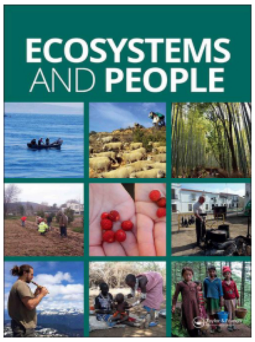

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REVIEW

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Valuation of soil-mediated contributions to people (SmCPs) – a systematic review of values and methods

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ABSTRACT
Soils have the capacity to contribute to human wellbeing through a variety of pathways. Preserving these contributions in light of human and climate-induced changes requires consideration of the numerous benefits – both in research and policy-making. Previous research has demonstrated how the benefits can be recognized through valuation, but a comprehensive understanding of how different types of valuation of soil-mediated contributions to people (SmCPs) are incorporated across various contexts is missing. Under the framework of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), the current study undertook a systematic review of the literature to identify knowledge gaps and future research agendas in understanding the value of SmCPs to people. We analyse the frequency of methods, data and actors included in the studies as well as the consideration of drivers and quality of life categories linked to the valuation of SmCPs. Although the majority of studies were solely concerned with either monetary or non-monetary valuation approaches, several studies acknowledged the limitations of pure economic valuation and attempted an integrated valuation of both non-monetary and monetary approaches. Despite these efforts, there is further potential for fully integrating both monetary and non-monetary valuation methods to encompass a more comprehensive valuation approach through interdisciplinary approaches.

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Monetary valuation; non-monetary; nature's contributions to people; soil; ecosystem service

KEY POLICY HIGHLIGHTS

- Soils provide important contributions to human wellbeing that have so far been given too little consideration in policymaking
- The value of soil mediated contributions to people is manifold and clearly calls for an interdisciplinary perspective to understand and to acknowledge the complexity of soil ecosystems
- The contributions can be valued with both monetary and nonmonetary methods, and integrative approaches that incorporate both types of methods and better take the diversity of values into account.
- Recognising the values of soils by taking an interdisciplinary and integrated perspective that capture the value of the full range of contributions and the associated tradeoffs with changes in soil management improves policy outcomes

1. Introduction

Soils provide essential benefits to human wellbeing while being threatened by continuing land degradation through human activities (IPBES 2018). Soils have the capacity to store and supply nutrients to plants, regulate water supplies and detrimental organisms (e.g. Samaddar et al. 2021), provide habitat to soil organisms, produce raw materials and store carbon (Greiner et al. 2017). Hence, soils are critical to food supply, to the adaptation and mitigation of climate change, and water security.

At the same time, soils are affected by multiple drivers of change, such as climate, natural hazards, land use change, and farming practices, that directly impact soil ecosystem services and soil biodiversity (Dominati et al. 2010). For instance, in the future, extreme weather events, such as heavy rainfall or drought, will likely have an impact on provisioning services, as they can directly damage crops or negatively impact water supply that reduces plant productivity (Orwin et al. 2015). These climate-induced effects on soil functioning are intensified by changes in land use management, such as intensifying agricultural management through harvest frequency, monoculture, over-fertilization or overgrazing (Smith et al. 2015). Particularly, the multiplicity of stressors, such as the concurrent incidence of

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pesticides, microplastics and general human disturbance can negatively impact the provision of soil ecosystem services (Rillig et al. 2023). As most of the soils' benefits happen underground, despite their vital importance to human life, they frequently remain unseen and often unacknowledged by their recipients.

Given this vital importance, it is critical to build the foundational aspects of value under the umbrella of Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), encompassing a diverse range of worldviews and knowledge systems onto which broad and specific values are based in order to understand how nature contributes to the wellbeing and good qualities of humans (Balvanera et al. 2022), the plural values categorized as 'Nature's contribution to people' (NCP). This diversity of perspectives allows for the understanding of specific values, including instrumental, intrinsic and relational values, under which value indicators can be used for elicitation of values to support policy and decision making in informing, deciding and designing. Monetary valuations, for example, can be incorporated into cost-benefit analyses under the total economic value framework (Pearce and Moran 1994), and are used for awareness raising while also providing both the opportunity to prioritize policy options ex ante as well as to legitimize policy decisions ex post (Dehnhardt et al. 2022). Drawing on a broader range of disciplines, non-monetary valuation with, for example, socio-cultural valuation approaches sheds light on the preferences, importance or needs with regard to nature-people connections (Chan et al. 2012). Within this framework, such a holistic approach makes it possible to recognize that a good quality of and a fulfilled human life is dependent on the (perceived) wellbeing of various involved actors and how the achievement of social, security and cultural identity needs are achieved through the connection to nature (Díaz et al. 2015). The definition of a good quality of life can therefore vary from society to society along the dimensions of the security of food, water and energy, physical, mental and emotional health, cultural heritage, identity and stewardship, and environmental justice and equality (Christie et al. 2019).

With this lens, the elicitation of instrumental values is the focus of this systematic literature review, with emphasis on the elicitation of monetary and non-monetary values. These two perspectives are part of the valuation method families as defined within the IPBES framework as nature-based, statement-based, behavior-based and integrated valuation methods (Termansen et al. 2022). To increase the visibility of soil functions and the relevance of soils for society, several studies have valued soils and associated ecosystem services in the past. Given the similarity between the concepts of ecosystem services and NCPs (Kadykalo et al. 2019) and in line with the framework of IPBES, we refer to these ecosystem services associated with soils as 'soil-mediated contributions to people' (SmCPs). Research on the multi-functionality and related value of soils emerged in the mid 1960's, gaining momentum with the rise of the ecosystem services concept in 1997 and the Millennium Ecosystem Assessment in 2005 (Baveye et al. 2016). Similar to other realms of ecosystem research, studies initially mostly focused on monetary values generated by soil functions, leaving non-monetary values underexplored (Scholte et al. 2015). Two literature reviews on the topic reveal which soil-mediated ecosystem services are subject to monetary valuation, which valuation methods were used and the range of monetary values that were assessed for these ecosystem services (Jónsson et al. 2017; Bartkowski et al. 2020). However, the sole use of monetary methods is disputed, mainly based on the difficulty of quantifying soil functions and services and determining adequate indicators, which makes the assignment of monetary values extremely difficult (Baveye et al. 2016). As in other realms of ecosystem research, the use of monetary methods for the valuation of SmCPs can be criticized for its narrow focus on instrumental values, which often coincide with only material NCPs, and neglecting relational values that specify how people relate with nature and with others conducive to a good life (Chan et al. 2016). Here, the consideration of non-monetary values provides an opportunity to explore a more comprehensive set of values associated with SmCPs (Harrison et al. 2018). An interdisciplinary research approach to assess the plural values of SmCPs and soil biodiversity is essential for studying interactions between socio-economic and ecologic soil systems.

