Participatory research on ecosystem services in the face of disputed values and other uncertainties: A review

Cécile Barnaud, Florence de Longueville, Gabriel Gonella, Martine Antona, Nicolas Dendoncker, Kerry A Waylen

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Summary

Participatory approaches are widely used in ecosystem services (ES) research. They are particularly advocated for situations characterized by complexity, uncertainties and multiple values. However, behind the term participatory research, there is likely a wide range of practices. In this paper, we undertook a systematic literature review to examine how participatory ES research is implemented in practice. Drawing on 93 reviewed articles, we explore how – and how far – various practices elicit and consider different types of uncertainties related to ES; namely ethical uncertainties (plurality of worldviews, values and interests), epistemic uncertainties (multiple representations) and radical uncertainties (unpredictability). Our review shows a high level of diversity of methods within participatory ES research. Three main types of studies were identified: (1) those centered on socio-cultural valuation of ES, that acknowledge plurality of specific values; (2) those describing more scientifically driven processes focusing on assessments of representations of ES dynamics, that partially acknowledge epistemic uncertainties; and (3) those adopting post-normal approaches to ES, i.e. more deliberative and collective processes that navigate all uncertainty types, including plurality of interests, plurality of knowledge systems and radical uncertainties. We identify three main conclusions from this review. First, plurality of worldviews is seemingly not a strong concern for participatory ES research. This lends credence to concerns that ES framings may encourage a dualistic, anthropocentric, and utilitarian framing of nature. Second, although a plurality of ES values is often acknowledged, disputed values, trade-offs and conflicts of interests are much less often considered, which potentially reflects a lack of connection to real life decision making, and a limited ability to navigate power asymmetries and strategic political agendas. Third, whilst there was often appraisal of non-scientific stakeholders' representations of ES dynamics, radical uncertainties and differences between scientific and non-scientific representations were rarely addressed. This suggests that participatory ES research remains largely anchored in a Western scientific positivist stance.

1. Introduction

In the last two decades, participatory research methodologies have been increasingly used in the research on ecosystem services (ES) - and more generally in the environmental sciences dealing with the unprecedented challenges of global environmental changes. Participatory approaches arise from various research communities, with key concepts (and terminology) ranging from knowledge co-production (Norström et al., 2020), transdisciplinary research

(Reyers et al., 2010), post-normal science (Ainscough et al., 2018), or collaborative research (Cockburn et al., 2020), to cite just a few. These approaches all aim to include in the process of knowledge production those non-scientific stakeholders with a stake in the focal environmental issues. These stakeholders can potentially participate at different stages of ES research, ranging from identification of ES, assessment of specific values for ES, appraisal of processes that underpin ES co-production, or analysis of ES management options.

There are multiple reasons why participatory approaches are advocated in ES research. These reasons generally fall into three overlapping categories: ES are related to complex and uncertain socio-ecological systems (Bennett et al., 2009; de Groot et al., 2010; Walker et al., 2002); they concern a plurality of stakeholders, framings, values and forms of knowing (Kenter et al., 2019; Pascual et al., 2017); and they are linked to high social stakes and decision making processes (Loft et al., 2015; Turkelboom et al., 2018). All in all, ES are often associated with situations in which "facts are uncertain, values in dispute, stakes high and decisions urgent." (p.744) (Funtowicz and Ravetz, 1993). They concentrate and combine three types of uncertainties that are commonly distinguished: ethical uncertainties (plurality of worldviews, values and interests), epistemic uncertainties (multiple representations, absence of consensus) and radical uncertainties (unpredictability) (Barnaud and Antona, 2014; Brugnach et al., 2008).

In those situations, the participation of non-scientists in knowledge production and validation – what post-normal science calls an “extended peer community” (Funtowicz and Ravetz, 1993) – is advocated as a way to ensure the quality and the relevance of the knowledge produced, despite the uncertainties. Participatory approaches are expected to recognize and include a plurality of legitimate perspectives (Norström et al., 2020), to enrich the produced knowledge by integrating non-scientific forms of knowing (Langemeyer et al., 2018; Roux et al., 2010), to ensure that the produced knowledge is useful and used for decision making (Argyris, 1996; Carmen et al., 2018), and to increase stakeholders’ ownership of knowledge (Cundill et al., 2015; Saarikoski et al., 2018). Participation is also advocated as a bottom-up governance tool to foster and accompany multi-stakeholder collaborative management of ES, through social learning, better understanding of each other’s values and perspectives, and collective exploration and discussion of ES management options (Barnaud et al., 2018; Cockburn et al., 2020; Galafassi et al., 2017). In the latter situations, it is particularly critical to acknowledge the existence of multiple uncertainties.

However, behind the intention to do participatory research on ES, there is likely a wide range of practices. After two decades of abundant literature on participatory ES research (DeFries and Nagendra, 2017; Jacobs et al., 2016; Jax et al., 2018; Raymond et al., 2014; Reyers et al., 2010), an overview of how participatory methodologies in ES research address uncertainties in practice is needed.

Several existing reviews, often based on selected case studies, have explored different aspects of participatory ES research, including the advantages and drawbacks of using the ES concept (Spyra et al., 2018), how ES are identified and selected (Boeraeve et al., 2018), how ES values are assessed (Cheng et al., 2019; Christie et al., 2012); or how ES knowledge is operationalized (Jax et al., 2018; Saarikoski et al., 2018). These reviews suggest that a diversity of methodological approaches have been used to elicit and discuss ES – especially cultural ES – but without providing a clear overview of the range and types of participatory practices. To our knowledge, there is no review of the whole literature on participatory ES research that examines how participatory ES research is implemented in practice – e.g. who participates at which stage

of the research process, and how – and how these diverse methods address and manage the different types of uncertainties related to ES.

To address this gap, we undertook a literature review to examine the variety of methodological choices made in participatory ES research, with a special focus on uncertainties. Our research question is: how - and how far – do different participatory practices in ES research consider the different types of uncertainties related to ES? We have based this on systematic mapping, an approach which has been proved useful for collating and cataloguing available evidence relating to a topic (Haddaway et al., 2016). All types of ES are included in this review, i.e. provisioning, regulating and cultural ES.

This paper starts with a conceptual framing section which defines the different types of uncertainties, how they apply to ES, and how they could be acknowledged or handled through participatory ES research methods. We then present the systematic methodology we adopted for the review, followed by a result section that characterizes the diversity of existing practices in participatory ES research, identifying three main types of articles that focus on different types of uncertainties. Finally, in our discussion we examine the gaps and strengths of current participatory ES research in the face of these results.

2. Linking ES uncertainties and participatory research practices

Several definitions and typologies of uncertainty have been proposed in the literature (Arts and Woerkum, 2002; Brugnach et al., 2008; Mehta et al., 1999; Röling, 2002). Broadly defined, uncertainty refers to a "situation in which there is not a unique and complete understanding of the system to be managed"(Brugnach et al., 2008). This definition embraces three types of uncertainty: ethical uncertainties, that results from the existence of contrasting worldviews and disputed values, leading to a plurality of perspectives on a problem or a given reality –; epistemic uncertainty that derives from a lack of knowledge or an absence of scientific consensus on the functioning of a system; and radical uncertainty that is related to the unpredictable and chaotic dynamics of a complex system.

While it is conceptually useful to distinguish them, these different types of uncertainties are in practice intimately intertwined. When there is a lack of consensus on the causes or consequences of a phenomenon (epistemic uncertainty), it might be due, in part, to the unpredictable nature of the system (radical uncertainty), and this often gives rise to controversies in which plural values, interests and worldviews are disputed (ethical uncertainties) (Ainscough et al., 2018; Latour, 2004). Society then faces "wicked" problems, i.e. problems which are not clear-cut and well-defined, but rather subject to multiple interpretations (DeFries and Nagendra, 2017; Jax et al., 2018).

In this section, we draw on literature to explain why ES are concerned by these different types of ethical, epistemic and radical uncertainties, and how these uncertainties can be acknowledged or handled through participatory research practices. We then highlight the resultant analytic factors we applied in the systematic literature review.

2.1 Ethical uncertainties - plurality of worldviews

There have been numerous debates around the idea that the ES concept corresponds to a partial vision of human-nature relationships that does not account for the many ways in which human beings relate to nature (Diaz et al., 2015; Raymond et al., 2013; Sullivan, 2009). The ES concept

has notably been criticized for reinforcing a conceptual separation between nature and people, while this idea of a "nature" that exists independently of human beings is an occidental social construction (Descola, 2013). The ES concept has also been criticized for supporting an instrumental vision of nature, framing nature as a means for human ends. Again, this Western conception of nature is incompatible with many other worldviews. Some authors suggest that nature matters to people in four ways: (i) we live from it (nature sustains us), (ii) we live in it (it defines the place where we live and how we relate to it), (iii) we live with it (human species co-exist with non-human species – and can care for them), and (iv) we live as the world, as an entity that transcends human-nature duality (O'Connor and Kenter, 2019; O'Neill et al., 2007). The ES concept should thus be seen as one among many other possible visions of human-nature relationships, and participatory ES research in particular should acknowledge the complexity and diversity of these visions (Kenter, 2018; Raymond et al., 2013).

In our review, to assess how this plurality of worldviews is addressed methodologically in participatory ES research, we asked whether or not the ES concept was explicitly used with the participants, whether the concept was debated with them, and whether they had the possibility to opt for another term or concept (see figure 1 for an overview of the questions asked in the review to query how different forms of uncertainties are attended to in participatory ES research).

