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Article

Ecosystem Scenarios as Environmental Futures – Implications for Participatory Framework Designs Integrating Social Capital Formation and Natural Capital Preservation

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Ecosystem Scenarios, Social Systems, Social and Natural Capital, Knowledge Management

Abstract

In integrated ecosystem assessment projects, scenarios provide alternative images of environmental futures as orientation knowledge for opinion-forming and decision-making. Participatory scenario frameworks provide the methodological basis for ecosystem scenario building as multi-stakeholder process. These processes combine scientific assessment of natural capital and related ecosystem services with the formation of social capital as stakeholders' identification and trust with the research process and results. The article reviews the ecosystem scenario concept from a futures studies perspective and traces its practice from the origins in the UN Millennium Ecosystem Assessment to its present forms and application potentials. The theoretical argumentation also derives relevant aspects for combining natural capital preservation and social capital formation in ecosystem scenario processes and discusses implications for participatory framework designs. Overall, it contributes to the wider establishment of ecosystem scenarios in the futures studies community and to interdisciplinary exchange with related fields such as the natural, environmental and sustainability sciences.

Introduction

Ecosystem scenarios are linking epistemic and methodical elements of futures studies to research in the fields of natural sciences such as geological, biological, environmental, sustainability or earth system sciences as well as to related social sciences such as human ecology within the environmental humanities (Bennett el al., 2003; Carpenter et al., 2006; Moss et al., 2010). This is in line with earlier calls for futures studies better integrating with normative disciplines such as sustainability or climate sciences both in education, research and transformative efforts (Carter & Smith, 2003; McGrail, 2010). Considering biophysical, socioeconomic and also cultural factors within environmental assessment projects (Abson et al., 2014; Chan et al., 2012; Tibbs, 2011; Turner & Daily, 2008), envisioning future states of nature as environmental futures has become a valid application field of future-oriented research, and the methodological contribution of futures studies to environmental research has been discussed in futures-related literature (Berg, 2016; Fauré et al., 2017; Gibbs & Flotemersch, 2019; Granjou, 2016; Mathews & Barnes, 2016). Established

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frameworks and research projects such as the IPCC Shared Socioeconomic Pathways (O'Neill et al., 2012), the IPBES Nature Futures Framework (Pereira et al., 2020) or the Seeds of Good Anthropocenes initiative (Bennett et al., 2016) have brought the ecosystem scenario practice as environmental futures approach to wider attention.

In applied and strongly stakeholder-oriented research projects, ecosystem scenarios as part of integrated environmental assessments provide future-oriented orientation-knowledge about possible ecological developments for integrative opinion-forming and decision-making (Daily et al., 2009; Gibbs & Flotemersch, 2019; Guerry et al., 2015). In these assessments, the concepts of natural capital and related ecosystem services have come to prominence. Historically, global efforts such as the United Nations Millennium Ecosystem Assessment (MA, 2003, MA, 2005a) have widely established the concept of ecosystem services as "the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life" (Daily, 1997, p. 3). The related concept of natural capital as "the living and nonliving components of ecosystems […] that contribute to the generation of goods and services of value for people" has been promoted to preserve nature for human and non-human well-being (Guerry et al., 2015, p. 7349).

As part of the UN Millennium Ecosystem Assessment, a distinct scenario working group established a theoretical and practice foundation for the use of scenario methodology in environmental assessment projects (Alcamo, 2008; MA, 2003; MA, 2005b); their work also substantiated the ensuing Natural Capital Project (Natural Capital Project, 2016; Turner & Daily, 2008). This group stressed the importance of participatory scenario methods to engage stakeholders throughout the ecosystem scenario process and create among decision makers a deeper understanding of, identification with and trust towards the research process and its results. Subsequently, a range of participatory scenario approaches have been implemented in environmental research and have been discussed from a participatory futures perspective (Garteizgogeascoa et al., 2020; Hasegawa & Okabe, 2018; Keeler et al., 2019; Whitfield, 2012).