In this study, we explore the extent to which previous research has assessed the values of soil-mediated contributions to people and ecosystem services aiming to identify knowledge gaps and future research agendas for a full account of the multiple values associated with soils and soil biodiversity. Leaning on recent publications of the IPBES, we explore the extent to which research has assessed the value of SmCPs with regard to the main components of IPBES (which provides a clear synthesis of interlinkages between people and nature). Our research questions are:

- Which bio-geographical aspects and components relevant to the IPBES conceptual framework (i.e. indirect and direct drivers, and aspects of quality of life) are prevalent in studies that examine SmCPs?
- Which SmCPs are subject to valuation in research?

- Which direct and indirect drivers and which aspects of a good quality of life are mostly associated with specific SmCPs?
- Which monetary and non-monetary methods and indicators are used to assess SmCPs and how were the corresponding data collected (data types, actors)?

2. Methods

In order to investigate which SmCPs are valued in the literature and which methods were used for valuation, we performed a keyword search in February 2022 following the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) protocol in Clarivate's Web of Science Core Collection (Page et al. 2021), as described in supplementary materials S1, S2 and S3. The search was conducted for academic publications that featured 'soil' and one of several further keywords (in varying notations) ('preference', 'perception', 'socio-cultural value', 'cultural value', 'ecosystem services', 'ecosystem benefits', 'nature's contribution to people'). Although we make use of the IPBES framework (Díaz et al. 2015) for the classification of SmCPs, we rely on 'ecosystem services' and 'ecosystem benefits' in our search string. Given the novelty of the IPBES framework, the term 'nature's contributions to people' has rarely yet been applied in soil research and its single use in the search string does not provide meaningful results.

A total of 557 peer-reviewed studies were retrieved, and all abstracts were reviewed for fit. After excluding studies in other languages than English ($n = 10$) and studies that either could not be retrieved ($n = 6$), did not perform a monetary or socio-cultural value assessment of ES or NCPs (e.g. conceptual frameworks, biophysical assessments; $n = 269$), were meta-analyses of several studies ($n = 50$), were not explicitly linked to the concept of NCPs/ES, or the results were not comprehensible ($n = 3$), 214 publications were included in the analysis (see supplementary materials S4 for a list of the articles).

In a double-blind review process, a list of items for each of these studies was recorded that served as a basis for analysis. For each of these items, a list of possible classes was assigned to simplify the subsequent analysis. The following items (and classes) were included: (1) biome (i.e. arable, grassland, woodland, wetland or other), (2) land use (i.e. agriculture, livestock, pasture, forest, recreation and protected area), (3) direct drivers (i.e. land use change, climate change, pollution, natural resource use and invasive species, status quo and other), (4) indirect drivers (i.e. socio-economic trends, demographic trends, technological innovation, culture trends, government and other), (5) land use change (i.e. intensity, sustainable soil management, crop management, sward management, forest management and landscape management), (6) ES (Table 1), (7) NCPs (Table 1), (8) quality of life indicator (i.e. security, health, heritage and justice), (9) valuation type (i.e. monetary, non-monetary and mixed), (10) methods in valuation, (11) data type (i.e. survey, interview, workshop, observation, model and statistic), (12) actors (i.e. local people, farmers, visitors, landowners, decision-makers, experts and managers), (13) classes of indicators (i.e. WTP, preference score, perception-based valuation, unit value, functional value and net ecosystem production/potential) and (14) method families (statement-based, behavior-based and integrated valuation). The data from each paper was independently extracted by two reviewers in an uncoupled database with room for comments. After the data extraction was concluded, the reviewers met to discuss discordances between the entries. Issues that could not be resolved were discussed within the full author team. The dataset was finalized and organized in a shared database.

To explore SmCPs, we associated the ecosystem services we encountered in the reviewed studies with one of the 18 NCPs based on (Díaz et al. 2018), as shown in Table 1. To allow for a precise attribution in studies that value more than one NCP, the valuation method, indicator classes, data source, and actors were recorded individually. This resulted in a total of 1177 SmCP valuation applications with one entry of data for each valuation.

We analysed the above-mentioned items in terms of their frequencies, relative frequencies and distributions, using their differences in counts or, where applicable, their means, as summary measures. Data were displayed in barplots for total and treemaps to show relative frequencies. For the SmCPs, we additionally conducted a network analysis to explore the co-occurrence of SmCPs in our sample. In the network, nodes represent SmCPs and the links between the nodes (i.e. edges) represent the number of co-occurrences between the SmCPs. The weight of the edges is therefore based on the number of studies in which a pair of nodes appear together.

3. Results

3.1. Content of bio-geographical aspects and components of IPBES framework

The systematic literature screening resulted in the review of 214 publications from a range of geographical contexts under a variety of land uses that were categorized along a set of similar ecosystems including arable land, woodland, grassland, wetland and other ecosystems. The majority of publications stemmed from Asia (35%) and Europe (29%)

Table 1. List of nature's contributions to people and a brief description based on Díaz et al. (2018) as well as the associated ecosystem services.