2.2 Ethical uncertainties - plurality of values

There are multiple understandings of the term 'value' in ES research (Kenter et al., 2019; Raymond et al., 2019a), as highlighted by the recent value assessment of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). This assessment adopts a broad definition of values that encompasses and distinguishes: (i) worldviews, (ii) knowledge systems, (iii) broad ethical values, (iv) specific values (that include instrumental, relational and intrinsic values) and (v) value indicators (IPBES, 2022). In this paper, since we focus on uncertainties, we adopt a slightly different typology. The ethical uncertainties related to plurality of worldviews presented in the previous section encompasses both "worldviews" and "broad ethical values" within IPBES categories. What we name plurality of values in this paper includes what IPBES named specific values (how important nature is for someone), and value indicators (the estimated, ranked or quantified value that results from a valuation process, that is supposed to reflect the specific values) (Kenter et al., 2015).

These different values involve different disputes. Specific values of ES are disputed in the sense that different people have different preferences for different ES or different ways to value nature, e.g. a mountain farmer might value highly the grass produced by a moorland to feed his sheep (an instrumental value), and/or have an affective attachment to this place (a relational value), while a naturalist would value its biodiversity (intrinsic value of nature). For the value indicators, it is the valuation process itself that is often disputed. An abundant literature has emphasized the need to go beyond economic valuations, which are based solely on instrumental and individual rationality, in order to integrate other kinds of values, notably intrinsic and relational values (Chan et al., 2016; Raymond et al., 2019b). This has led to the rise of numerous approaches for social valuation of ES, that all rely on some sorts of participatory methodologies to assess these social values (Dendoncker et al., 2018; Himes and Muraca, 2018; Jacobs et al., 2016). In the meanwhile, further questions have emerged regarding how preferences are shaped, and how to inform collective values, whether by aggregating individual values or through deliberative valuation (Kenter et al., 2015; Raymond et al., 2014). In deliberative valuation, the assumption is that values are not pre-existent and emerge through social interactions. When people discuss and exchange their views on what is important for them, there might be a

collective learning and negotiation process going on, and the values on which people collectively agree might be different than the sum of their individual values without discussion.

In order to examine how far participatory ES research addressed these uncertainties related to the plurality of values, our review thus assessed the way the participants attributed values to ES (individually and/or collectively), and how far the differences between different stakeholders' ES specific values were taken into account – whether they were analyzed in the paper and/or collectively debated with the participants (figure 1).

2.3 Ethical uncertainties - plurality of interests

The notion of interest refers to how important a given stake is for a given stakeholder. Compared to the notion of value discussed above, the notion of interest triggers analysis in terms of winners and losers, strategic behaviours and individual rationalities (Morrison et al., 2019; Reed et al., 2009). Although it is obviously connected with the notion of instrumental value, the two are not totally overlapping (Jax et al., 2013). The instrumental value that a stakeholder attributes to an ES reflects his or her interest as a beneficiary of the ES. However, there are also other sources of interests in a given ES. For example, a stakeholder might be interested in the payment or the social recognition he or she could get as a co-producer of this ES. In the same way, an ES manager could be interested in a given ES because his or her professional mission is to protect this ES. This notion of interest is particularly pertinent in the critical step of selecting ES during a participatory process. Indeed, when stakeholders select a given ES, this reflects their interest in this ES, whatever the reasons that underpin their interest, be it as a beneficiary of this ES (thus aligned with specific value), or as a co-producer or indirect manager of this ES.

The notion of interest also triggers analysis in terms of winners and losers. Plurality of interests are thus especially at stake when there are trade-offs among ES, i.e. when multiple ES cannot be delivered all together – for example, when the delivery of a provisioning ES such as timber, reduces the potential to deliver some other ES, such as forest aesthetic. Such trade-offs generate conflicts of interests (Bennett et al., 2009; Turkelboom et al., 2018). They are directly related to decision-making and social choices, which, for the sake of justice and inclusion, should be explicitly and collectively deliberated in participatory ES research (Barnaud et al., 2018).

To appraise how a participatory process addressed these uncertainties related to a plurality of interests, our review assessed whether trade-offs among ES were analyzed in the paper and collectively debated with the participants. We also assessed who selected the ES under study in the participatory process (leading researchers and/or non-scientific participants), and whether or not this selection involved some kind of collective discussion or negotiation with and among the participants (figure 1).

2.4 Epistemic uncertainty – plurality of representations and knowledge systems

The delivery of ES involves highly uncertain processes, due to the multiple dynamics interacting at different levels within socioecological systems, with nonlinear, stochastic relationships and multiple feedback loops (Bennett et al., 2015; Fedele et al., 2017; Norgaard, 2010; Walker et al., 2002). The uncertainties underlying ES provision are said to be either epistemic, when they result from a lack of knowledge or consensus, or radical when the systems being considered are, by their very nature, chaotic and unpredictable.

This section addresses epistemic uncertainty, which refers to situations where there are multiple and potentially contradictory understandings of reality that co-exist. This echoes the plurality of knowledge systems within the IPBES framework on values assessment. Different scientists

can have different visions of the functioning of a system, and non-scientist stakeholders can also have their own interpretations, based on other types of knowledge. In such situations, participatory approaches are encouraged in order to recognize, confront and eventually combine these multiple visions and sources of knowledge in order to, firstly, enrich the quality of the produced knowledge (Langemeyer et al., 2018; Norström et al., 2020), and, secondly, be transparent towards stakeholders and explicitly acknowledge the existence of epistemic uncertainties on certain processes (Funtowicz and Ravetz, 1993; Jax et al., 2018).

In our review, in order to assess how participatory ES research addresses these epistemic uncertainties, we asked whether there were discussions among the participants about their representation of the functioning of the ecosystems, and whether the differences of knowledge and representations between scientists and non-scientists were addressed in the paper and eventually collectively discussed in the participatory process (figure 1).

2.5 Radical uncertainty – unpredictability

A key idea that underpins post-normal science is that uncertainties should not be banished, but managed (Funtowicz and Ravetz, 1993). In the face of environmental changes such as climate change or the decline of biodiversity, urgent decisions need to be taken despite our inability to predict with certainty the effects of these decisions. This is especially true in the case of radical uncertainty, i.e. when systems are by nature unpredictable. In the face of these uncertainties, participatory approaches are encouraged to increase the ability of stakeholders to take decisions on the basis of an awareness of uncertainties, notably through collective explorations of desired scenarios rather than predictions (Arts and Woerkum, 2002; Bohensky et al., 2006; Bousquet et al., 2002; Oteros-Rozas et al., 2015).

Thus, to assess how a participatory process addressed radical uncertainties, we assessed whether the unpredictability of the socio-ecological system was considered in the study and discussed with the participants (figure 1).

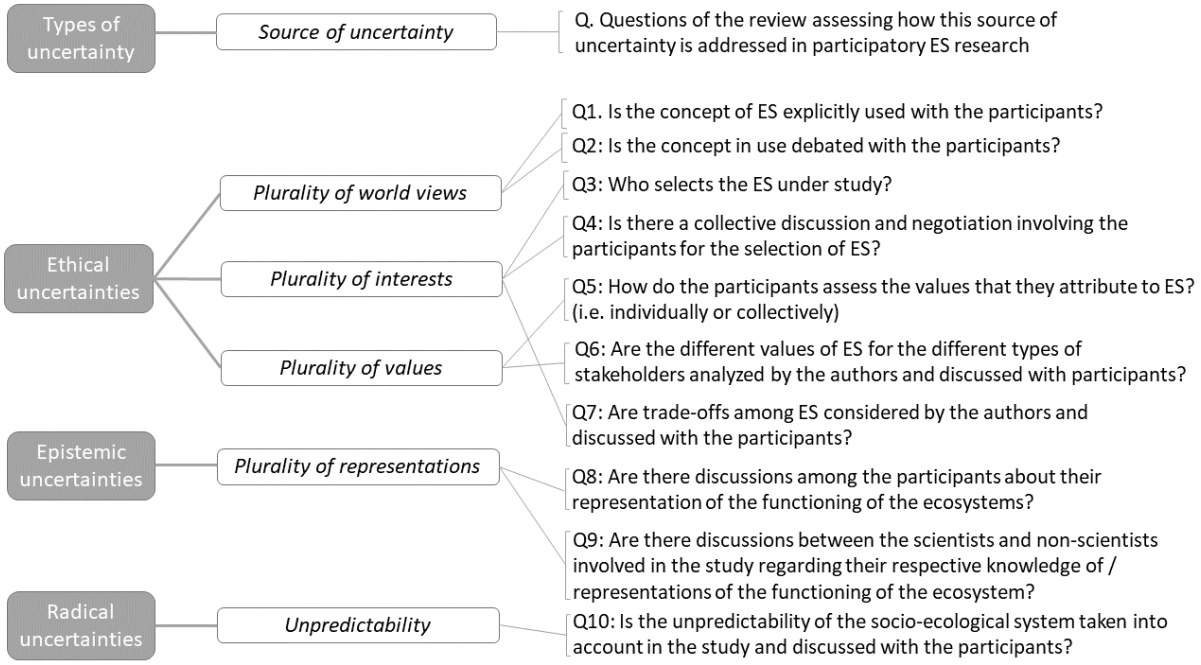

Figure 1. Synthesis of the questions of the review assessing how the different types of ES uncertainties are addressed in practice in participatory ES research – NB: all these questions are multiple choices questions; for a full description of the possible answers, see annex 1.

3. Methodology: a systematic literature review

3.1 Selection of reviewed articles

We searched the WoS database[1] on November 8, 2019 with the aim of identifying and selecting papers describing cases of research on ES based on participatory methodologies (figure 2). In order to capture such articles, our query searched for a combination of an adjective (participatory, deliberative or collaborative), with a variety of nouns, such as 'process', 'approach', 'method', 'valuation', 'assessment', 'scenario' or 'planning'. These combinations were chosen to cover broadly the different existing schools of participatory ES research. In the end, 93 papers were identified and screened as relevant for analysis.