In this light, researchers providing ecosystem scenarios as decision support tools in environmental discourse and policy formation have assumed communication and consulting roles at science-society interfaces in relevant sectors, such as the socioeconomic, socioecological or political sector (McKenzie et al., 2014; Posner et al., 2016). Their changing roles in such praxis-oriented research have been reflected in literature on transdisciplinary (Hemmati, 2002; Polk, 2015, Popa et al., 2015) or transformative research (Hilger et al., 2018; Wittmayer & Schäpke, 2014). Addressing environmental uncertainty in decision-making processes (Bennett el a., 2003, Carpenter et al., 2006), these forms of research can build social capital between stakeholders as "the goodwill that others have toward us […] [as a] valuable resource" (Adler & Kwon, 2002, p. 18). In environmental decision-making informed by ecosystem scenarios as tools of science communication and consulting, social capital creates a basis of mutual trust between scientific and non-scientific actors on structural, intellectual and relational level, which encourages social acceptance, integration and sustained implementation of research results (Lang & Ramirez, 2017).

Besides producing knowledge about possible environmental states of the future in assessing *natural capital* developments, ecosystem scenario processes in their participatory and applied character also produce *social capital* among researchers and process stakeholders. Archer et al. (2015) describe science's capacity to co-produce different value or 'capital' categories for praxis application as forming *science capital*. In this sense, this article reflects how futures studies methodology can further support ecosystem scenario projects as inter- and transdisciplinary research practice in creating social capital while assessing and preserving natural capital and related ecosystem services. The argumentation presents impulses for scenario framework construction and

application based on the study of project materials and existing literature. This work derives from a theoretical examination of ecosystem scenario practices within *Stanford University*'s Natural Capital project as Master thesis in M.A. Futures Studies at *Freie Universität Berlin*. Overall, the paper aims to theoretically substantiate the ongoing development and testing of a participatory scenario framework to improve relevance, applicability and efficacy of ecosystem scenario projects from a stakeholder perspective; in this, the paper contributes to a deepened exchange between the futures studies community and environmental researchers on the interdisciplinary assessment of environmental futures (Groves, 2017).

Forms of Capital in Ecosystem Scenario Processes

Different forms of capital denoting "society's productive base" have been identified as fundamental in ecosystem assessment projects (MA, 2003, p. 29). Among them, analogous to economic capital, the concept of natural capital defines 'capital stocks' as existing natural resources and 'capital flows' as ecosystem services available from these resources (Bateman & Mace, 2020). Figure 1 shows interrelations between different forms of capital underlying value assessment and negotiation within the United Nations Millennium Ecosystem Assessment: *manufactured capital* and *natural capital* represent a material value dimension characterized by an economic framing, while *social capital* and *human capital* form an immaterial value dimension based on human relationships and capacities. In ecosystem scenario processes, the latter dimension aims to highlight and improve collaboration between stakeholders from the private and public as well as governance and administration sectors by providing reliable orientation knowledge for decision and management processes in complex and dynamic (organizational) environments (MA, 2003, pp. 47-48). This section discusses natural capital and social capital as relevant to ecosystem scenario processes.