Soil-based contributions to people	Description	Associated ecosystem services	Reference for ecosystem services
Habitat creation and maintenance	The ecosystem forms the ecological conditions for living beings, such as growing sites for plants, nesting sites for animals.	Habitat, habitat creation	Costanza et al. (2017)
Pollination and dispersal of seeds and other propagules	The ecosystem helps the movement of pollen.	Pollination	Costanza et al. (2017)
Regulation of air quality	The ecosystem helps to improve air quality by filtering air pollutants.		
Regulation of climate	The ecosystem regulates the climate by reducing emissions of greenhouse gases and by local cooling effects.	Carbon sequestration, climate regulation	MEA (2005), Costanza et al. (2017)
Regulation of ocean acidification	Regulation, by photosynthetic organisms (on land or in water), of atmospheric CO_2 concentrations		
Regulation of freshwater quantity, location and timing	The ecosystem provides freshwater for people and natural habitats.	Water provision	Costanza et al. (2017)
Regulation of freshwater and coastal water quality	The ecosystem improves freshwater quality by filtering sediment, nutrients and other contaminants.	Water quality	MEA (2005)
Formation, protection and decontamination of soils and sediments	The ecosystem forms and maintains soil structure and soil processes (by plants and soil organisms).	Nutrient cycling, mediation of wastes, soil erosion prevention, soil fertility	Costanza et al. (2017), MEA (2005), Costanza et al. (2017), MEA (2005)
Regulation of hazards and extreme events	The ecosystem reduces the impacts from extreme weather events (floods, storms, heatwaves) and hazards like high noise levels or fire.	Flood regulation, natural hazard regulation	Costanza et al. (2017), MEA (2005)
Regulation of detrimental organisms and biological processes	The ecosystem reduces pests and diseases.	Biological control, pest control	Haines-Young and Potschin (2018)
Energy	The ecosystem provides biomass which can be used for fuel (biofuel crops, animal waste, fuelwood, peat).	Biomass production/raw materials	Costanza et al. (2017)
Food and feed	The ecosystem provides food from wild or managed organisms (fish, bushmeat, livestock, insects) and feed for domesticated animals (hay, grains, etc.).	Food production, biomass production	Costanza et al. (2017)
Materials, companionship and labor	The ecosystem provides materials derived from organisms for construction, clothing, printing, or ornamental purposes.	Timber production, biomass production	Costanza et al. (2017)
Medicinal, biochemical and genetic resources	The ecosystem provides materials derived from organisms used for medicinal, veterinary, and pharmacological purposes.	Genetic resources, medicinal plants	Costanza et al. (2017)
Learning and inspiration	The ecosystem provides opportunities for education, acquisition of knowledge, and development of skills for wellbeing and art.	Education, scientific value	Haines-Young and Potschin (2018)
Physical and psychological experiences	The ecosystem provides opportunities for relaxation, healing, recreation, leisure, tourism and aesthetic enjoyment based on close contact with nature, for example hiking, birdwatching, fishing, or hunting.	Aesthetic value, recreational value	Haines-Young and Potschin (2018)
Supporting identities	The ecosystem provides the landscapes, habitats or organisms which are the basis for religious, spiritual and social-cohesion experiences (for example providing a place of belonging, connectedness, as the basis for narratives or rituals).	Heritage, spiritual value	Haines-Young and Potschin (2018)
Maintenance of options	The capacity of ecosystems to support a good quality of life also including those of future generations.	Existence value, bequest value	Haines-Young and Potschin (2018)

(Figure 1a) and carried out their studies in agricultural (36%) forest (33%) and grassland settings (23%) (Figure 1b). Accordingly, the land uses most frequently explored are agriculture (32%), forest (26%) and pasture (13%) (Figure 1c).

3.2. Soil-mediated contributions to people

From the overall 1177 SmCPs valued in the reviewed publications, regulating SmCPs were the most prevalent followed by material and non-material SmCPs (Figure 2). Given the keywords of the search criteria, soil formation and protection received the highest number of valuations, whereas several different contributions were valued under this SmCP. For example, Zhou et al. (2020) estimated the willingness to pay to preserve cropland and grassland at the urban-rural fringe of Amstelland in the Netherlands. Contrarily, Zhang et al. (2012) estimated the monetary value of waste water treatment with rice paddy agriculture, although this only made up only the smallest percentage of all those monetarily valued. Interestingly, although regulation of the climate as well as food and feed production also ranked highly among the valued SmCPs, physical and psychological experiences were the focus of 131 valuations for a variety of ecosystems. Only four studies evaluated this SmCP under the IPBES framework as an NCP, whereas the majority of studies accounted for aesthetic or recreational values under the ecosystem service framework, such as the non-monetary valuation and analysis of perceptions provided by Vanermen et al. (2021) that provided insights on the differentiation between recreational users and

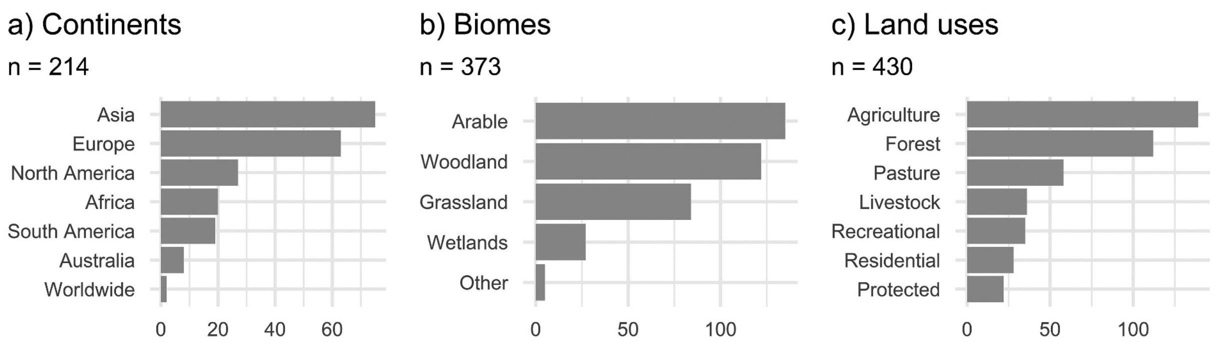

Figure 1. (a) number of studies conducted per continent, (b) number of studies per biome and (c) number of studies per land use type. Sample size deviates from number of reviewed studies as several publications examine more than one biome and land use type.

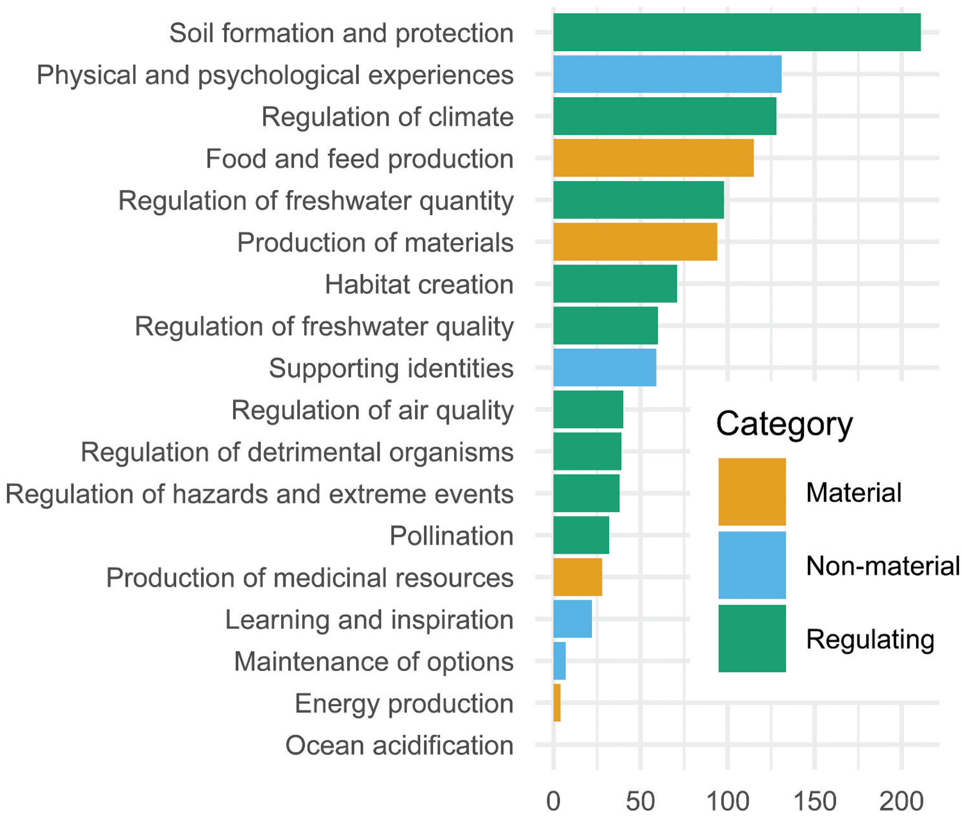

Figure 2. Number of SmCP valuations.