[1] We excluded the papers that came from the database WoS-generated "Keyword plus", which did not send relevant results.

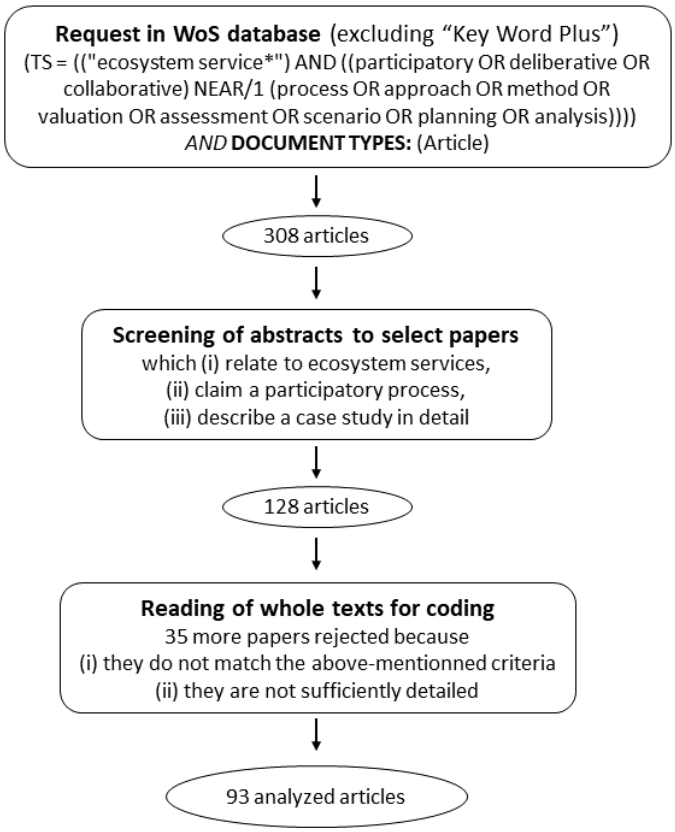

Figure 2. Description of the process of selection of papers

3.2 Analytical factors & coding process

The 93 papers were analyzed through a set of 10 multiple choices questions (Q1 to Q10) about the concrete methodological choices made in the participatory process described in the paper. As seen in the previous section (figure 1), these questions aimed to address different forms of uncertainties related to ES. For each question, several potential choices were proposed (from 3 to 5 choices), covering the range of possible situations, ranging from an absence of consideration of a given aspect in the article, to the description of a collective and deliberative process about it (see annex 1 for a full description of the multiple choices questions). An additional set of questions addressed diverse contextual factors, such as the objective of the participatory process, the type of participating actors, or the location of the case study (see annex 1), but they were not part of the statistical analysis.

The coding process was as follows. The selected articles were shared among the co-authors who each read and coded a set of articles. To limit the readers' biases, 20 articles were randomly selected and double-read by two co-authors, initiating an iterative process of collective learning and individual re-coding. The two readers first compared their coding, discussed the eventual differences and tried to find an agreement. When they disagreed or doubted, they asked the opinion of a third reader. Since any coding difference reveals a potential ambiguity in the formulation of questions, or a reader's coding bias, these discussions were shared with all the co-authors. This induced changes in the formulation of some questions and possible answers, and clarified the way to answer them – the co-authors could then check and correct their own coding in the light of these clarifications.

3.3 Statistical analysis

We first conducted a descriptive analysis for questions Q1 to Q10, to get an overview of the distribution of practices reported by the 93 papers. We then analyzed correlations between each pair of questions, applying Fisher's exact test to contingency tables (Agresti, 2003). Fisher's Exact test is used in place of chi-squared test when the sample sizes are small, marginals are very uneven, or there is a small value (less than 5) in one of the cells (Bower, 2003). This test computed the so-called exact p-value, which was then compared to the general significant level of 0.05. We also performed an analysis of Pearson residuals. This complementary analysis provided a sense of the relation between two given levels (weak or strong association between these two levels) and the contribution of a cell to the magnitude of the dependency between two variables in case of reject H0. Finally, we conducted a Multiple Correspondence Analysis (MCA) on the responses to the questions Q1 to Q10 in order to identify clusters of articles with similar patterns of responses (Roux and Rouanet, 2010).

3.5 Description of our sample of articles

Our final sample contains 93 articles published between 2007 and 2019, with more than 70% in the last 4 years of this period. The case studies are distributed across all continents, with a majority in Europe (51%), and they concern diverse ecosystems (coastal, agricultural, forest and watershed ecosystems are the most frequent ones) (see annex 2 for the list of 93 references included in the final review sample).

4. Results: how participatory ES research addresses uncertainties

Section 4.1 presents how participatory ES research addresses ethical uncertainties, i.e. plurality of worldviews, values and interests (Q1 to Q7), and section 4.2 how epistemic and radical uncertainties are dealt with (Q8 to Q10). These two sections draw on the distribution of answers to Q1 to Q10 questions (figures 3 to 8), and on some statistical correlations between answers to these questions (see annex 3 for the correlation analysis). Section 4.3 presents the results of the clustering analysis, that highlights three main families or types of participatory practices in relation to uncertainties.

4.1 How participatory ES research addresses plurality of worldviews, values and interests

How the ES concept is used and debated (or not) (Q1 and Q2) – plurality of worldviews

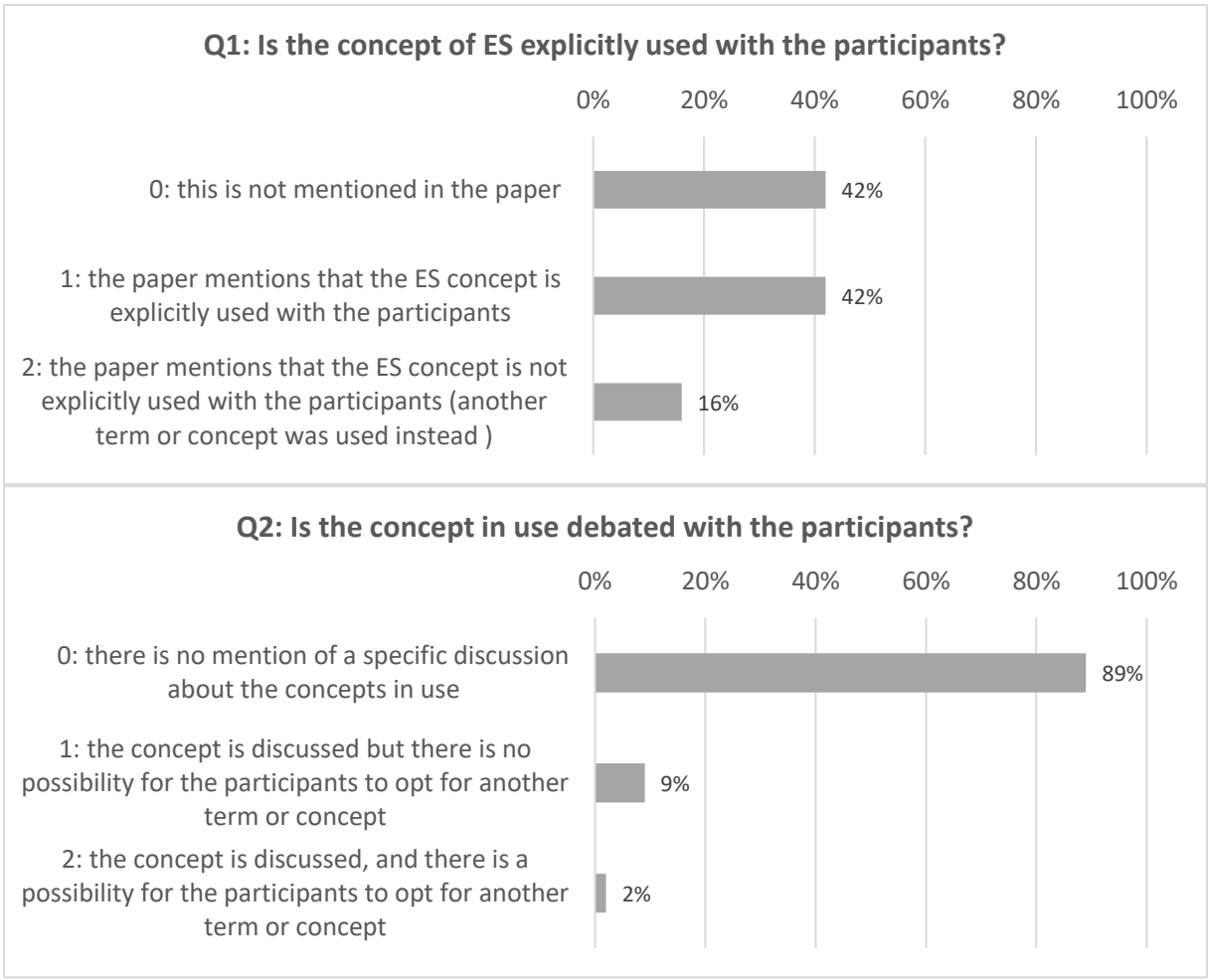

Figure 3. Answers to questions Q1 and Q2 about how the ES concept is used and debated

Answers to Q1 and Q2 summarize how the ES concept is used and debated (or not) in participatory processes (figure 3). This indicates that plurality of worlds views, i.e. the fear that the ES concept might not fit the participants' representations of human-nature relationship, was not a strong concern within participatory ES research. Most of the time, these issues were simply not mentioned in the articles. When they were, articles usually framed it as ES familiarization session for participants (e.g. Ciftcioglu, 2018; Muhati et al., 2018). Nevertheless, a few articles mentioned a debate with the participants about the limitations of the ES concept (e.g. Plieninger et al., 2015) and some authors deliberately chose not to use the word ecosystem services with the participants, considered as too academic or not adapted to the participants' views and language (e.g. Kaltenborn et al., 2017; Moreau et al., 2019; Ruoso et al., 2015).