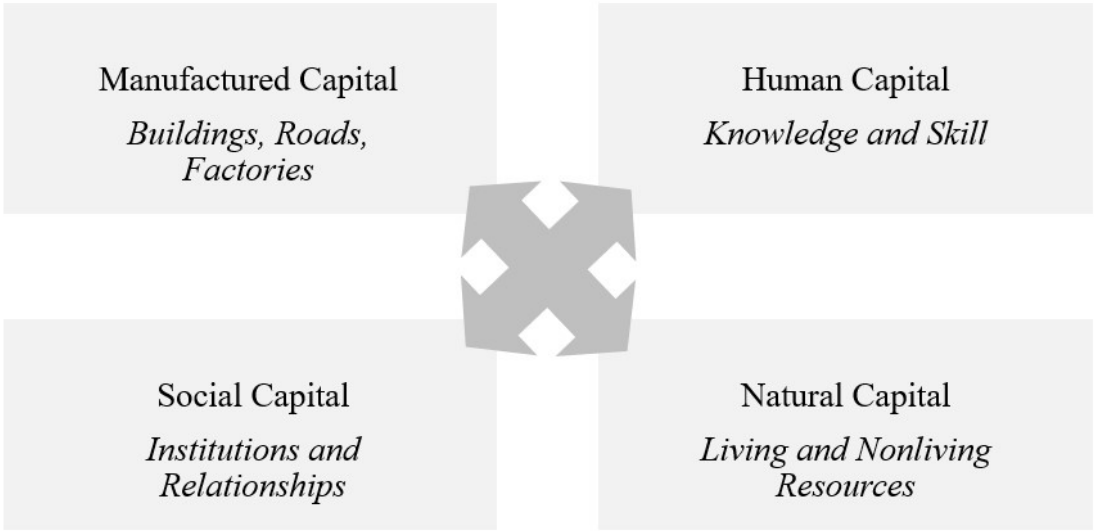

Fig 1: 'Society's productive base', shaped by the interrelations and conversion processes between manufactured and natural capital as material value dimension, and social and human capital as immaterial value dimension (adapted from MA, 2003, p. 29).

Natural capital

Natural capital as "the spectrum of physical assets within the natural environment that deliver economic value through ecosystem services" considers natural resources in ecosystems as a kind of "savings account" which "can pay interests or be liquidated" (Voora & Venema, 2008, p. 3). This profit-oriented view appears problematic, and related concepts of ecosystem services (Bekessy et al., 2018; Schröter et al., 2014) and especially payments for ecosystem services (Kaiser et al., 2021) have been critically discussed from a variety of angles: (i) "putting a price tag on nature" adds economic weight to the ecological impetus of ecosystem preservation, where "innovative financial mechanisms" integrate conservatory services with the production of goods e. g. in agriculture, forestry or mining (Daily et al., 2000, p. 395); (ii) economic metaphors in environmental policy and research, such as "natural capital, natural assets, ecosystem services, and ecological debt", may require clarifying discourse about the extent of an economic framing of natural capital resources and certificates necessary and desirable in public and private sector ecosystem management (Coffey, 2015, p. 203); (iii) possessing and trading natural resources has been historically contested e. g. from a critical postcolonial perspective, as "[w]hat we call land is an element of nature inextricably interwoven with man's institutions. To isolate it and form a market for it was perhaps the weirdest of all the undertakings of our ancestors". (Polanyi, 1944/2001, p. 243)

Positively, "putting a price tag on nature" and its services beyond extractable resources adds economic to ecological interest in the conservation of ecosystems, which for centuries of free exploitation have been "poorly understood, scarcely monitored, and […] undergoing rapid degradation and depletion"; it encourages cross-sectoral efforts to integrate conservatory services with the production of goods e. g. in agriculture, forestry or mining; it requires cataloging and documenting service flows on different geographical scales; it demands to research specific ecosystem dynamics such as perturbation response and to weigh costs and benefits e. g. in establishing recovery mechanisms and periods (Daily et al., 2000, p. 395). To link social, economic and ecological interests, the valuation of ecosystem services combined with "financial instruments and institutional arrangements" as a tool more than a "solution or end in itself" can produce "profoundly favorable effects" in (political) ecosystem management (ibid., p. 396). The concept's potential lies especially in revealing and restoring natural alternatives to technological solutions, the former becoming profitable with a broader ecosystem services valuation approach of the natural systems examined.

In ecosystem scenarios, identifying such possible alternatives, assessing their short- to long-term social and natural impact and subsequent translation and valuation of the consequences on human well-being aims to "quantify uncertainties and the risks of proceeding" with each alternative image of an environmental future, where the "common measuring unit is typically monetary" (ibid., p. 396). In this view, the natural capital approach emphasizes the normative application of the ecosystem services concept not as scientific measuring of exploitable resources, but as the socially embedded assessment of nature's contributions to human well-being (Chan et al., 2012), calling for decision-makers to better acknowledge natural capital preservation in long-term decision-making (Chan et al., 2006; Daily, 2000; Guerry et al., 2015; McKenzie et al., 2014; Turner & Daily, 2007).

