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REVIEW

A bibliographic review of the relationship between ecosystem services and human well-being

Yuchen Zhou[1,2] · Qingxu Huang[1,2] · Chunyang He[1,3,4] · Peiyuan Chen[1,2] · Dan Yin[1,2] · Yihan Zhou[1,2] · Yansong Bai[1,2]

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Abstract

Although the relationship between ecosystem services and human well-being (REH) has been widely recognized and has become an important basis for policy-making, a quantitative review of the relationship is still lacking. To address this gap, we conducted a systematic review of empirical studies focusing on the REH based on the PRISMA framework. Our review highlighted the progress and challenges in terms of conceptual frameworks, methods, and major themes. We found that there was no consensus on the classification systems for human well-being, and only 35% of the empirical studies applied one of these systems. More than half (53%) of empirical studies on REH were qualitative, and the participatory approaches were the most popular method. In terms of the types of ecosystem services and human well-being, provisioning services and basic material for a good life received the most attention with 191 (out of 482) and 57 (out of 131) mentions, respectively. Future research must be more clearly framed in terms of defining types of human well-being. Methodologically, on the one hand, we should factor in stakeholder preferences and characteristics through the participatory approaches. On the other hand, we should develop methods revealing the mechanisms and pathways between ecosystem services and human well-being.

Keywords Participatory approach · Subjective well-being · Systematic review · Sustainability · Sustainable development

Abbreviations

ES	Ecosystem service
HWB	Human well-being
MEA	Millennium ecosystem assessment
REH	The relationship between ecosystem services and human well-being
SDG	Sustainable development goals

Extended author information available on the last page of the article

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1 Introduction

After the Millennium Ecosystem Assessment (MEA), which provided the first comprehensive evaluation of the relationship between ecosystem services and human well-being (REH) at the global scale, a large number of studies have interpreted the relationship from different perspectives. ES can have positive impacts on HWB, and their relationships can be influenced by socio-economic and natural factors (MEA, 2005). The changes in the supply and demand of ES can lead to complex changes in human well-being (Fig. 1a). Meanwhile, there are also feedbacks on ES through socio-economic and natural factor mediated by HWB (Leviston et al., 2018; Fig. 1b).

Socio-economic factors can have direct or indirect effects on ES. In terms of direct impacts, socio-economic factors can directly influence the ability of specific stakeholder groups to acquire ES, thus affecting the level of HWB (Fig. 1c). For instance, urban green space can provide residents with multiple ESs such as recreation, air purification, and carbon sequestration (Chang et al., 2017). However, green space accessibility and utilization may be affected by residents' socio-economic attributes. Communities with lower income levels are likely to have less green space in terms of area and quality, and therefore lower levels of ES. In terms of indirect impacts, socio-economic factors can affect REH indirectly through natural factors (Fig. 1d). For example, urbanization and environmental policies may lead to the changes in land use, which affects the hydrological processes. Li et al. (2022) found that the land use policy led to an increase of water yield service in Beijing's ecological conservation zone and a decrease of such service in urban area.

Natural factors can exert substantial impact on the REH (Fig. 1e). Taking climate change as an example, energy consumption plays a crucial role in the process. On the one hand, the increase in carbon emissions from fossil fuels will exacerbate the trend of global warming, which will affect the structure and function of forest ecosystems, leading to the decline of ES such as carbon sequestration and water retention (Weiskopf et al., 2020). Therefore, there is a consensus to mitigate climate change through carbon neutrality and other environmental policies (Liu et al., 2023). On the other hand, these actions may also

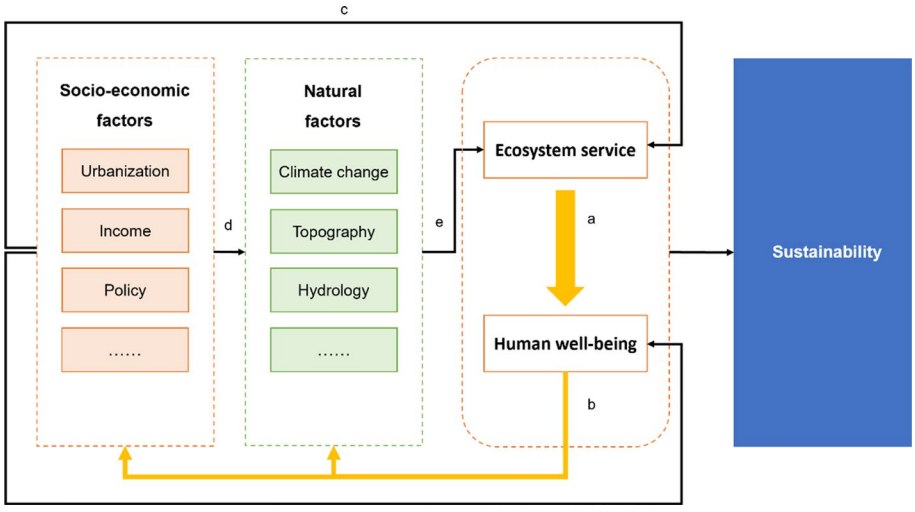

Fig. 1 The conceptual framework on the relationship between ecosystem service and human well-being

have complex impacts on the REH. For example, to achieve the goals of SDG13 (Climate Action), the COP28 meeting in late 2023, called for a reduction in the use of fossil fuels (UN Climate Change, 2023). Green energy can be used as substitutes, including the biofuels (one of the provisioning ecosystem service). This implies that ES can positively contribute to achieve sustainability. However, with the restriction of energy efficiency and prices, these measures often came with higher costs (Adebayo & Alola, 2023). As a result, specific domains of HWB may suffer and ultimately exhibit complex impacts on REH (Neve and Sachs, 2020).

To gain a better understanding of REH, conceptual frameworks of the relationship have been constructed from the perspectives of economic, social, ecological and other disciplines (Huang et al., 2020). According to the review of Cruz-Garcia et al. (2017), more than 29 frameworks have been proposed to describe REH. Among all the frameworks, the MEA classification system is the most widely used (Cruz-Garcia et al., 2017). It classifies ES into four types, provisioning services, regulating services, cultural services, and supporting services, and separates HWB into five dimensions (security, basic materials for a good life, health, social relations, and freedom of action and choice). This framework also highlights the potential strengths of the links between different ES and HWB. However, there are various views on the relationships and pathways between ES and HWB. For example, Costanza et al. (2014) stated that ES does not have a direct effect, but affects HWB by interacting with other capitals. In the cascade framework, not only can ES influence well-being, but the assessment of HWB can vary at different times and locations across stakeholder groups (Potschin & Haines-Young, 2011).

Several reviews have summarized the advances in ES, HWB, and REH research. However, most of these reviews only focused on either ES or HWB without a detailed investigation of the links between them. For the reviews on ES, they have focused on ES classification, quantification, trade-off and synergy, flow and their connections with policymaking (Fisher et al., 2009; Hayha et al., 2014; Wang et al., 2022; Mandel et al., 2020). For the reviews on HWB, they have focused on HWB classification, measurement, and application. For example, King et al. (2014) reviewed the concepts, dimensions and measuring methods of HWB in the context of social ecology. Agarwala et al. (2014) collated the mainstream human well-being frameworks in developing countries. Concerning REH, researchers have proposed conceptual frameworks, and summarized an overall situation in certain regions or some specific types of REH. For example, Suich et al. (2015) focused on the impact of ES on poverty alleviation, pointing out that existing studies focused excessively on the role of provisioning services and material poverty and lacked an understanding of the mechanisms between them. Cruz-Garcia et al. (2017) reviewed the REH in developing regions based on empirical studies in Africa, Asia, and Latin America. Leviston et al. (2018) proposed an interdisciplinary REH framework to study the interaction between ES and HWB. Huynh et al. (2022) considered mechanisms between cultural service and HWB and summarized 16 possible pathways in which cultural services affect human well-being, including cognition, cohesion, and communication. Wang et al. (2021) conducted a bibliographic analysis of REH research, collating publication characteristics and research themes in the field. Liu et al., (2022a, 2022b) incorporated land use factors and concluded its relationship with ES and HWB. In a summary, most previous reviews focused on certain regions or some specific types of ES and HWB (Haase et al., 2014; Lee & Lautenbach, 2016; Milcu et al., 2013). Therefore, a comprehensive and systematical review on the REH is still lacking.