How the studied ES are selected and debated (or not)(Q3 and Q4)-plurality of interests

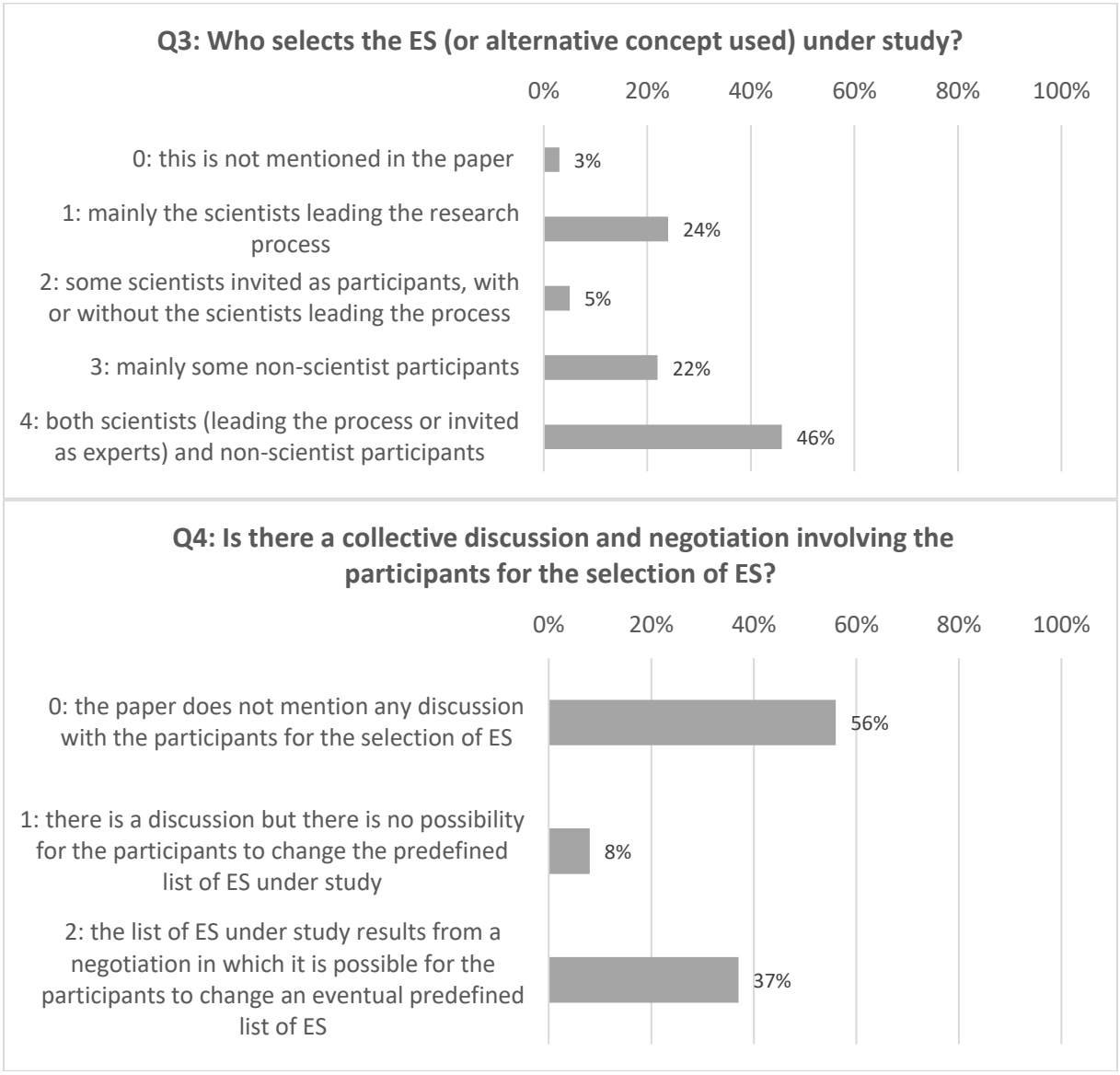

Figure 4. Answers to questions Q3 and Q4 about ES selection

Answers to Q3 and Q4 shows that participatory ES research generally pays attention to the process of ES selection. In most papers these methods were well described, illustrating a diversity of tools, such as individual interviews, focus groups, mapping or literature review. Non-scientific stakeholders were usually involved in this selection process, though not necessarily in a collective and deliberative process (figure 4). When such discussions were mentioned, the participants may had either *carte blanche* (e.g. Burdon et al., 2019; Chaigneau et al., 2019) or start from a predefined list of ES from which they removed or added items (e.g. Ingram et al., 2020; Levrel et al., 2017).

How specific ES values are elicited, analyzed and debated (or not) (Q5 and Q6)- plurality of values

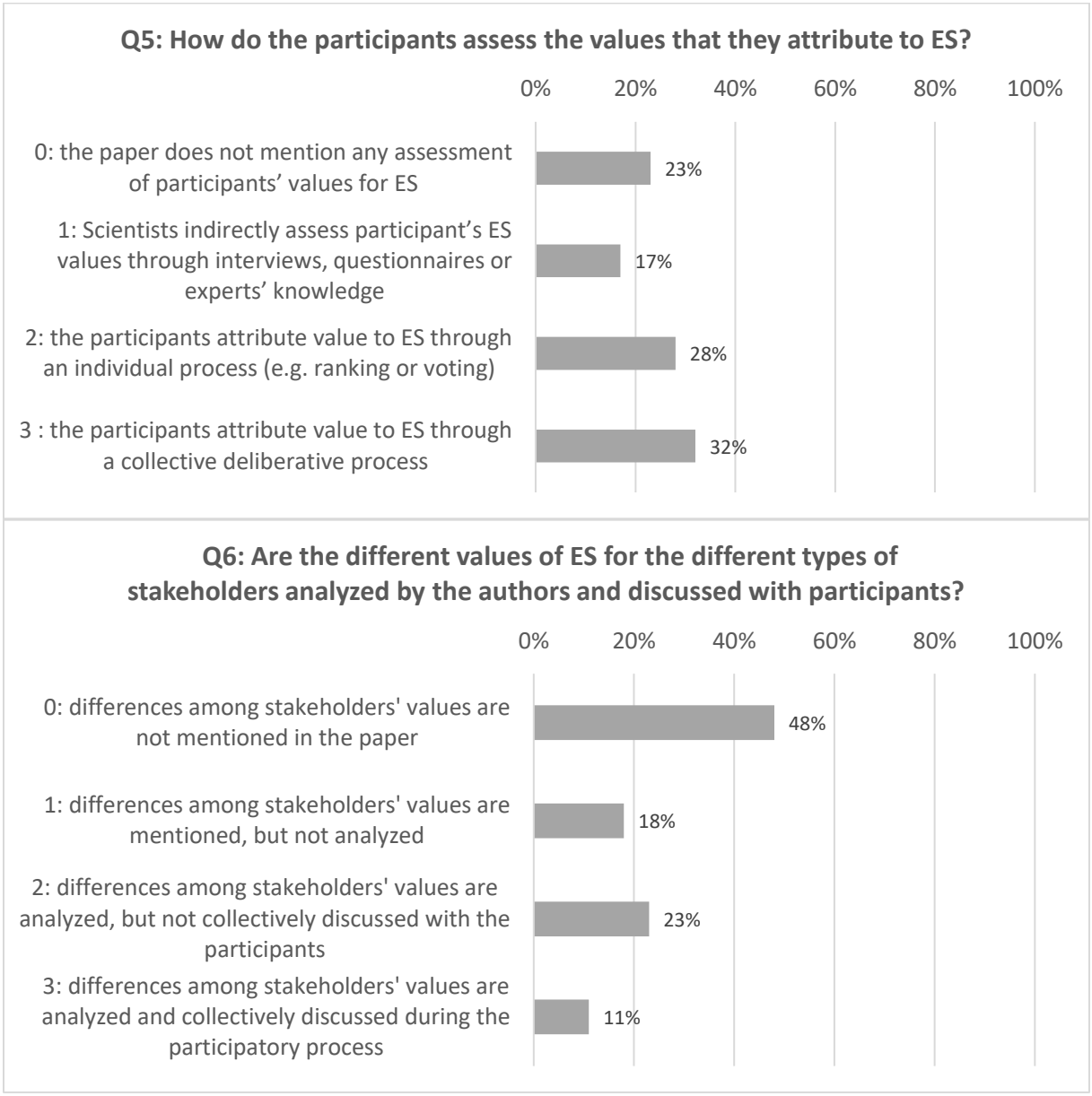

Figure 5. Answers to Q5 an Q6 about assessment of ES specific values

Most participatory ES research included a sort of assessment of specific ES values (figure 5). In a few cases, the scientists indirectly assessed these values, through expert knowledge or literature review (e.g. Kaltenborn et al., 2017), but most of the time, participants directly attributed a value, through non-monetary techniques such as ranking (e.g. Bogdan et al., 2019; Mugari et al., 2019) or individual and/or collective scoring exercises (Brummer et al., 2017; Derak and Cortina, 2014). In collective settings, the participants were often asked to deliberate until they reach a consensus or compromise on a common ranking (Mavrommati et al., 2017) or a group monetary value (e.g. Kenter, 2016; Orchard-Webb et al., 2016).