Social capital

As illustrated with Figure 2, forms of social capital as described by Bourdieu (1986) combine and convert into each other to create social values such as *power* or *decisional competence*. Besides economic capital as prerequisite for social influence, social capital according to Bourdieu further differentiates into: (i) *cultural capital* as cultural competences obtained through educational and

practical knowledge which "may be institutionalized in the form of educational qualifications"; (ii) *social capital* as "social obligations ('connections'), which […] may be institutionalized in the form of a title of nobility", or as "resources which are linked […] to membership in a group" (ibid., p. 243, 248). Cultural and especially social capital serve as (iii) symbolic capital, which in contrast to economic (material) capital accumulation creates social influence by means of respect, reputation and trust: "[s]ymbolic power is a power of creating things with words" (Bourdieu, 1990, p, 183). Symbolic power thus bears special importance for the informal reproduction of social structures – implying that environmental assessment projects should sufficiently acknowledge and represent the cultural and social capital of relevant stakeholders for widespread acceptance and social integration of their decisions based on research results.

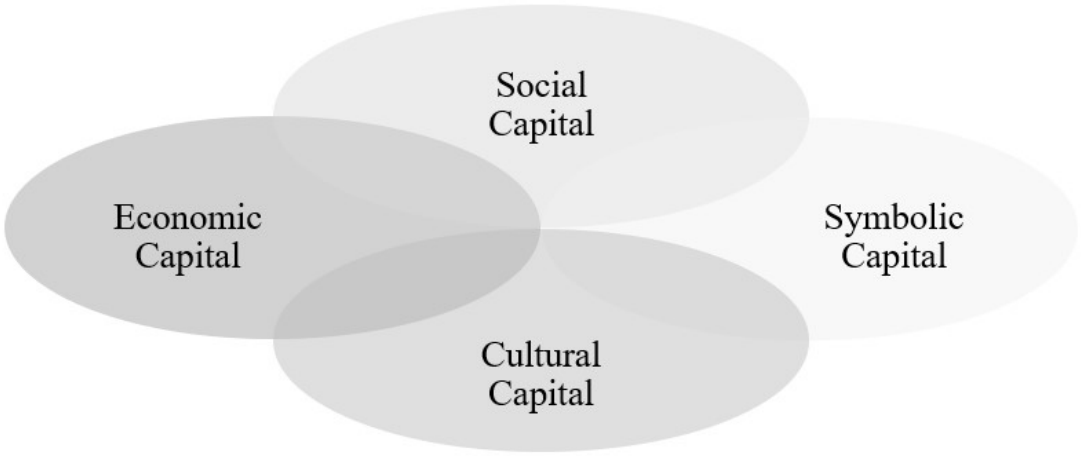

Fig 2: Forms of capital following Bourdieu (1986)

The overlaps mark relevant conversion processes: compared to Figure 1, economic capital captures all values directly convertible into monetary assets, such as manufactured and natural capital; social capital matches its correspondence, while cultural capital includes educational values and skills within human capital, and symbolic capital denotes the hidden dimension of social power based on reputation and social authority.

In scenario processes, Lang & Ramirez (2017) characterize three relevant dimensions of social capital: (i) with reference to Bourdieu (1986), a structural dimension depending "on the networks of relationships that actors have access to"; (ii) a relational dimension determined by "the quality of relationships within a network"; (iii) a cognitive dimension "consisting of shared systems of meaning which make communication and interpretation possible among a group of actors" and which is crucial for trust-building among them (Lang & Ramirez, 2017, p. 53). Consequently, involving stakeholders from the beginning and in all phases of an ecosystem scenario project may build a trust basis between researchers and non-scientific participants for an improved acceptance and social integration of scenario results and related opinion-forming and decision-making (compare to the transparency criterion of stakeholder participation in: Hemmati, 2002). Even

beyond the scenario process, stakeholders can expand their basis of common significance and trust with further steps of scenario-based interpretation, planning and strategy formation. In scenario-based decision-making, emerging social capital may prove its structural, relation and cognitive benefits between stakeholders as: "access to, and the flow of, new information […]; a shared appreciation of a strategic situation […]; increase[d] solidarity or common interests […]; generate[d] novel strategic opportunities or options […]" for collective environmental action (Lang & Ramirez, 2017, p. 51).