Considering the importance of the REH for achieving sustainable development, in this review we comprehensively and systematically assess the current status of the REH research. This review will address the following questions: what kind of relationship has

been identified between ES and HWB in empirical studies? What conceptual frameworks, research methods, and themes have been developed in existing REH studies? More importantly, what are the challenges in the future? We first selected empirical studies on REH worldwide between 1997 and 2020 based on bibliometric analysis and summarized the information of these studies. Then, we examined the relationship between each ES and each human well-being based on the MEA framework, focusing on the conceptual framework, research methods, and research themes. Finally, we summarized the progress in these sections based on the extracted information. The summary will identify regions and types of REH that were not fully investigated in existing reviews. The review will contribute to the establishment of new theoretical and/or methodological frameworks for future research, and guide future efforts to achieve in-depth understanding on the quantitative REH.

2 Methods

This review was based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) process. First, we searched the Web of Science core collection for empirical-type articles mentioning ES and HWB from 1997 to 2020, with two screenings. The first search with the keywords "ecosystem service*", "human well-being*" and "case*" yielded a total of 276 records. Articles not related to ES and HWB were then excluded based on title and abstract, and the initial screening resulted in 85 articles. Some of the studies focused on the relationship between ES and HWB (REH) but used other expressions or focused on specific types of services and well-being without mentioning the concept of ES and HWB. Using only "ecosystem service*" and "human well-being*" as search terms would omit this part of the literature. Therefore, we added keywords in the second search, including "environmental service*" and "landscape service*". For HWB, we added well-being keywords that were mentioned more than 5 times in the initial screening, including "health*", "income*", "earning*", "security*", "poverty*", "livelihood*", "earning*", "economy*", "food*" and "water*", and retrieved a total of 6658 articles. Screening was performed again and the results of the first search and irrelevant articles (n = 6472) were excluded. Ultimately, 186 articles were retained.

Combining the results of the two initial screens yielded 271 articles, and we read the full text of studies, excluding reviews and articles that only included ES and HWB as the subject of the study (n = 200). There were 71 empirical papers focusing on REH.

When collating the results, we classified ES and HWB mainly according to the MEA framework, which proposes a relationship between ES and HWB. ES is divided into provisioning services, regulation services, cultural services and supporting services, and HWB is divided into five dimensions: safety, good life of the basic material, health, good social relations and action and choice of freedom. In the actual collation process, we replaced freedom of action and choice with other dimensions because it was less related to ES (MEA, 2005). On the one hand, the MEA framework is the most widely used in previous studies (Cruz-Garcia et al., 2017), and on the other hand, other ES classification systems developed subsequently have exhibited good consistency with the MEA framework; for example, the TEEB framework classifies ES into provisioning services, regulating services, habitat services, and cultural services (TEEB, 2010), while the CICES system also follows the MEA classification (Haines-Young & Potschin, 2018). Therefore, the MEA framework is compatible with different classifications.

3 Results

3.1 Overview of REH research

By 2020, there were 6658 articles mentioning ES and HWB. The number of annual publications was below 100, and the number of citations was only approximately 1000 until 2008, after which the increase accelerated (Fig. 3a). This indicates that the proposed framework of the ES and HWB relationship in the MEA in 2005 contributed greatly to the research in this direction.

Since then, the annual number of publications and citations increased annually and reached 1088 publications and 36,140 citations by 2020, indicating that ES and HWB became an important research topic. From these, a total of 71 empirical articles examining the relationship between ES and HWB were further screened. These 71 articles were mainly published after 2010 (Fig. 3b), suggesting that the publication of empirical papers

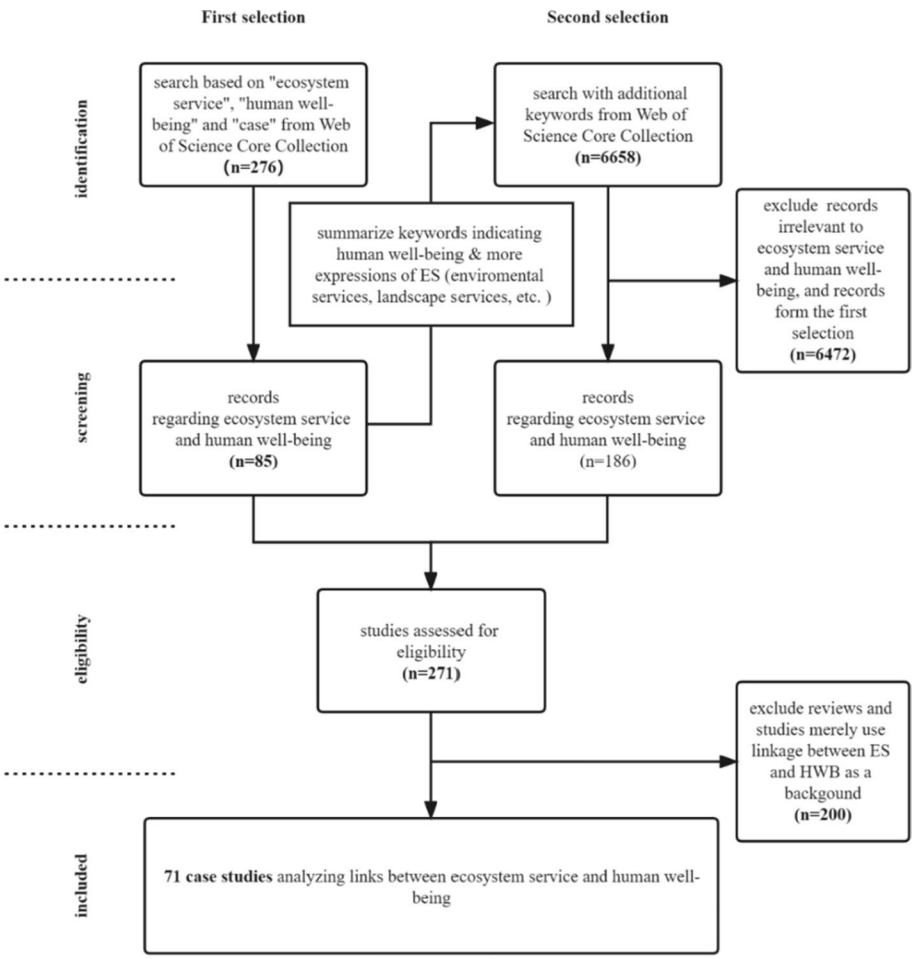

Fig. 2 Selection process of publications based on PRISMA

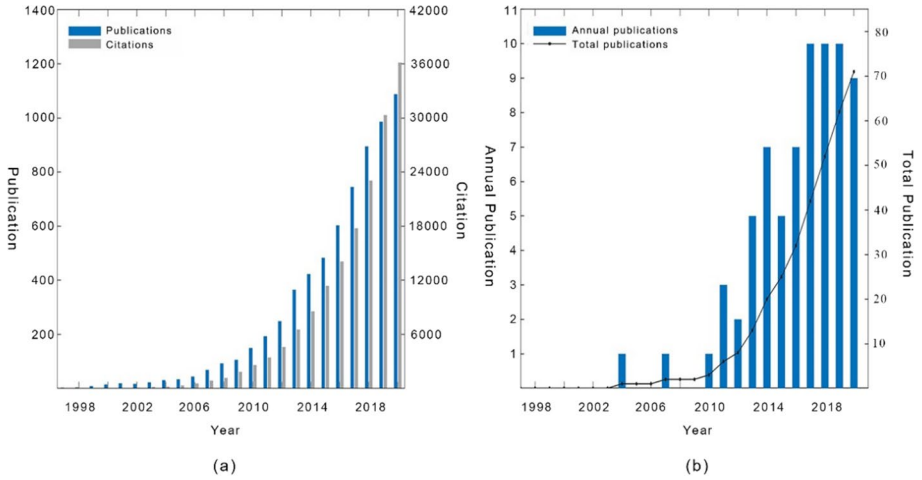

Fig. 3 Publications and citations (**a** annual publications and citations of all articles. **b** annual and total publications of selected articles)

lagged behind the emergence of framing conceptual papers. On the other hand, the number of annual papers did not change after 2017 and remained at approximately 10 (Fig. 3b), which also indicates that many bottlenecks and challenges remain in this research.

