained by the rate of natural, renewable return flows. Therefore, the match between the ecological realities and the worldview worked best for the precautionary approach of the egalitarian. However, in the egalitarian case, economic, technological, and social development opportunities could be lost, avoiding them for the sake of precaution, and therefore, the features on which society's wellbeing depends would not have been reached.

Results also indicate that the free-market approach (individualistic) performed best at the beginning of the simulation, but this lasted for just a few years. As its focus was on the economic output of the ES and neglected many requirements of resilience (such as participation or understanding the system as a complex system), the system management deteriorated, and the curve of its resilience showed the steepest decrease pattern until the end of the simulation.

Finally, the hierarchical management approach presents the highest resilience from 2025 onward, which might be indicative of the prevalence of good governance over the precautionary and the free-market approach for the case under study, but the underlying assumption is that decision-makers (hierarchists) know best how to manage the system, which is seldom the case under the theoretical perspective of open complex systems (Oreskes et al., 1994; Sterman, 2002).

The implications of these results on management are relevant once they show that the unbounded free markets will present the worst results to the SES, not only to the ecological system as commonly claimed. In addition, the understanding that a hierarchical governance might solve all the problems only makes sense with severe assumptions, such as they have all the tools, knowledge, and power to shape the system behavior, which is known to be false assumptions as discussed previously. Finally, the precautionary principle can collaborate with the resilience of the system but at the expense of economic and social development. Finally, as the three worldviews have something to contribute and something to avoid to thrive in the SESs, an ideal in-between solution would possibly be constructed by using the best (and denying the worst) from each of them.

As the nature of wicked problems comes from plurality and these rationalities in their pure or hegemonic form (Figure 4) seldom occur in the system, questions emerge, such as what worldview the system is currently presenting and which one it should pursue.

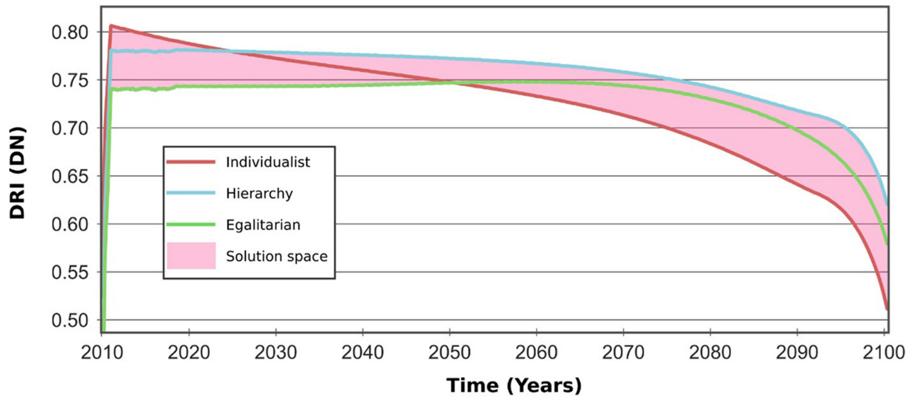

FIGURE 4
Individualists (*Homo economicus*) present the most evident decay curve for resilience along with the simulation but also present the highest values at the beginning of the simulation period. Egalitarians form the only curve that shows a little positive variation in DRI with a peak in ~2,060. Hierarchists show the best result, in the end, having the highest values in ~2,025 and remaining on top of the other three throughout the whole simulation.

3.2 Which of these possible sets of resilience do we see in the system, assuming it could be objectively measured?

The answer is none of them particularly but a combination of all of them. Wicked problems are strongly dependent on social perspectives and filled with uncertainties (Rittel and Webber, 1973), or Rayner's (2006) contradictory certitudes, because they emerge from the following ideas (among others): that no public good (or policy) is indisputable . . . and that there can be no optimal solution to social problems without the price of imposition (and thus lack of legitimacy) (Rittel and Webber, 1973). This means that for the case of our SES (Figure 4) and virtually many others, there are conflicts of worldviews when determining the desired state of the system.

Some of the consequences of sharing worldviews are institutions and social groups with common ideas and values: "Individuals tend to work together if they share a particular frame" (Ney, 2009) in what have been called "advocacy coalitions or discourse coalitions" (Ney, 2009). But this also implies that other people share a different worldview and that then conflict arises. The three behavior possibilities (Figure 4) are the representation of what would happen with the resilience of this SES case if one coalition has the power to overwhelm opposing views (usually named hegemony). In that case, our system would present an individualistic, egalitarian, or hierarchical resilience. But, as different worldviews are present, the resilience in the system will be somewhere between the possibility of each isolated case, a composite resilience made of different worldviews created by different institutions, a noisy behavior that can present virtually any value and vary in any direction: a random dissonance in these voices.