Science capital

Ecosystem scenarios as tools of participatory science communication and science consulting can provide orientation knowledge for environmental opinion-forming and decision-making. According to Archer et al. (2015), they are building "science capital" as "conceptual device for collating various types of economic, social and cultural capital that specifically relate to science – notably those which have the potential to generate use or exchange value for individuals or [stakeholder] groups to support and enhance their attainment, engagement and/or participation in science" (ibid., p. 928).

As related above, both economic (natural) and social capital can be considered integrative elements of ecosystem scenario building – either explicitly assessed or implicitly created. A cultural capital dimension can also be assigned to the research process: either in considering the cultural value of ecosystems as ecosystem services approach (Abson et al., 2014; Chan et al., 2012), or in the cultural capital formation through the valuation of nature along the research process itself. Science capital can thus serve as a useful term to describe the collective value creation of an ecosystem scenario process.

Making science capital: shared values in participatory scenario building

Besides their focus on material values, ecosystem services also capture immaterial, i. e. social and cultural services provided by natural resources, such as spiritual or historical, recreational, educational or scientific values. Their quantification in monetary equivalents appears difficult and requires an integrative value discourse about aspects of natural capital worth protecting beyond its mere functional value for livelihood and resources production (Jacobs et al., 2013). For this purpose, Chan et al. (2012) aim to disentangle "the myriad ways that ecosystem change matters to people" (ebd., p. 16). Distinguishing 'value' between human underlying ideals and the underlying importance of things, they propose a number of ethical dimensions such as market-mediated vs. non-market-mediated, self-oriented vs. other-oriented, individual vs. holistic, transformative vs. non-transformative, anthropocentric vs. biocentric for a greater normative variability in applications of the ecosystem services concept. Continuing the discourse, Chan et al. (2018) propose an overlapping value concept including assigned values (e. g. economic value), relational values (e. g. meaningful relationships), moral values (e. g. human rights) and held values (e. g. ideals) with respect to human-nature relationships. Especially the concept of relational values has been emerging from this ethical discourse as people's "[p]references, principles, virtues about/based on meaning-saturated relationships" with nature, but also among each other with regard to a shared appreciation of a healthy human-nature relationship (ibid., p. A3). The concept of relational values aligns well with the call for a stronger normative integration of a wider ecosystem services concept in sustainability sciences by Abson et al. (2014), which frames ecosystem services as a potent tool for scientists to inform, prepare and engage praxis stakeholders for a more holistic understanding of

sustainability transformation and ecosystem care.

In this sense, constructing individually and collectively meaningful scenarios of desirable ecosystem management and natural capital preservation is a key objective of multi-stakeholder processes creating and interpreting ecosystem scenarios – such processes require a sufficient motivational, identification and trust basis between scientific and non-scientific process stakeholders. Besides their conceptional, methodical and result-oriented character, ecosystem scenario frameworks thus assume an important *procedural* role for the formation of functional stakeholder relationships. Stakeholders' variety in backgrounds is illustrated with their definition as "those who have an interest in a particular decision, either as individuals or representatives of a group […] [, including] people who influence a decision, or can influence it, as well as those affected by it" (Hemmati et al., 2002, p. 2). Among the diverse social actors meeting these criteria, building a basis for mutual collaboration represents a distinct quality feature of participatory scenario frameworks, besides their focus on good practice criteria such as accessibility, transparency and scientific rigor; managing the formal and informal relationship-building between stakeholders then becomes an important task for researchers as scenario process facilitators (Lang & Ramirez, 2017), besides their roles in knowledge management or interpretation of results.