The study areas chosen for the empirical studies focusing on REH were mainly distributed in Europe (39, 30%), followed by Asia (35, 27%), North America (24, 18%), Africa (21, 16%), South America (8, 6%) and Oceania (3, 2%). Eleven (17%) of the studies included multiple regions. The Manas River Basin and Huailai in China and Mozambique and Kenya in South Africa were selected as the study areas in more than two articles.

In terms of the number of landscape systems, the most frequently mentioned in articles was urban landscape systems (20%). Cities were only studied in two articles, with Elmqvist et al. (2015) selecting 25 cities, accounting for 96% of the total number of this landscape. Coastal and marine systems (13%), watersheds (9%), and forests (8%) also received some attention in the study, followed by protected areas (6%) and wetlands (4%). Agricultural systems (2%) and mountains (1%) were mentioned with the lowest frequency. In addition, some of the studies did not specify the landscape type of the study area but only described the geographical location and extent of the study area; this is summarized as "other types" in this paper (36%).

3.2 Research frameworks and methods

3.2.1 Classification framework

Thirty-nine (55%) studies classified ES, and the Millennium Ecosystem Assessment (MEA) framework was the most widely used (Tables 1, 2). It classifies ES into provisioning services, regulation services, cultural services, and supporting services and classifies HWB into five dimensions (security, basic materials for a good life, health, good social relations, and freedom of action and choice) (MEA, 2005). In addition to the MEA framework, studies also used the Economics of Ecosystems and Biodiversity (TEEB) framework, the Common International Classification of Ecosystem Services

Table 1 Classification frameworks of ecosystem services and human well-being

Classification		Ecosystem service frameworks					
		MEA	TEEB	CICES	HWBI	Adapted or original framework	No framework
Human well- being frameworks	MEA	2, 4, 7, 10, 20, 28, 29, 33, 39, 42, 43, 50, 55, 56, 64	56			28	70
	CCF						59
	GNH	46					49
	TEEB		31				
	HWBI				71		
	SLAF	56	56				63
	Adapted or Original					32, 60	5, 22, 59, 68
	No Framework	8, 9, 12, 13, 15, 16, 21, 24, 26, 27, 30, 34, 39, 53, 58, 66		67, 69		1, 62	3, 6, 11, 14, 17, 18, 19, 23, 25, 35, 36, 37, 38, 40, 41, 44, 45, 47, 48, 51, 52, 54, 57, 61, 65

(CICES) framework, and other original or adapted ES frameworks (Table 1). The TEEB framework builds on the MEA by replacing supporting services with habitat services (TEEB, 2010), while the CICES framework includes three main types of ES: provisioning services, regulating and maintenance services, and cultural services (CICES, 2010, 2018). The Human Well-Being Index (HWBI) framework proposed by the U.S. Environmental Protection Agency focuses on five ESs: air quality, food, fiber and fuel supply, green space, water quality, and water quantity (Smith et al., 2014).

A total of 25 (35%) articles used the classification framework for the HWB. In addition to the MEA system, there were articles that used the TEEB framework to calculate the value of well-being (Terrado, 2016). There were also studies that used capital-related frameworks, such as the sustainable livelihood framework, which focuses on livelihood assets at the human, social, physical, natural and financial levels (Wei et al., 2019). The Community Capitals Framework (CCF) considers seven types of assets: natural, financial, social, human, physical, cultural, and political. Some of the articles used specific frameworks proposed by the countries in the study area, including the Gross National Happiness (GNH) framework in Bhutan and the HWBI framework in the U.S. (Table 1). The GNH framework includes socioeconomic development, cultural preservation and promotion, environmental protection, and four dimensions of good governance (Kandel et al., 2018; Sears et al., 2018). The HWBI framework divides well-being into eight dimensions: nature's connection, cultural fulfillment, education, and health (Yee, 2020).

Table 2 Conceptual frameworks of relationships between ES and HWB

Conceptual frameworks		Ecosystem service frameworks					
		MEA	TEEB	CICES	HWBI	Adapted or original framework	No framework
Connection frameworks	MEA	2, 7, 9, 10, 16, 20, 21, 27, 29, 33, 39, 50, 55, 56, 64	56				
	TEEB	29	31				
	SES			69		1	70
	DPSIR						18
	Cascade	24				62	18, 35, 38
	HWBI				71		
	Adapted or Original	4, 16, 26, 28, 29, 39,43, 56, 64	56	69		28, 60, 62	5, 18, 36, 38, 40, 49, 52, 54, 57, 63, 68
	No Framework	8, 12, 13, 15, 30, 34, 42, 46, 53, 58, 66		67		32	3, 6, 11, 14, 17, 19, 22, 23, 25, 37, 41, 44, 45, 47, 48, 51, 59, 61, 65

The references corresponding to the numbers are in Additional information

① *MEA* Millennium Ecosystem Assessment

② *CCF* Community Capitals Framework

③ *DPSIR* Driver−Pressure−State−Impact−Response

④ *EEB* The Economics of Ecosystems and Biodiversity

⑤ *CICES* Common International Classification of Ecosystem Services

⑥ *HWBI* Human Well-Being Index

⑦ *GNH* Gross National Happiness

⑧ *Cascade* Ecosystem Cascade Framework

⑨ *SES* Social-Ecological System

3.2.2 Framework of REH

More than half of the articles (39 articles, 55%) used conceptual frameworks to study REH, mainly the MEA framework mentioned above. Other frameworks were also used in the research, such as the Ecosystem Cascade Framework, the Social-Ecological System (SES) framework, the Driver−Pressure−State−Impact−Response (DPSIR) framework, and the TEEB and HWBI frameworks (Table 2). In the cascade framework, ecosystem services connect ecological structures/processes and human well-being in the chain (Haines-Young and Potschin, 2010). The DPSIR model categorizes indicators into five components:

drivers, pressures, states, impacts, and responses, which can reflect the impacts and anthropogenic responses of social systems to the environment (Gabrielsen and Bosch, 2003). Hou et al. (2014) adapted the DPSIR framework in conjunction with the cascade framework to divide the impacts into two parts: ecosystem services and human well-being. The MEA, TEEB and HWBI frameworks provide a clear classification of ES and HWB and relate the two, which can be used as a complete system for ES-HWB relationship studies. In addition, it is also possible to use different frameworks in combination, such as classifying ESs based on the MEA framework and substituting them into an adapted cascade framework (Felipe-Lucia, 2015).

In addition, 24 articles (34%) applied an original or adapted framework. Some studies first identified a conceptual framework before studying REH; for example, Wei et al. proposed a research framework linking ES supply, social demand, and HWB in the Manas River Basin, Xinjiang. There were also articles that proposed a framework for the relationship between the two based on the results of the study. For example, Hossain et al. (2017) used logistic regression in Bangladesh to reveal the link between provisioning services and well-being, such as material conditions and health, and summarized a system dynamics framework.