Despite that, answers to question Q6 indicate the differing values among stakeholders (e.g. farmers, hunters, biodiversity managers) were rarely emphasized and discussed collectively in those settings (figure 5). Most participatory ES research, at least as reported, seemingly

considered the voices and values of local people in general, but did not highlight and discuss disputed values and conflicts of interests. The next section on trade-offs among ES reinforces this impression.

How trade-offs among ES are considered and debated (or not) (Q7) – plurality of interests

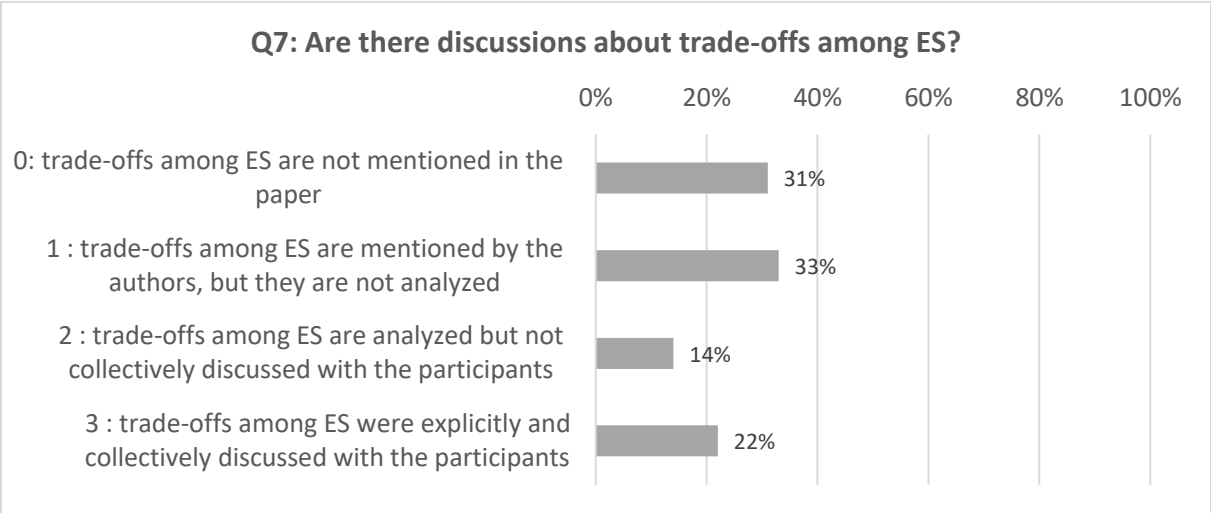

Figure 6. Answers to Q7 about consideration of ES trade-offs

Answers to Q7 suggests that only a fringe of participatory ES research involved collective discussions about trade-offs between ES (figure 6). It is noteworthy that this fringe often uses participatory simulation and gaming tools (Daw et al., 2011; Moreau et al., 2019). Interestingly, when trade-offs were collectively discussed, there were often also collective discussions on ES selection (correlation Q7-Q4, annex 3) and on stakeholders' values (correlation Q7-Q6; annex 3). This suggested the existence of a small sub-set of studies that were both aware of and dealing with conflicts of interests, explored further by the cluster analysis in section 4.3.

4.2 How participatory ES research addresses epistemic and radical uncertainties – and how this relates to ethical uncertainties

How different representations of ES dynamics are considered and debated (or not)(Q8 and Q9) – epistemic uncertainties

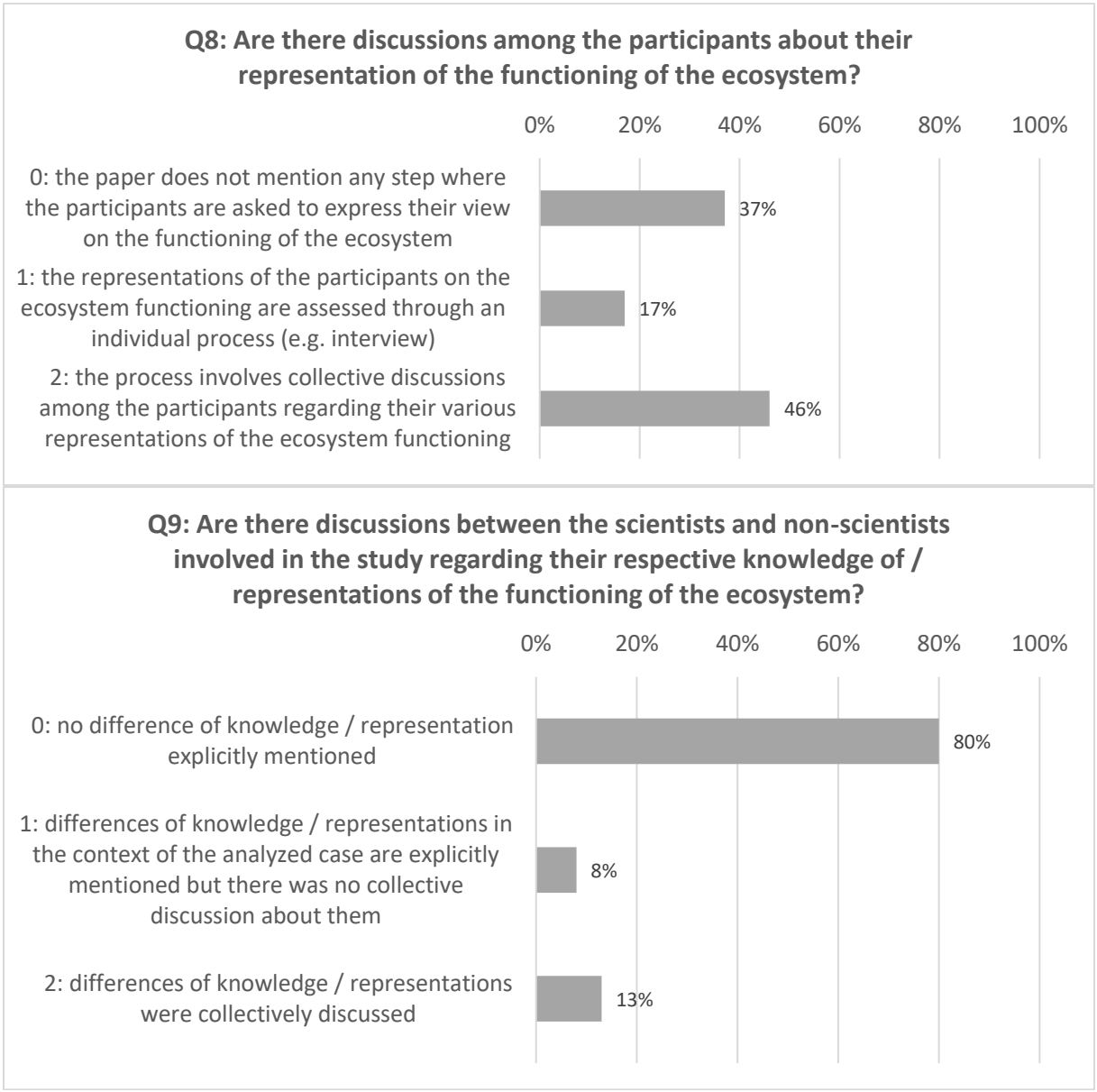

Figure 7. Answers to Q8 and Q9 about how representations of ES dynamics are considered

Answers to Q8 suggest a reasonable level of attention to epistemic uncertainties. Most articles mentioned a methodological step to assess participants' representations of the socio-ecological system and its functioning, in some cases through an individual process, but more often through collective discussions (figure 7). For example, matrixes indicating the impacts of different scenarios of land-uses on ecosystem services were used in discussions with participants in participatory scenarios planning (Malinga et al., 2013) and deliberative multi-criteria evaluation processes (Bryan and Kandulu, 2011; Grêt-Regamey et al., 2017).

However, while differences of representations among stakeholders were quite widely considered, Q9 suggests that differences between scientific and non-scientific representations

were much more rarely addressed (figure 7). It is indeed noteworthy that a large majority of articles do not mention anything about it. Only a few articles reported differences between knowledge systems. For example, Tarrasón et al. (2016) describe a process of participatory assessment of land degradation that capitalized on complementarities between local knowledge and scientific knowledge and critically deconstructed their respective assumptions (Tarrasón et al., 2016).

Answers to Q8 and Q5 were correlated (annex 3) in a way that suggested the existence of a specialization of many articles that focused either on values or representations. Three types of studies seemingly emerged: those focused on assessment of ES values through individual processes; those focused on assessment of representations, also through individual processes; and those that considered both representations and values, through collective assessments for both. This third sub-set of articles also involved collective discussions on trade-offs (correlation Q7 – Q8), thus paying attention to conflicts of interests.