Ecosystem assessment projects are characterized by "wider ethical debates surrounding human–nature relations", which are increasingly shaping environmental decision-making and are going along with multiple "integrative perspectives that involve and balance different scientific disciplines and divergent stakeholder groups and perspectives" (Jax et al., 2013, p. 266). This underlines the relationship-forming value of ecosystem scenario processes and draws special attention to the design of suitable scenario frameworks. Ideally, frameworks enable social discourse in support of integrative decision-making and policies for desirable socioecological developments; this notion shifts the common biophysical and socioeconomic focus of the ecosystem services concept towards a stronger cultural appreciation of natural capital preservation as part of a wider social debate. Consequently, in a care-based environmental humanities framing (van Dooren, 2014), the participatory negotiation of shared environmental values as 'relational value approach' highlights human pro-environmental behavior and active care for nature as opposed to the passive consumption of environmental resources as ecosystem services with an a solely monetary value assigned (Chan et al., 2018, Jax et al., 2018).

By including stakeholders from diverse backgrounds in scenario processes, a combined natural scientific (Chaplin-Kramer et al., 2017 & 2019) and social scientific (Hackmann & St. Clair, 2012) ecosystem assessment can particularly integrate ecological with social value dimensions; consequently, combining natural capital as financial assessment tool and social capital as relational value base for concerted ecosystem preservation efforts supports a better integrated, long-term environmental decision-making (Daily, 2000; Guerry et al., 2015; McKenzie et al., 2014; Mooney et al., 2013; Turner & Daily, 2007). Both the biophysical, socioeconomic and cultural framing of scenario-building within ecosystem assessment projects then define relational values shared and validated from multiple stakeholders' perspectives. Especially a cultural value dimension may acknowledge ecosystem services contributions to human livelihood and wellbeing, which are often insufficiently represented due to their lack of materiality.

Implications for participatory ecosystem scenario frameworks

Futures studies literature provides a variety of scenario classifications: state scenarios vs. process scenarios (Puglisi, 2001); predictive, explorative, and normative scenarios (Börjeson et al., 2006); quantitative vs. qualitative, normative vs. exploratory scenarios (Gordon & Glenn, 2018). Similar

distinctions can be found for ecosystem scenarios: exploratory vs. anticipatory scenarios, reference vs. policy scenarios and quantitative vs. qualitative scenarios (Alcamo, 2008, pp. 19-22). Gordon and Glenn (2018) name plausibility of narrative, internal self-consistency and usefulness in decision-making as key measures of interactive scenarios built in "creative processes that involve people" (ibid., p. 34). Highlighting their participatory character, numerous frameworks for ecosystem scenario building have been presented, tested and evaluated (Hasegawa & Okabe, 2018; O'Neill et al., 2020; Poskitt et al., 2021; Quintero-Uribe et al., 2022; Thorn et al., 2020). Their contextual application focus, normative approach and participatory character are in line with the natural capital approach outlined by Daily et al. (2000) – it characterizes the natural capital approach to 'measuring uncertainty' in ecosystem assessment projects by three general principles:

(1) Incremental, not disruptive (revolutionary) changes
Ecosystem services-based policies should address small increments of ecosystems to measure and evaluate changes for their desirability in observable units. Ecosystem scenario projects should thus focus on local, tangible, situated contexts with a strong *personal identification and relational character*.

(2) Democratically negotiated values in social decision-making
Citizens of a democratic society should determine their common values in public debate. Applied to the concept of ecosystem services and incremental changes towards mindful ecosystem management, their value results from the collective valuation of these changes. In this sense, *participatory designs* of ecosystem scenario frameworks point to the *normativity* of scenario processes. In relying on sufficient individual knowledge, good will and agency among process stakeholders towards protecting nature, this motivates a stakeholder-centered and *competence-based* scenario approach.