3.3 Why not hegemony?

An additional remark about the hegemony of these groups is that it is not a good option to have a hegemonic worldview whatsoever. First, there are no "right or wrong" worldviews. All of them were created using reason and logic (Rayner, 2006; Verweij et al., 2006). "None of them is wrong in the sense of being implausible or incredible" (Ney, 2009). All of them bring values and flaws, which, first, define them in opposition to each other but, additionally, provide creative and plausible goals for complex SES problems. Second, when the entire system is on the same trajectory, it can become stiff in a system trap, like "the rigidity trap" (Holling and Gunderson, 2002; Fath et al., 2015) or another, that will decrease its resilience in the long run.

Culture theorists claim the necessity of all those groups to exist—the requisite variety (Thompson et al., 1990, 2019; Rayner et al., 1999; Ney, 2009; Rayner, 2012). All of them are incomplete, although all have something to say (Gunderson and Holling, 2002; Holling et al., 2002). Legitimacy and social adherence to solutions gain power, the argument goes, when all solidarities are present and the risk of a lack of compliance and even sabotage increases if one or more active groups are expelled (Schwarz and Thompson, 1990; Oliveira, 2022). In Rayner's (2006) words, "You don't want to push one particular value set—the hierarchical, egalitarian, or competitive—out of the picture because they all have something to bring to the table in terms of solutions." In that manner, it is the interplay and juxtaposition of the various voices that give rise to a theory of plural rationalities. While there is much research in the social sciences on how two opposing positions can form a stable union (a classic dialect of state and markets), an interesting question arises about the dynamics of more than two worldviews.

The way to deal with those opposite frames, authors claim (Verweij et al., 2006; Ney, 2009), is to understand the arguments they provide to justify their worldviews, moving the conflict into a negotiated space: "the loser may be more willing to accept the loss if losing does not mean that society will become callous to the values he or she held" (Shapiro, 1988). The output of the negotiation process (the solution) is a policy filled with elements of all active advocacy groups, named the clumsy solution (Shapiro, 1988; Rayner, 2006; Verweij et al., 2006; Ney, 2009; Linnerooth-Bayer et al., 2016; Scolobig et al., 2016). A clumsy solution happens when the hierarchist's call for "rules and wise guidance," the individualist's call for "optimal technical solutions and entrepreneurship," and the egalitarian's call for a "whole new relationship with nature" coexist, cope, and, despite the volume of the discussion, manage to co-create a constructive path forward. The graphical bidimensional representation of this clumsy solution is the "solution space" shown in Figure 4.

Finally, resilience will vary through three possibilities determined by the worldviews: (a) it can assume one of the hegemonic values (Figure 4), (b) it can vary randomly due to the conflict among worldviews, or (c) it can be inside the negotiated space (the solution space) formed by those three curves when a legitimate and dialogued agreement has reached a clumsy solution.

4 Conclusion

This work simulated three distinct management approaches based on the commensurate worldviews regarding their underpinning principles and their influence on the system. The behavior of the system in terms of resilience was assessed using the DRI, in the case of a coastal SES in Brazil.

The simulation showed that different management approaches aligned with three possible behaviors for resilience in the system and that the social interactions will decide in which of them the system will land. The first is obtained by the hegemony of one view. In this case, the results showed a better result for the individualist at the beginning of the simulation with a sharp decrease to the end. An intermediate behavior came from the egalitarian, showing that the precautionary principle can present good results even when compared to the entrepreneur's free market. The hierarchist worldview showed the best result in resilience from 2025 to the end of the simulation, despite the heavy assumptions required for this worldview. The second possibility is a dissonant variation from a non-negotiated conflict among worldviews, in which case resilience would assume random values.

A negotiated, suboptimal, yet legitimate solution might be reached: the clumsy solution. In that case, resilience would be in an intermediary state between the lines delimited by each hegemonic value but limited inside this solution space, which was presented and discussed.

The results of this study are consistent with others that advocate for the construction of plural solutions, that are widely accepted, and that are democratically legitimated. In opposition to the idea of rational policymaking, in which the "optimal solution" (the elegant hegemonic solution) is imposed, emerges pluralist politics, in which solutions come from deliberation and argument in a disputed terrain. Understanding this solution space requires a humble perspective of the human capacities in guiding the SES, where the "perfect solution" must be abandoned in the promotion of a negotiated suboptimal one.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

BO: Conceptualization, Investigation, Software, Writing – original draft. RB: Conceptualization, Investigation, Software, Supervision, Writing – review & editing. BF: Conceptualization, Investigation, Supervision, Writing – original draft. JH: Conceptualization, Investigation, Supervision, Writing – review & editing.

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Conflict of interest

RB was employed by Accounting for Desirable Futures LLC.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsrma.2024.1352707/full#supplementary-material

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