3.2.3 Research methods

We categorized and counted the research methods of ES, HWB, and REH and further divided the studies in each category into three types of methods: qualitative, quantitative, and a combination of qualitative and quantitative methods (Fig. 5). The ES studies were divided into seven types of methods, such as interviews/surveys, monetary value assessment, and participatory methods. The HWB studies were divided into five method types, and the REH studies, compared to the first two, had more statistical methods, such as correlation and regression. The interview/survey mostly collects information related to ES and HWB through face-to-face interviews, questionnaires, and other formats. The monetary value assessment is used to present the results in a monetized manner and is usually quantitative. Participatory approaches refer to stakeholders joining in the ES or HWB identification process in a participatory manner and expressing preferences, thus providing different information to the researcher (Burdon et al., 2019). Statistical methods such as correlation and regression are based on the quantification of ES and HWB and use statistical principles to quantitatively describe the relationship between the two (Jiao et al., 2019; Maltitz et al., 2016).

Participatory approaches were the most widely used in ES research (35%), followed by interview/survey and indicator/model methods (22% and 21%, respectively). Both qualitative and quantitative studies were found in the three categories of participatory methods, interviews/surveys and ES mapping. Of the studies that used participatory methods, 75% yielded qualitative results, and 12.5% yielded a combination of both qualitative and quantitative results. The monetary value assessment and the assessment using indicator/model were all quantitative studies (Fig. 4a). ES were also assessed in 6% of the studies using a fully qualitative approach (Fig. 5a).

For HWB, participatory approaches were again the most used research method (41%), followed by interview/survey, indicator/model, and monetary quantity assessment methods (24% and 21%, respectively). Both qualitative and quantitative studies were found using participatory and interview/survey methods, while articles using indicators/models as well as value-volume assessments are conducted as quantitative studies. However,

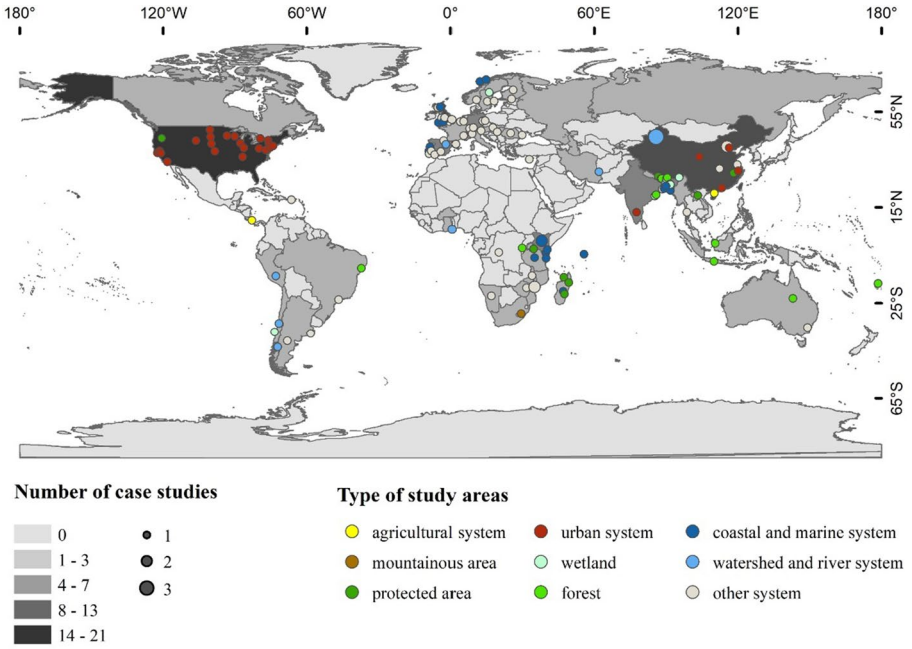

Fig. 4 Locations and types of study areas

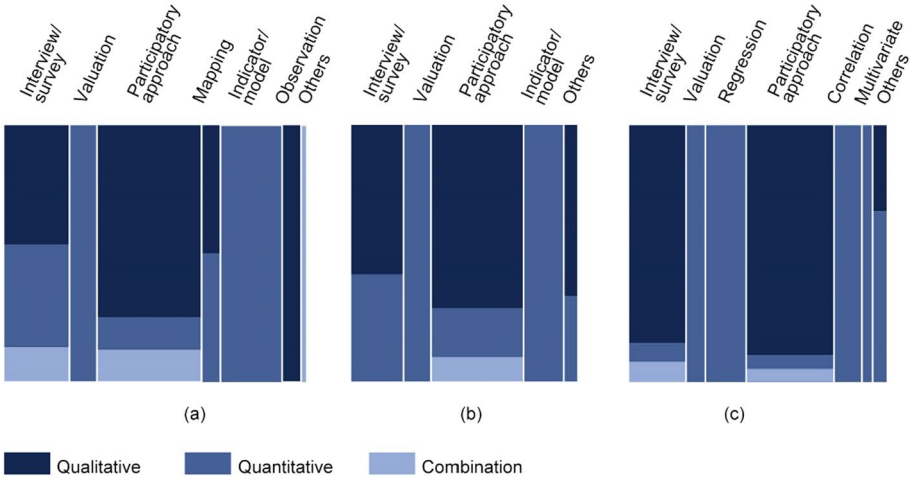

Fig. 5 Analytical methods in selected articles

compared to ES, HWB had fewer evaluation methods and applications. Seven and five categories of evaluation methods were used in ES and HWB, respectively, with 68 and 51 applications, respectively. This also indicates that the assessment method of HWB is not as mature as the ES assessment at present.

For REH, the percentage of qualitative studies was 53%, which was higher than the percentage of qualitative studies in the ES and HWB assessments. Although participatory methods and survey/interview methods were the dominant research methods for ES, HWB, and REH, the proportions of qualitative studies using both methods in the study of REH were 90% and 85%, respectively, both higher than the corresponding proportions in ES and HWB assessments. In contrast, the monetary value assessment and statistical methods such as regression, correlation analysis and multivariate statistics yielded quantitative results (Fig. 5c).

Overall, of the total studies analyzed for ES, HWB, and REH, qualitative studies accounted for 48% of the total, quantitative studies accounted for 46%, and the remaining 6% obtained both qualitative and quantitative results. The proportion of qualitative studies was higher than average in the analysis of REH. The participatory approach, which can integrate stakeholders' perspectives (Lopes & Videira, 2016), accounted for the largest share of all research methods, most of which were qualitative (Fig. 5).

3.3 Focused ES, HWB and REH

In terms of ecosystem services, provisioning services received the most attention. They were mentioned 191 times, including 13 service types, with freshwater, food, wood and medicine mentioned more than 20 times. Supporting services received the least attention, with only 38 mentions of services such as habitat, biodiversity, nutrient cycling and soil formation. Regulating services were mentioned 116 times, including 10 types of water regulation, climate regulation and erosion control. Cultural services were mentioned 137 times, including 9 types of services such as recreation, education and research, and tourism (Fig. 6).