environmentalists for forest soil biodiversity. Material SmCPs were naturally evaluated to a significant degree in the literature given the necessity of productive soils for maintaining the quality of life in terms of security of food resources.

Given that almost all studies evaluated more than a single SmCP, a further investigation into the co-occurrence of SmCPs in valuation studies provides some insights. Figure 3 depicts the frequency of SmCPs valued as well as the frequency of simultaneous valuations within the same study. Soil formation and protection was valued in combination with almost all other SmCPs but most frequently with regulation of climate, habitat creation and physical and psychological experiences. Although some regulating SmCPs, such as the regulation of freshwater quality, received less attention in the literature, they were still valued frequently in combination with other SmCPs.

The status quo of the ecosystem services value was most frequently subject to valuation (47%), followed by drivers such as a change of value through land use change (45%) (Figure 4a). Barely 5% of the reviewed studies focused on a change of ecosystem services value through climate change. Of the studies that investigate the effects of land use change on SmCP valuation (Figure 4c), 29% examine opportunities of landscape management, such as Admasu et al. (2021), who estimate Ethiopian farmers' willingness to pay for attributes like slope, irrigability and water holding capacity or Ahiale et al. (2019), who explore the determinants of Ghanaian farm household's willingness to accept for conservation technologies such as soil and stone bunds. Other studies investigate the effects of forest management (10%), crop management (5%), management intensity (5%) or sustainable soil management (5%). Of the 76 studies that indicate indirect drivers (Figure 4b), most consider socio-economic trends, such as Chuvieco et al. (2013), who consider socio-economic factors to assess wildfire vulnerability or government-related issues, such as Bernués et al. (2015), who consider implications of socio-cultural and economic valuation for policy design.

Less than half of the studies cited direct links of management changes or pressures to quality-of-life concerns (Figure 4d). Of those food, energy and water security (42%) or environmental justice and equity (33%) were the primary concerns such as in Acharya et al. (2019) concerning fragile mountain ecosystems in Nepal. The distribution of these categories among the NCPs was mostly uniform (Figure 5). Given the direct damage associated with poor air quality, maintaining and improving physical, mental and emotional health made up the largest proportion of citations in regulation of air quality valuations. Liu et al. (2014) provided an example of how traditional eco-cultivation can produce oxygen and valued this contribution through the avoided costs of industrial oxygen production. The quality-of-life category concerning cultural heritage and identity was expectantly mentioned primarily in non-material NCP valuations. Dou et al. (2019) assessment of the perceptions of locals in the rural communities on agricultural landscapes to provide for cultural heritage and a sense of place in western China showed

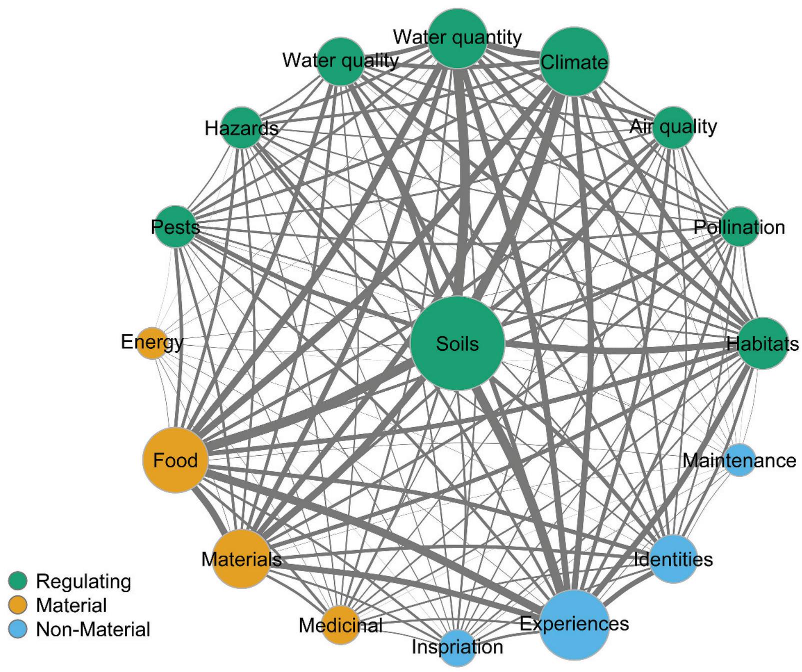

Figure 3. Network analysis of interactions of SmCPs.