(3) People's values revealed in actual decisions
Environmental decisions and subsequent social action embody personal and collective values more immanently than theoretical debate. Facing uncertainty in environmental decision-making, actions based on incomplete information (e. g. about system behavior) can be mandatory to protect and maintain ecosystems, while waiting for more complete information can be harmful. Incorporating future estimates about ecosystem services costs and benefits in ecosystem management can lead towards an 'equal treatment' of future generations aiming to preserve livable conditions in nature, as opposed to trading natural capital against presumed better lives of future generations as 'future discounting' at the cost of presently unsustainable resource exploitation. This points at an *action-oriented character* of ecosystem scenario processes.

Translating the above related points into ecosystem scenario frameworks faces the challenge of including (i) assessment information about natural capital, which is often presented as abstract, codified knowledge as in empirical data; (ii) discursive information produced in the explicit exchange between (non-)scientific stakeholders during a scenario process; (iii) personal and cultural values as mostly tacit knowledge dimension, where (ii) and (iii) relate to social capital formation. Scientists as process facilitators need to bridge the natural scientific assessment of ecosystems with the social dimension of including people's diverse individual knowledges about and relations with the research question. Especially the latter adheres to trust-building as crucial element of successful praxis research (Funtowicz & Ravetz, 1993) and of science communication meeting the truth, belief

and justification conditions of scientific knowledge production (Neta & Pritchard, 2009). Ecosystem scenario frameworks thus need to produce relevant and applicable scenario results for environmental uncertainty absorption from a praxis stakeholder perspective (Petersen et al., 2012).

Figure 3 displays the above identified criteria and degrees of freedom for the design of ecosystem scenario frameworks in the overall categories: process character, knowledge dimensions (derived from Daily, 1997 and MA, 2006) and stakeholder competences (derived from de Haan, 2010). The depiction aligns and interprets these findings in a way that attributes them to the integrated process of natural capital assessment and social capital formation in ecosystem scenario processes. Accordingly, participatory frameworks for ecosystem scenario building should balance and integrate the biophysical and socioeconomic information from natural capital assessment with the less formalized, partly tacit and relational character of social capital formation among process stakeholders. Scenario frameworks enabling such integrated scenario building may be suited to produce science capital with sufficient praxis relevance and value.

	Natural capital assessment		Social capital formation
Process character (Puglisi, 2001; Alcamo, 2008; Börjeson et al., 2006; Gordon & Glenn, 2018)	State scenarios		Process scenarios
	Reference scenarios		Policy scenarios
	Predictive	Explorative	Normative
	Quantitative		Qualitative
Knowledge dimensions (Daily, 1997; MA, 2006)	Objective		Subjective
	Abstract	Explicit	Tacit
	Data assessment	Social discourse	Personal values
	Systemic	Contextual	Tangible
	Global		Local
	Descriptive	Decisional	Action-oriented
Stakeholder competences (de Haan, 2010)	Distancing	Integration	Openness
	Handle incomplete / overly complex information	Solidarity	Empathy
	Systemic thinking		Participation
	Reflection	Communication	Motivation
	Gather & integrate new knowledge	Plan & act autonomously	Cooperation

Fig 3: Design aspects for participatory frameworks of ecosystem scenario building grouped into the categories: process character, knowledge dimensions and stakeholder competences (horizontal). To integrate

natural capital assessment and social capital formation in a scenario process, aspects from both sides should be included and combined in framework construction (vertical).

Discussion

To preserve natural capital for human well-being, ecosystem scenarios as environmental futures approach are linking the scientific assessment of ecological values and services with social value systems. Social capital formation can thus be considered an important dimension of multi-stakeholder projects assessing possible environmental developments of the future. Scenario frameworks are outlining the methodically structured process of ecosystem scenario building. Their often participatory character involves non-scientific stakeholders in various phases of the research process, to improve their structural, relational and cognitive identification with the process and results (Lang & Ramirez, 2017). Besides the biophysical and socioeconomic assessment of natural capital providing ecosystem services, especially the relationship- and trust-building function of participatory scenario designs as social capital formation promises higher relevance, applicability and efficacy of the research results. It may also increase individual and collective motivation to cooperate, decide and act in favor of functional human-nature relationships in the future.