Of the five dimensions of human well-being, the basic substances needed for a good life received the most attention, with 57 mentions. Including livelihood, income, food, water,

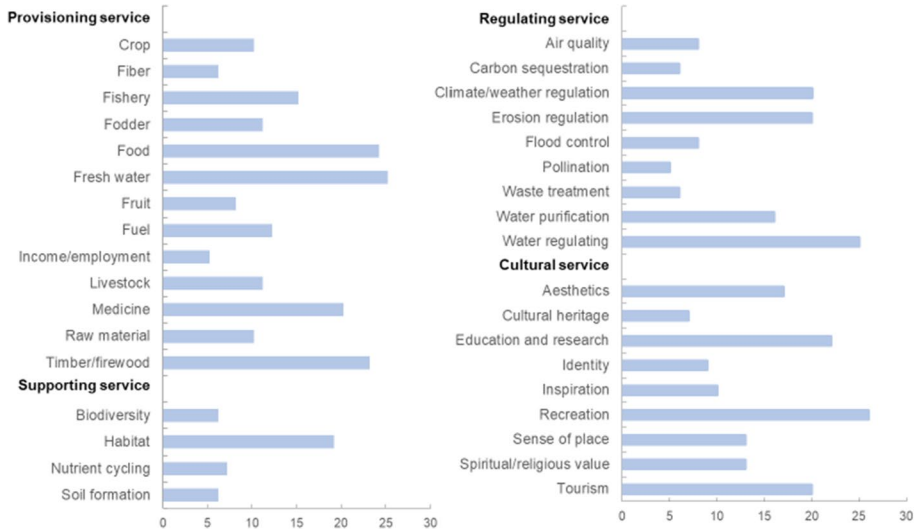

Fig. 6 Types of ES mentioned in selected articles

shelter, and other basic substances, the type and number of mentions of well-being were higher than for the other dimensions (Fig. 7). The health dimension also received more attention, with 31 mentions, but 19 of the articles did not distinguish between physical health and mental health and only generalize to good health. The social relationship dimension was mentioned 20 times, with four articles focusing on family relationships. In addition to the security of the stakeholders themselves, resource security also received some attention in the security dimension. In addition, freedom and choice, knowledge/skills, and decision-making ability were also studied 12, 7, and 4 times, respectively.

The studies focused on the relationship between a total of 26 ESs and 14 HWBs (Table 3). The two mainly exhibited a positive relationship, accounting for approximately 71% of the total, with only 4% of the ESs having a negative relationship with HWB. The relationship between ES and HWB was more complex in another 25% of the papers, and the findings were potentially contradictory in different studies, or it was not possible to clarify whether the effect was positive or negative. For example, Berbes-Blazquez (2012) used photovoice in Costa Rica and found that stakeholders perceived a positive effect of outdoor rest on health. In contrast, Henke et al. found only a weak correlation between ESs and health in Wales, demonstrating the potential for different relationships in different locations.

Provisioning services were mainly associated with the basic materials needed for a good life, and the relationship between them was predominantly positive, but there was a negative relationship between some services and social relations and health. Taking agricultural products as an example, in the Sistan Delta region of Iran, agriculture was the most important source of income for some residents (Meijer & Beek, 2011). In contrast, Berbes-Blazquez (2012) found that in Costa Rica, pineapple and sugarcane were able to increase income but had a negative impact on health. In addition, stakeholders in this study also perceived livestock and water ponds to be detrimental to health (Table 3).

The number of studies on the relationship between cultural services and well-being was second only to that of provisioning services. The relationship between cultural services and well-being was mainly positive, except for the more complex impact of leisure and

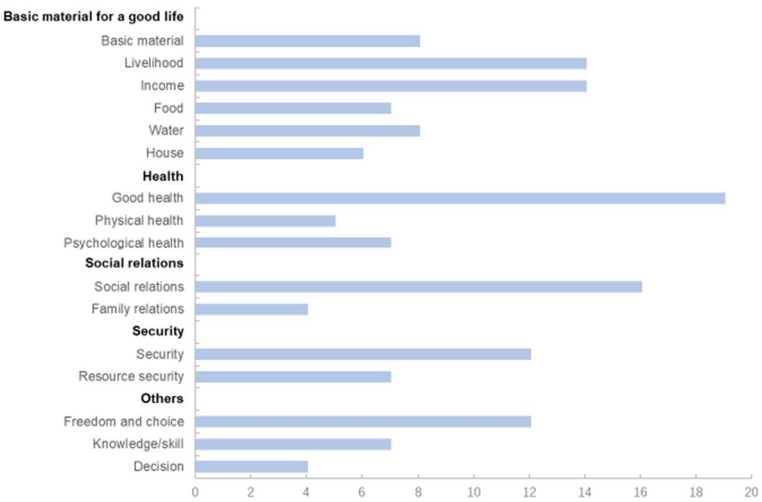

Fig. 7 Types of HWB mentioned in selected articles

Table 3 The relationship between different types of ES and HWB (red, blue and green color represents synergy, trade-off and mixed effects, respectively, and the number denotes the count of cases)

			Human well-being															
			Basic material for a good life						Health			Social relations	Security		Others			
			Food	House	Income	Livelihood	Nutrition	Water	Basic material	Good health	Physical/psychological health	Social relations	Security	Resource security	Freedom and choice	Traditional belief	Unspecified well-being
Ecosystem service	Regulating service	Air quality								2			1				2
		Erosion regulation			1	1			1	2							4
		Carbon sequestration							1	2							4
		Climate regulation		1	1					1							3
		Pollination															1
		Water purification															1
		Water regulation			1					1							1
		Regulating service				1		1	2	2	1	1	2	1			5
	Cultural service	Aesthetics				3			1	1		2			1		2
		Cultural heritage										1					1
		Identity				1						1					2
		Inspiration															1
		Recreation			1				1	4		2	1		1		5
		Sense of place				1			1	1		2	1		2		4
		Spiritual/religious value										1	1		1		1
		Tourism			2	1			1	1		1	1		1		3
		Cultural service				2			1	2	1	3	1	1			3
	Provisioning service	Fresh water				4		1		4		1					1
		Fishery	2		5	1	1		1	3		2		1		1	2
		Agricultural product	1		5	7			2	2		2					1
		Hunting	1		2												
		Husbandry	1		1	3						1					
		Medicine			2	2				6		1					1
Ecosystem service		Puddles								1							
		Timber				5			2					1			1
		Provisioning service	1	1	3	3		1	4	2	1	2	1	3	1		5
	Supporting service	Biodiversity			2												1
		Habitat															4
		Soil formation															1
		Supporting service				1			2	4	1		2	1	1		1

recreation (Table 3). For example, Tubul-Raqui residents perceived aesthetic values as contributing significantly to well-being (Marín et al. 2014). Ecotourism and recreation services in Røst, Norway, could increase income sources and environmental knowledge, reduce diseases, and thus increase well-being (Kaltenborn et al., 2017). However, Xu et al. (2019) found a negative relationship between cultural services overall and basic material needs and health in the Manas River Basin, Xinjiang.

Some of the regulating services were negatively associated with basic substances such as income but were dominated by positive effects on the health and security dimensions (Table 3). For example, Wang et al., (2017a, 2017b) found that economic growth in the Manas River basin occurred without an increase in regulation services, but services such as climate regulation were positively associated with resource security. In Bhutan, regulating services mainly had positive effects on human health and environmental health (Kandel et al., 2018).

Few empirical studies supported the relationship between supporting services and well-being, with only 17 articles considering the relationship between the two, suggesting a compound or negative relationship with basic material, safety and health (Table 3). For example, Simpson et al. (2016) found that stakeholders did not consider habitat

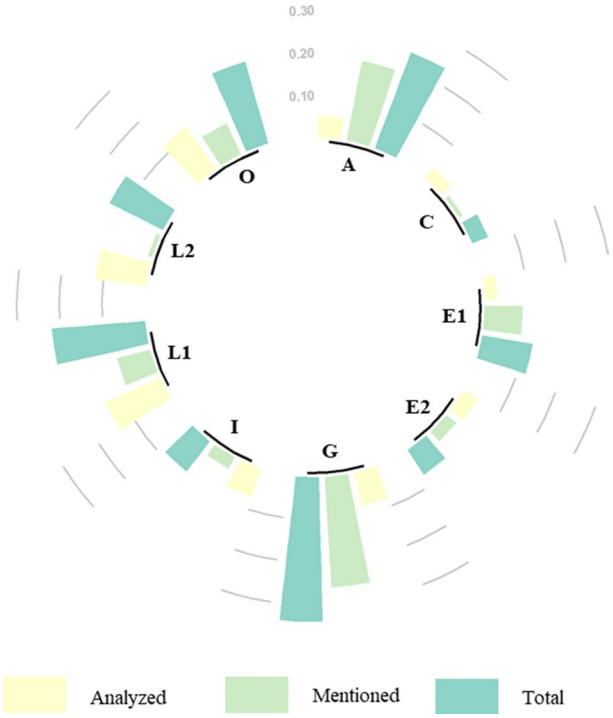

Fig. 8 Attributes that may make differences in ES/HWB between stakeholders (*A* Age, *C* Caste, *E1* Education, *E2* Ethnicity, *G* Gender, *I* Income/wealth, *L1* Livelihood activity/occupation, *L2* Location, *O* Others)

provisioning services to be important for shore-based livelihoods. In a study by Schneider et al. (2020), biodiversity in Myanmar was gradually reduced, while income continued to increase due to land use change.