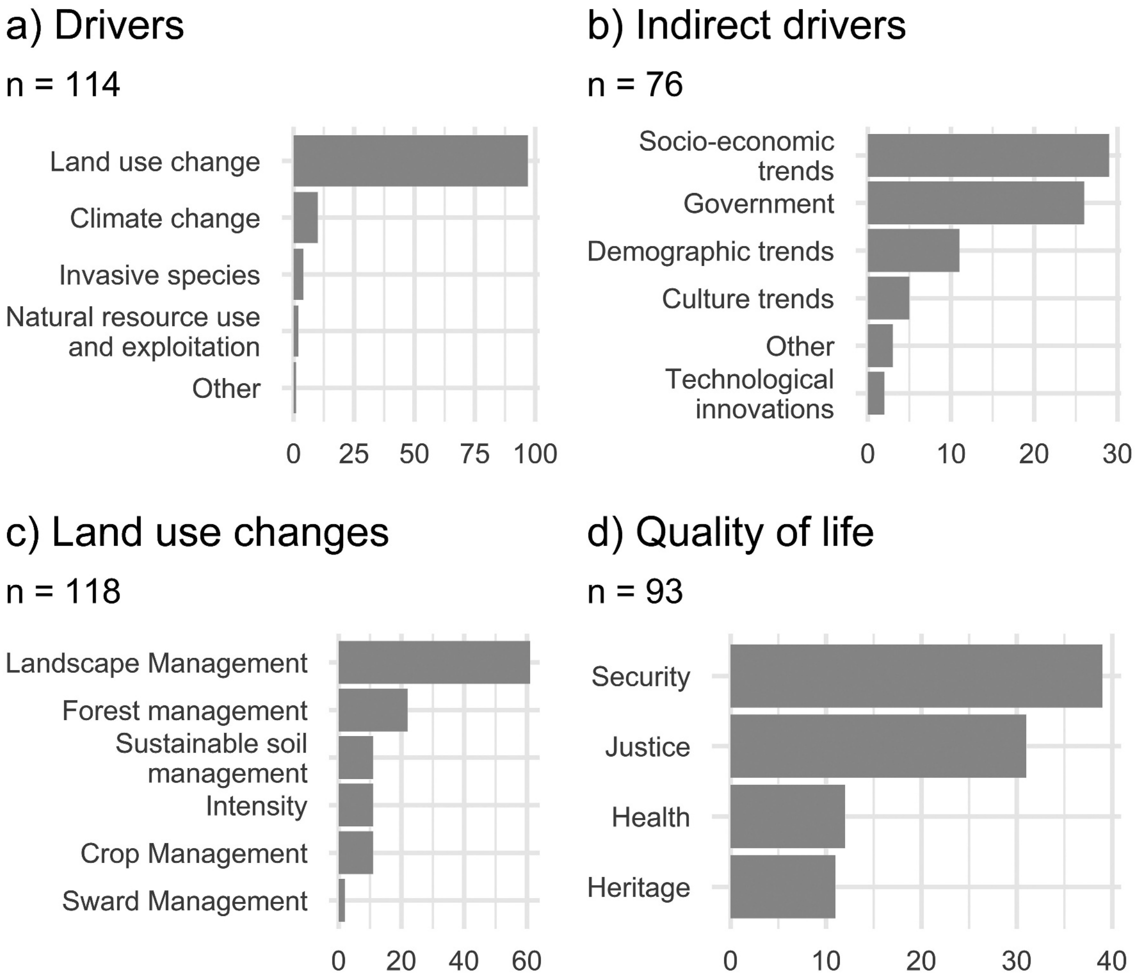

Figure 4. Percentage of studies considering (a) drivers, (b) indirect driver, (c) land use changes, (d) quality of life categories.

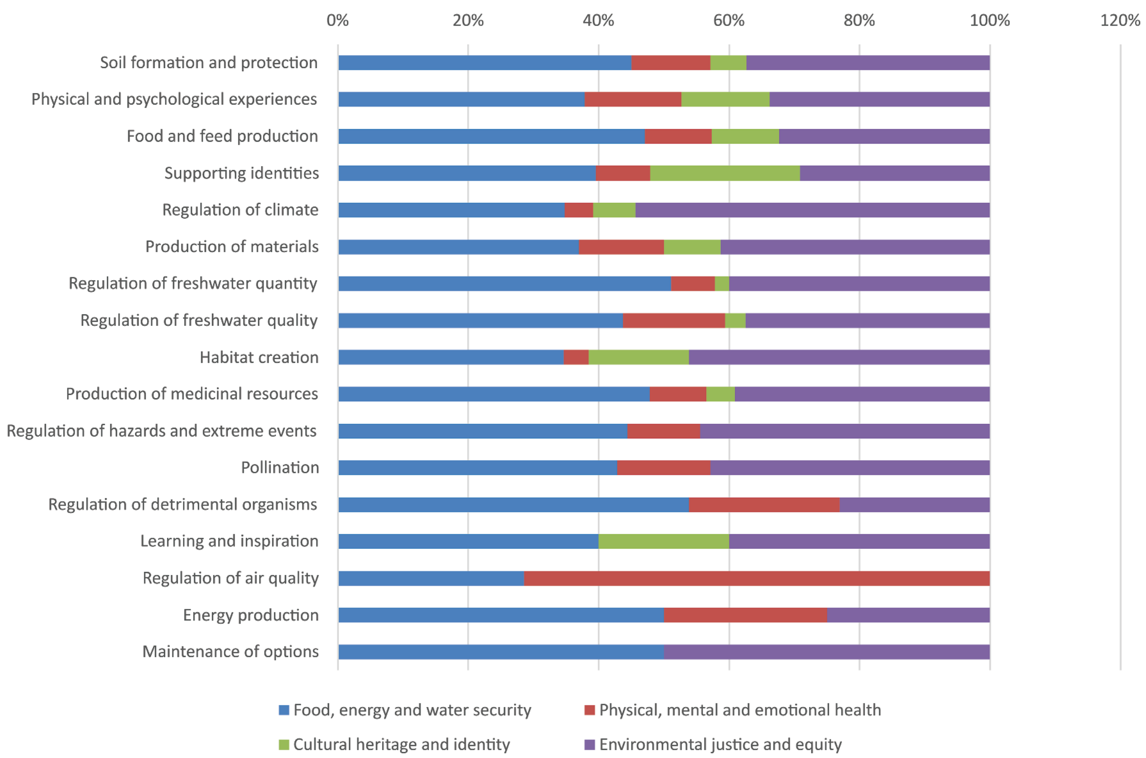

Figure 5. Distribution of quality-of-life categories per SmCP.

how only recreational services outranked cultural heritage as opposed to mental and physical health or education and science.

4. Methods of valuation

In the literature, monetary valuation methods have received more attention than non-monetary methods overall (Figure 6a). The majority of valuations relied on data stemming from statistics or models (59%), but surveys and interviews still accounted for a significant portion of the data types (33%, Figure 6b). Several studies incorporated multiple types of data, and especially statistics and models were used together in 23% of the valuations. Among those actors in participatory data collection methods, locals and farmers represented the largest shares (Figure 6c). Figure 7 furthermore depicts the relative frequency of valuation methods per study (i.e. as opposed to per SmCP) according to the method families of IPBES considered in this study. This depicts a relatively high number of statement-based methods when considering the study-based totals over the total number of methods for each SmCP. Figure 8, moreover, highlights the share of the methods from the method families according to the valued SmCP.

4.1. Statement-based valuation

The most prevalent non-monetary valuation method across the NCPs was the preference assessment (Figure 7, applied in 29% of the reviewed studies). Preference assessment allows for the simultaneous elicitation of preferences for multiple SmCPs. In practice, preference assessments come in different forms such as the elicitation of importance on Likert-based scales ('not important at all' to 'very important') for eliciting the importance of maintaining soil fertility, as in Bernués et al. (2015) for example, or the ranking of different SmCPs against one another to provide an overall prioritization of contributions (Acharya et al. 2019). Such methods were applied in surveys (72%), interviews (24%), or workshops (17%) and allowed for the elicitation of preferences across all stakeholder groups in the studies.