How the unpredictability of ES dynamics is considered and debated (or not) (Q10) – radical uncertainties

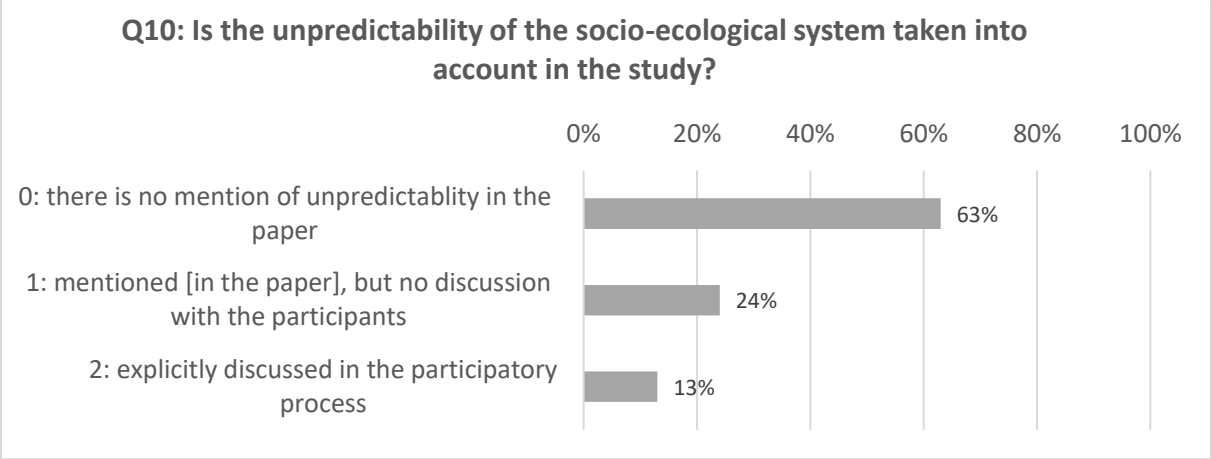

Figure 8. Answers to Q10 about how unpredictability of ES dynamics is considered

Answers to Q10 indicate little attention to radical uncertainties in our dataset. Most articles did not mention anything about the unpredictability of socio-ecological systems, and it was explicitly discussed with participants in very few cases (figure 8). We observe that answers to Q9 and Q10 were strongly correlated (annex 3): papers that seriously considered epistemic uncertainties linked to differences between knowledge systems also considered radical uncertainties. This correspond to studies acknowledging facts uncertainties underpinning scientific knowledge, such as Van Dam et al. (2013) who used a Bayesian Network Model to characterize uncertainties on cause effects relationships in a wetland socio-ecological system (van Dam et al., 2013).

Interestingly, attention to unpredictability (Q10) and trade-offs among ES (Q7) were also correlated (annex 3). We could thus make the hypothesis that the sub-set of articles attending to conflicts of interests also attended to radical uncertainties.

4.3 How different types of articles address different forms of uncertainties - Cluster analysis

The pairwise correlations of the previous section suggested the existence of three different families of approaches. The results from the cluster analysis indicated three clusters of articles that confirmed these assumptions and enabled a more integrated understanding of the characteristics of these three families of approaches. We also identify the papers belonging to each cluster, and returned to their full texts to increase our qualitative understanding of the internal logics of the original studies.

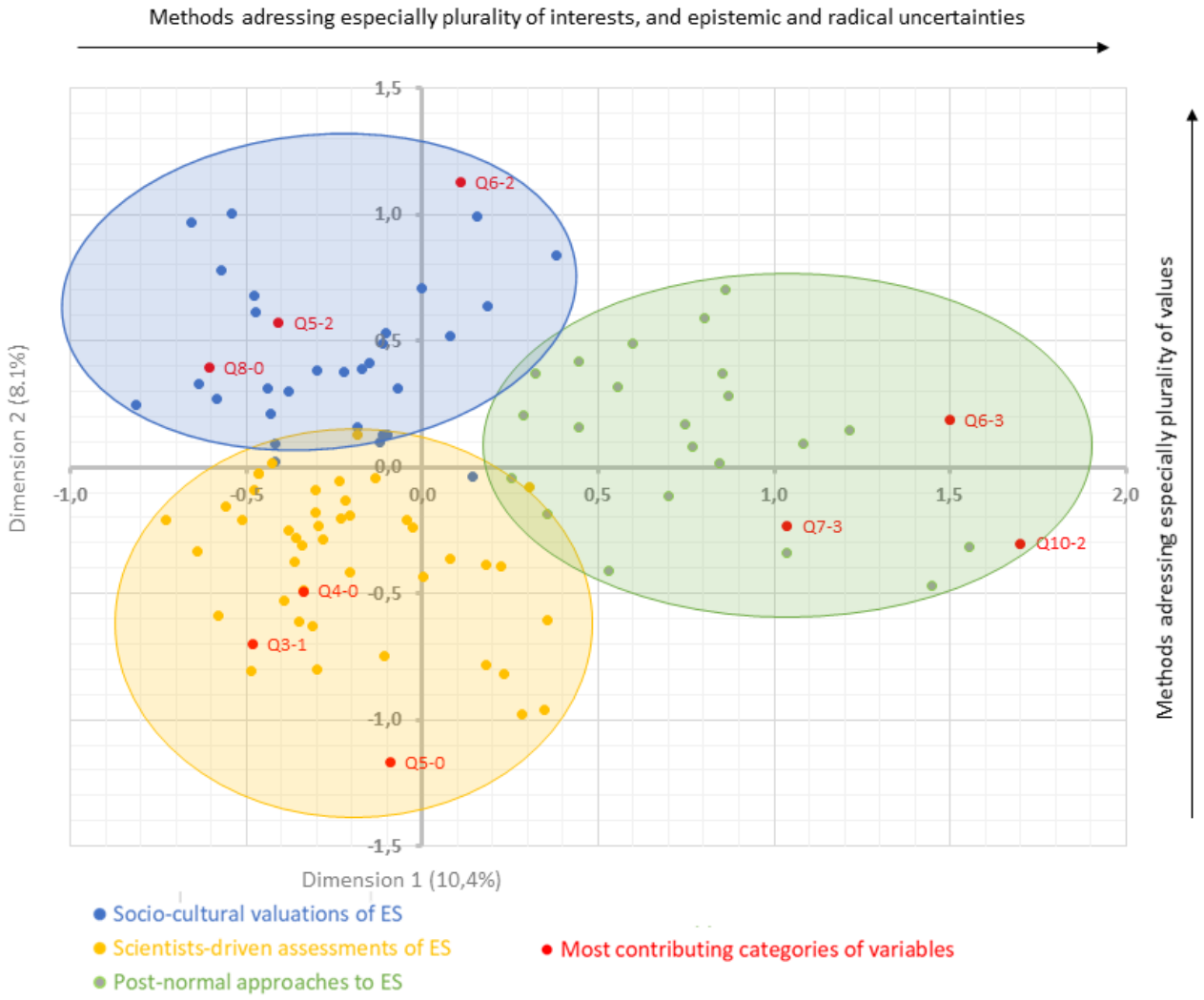

Figure 9. Results of ACM clustering based on the answers to Q1 to Q10 questions (factor map above, and variable categories below). The x axis is mainly linked to Q7, Q10 and Q8 (representing attention to plurality of interests, epistemic and radical uncertainties), and the y axis is mainly linked to Q5 and Q6 (representing attention to plurality of values).

Name of the cluster *Main forms of uncertainties attended to*	Typical methods characterizing the cluster – the statistically most contributing variables are marked with an asterisk*
Cluster 1: socio-cultural valuations on ES (n=33) *Plurality of values*	Individual assessment of specific ES values (Q5-2)* Analysis of different stakeholders' values (Q6-2)* – but no deliberation about these differences Poor attention to trade-offs among ES (Q7-1) No consideration of different representations of SES (Q8-0)* No consideration of unpredictability (Q10-0)
Cluster 2: scientist-driven assessment of ES (n=39) *Epistemic uncertainties (partially)*	ES selected by leading scientists (Q3-1)* No discussion about ES selection with participants (Q4-0)* No mention of assessment of stakeholder's values (Q5-0)* Individual assessments of participants' representations of SES (Q8-1)
Cluster 3: post-normal approaches to ES (n=21) *Plurality of interests, epistemic and radical uncertainties*	Collective discussions on ES selection (Q4-3) Collective discussions on different stakeholders' values (Q6-3)* Collective discussions on trade-offs (Q7-3)* Collective discussions on differing representations among stakeholders (Q8-2) Collective discussions on differing representations between scientist and non-scientific stakeholders (Q9-2) Collective discussions on radical uncertainties (Q10-2)*

Table 1: synthetic characteristics of the three clusters, based on the identification of the most contributing variables of the clusters, i.e. what differentiates mostly the articles from each other. NB: these are statistical tendencies that present some kinds of archetypes, and many articles that fall into these clusters are not coded this way. However, statistically speaking, they do share some similarities.

The first cluster corresponds to studies that focus on socio-cultural valuation of ES, especially through individual valuation processes. These articles generally paid attention to plurality of values, but not to conflicts of interests and epistemic and radical uncertainties (figure 9, table 3). A closer look at the articles of this cluster shows that it embraces various non-monetary methods of ES valuation, such as ES ranking and scoring exercises (Lopes and Videira, 2019; Rigal et al., 2018), participatory mapping of ES and community values (Fagerholm et al., 2012; Paudyal et al., 2015; van Oort et al., 2015), or photo voice methods (Berbés-Blázquez, 2012). This type of study focused on socio-cultural valuation of ES seemingly attends to values so as to consider the voices and values of communities, citizens or local people in general, but did not explicitly highlight and discuss disputed values and conflicts among stakeholders.

The second cluster highlights more scientist-driven studies focused on assessments of the functioning of socio-ecological systems, notably through individual assessments of participants' representations. They generally paid little attention to forms of uncertainties other than epistemic uncertainties (figure 9). This cluster embraced diverse modelling approaches such as Driver-Pressure-State-Impact-Response Framework (Hermanns et al., 2017), multi-criteria decision analysis (Grêt-Regamey et al., 2017), participatory GIS (Hodbod et al., 2019; Sulistyawan et al., 2018) and Bayesian Network models (van Dam et al., 2013). These approaches integrate scientific and non-scientific knowledge for further understanding the linkages between ecosystems functioning and ES, and assessing the impacts of various

scenarios or management alternatives on ES. Non-scientific knowledge was included mainly to complement and enrich the scientists' understanding of the socio-ecological systems.