3.4 Influence of stakeholders in REH research

REH may vary across interest groups, so some studies considered the impact of stakeholder attributes. Common attributes included age, social status, education level, ethnicity, gender, income/wealth, livelihood activity/occupation, geographic location, and other factors (Fig. 8). Overall, fewer studies focused on differences among stakeholders, and even the most frequently analyzed livelihood activity/occupation was mentioned in only approximately 15% of the articles (Fig. 8). Gender and age were mentioned more frequently (Fig. 8) but mainly as a background introduction to the stakeholders involved in the study, rather than as the main subject of study, and were often used to present a basic picture of the study area or to demonstrate that the respondents selected for the article were representative. In contrast, livelihood activities and geographic location may be directly related to ES and therefore serve as the primary study attribute.

Specifically, residents in the study area were the most important stakeholders, and more than half of the articles focused on their ES and well-being (Fig. 9); only a small number of articles further differentiated between residents based on attributes such as gender and occupation. For example, in the study by Song et al. (2018), differences in

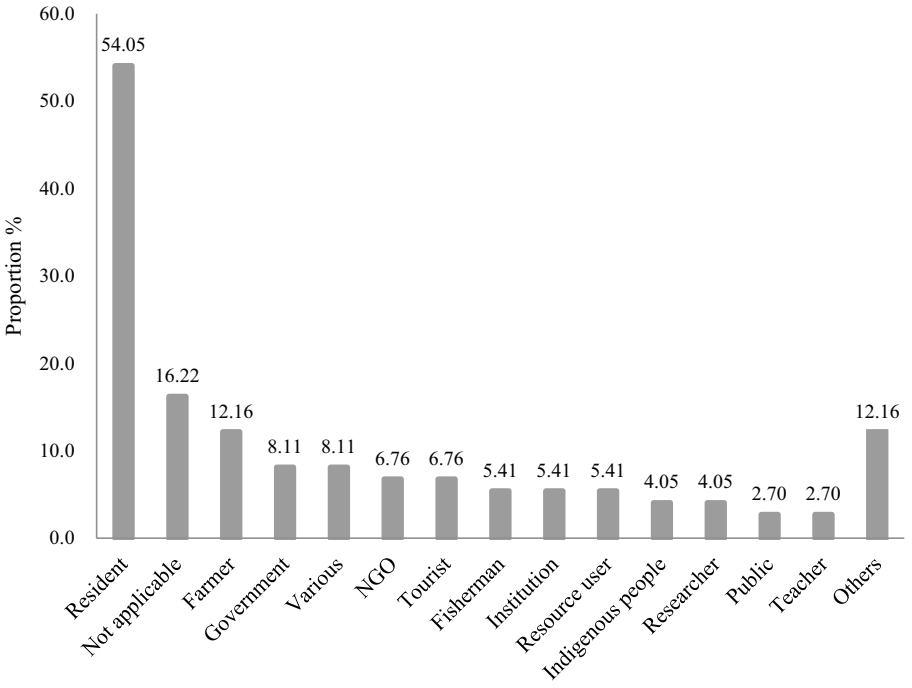

Fig. 9 Types of stakeholders

well-being from the environment between urban and rural residents in Hubei, China, were considered. Farmers and government workers also received more attention, followed by stakeholders such as tourists and fishermen. In addition, 16% of the articles had no stakeholder involvement, and 8% did not specify specific categories of multiple interest groups (Fig. 9). Other categories included interest groups that were mentioned less frequently, such as technicians, businessmen, and women. For example, since women in Fiji are more dependent on mangroves, Pearson et al. (2019) compared the differences in ES and well-being that women and men in Bua Province received from mangroves. There were also studies that differentiated the importance of stakeholders, such as Simpson et al. (2016), who categorized the salience of stakeholders (salience) into high, medium, and low levels based on power, legitimacy, and urgency to compare the importance of different groups' opinions on ES.

4 Discussion

4.1 The temporal and spatial characteristics of REH research

After the proposal of the MEA framework, REH has gradually become a hot topic. However, most of the studies only considered the linkage between ES and HWB in the background and did not assess it empirically. After screening, only 71 empirical studies on REH were included in this review; they were first published in 2004, and the number increased

annually after 2010. However, the growth in annual publications did not increase further after 2017. This indicates that there have also been bottlenecks in this field, including the spatial and temporal scales of research, conceptual frameworks and methods. It is therefore necessary to summarize the development status of previous REH studies to guide future research.

For the time scale, most of the selected articles focused on REH at specific time points, and REH studies on multiple time periods or long time series need to be further studied (Yin et al., 2022; Zhou et al., 2024). ES and HWB are influenced by other factors, such as climate change, land use, and socioeconomic factors (Henke et al., 2013; Nelson et al., 2013; Wang et al., 2017a, 2017b; Schneider et al., 2020; Yee et al., 2021), and REH does not remain static. Leauthaud et al. (2013) measured the effects of dam construction on wetland ES and HWB in Kenya and found that water depletion in the region from 1960 to 2010 led to a reduction in human well-being through multiple pathways. Marin et al. (2014) also focused on the effects of a natural hazard on REH, comparing changes in the importance of ES on well-being before and after the 2010 earthquake in Tubul-Raqui, Chile. Understanding the process of changes in REH can lead to better guidelines for ES management and policymaking (Leauthaud et al., 2013).

REH in specific areas and landscape types deserves more attention. First, in terms of geographic locations, the study areas were mainly distributed in Europe, Asia, and North America, and gaps exist in assessing REH in less developed regions. Although REH in Asia has started to receive more attention compared to the results of the review by Cruz-Garcia et al. (2017), there have still been few empirical studies in Africa and Latin America (Fig. 2). These regions have many developing countries with struggling economies and severe social inequalities (Rincón-Ruiz et al., 2019), which may cause drastic conflicts with environmental protection in the development process (Cruz-Garcia et al., 2017). To achieve sustainable development goals, it is necessary to focus on REH in underdeveloped areas, especially in Africa and Latin America, which have been less frequently studied.

In addition, more attention should be paid to REH within cities in future studies. Natural landscapes account for the majority (43%) of studies that explicitly present the type of landscape in the study area, including coastal and marine systems, watersheds, and forests. Only a limited number of studies were conducted in cities. However, urban areas are increasing steadily, which may cause intense human interventions in ES. The type of ES within urban areas also differs significantly from that in natural systems (Hasan et al., 2020). In natural landscapes, provisioning services play a fundamental role in enhancing well-being, including food, fresh water, fishery, and medicine. Urban systems, on the other hand, are covered by large impervious surfaces and provide few provisioning services (Gómez-Baggethun et al., 2013). Moreover, while the well-being of urban residents relies heavily on ES from areas outside cities (Gómez-Baggethun et al., 2013), there are also many services that can only be provided by urban ecosystems (Bolund et al., 1999), especially the regulating services provided by urban green spaces and blue infrastructures, such as microclimate regulation and air purification, which play an important role in enhancing the well-being of residents (Elmqvist et al., 2015; Haase et al., 2014).