In addition to preference assessments, stated preference methods primarily for monetary valuation were also common in the literature (15%). Whereas contingent valuation studies elicit directly the willingness to pay (WTP) for a change in provision of SmCPs, discrete choice experiments further offer the opportunity to make trade-offs between the provision of several SmCPs. Dupras et al. (2018) highlighted the importance of including landscape aesthetics as a part of agri-environmental beneficial management practices for a study site in the Saint-Jacques region of Canada, estimating a high WTP for improved landscape aesthetics through a contingent valuation method and integrating this with trade-offs of other contributions like water quality and fish and bird biodiversity in light of the evolution of the agricultural landscape.

Less common was the employment of narrative analysis, which offers a more holistic approach to capturing people's experiences and perceptions than the preference assessment as it relies on the expertise of participants (6% of the studies). Farley and Bremer (2017) use narrative analysis to explore local perceptions associated with Payment for Ecosystem Services (PES) in Parámo grasslands in the Ecuadorian Andes linked to basic needs, security, health, and social relations. Here, the improved understanding of local perception was found useful to design more effective policies and programs. Hegazy et al. (2014) explore differences between indigenous and scientific knowledge of wild plants in the highlands of southwest Saudi Arabia. They highlight the added value of the approach for capturing indigenous knowledge by going beyond the supply of information to portraying socio-cultural realities.

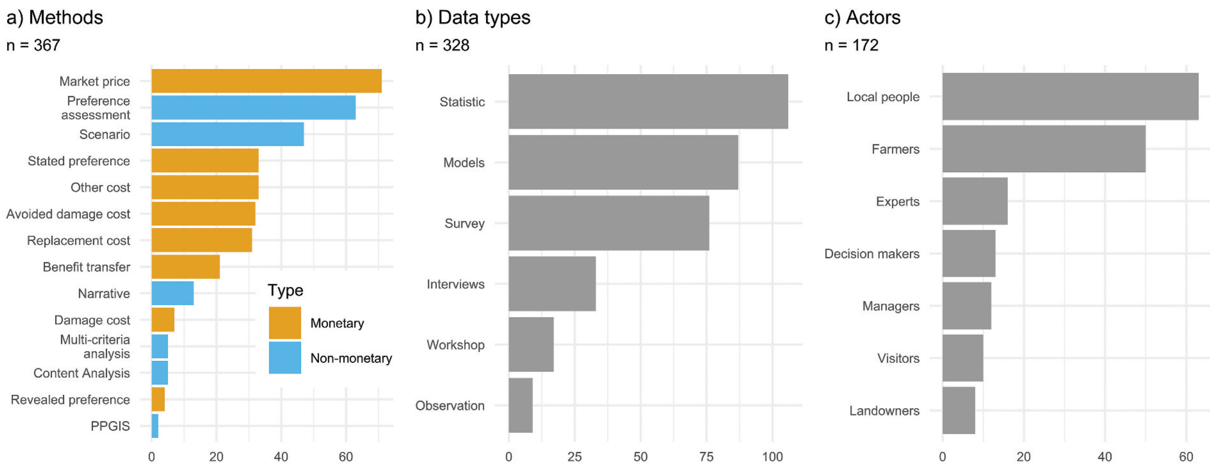

Figure 6. Frequencies of (a) methods of valuation, (b) data types, (c) actors.

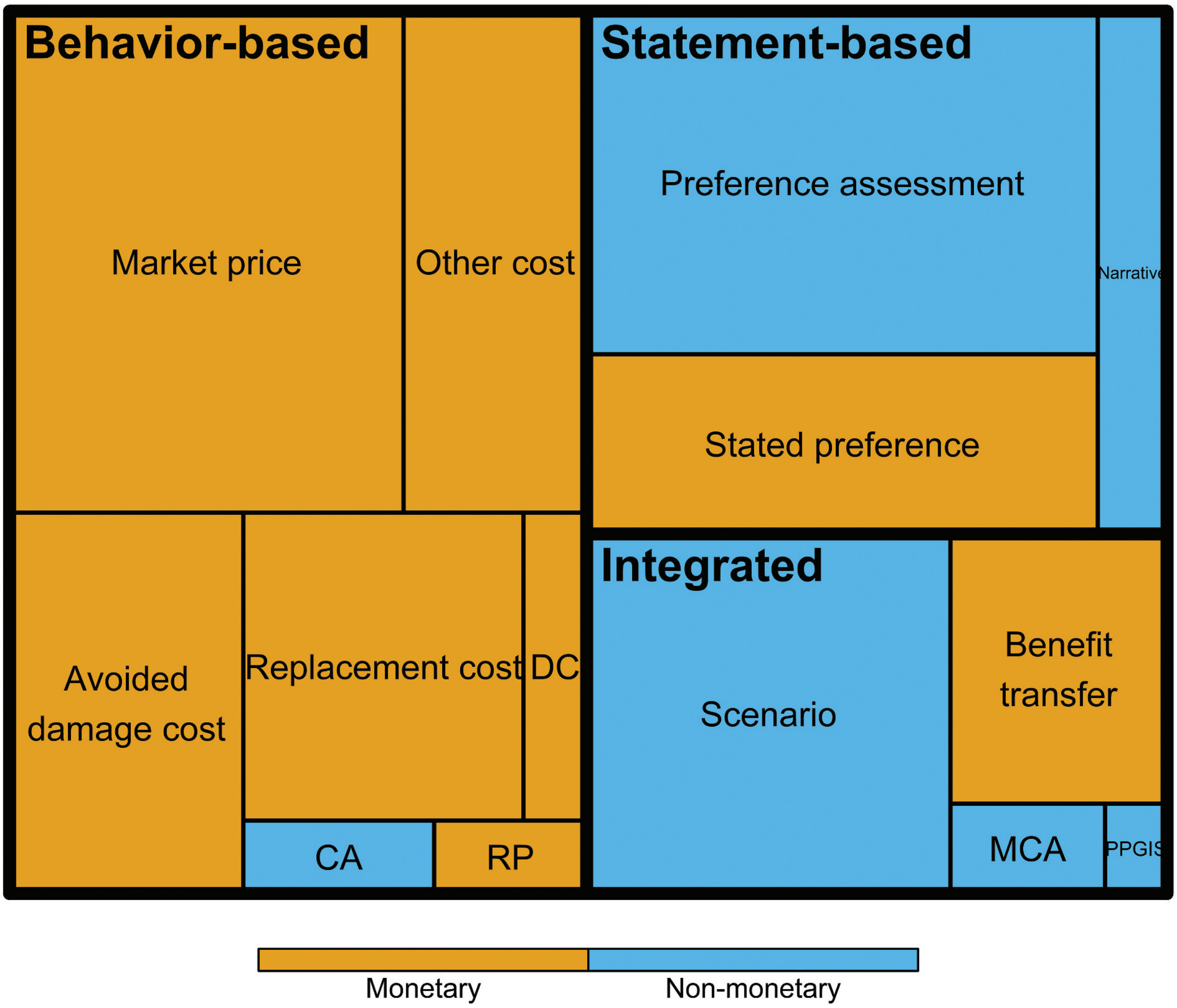

Figure 7. Relative distribution of valuation methods within sample (content analysis = CA, revealed preference = RP, damage cost = DC, multi-criteria analysis = MCA, public participation geographic information system = PPGIS).