The third cluster corresponds to studies with highly collective and deliberative processes, that deal more than others (and in a more deliberative way) with conflicts of interests, trade-offs and disputed values, as well as radical uncertainties and differences between scientific and non-scientific knowledge systems (figure 9, table 3). This third cluster is in accordance with post-normal approaches, that promote stakeholder engagement in all parts of research to deal with those multiple uncertainties (Funtowicz and Ravetz, 1993). It embraced various methods, such as simulation and gaming tools (Daw et al., 2015; Moreau et al., 2019), participatory mapping (Burdon et al., 2019), participatory multi-criteria analysis (Saarikoski et al., 2019), participatory scenario development (Malinga et al., 2013; Muhati et al., 2018). Some of these methods were similar to those found in the first two clusters, reflecting that one method can be applied in different ways, paying more or less attention to certain forms of uncertainties.

5. Discussion

5.1 The need to increase reflexivity on uncertainties in participatory ES research

Our review shows a high level of diversity of methods within participatory ES research, with diverse methodological choices that put emphasis on different forms of uncertainties. Three main types of articles dominate: (1) those centered on individual socio-cultural valuation of ES that acknowledge plurality of values, (2) those describing more scientific driven processes that focus on individual assessments of representations of SES, that partially address epistemic uncertainties, and (3) those (less numerous) describing more collective and deliberative processes, connected to conflict resolution and decision making, that navigate all sources of uncertainties, including plurality of interests and radical uncertainties – hence named post-normal approaches to ES.

The majority of articles are thus rather specialized, i.e. focusing on some issues and uncertainties. It is possible that some processes are more integrated than they appear, as reporting studies in the form of journal articles often entails that only some aspects and details of a process are explicitly reported. However, if this is the case we query why some issues (e.g. valuation) are foregrounded over others (e.g. conflict) in the literature.

Assuming that most studies are indeed relatively specialized, this is not necessarily a problem in itself. Indeed it may not be possible for participatory process to deal with all sources of uncertainties. Different types of methods focus on different types of uncertainties. As in ES valuation methods, there is no one size fits all methodology, and the most relevant and robust methods (or combination of methods) to choose depend on each study context (IPBES, 2022). What is important is to be explicit about this choice, acknowledging the domains of uncertainties that are left in the shadow, and the consequences – i.e. to increase ES scientists' reflexivity on these issues.

5.2 Plurality of worldviews: not a prior concern in participatory ES research

Participatory research aims by essence to include a diversity of representations. It was therefore surprising to observe that only very few articles on participatory ES research mention the existence of debates with participants about the ES concept, or the use of other terms or concepts that are better adapted to local representations of human-nature relationships (Abunge et al., 2013; Berbés-Blázquez, 2012; Burdon et al., 2019; Mahajan and Daw, 2016). This counters recommendations in ES research that concepts should be adapted to contexts and stakeholders,

so as to enable the expression of diverse worldviews (Jax et al., 2018; Raymond et al., 2013). Some researchers might have considered these issues in practice but felt that this was not an issue that worthy of mention in a scientific paper. In any case, this suggests that plurality of world views is not a prior concern in participatory ES research. Since non-participatory researches into ES are even less likely to attend to it, it means that worries about the potential downsides of ES research may be justified; i.e. that it may not respect or reflect the diversity of cognitive frameworks of human-nature relationships (Barnaud and Antona, 2014; Diaz et al., 2015; Muradian and Pascual, 2018; Pascual et al., 2017). The concept of 'nature's contributions to people' (NCP) (Diaz et al., 2018) has emerged as an attempt to overcome these limitations. However, although this new term has less economic and market-oriented connotations on the surface, it remains rooted in a dualistic, anthropocentric and utilitarian vision of human-nature relations (Muradian and Gómez-Baggethun, 2021). One step further, one might question the very use of ES or NCP concepts in participatory processes, since they are by essence scientific concepts, anchored in Western science, and reproducing its cognitive bias. A few papers in our sample explicitly explain though that they did not use the ES concept to avoid such bias and ensure they captured the richness and diversity of participants' worldviews (Bogdan et al., 2019; Bremer et al., 2018). However, there are so few of them that it should be a matter of concern for the ES science community.

5.3 An attention to values, but not to conflicts: inability to navigate power asymmetries and strategic political agendas

It is widely acknowledged that for ES research to contribute to decision making, it should integrate the diverse values and interests of non-scientific stakeholders (Ainscough et al., 2018; Hauck et al., 2013; Jacobs et al., 2016). Two methodological steps in participatory ES research are often emphasized for that purpose: ES selection (Boeraeve et al., 2018; Jax et al., 2018) and assessment of ES specific values (IPBES, 2022; Pascual et al., 2017).

The majority of our sample reflects this, with stakeholders commonly involved in ES selection, and a majority of studies integrating some form of assessment of the specific values stakeholders attribute to ES. Almost one third of the articles even mention a collective process for assessing ES specific values – which, if done through rigorously, is seen as promising for both debating different normative positions and for building shared values (Kenter et al., 2015; Raymond et al., 2014). This bodes well for understanding and representing diverse values in ES research. However, there are some caveats. Firstly, we note few descriptions of *how* selection of ES occurred, which suggests that more attention should be paid to this critical stage (Boeraeve et al., 2018) – it is not sufficient to tick the box "stakeholders were involved" – attention is needed to how they are involved and why. Additionally, regarding ES values, only a few studies analyze the different values held by different types of stakeholders, and the associated conflicts of interests. In the same way, a minority of articles mention collective discussions about priorities and choices in the face of ES trade-offs.

This lack of attention to disputed values, conflicts of interests, winners and losers, and hidden agendas suggests most participatory ES research actually lacks connection with real life decision-making, where these issues would be unavoidable (Jax et al., 2018). Previous studies also highlighted this lack of connection between ES and decision making (Hauck et al., 2013; IPBES, 2022; Jax et al., 2018; Langemeyer et al., 2018). It has been observed that ES knowledge "played a small role particularly in those planning and policy-making situations where it challenged established interests and the current distribution of benefits from ecosystems" (Saarikoski et al., 2018).

There are several possible and non-exclusive explanations. Since discussions about trade-offs and decision-making logically occur later in a participatory process, lack of reporting on these might simply occur because these discussions have not yet happened. In addition, the impacts of ES knowledge on decision making might be hard to discern or yet to become evident (Waylen and Young, 2014). Furthermore, decision-makers might be unable or unwilling to acknowledge new knowledges, and researchers unable to navigate coercive situations and strategic political agendas. And yet, capacity and willingness to engage is required both by researchers and decision-makers (Waylen et al., 2023). This engagement and the willingness to actually contribute to the radical societal changes that are needed to face the environmental crisis are at the heart of a transformative turn within research (Loorbach, 2022). While participatory approaches are seen as a main lever of such transformative research, it seems necessary to rethink their conceptual foundations. Participation has indeed long been conceptualized in terms of collective learning, with an assumption that what prevents people from collaborating is a lack of mutual understanding (Pahl-Wostl et al., 2007; Pretty, 1995). Since conflicts of interests, hidden agendas and power asymmetries can also be major obstacles to collaborative governance and transformative changes, participatory processes should instead be conceptualized in terms of negotiation and conflict resolution, explicitly taking into accounts power asymmetries (Barnaud and Van Paassen, 2013; Cornwall, 2004; Hendriks, 2009; Leeuwis, 2000; Turnhout et al., 2020). This strongly echoes the conclusions of the recent report of IPBES (IPBES, 2022) which insists on the need to consider power dynamics and asymmetries in nature's values assessments.

5.4 Lack of acknowledgment of scientific epistemic and radical uncertainties: participatory ES research remains largely in a Western science's positivist stance

Our review shows that epistemic uncertainties are only partially reflected in participatory ES research. When multiple representations of SES are considered, it is mostly to integrate local stakeholders' representations. By contrast, divergences between scientific and non-scientific representations are much more rarely addressed. This reflects an implicit reliance on local knowledge to fill the gap left over by scientific knowledge. Local knowledge is mobilized to enrich the produced knowledge, or illuminate parts of the socio-ecological system that are not understood with the available scientific data (Ainscough et al., 2018). However, if scientific knowledge conflicts with local knowledge, then science knowledge is privileged (Taylor and de Loë, 2012). Participatory ES research thus remains largely dominated by the traditional vision of knowledge that dominates in Western sciences, which establishes a hierarchy between scientific knowledge and local or empirical knowledge. As noted by Muradian and Gómez-Baggethun (2021), despite its desire to acknowledge a plurality of knowledge systems, the NCP framework (Diaz et al., 2015) implicitly reproduced this hierarchy, by describing scientific knowledge as "generalizing" in opposition to non-scientific knowledge which would remain "context-specific". In the same vein, Turnhout et al. (2020) suggest that by failing to address the political and power dimensions of knowledge co-production, these co-production processes "end up reinforcing traditional modes of knowledge production, in which scientists are cast as holders of knowledge and other stakeholders holders of values or perspectives to be corrected by science, as receivers of scientific expertise".

This absence of consideration of conflicting representations between scientific and non-scientific knowledge systems in our review could also be explained by the requirement of scientific articles, which might encourage a clear linear and ideally positive narrative and discourage discussion of unresolved challenges. As a result, many aspects of research go unreported, simplified or get reported in separate publications. Even if so, it is interesting to note that these issues are considered unworthy of publishing in ES research.