4.2 Conceptual framework and methodology

ES classification systems have been relatively well developed, and the research methods are relatively solid, including biophysical models, monetary assessments and other quantitative

methods. In contrast, the conceptual frameworks and methods of HWB and REH have not yet reached consensus and need to be further developed.

Overall, the MEA framework was most widely used in the aspects of ES, HWB, and REH (Table 1). More than half of the studies applied more than one ES classification system. In addition to the MEA framework, TEEB and CICES (which were developed from MEA) were used twice each (Table 1). There were also articles that identified the type of ES based on MEA and its derivative frameworks, although they did not specify the classification framework.

The classification of HWB requires further research, consistent with Rendón et al. (2019). The fact that the categorization of HWB has not reached a consensus could be a barrier to include them in policy and management. And there were relatively few quantitative studies of HWB (Smith et al., 2013). Most studies did not classify HWB. They merely focused on specific types of HWB or treated it as a whole. For example, Liu et al. (2010) did not classify types of HWBs according to any framework but considered livelihoods, culture, and environmentally relevant social welfare. Some studies applied the concept of HWB but did not subdivide it (Bieling et al., 2014; Marin et al., 2014). In addition, HWB lacks a dominant classification system. The number of HWB classification systems used in the selected articles was much larger and more scattered, and there were massive differences in the way different systems define and classify HWB. For instance, the TEEB framework quantifies well-being using monetary terms (Terrado, 2016), while the GNH classifies well-being into four dimensions: socioeconomic development, cultural preservation and promotion, environmental protection, and good governance (Kandel et al., 2018; Sears et al., 2018). This suggests that a consensus on well-being has not been reached in the literature. Beyond that, there were also crossovers between ES and HWB definitions. A total of five articles classified income or occupation as a provisioning service, while income was considered a measure of well-being in another 15 articles.

REH is influenced not only by the characteristics of ecosystems but also by the preferences and management of stakeholders (Felipe-Lucia et al., 2015). Moreover, stakeholders have different classes, races, wealth, power, genders, and other socioeconomic attributes (Chaudhary et al., 2018). These features result differences in their ability to attain ESs and participate in management (Vallet et al., 2019), which affects the access and allocation of their well-being. However, previous REH studies rarely considered differences in stakeholder attributes. Livelihood activity/occupation was the most focused attribute but was mentioned in only 15% of the articles. Attributes such as age, class, and education level were mentioned by fewer than 10% of the publications.

The participatory approach can reflect local stakeholders' understanding and preferences for ESs (Simpson et al., 2016). This method can show the impact of ES on the HWB of different stakeholders and, thus, provide more information for ES management and decision-making (Noor et al., 2022), which has wide applications. M. Liu et al., (2022a, 2022b) pointed out the paucity of studies elucidating stakeholders' preferences and perceptions of ES. However, our results indicated that participatory approaches are emerging as an important REH research method.

For example, Berbes-Blazquez et al. (2012) combined photovoice with other participatory methods to gain an understanding of the REH of community residents and use local knowledge to guide ecosystem management. Fritz-Vietta (2016) used participatory rural appraisal to discuss different stakeholder groups in protected areas to explore the types of local REH. Therefore, in future REH studies, it is necessary to strengthen stakeholders'

participation and use a participatory approach to obtain their perceptions of REH and to distinguish the REH of stakeholder groups with different socioeconomic attributes.

Participatory approaches were mainly used for qualitative research. Conducting large-scale studies is difficult. Therefore, it is necessary to combine participatory approaches with other methods in future REH research (Lopes & Videira, 2016). For example, statistical methods accounted for the largest proportion of current quantitative studies of REH (Fig. 4), including correlation, regression, and multivariate statistical methods. These methods not only determine whether the relationship between ES and HWB is positive or negative but also quantitatively assess the magnitude of the relationship (Jiao et al., 2019; Maltitz et al., 2016). However, statistical correlation cannot represent the actual REH (Xu et al., 2019). An explanation of the mechanism of association between the two is also needed. In contrast, participatory methods can provide abundant local knowledge and spatial information, which can be complementary to the mechanisms behind correlations. In addition, some researchers have also used structural equation modeling (SEM) combined with semi-structured interviews to investigate the impact of stakeholders' power on ES acquisition (Felipe-Lucia et al., 2015). Lopes and Videira (2016) developed a methodology for modeling the dynamics of stakeholder engagement, mapping the linkages between ES and factors such as management measures and feedback mechanisms.

4.3 Types of REH

Understanding REH is the key to enhancing HWB and achieving sustainable development goals. Overall, REH in the selected empirical studies showed predominantly positive relations (Tables 3), but the relationship between different ES and HWB varied profoundly. The direction and magnitude differed with location and landscape type (Liu et al., 2022a, 2022b; Wu, 2013). For example, provisioning services, which received the most attention in empirical studies, were primarily associated with the basic materials needed for a good life and had a positive relationship with most measures of well-being. However, hunting and husbandry inhibited people's health and social relationships in some areas (Table 3). A study in the Manas Basin, China, found an overall trade-off between cultural services and health, but with a specific type of well-being; it revealed that cultural services were positively associated with environmental health (Xu et al., 2019). This also suggests that focusing on specific types of ESs and HWB provides a deeper understanding of the direction and mechanism of REH.

In addition to provisioning services and cultural services, the relationship between other types of services and well-being also requires further consideration. Regulating services have an important impact on the resilience of ecosystems. They also have complex interactions with other ESs (Bennett et al., 2009) and the most obvious trade-offs with well-being. There are trade-offs between erosion control, climate and water regulation and material conditions such as income (Table 3), which is often associated with land use change. When natural landscapes such as forests are transformed into croplands or other plantations, some aspects of the well-being of residents may increase, such as income. However, climate and runoff regulation usually decrease (Schneider et al., 2020).

The fewest number of articles focused on the relationship between supporting services and well-being, largely due to the difficulties in quantifying supporting services (Cruz-Garcia et al., 2017) and their indirect link to HWB (MEA, 2005). However, supporting services have an equally important impact on the livelihood and development of residents

(Xu et al., 2019), and more consideration of the relationship and mechanisms between supporting services and well-being is also needed in future research.

4.4 Research themes

Although REH has received increasing attention in empirical studies and theoretical support by several conceptual frameworks, the current research themes have not been fully developed. Previous REH studies focused on four levels of themes (Fig. 10): the type of HWB contributed by ES, the direction of the relationship, the degree of association, and the mechanism of action. The first three levels dominated, and a relatively small number of studies considered the mechanisms between ES and HWB.