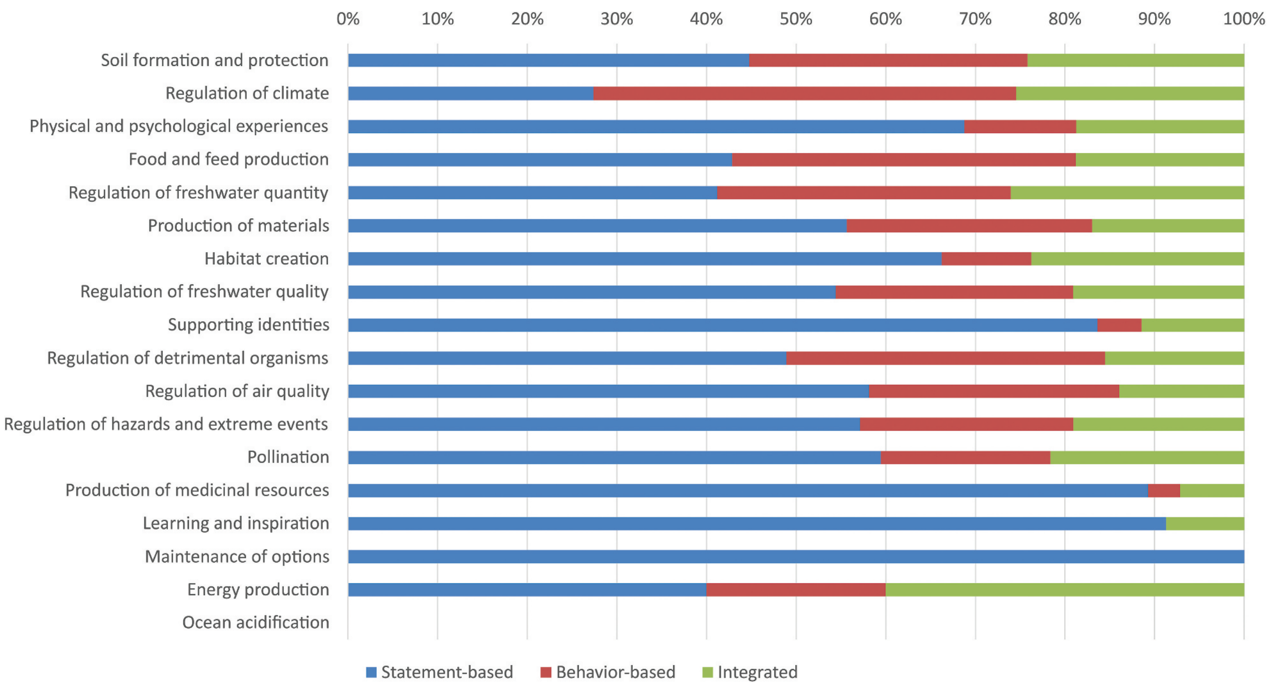

Figure 8. Distribution of method families per SmCP.

4.2. Behavior-based valuation

The market price method has been frequently employed for valuing various SmCPs such as the reduction of CO_2 emissions from soils based on the current market price of CO_2 permits on the EU Emissions Trading Scheme. Dominati et al. (2014) proposed a methodology to quantify and value the ecosystem services arising from agro-ecosystems and used the carbon market price of 13 NZD per ton for the valuation. Although CO_2 permits are traded in a market and allow for a valuation based on market prices, similar to other goods and services in typical markets, such methods do not account for the current and future damage through climate change incurred by society. Bartkowski et al. (2020) highlighted the concerns about using market prices instead of monetary estimates of societal damage caused by CO_2 emissions (i.e. social cost of carbon). Other studies in our review proposed using the social cost of carbon from integrated assessment modelling in order to account for the societal damages associated with climate change as opposed to relying solely on market prices. Fan et al. (2018) investigated the improvements in soil carbon sequestration following conversion from conventional to organic farming in Denmark and elicited the value thereof based on the social cost of carbon at 132.7 USD per ton. Such approaches were used to both elicit the current monetary value of damage given the land management (damage cost method) and the avoided damages following a change (avoided damage cost method). Edens et al. (2019) provide a thorough discussion on the advantages and disadvantages of different methods for the valuation of changes in CO_2 sequestration or emission.

The replacement cost was most commonly used to value soil formation and protection. Various aspects were covered under this SmCP in the literature such as improved fertility associated with reduced mitigation costs of nitrogen leaching (Dominati et al. 2014) or reduced soil erosion of agro-foresry systems based on the cost of new soil (Ghaley et al. 2015). Furthermore, valuations of groundwater recharge with agro-forestry (Kay et al. 2019), climate regulation in mangroves (Jerath et al. 2016) or flood prevention (Dominati et al. 2014) also utilized the replacement cost method.

4.3. Integrated valuation

As integrated valuation approaches emphasize the need for a comprehensive understanding of SmCPs, including not only their economic value but also their social, cultural and environmental dimensions, recognition of the interconnectedness of these dimensions is crucial for effective conservation and sustainable management. Integrated approaches stress the importance of engaging diverse stakeholders in the valuation process, including local communities, indigenous peoples, policymakers, and scientists. Such approaches incorporate multiple perspectives to capture a more nuanced understanding of the values placed on SmCPs. Under the IPBES conceptual framework, the valuation methods of integrated valuation found in the literature included scenario analysis, benefit transfer, multi-criteria analysis (MCA) and public participation geographic information systems (PPGIS). Moreover, we furthermore assess here valuation studies from the literature that included both monetary and non-monetary approaches to provide an integrated understanding of value.