This paper reviews the concepts of natural capital and related ecosystem services, social capital, and science capital as integrating economic, social and cultural capital produced in the praxis-oriented work of scientists facilitating ecosystem scenario projects (Archer et al., 2015). It also relates the argumentation to existing scientific discourse in relevant communities, such as futures studies, environmental and sustainability research. Participatory scenario frameworks are integrating interdisciplinary knowledge bases, as described in the theoretical line of argumentation. As a concrete result, the paper derives an overview of relevant aspects when combining natural capital assessment and social capital formation in scenario framework design (see Figure 3). Textbox 1 summarizes key implications for the design of participatory scenario frameworks from the theoretical argumentation of this paper. Specifically, it breaks down the presented aspects into concrete criteria of scenario framework design, drawing on (i) ecosystem scenarios absorbing environmental uncertainty and serving as orientation knowledge from a stakeholder perspective; (ii) social capital formation in multi-stakeholder scenario processes; (iii) individual value reflection and collectively shared values in participatory scenario building and application; (iv) diverse stakeholder backgrounds, ways of knowing and competences entering a scenario process; (v) relational aspects of scenario building. These points may contribute to the practical design, implementation and testing of participatory scenario frameworks; they may also provide evaluation criteria for ongoing scenario processes; and they may invite further alignment and exchange between different disciplines and research fields informing the ecosystem scenario practice from natural, social and human sciences backgrounds. Ultimately, advancing the ecosystem scenario practice for wider applicability may support concerted efforts to meet the challenges of the Anthropocene with the environmental futures approach (Bai et al., 2016; Bennett et al., 2016; Brondizio et al., 2016; Leinfelder, 2013; Moore & Milkoreit, 2020).

Textbox 1: Implications for combining natural capital assessment and social capital formation in ecosystem scenario processes – participatory scenario frameworks should:

- absorb environmental uncertainty in alternative scenarios by exploring a space of opportunities for present and future decisions, by providing comprehensible, sufficiently differentiated orientation knowledge for stakeholder opinion-forming and decision-making.
- strengthen motivation, identification and trust as social capital among process stakeholders, and emphasize the shared procedural value of collective scenario building, interpretation and application in environmental management policies.
- create a system of shared values between process stakeholders and promote an active integration of social (socioeconomic) and ecological (biophysical) value dimensions with related cultural values.
- understand relationship formation and cooperation as distinct quality feature of scenario processes with an activating, discursive and participatory focus.
- represent the diversity of educational, relational and action competences among multiple stakeholders in all process phases.
- acknowledge and integrate hidden power relations among stakeholders, which can be characterized by symbolic power and informal relationships.
- weigh the level of systemic abstraction and personal identification demanded from stakeholder perspective.
- provide a functional methodical design for stakeholder participation and create credibility and trust towards the scenario process and results.
- integrate different types of stakeholder knowledge such as abstract, explicit and tacit knowledge e. g. from quantitative, qualitative or narrative information sources based on a suitable knowledge management concept.
- allow the inclusion of personally and collectively meaningful information in scenario building.
- promote affective relationship-forming between stakeholders and with the research subject as relational value approach.

Conclusions

Ecosystem scenarios bear wide application opportunities and rely on an interdisciplinary knowledge base. To further establish their research practice in futures studies as an applied social science, this paper reviews terms and concepts relevant to participatory ecosystem scenario building. Among them, natural capital defining related ecosystem services and social capital are combining for a diverse scientific value creation in related research processes as science capital. The paper discusses theoretical premises and derives concrete implications for the design of participatory scenario frameworks defining ecosystem scenario projects as multi-stakeholder processes. It therefore contributes both to epistemic discourse in futures studies literature and to methodical considerations about the ecosystem scenario practice in interdisciplinary fields such as human ecology, sustainability sciences or environmental futures as an emerging branch of futures-oriented research. Motivating further development and establishment of the concept, the argumentation also frames environmental futures as a promising research field to be pursued for transdisciplinary research at science-society and science-policy interfaces.

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