Our review also shows that radical uncertainties (e.g. unpredictability) are rarely considered in participatory ES research. This is very likely for the same reasons, i.e. that ES research remains largely anchored in a positivist vision of Western sciences, and thus fails to truly consider scientific uncertainties about facts. If research is unable or unwilling to explore these uncertainties, this may also reflect a broader societal discomfort with complexity and uncertainties. Societal and governance systems implicitly still cling to modernist expectations of defining and controlling problems (Strand, 2002). Therefore, better acknowledging and handling radical uncertainties is a challenge relevant to science on ES but also for society.

Interestingly, our review shows that the studies of the cluster "post-normal approaches to ES" that address these epistemic and radical uncertainties are also those reflecting on trade-offs and conflicts of interests. When people start to deal with trade-offs, conflicts, and the messiness of real life decision-making and political agendas, then they do not have the choice, they have to put the uncertainties about facts on the table. To better deal with such situations where "facts are uncertain, values in dispute, stakes high and decisions urgent." (p.744) (Funtowicz and Ravetz, 1993), ES research would definitely gain in anchoring itself in the field of post-normal sciences (Ainscough et al., 2018). Without rejecting the traditional modes of knowledge production, post-normal science suggests that alternative modes are necessary in some specific situations characterized by high levels of uncertainty. Recognizing and addressing these uncertainties is a guaranty of rigor and quality in the knowledge production process.

6. Conclusion

This paper reviews how participatory ES research addresses different forms of uncertainties related to ES, namely ethical uncertainties (plurality of worldviews, specific values and interests), epistemic uncertainties (plurality of representations) and radical uncertainties (unpredictability). Three main types of studies were identified: (1) those centered on socio-cultural valuation of ES, that acknowledge plurality of specific values; (2) those describing more scientific driven processes focusing on assessments of representations of ES dynamics, that partially acknowledge epistemic uncertainties; and (3) those (less numerous) describing more deliberative and collective processes, that navigate all uncertainty types, including plurality of interests, plurality of knowledge systems and radical uncertainties. In total, we show that participatory ES research addresses some forms of uncertainties more than others. Plurality of specific values and plurality of stakeholders' representations are indeed commonly considered – often not together though. In contrast, pluralities of worldviews, conflicts of interests, differences between scientific and non-scientific knowledge systems and radical uncertainties remain insufficiently addressed. These results lend credence to the idea that the ES concept thus remains – and potentially reinforces - a dualistic, anthropocentric and utilitarian framing of human-nature relations ships, anchored in a positivist stance of Western sciences. It will be useful to reproduce this review in future years, to explore to what extent participatory research practices in ES research have changed. It would also be interesting to explore the extent to which such practices differ between different countries around the world.

Dealing with multiple uncertainties is critical if we aim to fully understand human relationships with nature, and to connect these with real life decision making for just and inclusive transformations. Eliciting and deliberating on all types of uncertainties at the same time may not be possible in practice, but choices i.e. about what issues to explore, and how, should be made much more explicit. The results of this review are thus an invitation to reflexivity. Designers of participatory research on ES should make a diagnosis of the situation and design their process accordingly: what types of uncertainties are at stake? What types of uncertainties shall we tackle in priority – given the context and the objectives? What methods (or combination

of methods) are the most appropriate to tackle them? Such reflexive processes would enable ES research to better acknowledge the multiple forms of uncertainties involved in environmental governance, and adopt the relevant methodological approach in their context. Researchers should be free to question the use of the ES concept, acknowledge its limitations in the context of participation or co-production, or opt for another more inclusive framework. Such reflections and flexibility also have implications for what funders and reporting bodies accept and embrace. They are essential for research to contribute to just transformations in the face of socio-environmental crisis.

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Annex 1. Set of 22 questions addressing the analytical and contextual factors, and the possible answers

Question / analytical factors	Possible answers
Q1: Is the concept of ES explicitly used with the participants?	0 : this is not mentioned in the paper 1 : the paper mentions that the concept is not explicitly used with the participants 2 : the paper mentions that the concept is explicitly used with the participants
Q2 : Is the concept in use debated with the participants?	0 : there is no mention of a specific discussion about the concepts in use 1: the concept is discussed but there is no possibility for the participants to opt for another term or concept 2: the concept is discussed, and there is a possibility for the participants to opt for another term or concept
Q3 : Who selects the ES (or equivalent if alternative concept used) under study?	0 : the paper does not mention who selected the ES under study 1 : mainly the scientists leading the research process 2: some scientists invited as participants, with or without the scientists leading the process 3: mainly some non-scientist participants 4: both scientists (leading the process or invited as experts) and non-scientist participants
Q4 : Is there a collective discussion and negotiation involving the participants for the selection of ES?	0 : the paper does not mention any discussion with the participants for the selection of ES 1 : there is a discussion but there is no possibility for the participants to change the predefined list of ES under study 2 : the list of ES under study results from a negotiation in which it is possible for the participants to change an eventual predefined list of ES
Q5 : How do the participants assess the values that they attribute to ES?	0: the paper does not mention any assessment of participants' values for ES 1: Scientists indirectly assess participant's ES values through interviews, questionnaires or experts' knowledge 2: the participants attribute value to ES through an individual process (e.g. ranking or voting) 3 : the participants directly value ES through a collective deliberative process
Q6 : Are the different values of ES for the different types of stakeholders analyzed by the authors and discussed with participants?	0: differences among stakeholder groups' values are not mentioned in the paper 1 : differences among stakeholder's values are mentioned, but not analyzed 2: differences among stakeholder groups' values are analyzed, but not collectively discussed with the participants 3: differences among stakeholder groups' values are analyzed and collectively discussed during the participatory process
Q7 : Are there discussions about trade-offs among ES?	0: trade-offs among ES are not mentioned in the paper 1 : trade-offs among ES are mentioned by the authors, but they are not analyzed 2 : trade-offs among ES are analyzed but not collectively discussed with the participants 3 : trade-offs among ES were explicitly and collectively discussed with the participants
Q8 : Are there discussions among the participants about their representation of the functioning of the ecosystems?	0: the paper does not mention any step where the participants are asked to express their view on the functioning of the ecosystem 1: the representations of the participants on the ecosystems functioning are assessed through an individual process (e.g. interview) 2 : the process involves collective discussions among the participants regarding their various representations of the functioning of the ES
Q9 : Are there discussions between the scientists and	0: no difference of knowledge / representation explicitly mentioned

non-scientists involved in the study regarding their respective knowledge of / representations of the functioning of the ecosystem?	1: differences of knowledge / representations in the context of the analyzed case are explicitly mentioned but there was no collective discussion about them 2: differences of knowledge / representations were collectively discussed
Q10 : Is the unpredictability of the socio-ecological system taken into account in the study?	0: not mentioned 1 : mentioned [in the paper], but no discussion with the participants 2: explicitly discussed in the participatory process

Question / contextual data	**Possible answers**
Q11: what is(are) the primary objective(s) of the participatory process ? (as mentioned by the authors)	Producing new scientific knowledge : 0/1 Improving participant's systems understanding : 0/1 Facilitate participant's decision-making : 0/1
Q12: which scientific domains are used to assess ES and their values (through a specific method in the study)?	Biophysical domain : 0/1 Socio-cultural domain : 0/1 Monetary / economic domain : 0/1
Q13: stakeholders involved in the study	Open answer
Q14 : stakeholders involved in the study	Direct ES providers : 0/1 Direct ES beneficiaries : 0/1 Indirect ES providers : 0/1 Scientific experts : 0/1
Q15 : Ecosystems under study	Open answer
Q16 : Ecosystem services under study	Provisioning services : 0/1 Regulating services : 0/1 Cultural services : 0/1
Q17: what methods are used to select the ES under study ?	Open answer (example : vote, individual interviews, workshop, literature review, grey literature review)
Q18: What methods are used to assess the values participants attribute to ES?	Open answer (example : ranking, voting, monetary valuation, interview)
Q19 : Process duration, as indicated in the paper	Duration in months or years
Q20 : Concepts other than ES used to describe human-nature relationships in the case	Open answer (example : NCP, natural capital, social ecological functions, socio-ecological system, etc.)
Q21 : location of the case study	Country
Q22 : scale of the case study	Local, national, international
Q23 : what terms are used for "participation"	Open answer (example : post-normal approach, participatory research, participatory scenario planning, deliberation, collaboration, etc.)

Annex 2. Full list of article integrated in our review

1. Abunge, C., Coulthard, S., Daw, T. M., 2013. Connecting marine ecosystem services to human well-being: insights from participatory well-being assessment in Kenya, *Ambio*, Springer Science and Business Media LLC, 42, 8, 1010–1021.
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Annex 3. Results from correlation analysis

Correlations between each pair of questions, applying Fisher's exact test:

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Q1								0.019		
Q2										
Q3				0.004						
Q4						0.008	0.074			
Q5						0.002		0.005		
Q6							0.015			
Q7								0.011		0.003
Q8									0.008	0.0006
Q9										0.044
Q10										

Analysis of Pearson residuals:

```
> tb47
    0  1  2  3
0 16 21  4 11
1  5  1  0  1
2  8  9  9  8
> tb58
    0  1  2
0  3  7 11
1  5  3  8
2 15  5  6
3 11  1 18
> tb67
    0  1  2  3
0 20 16  5  4
1  3  8  1  5
2  5  6  5  5
3  1  1  2  6
> tb78
    0  1  2
0 12  6 11
1 15  7  9
2  3  3  7
3  4  0 16
> tb710
    0  1  2
0 21  6  2
1 24  6  1
2  3  7  3
3 11  3  6
> tb910
    0  1  2
0 50 18  6
1  4  2  1
2  5  2  5
```