A handful of studies in the literature integrated both monetary and non-monetary valuation methods to address the need for a plural elicitation of values. Bernués et al. (2015) performed a sociocultural assessment of perceptions on multifunctional agriculture in fjords and mountains through qualitative interviews with farmers and stakeholders and furthermore elicited the WTP for several SmCPs by means of a choice experiment in a survey of local and nearby residents. This integrative approach captured in depth the interests of a variety of interests from stakeholders while further setting those interests and perceptions in the context of the preferences of the wider population. Other attempts at integrative approaches in the literature included the study by Eusse-Villa et al. (2021) that went beyond a simple choice experiment on the SmCPs of the Veneto Region in Italy by estimating a mixed logit model to account for spatial heterogeneity of both attitudes and welfare measures. Their study highlighted how the WTP for carbon sequestration, earthworm density, rainfall water infiltration and avoiding nitrates in groundwater is associated with attitudes towards soil conservation in different spatial contexts. Moreover, Eusse-Villa et al. (2021) proposed a link between the spatial heterogeneity and WTP in that a higher sensitivity to soil conservation may be associated with citizens residing within developed agricultural areas and found that strong attitudes towards soil conservation coincided with higher WTP for SmCPs in the majority of regions.

5. Discussion

In this review, we examined a growing body of literature on the valuation of soils contribution to human wellbeing. The analysis showed a great variety of values and emphasized an integrative perspective on values, valuation approaches and valuation frames to create necessary conditions for incorporating values into decision-making. In the following, we discuss some of the findings. The IPBES conceptual framework, as outlined by Díaz et al. (2015), connects nature and people, highlighting the interdependence of ecosystem services and human wellbeing and integrates the multiple social values and knowledge systems into assessments to support a holistic approach to ecosystem services. This framework has been instrumental in guiding research on NCP in various ecosystems. The valuation of NCPs, particularly with respect to soils (i.e. SmCPs), encompasses both monetary and non-monetary aspects. While monetary valuation methods are pragmatic and commonly used for communication within institutional contexts of politics and business (Legesse et al. 2022), it is crucial to acknowledge the limitations of economic valuation and consider alternative or non-monetary methods, especially for addressing social and cultural aspects of SmCPs (Bartkowski et al. 2020). Our review of the literature has found considerably more non-monetary valuations in addition to integrated valuation approaches, especially for non-material SmCPs, in contrast to the review by Bartkowski et al. (2020) and highlights the value of less mainstream methods, such as narrative analysis to portray indigenous and local knowledge to enhance the socio-ecological understanding.

The role of non-use values of soil ecosystems for society should not be disregarded (Eusse-Villa et al. 2021). The complexity of valuing SmCPs also requires interdisciplinary cooperation, including collaboration with anthropologists and archaeologists in soil science (Teuber et al. 2022). Such interdisciplinary approaches can provide insights into the cultural and social valuation of soils that go beyond the economic realm, contributing to a more comprehensive understanding of the value of soils to society. This provides the means to transcend knowledge and value systems by including the voices of different types of actors (Polk 2015) given that culture and society are intrinsic elements in the interdependencies of ecosystems and people (von Heland and Folke 2014). Moreover, the literature highlights the need to shift from static, purely monetary valuation toward the consideration of trade-offs between the current flow of benefits from ecosystems and the ability of those ecosystems to provide future flows (Abson and Termansen 2010). Indeed, our review of the literature showed that important direct and indirect drivers leading to SmCP loss were not always made apparent. This led to many valuations focusing on of the current state of ecosystems as opposed to a valuation of a change that is critical to provide policy information concerning agri-environmental practices, for example (Dupras et al. 2018).

Although not included in the review, the study by Prado et al. (2016) underlines the importance of identifying which ecosystem services should be assessed, the required data, and the methods for valuation in different contexts. This aligns with the concept of integrating different environmental valuation methods, as discussed by Majdalawi et al. (2016). Moreover, Makwinja et al. (2021) underscored the need for integrated valuation approaches to comprehensively assess the trade-offs and implications of land use changes on ecosystem services by investigating the impact of land use dynamics on various ecosystem services. Thereby, the authors emphasized the expansion of social and policy research in valuation, indicating the development of methods for valuation to supply indices for planning and policymaking (Chan et al. 2020). Such developments are crucially important for addressing growing calls for more pluralistic value integration into policy making processes to foster a transformative change (Pascual et al. 2023).

Alternatives for more integration in the valuation of SmCPs could be inspired from examples in the literature elsewhere. Saarikoski et al. (2016) compared multi-criteria decision analysis and cost-benefit analysis as frameworks for integrated valuation of ecosystem services. Their results indicate a generally better performance than cost-benefit analysis in several areas, such as the ability to account for multiple dimensions of wellbeing and facilitating more transparent discourses on the advantages and disadvantages of courses of action. Such approaches may aid in alleviating the concerns of policymakers and stakeholders in the use of cost-benefit analyses as a decision criterion for prioritizing measures (Dehnhardt et al. 2022). Furthermore, Czembrowski et al. (2016) proposed using non-monetary and monetary valuation methods including SoftGIS and hedonic pricing to provide a more comprehensive assessment of ecosystem services. Participatory mapping, systems modeling and deliberative monetary valuation provide further opportunities to pursue a holistic approach to valuation by assessing shared values of ecosystem services as demonstrated by Kenter (2016). Such approaches shed light on the issues discussed by Kronenberg and Andersson (2019), in which even if full integration is not possible or meaningful, the interdisciplinary combination of different valuation methods, both non-monetary and monetary, has the potential to support a more comprehensive depiction than simplistic, singular methods.

5.1. Limitations and future directions

Although steps were taken to ensure a thorough and comprehensive approach was maintained, there are a few limitations of the study. Given the search criteria, only peer-reviewed and original publications were assessed. However, it is possible that grey literature or literature published in languages other than English could have provided insights that were not summarized here. Furthermore, the aim of this study was to identify different methodologies behind valuation and propose future research agendas in this area, but a more comprehensive approach could have strived to understand further details of purpose and usefulness of the valuation procedures in the individual case studies.

6. Conclusion

A systematic review of the literature on the valuation of SmCP was performed in this study. In conclusion, the reviewed literature provided a comprehensive understanding of the challenges and approaches to valuing SmCPs. Indeed, a wide range of SmCPs has been valued in a variety of contexts and methods across the method families. Although the majority of studies were solely concerned with either monetary or non-monetary valuation approaches, several studies acknowledged the limitations of pure economic valuation and attempted an integration valuation of both non-monetary and monetary valuations. Such approaches provide the basis for adopting an interdisciplinary approach to fully capture the diverse values of SmCPs. However, there appears to be yet further potential for fully integrating both monetary and non-monetary valuation methods to encompass a more comprehensive valuation approach. Although the steps in this direction became apparent in the literature, a further stride towards bridging different worldviews and knowledge systems and eliciting the plurality of values associated with SmCPs would also require an investigation into how these aspects are incorporated into decision and policymaking.

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