The first-level studies only qualitatively identified the types of HWB associated with ES (Fig. 10a). These studies acknowledged that ES had a potentially positive contribution to HWB, and residents' perceptions were incorporated (Costanza et al., 2014). For example, Lopes and Videira (2016) asked residents of a Portuguese coastal protected area to identify the links between ES and HWB. In the participatory workshop, the residents perceived all cultural services to be related to "freedom of choice and action" but did not specify the magnitude and direction of the relationship. In addition, some of the studies further explored the direction of the relationship (Fig. 10b, positive, negative, no relationship) or the degree of correlation (Fig. 10c, Liu et al., 2022a, 2022b). These studies began

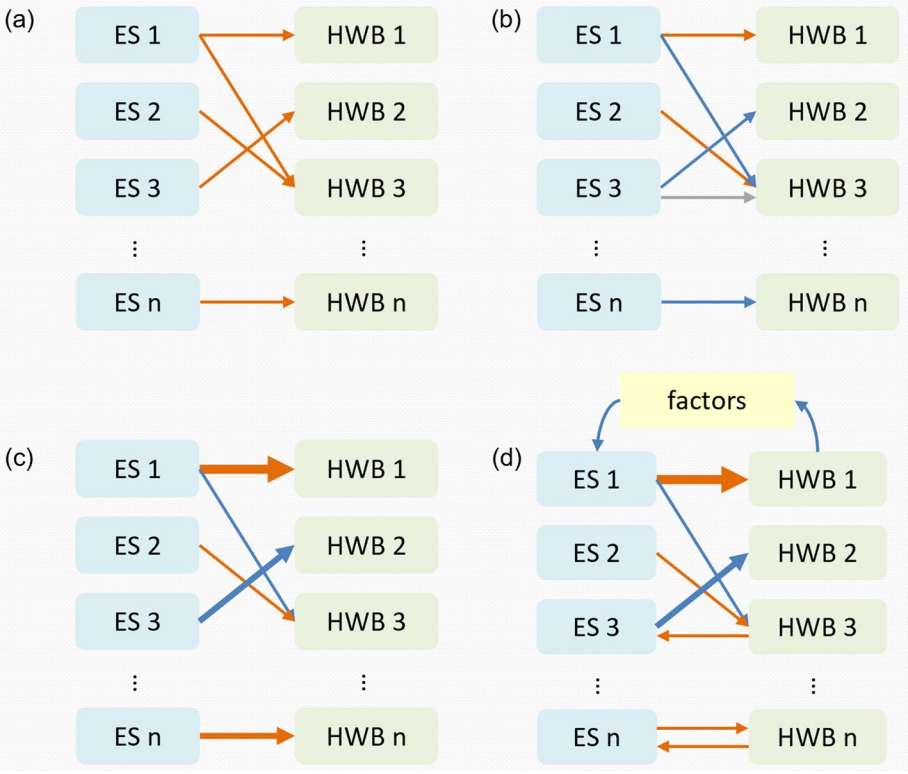

Fig. 10 The perceived REH in different level (red, blue and grey arrow indicates positive, negative and no relationship, respectively; and the width of the arrow indicates the degree of correlaiton)

to incorporate quantitative methods such as statistical models and consider the possible trade-offs between ES and different HWB, which can provide more robust implications for policy formulation.

The above research merely considered the impact of ES on HWB, but the interaction between ES and HWB is not a unidirectional process (Reyers et al., 2013). Future studies need to further delineate the mechanisms between ES and HWB and consider feedback to ES based on current well-being allocations (Fig. 10d). Huynh et al. (2022) summarized 16 mechanisms of interaction between cultural services and well-being, such as cognitive, formative (changing one's instant moods, feelings through interaction with nature), and others. In addition, frameworks such as DPSIR can reveal the interactions between social and environmental systems (Hou et al., 2014). The cascade framework describes the specific flow from ES to HWB (Felipe-Lucia et al., 2015). After further refinement, the cascade framework could provide a theoretical basis for the mechanisms of interaction, moderators and feedback between ES and HWB (Fedele et al., 2017).

In addition, SEM and system dynamics models can potentially be applied to the mechanistic study of REH, especially the impact of HWB on ES. Hossain et al. (2017) developed a system dynamics model based on ES and HWB indicators in Bangladesh and found that provisioning services had a strong positive effect on basic materials for a good life and were also influenced by the feedback of HWB. Felipe-Lucia et al. (2015) used SEM combined with stakeholders' and experts' opinions to simulate the flow patterns of ES related to different groups. The influence of power relations on ES flows was discussed, as different stakeholder groups had different capacities to manage and utilize ES. Lopes and Videira (2016) involved stakeholders of a Portuguese nature reserve in the system dynamics models, considering factors that may cause changes in ES to map causal loops. This approach can also be used to identify the impact of ES on HWB and the feedback between them. For example, the study found that food production can increase regional wealth through multiple pathways. The increase in regional wealth would lead to higher food demand through local brand marketing, which ultimately changes food supply, creating a complete feedback loop.

Furthermore, the factors influencing REH need to be explored comprehensively. The influence of geographic locations and spatial scales on REH has received considerable attention in existing studies (Liu et al., 2022a, 2022b; Wu, 2013). However, other socioeconomic and natural factors that can cause changes in the relationship, such as land use change, climate change, and population, have not been adequately considered (MEA, 2005). The temporal dynamics of the relationship have also received less attention in empirical studies than the ES and HWB at specific time points. Different landscape types may also lead to differences in REH (Bieling et al., 2014). For example, in China, regions with a higher proportion of forest had more trade-offs in REH, while REH was more likely to be uncorrelated in regions with a higher proportion of cropland and urban systems (Liu et al., 2022a, 2022b). Wei et al. (2018) divided the Manas Basin into mountains, hills, and deserts from upstream and downstream. The ES supply, demand, and REH also differed within different landscape systems. In addition, the types of stakeholders also played an important role in REH. Stakeholder groups with different socioeconomic attributes had different abilities and dependence on access to ES. For example, the impact of income and livelihood types. The well-being of impoverished people is more dependent on ES than that of other stakeholders (Agarwala et al., 2014).

With an understanding of the direction, magnitude and mechanisms of past REH and considering potential influential factors, future HWB can be projected based on changes in ES. For example, Liu et al. (2020) combined participatory approaches with Bayesian

networks to construct associations between grassland provisioning services and herdsmen's well-being between 1985 and 2015 and then conducted a scenario analysis of well-being based on existing associations. Yee et al. (2021) first projected the changes in social, economic, and ecosystem services of land use in Florida's Pensacola Bay watershed from 2010 to 2050 and then used the HWBI framework to predict the impacts of land use changes on HWB based on these services.

5 Conclusions

Understanding REH is the key to achieving sustainable development goals. In this study, we reviewed empirical research on REH and found that REH received wide attention after the MEA framework was proposed, and the annual publication and citation increased annually. However, most of the articles only mentioned REH as a research context. After selection, only 71 articles validated the link and the annual rate of publication was maintained at approximately 10 after 2017, indicating that development lagged after the conceptual frameworks. In addition, the temporal variation in REH and its large spatial scale have not received enough attention. Most research themes have been limited to the types of HWB contributed by ES and the direction and degree of association between them. The above findings indicate that there are still many limitations and challenges in REH research.

To overcome these limitations, the research framework, methods and themes need to be improved and deepened in the future. In terms of framework, it is necessary to classify HWB more specifically and elaborate the pathways between ES and HWB. In terms of methodology, the participatory approach should be combined with quantitative research and differences in the role of ES and the well-being of different groups should be considered to provide stakeholders' perspectives on sustainable development. In terms of theme, future studies need to focus on mechanism studies and simulations and consider the interactions and feedbacks between ES and HWB, which can contribute to the projection of HWB and REH based on the changes in observable influencing factors.

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Data availability Data sharing does not apply to this article as no datasets were generated or analyzed during the current study. All the selected case studies are provided in Additional information.

Declarations

Conflict of interest The authors declare that they have no conflicts of interest.

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Authors and Affiliations

Yuchen Zhou[1,2] · Qingxu Huang[1,2] · Chunyang He[1,3,4] · Peiyuan Chen[1,2] · Dan Yin[1,2] · Yihan Zhou[1,2] · Yansong Bai[1,2]

✉ Qingxu Huang
qxhuang@bnu.edu.cn

Yuchen Zhou
zhouyuchen@mail.bnu.edu.cn

Chunyang He
hcy@bnu.edu.cn

Peiyuan Chen
cpy16115980@163.com

Dan Yin
yindan1122@163.com

Yihan Zhou
zyhstory@163.com

Yansong Bai
202221051162@mail.bnu.edu.cn

[1] State Key Laboratory of Earth Surface Processes and Resource Ecology, Beijing Normal University, 19 Xinjiekouwai Street, Beijing 100875, China

[2] School of Natural Resources, Faculty of Geographical Science, Beijing Normal University, Beijing 100875, China

[3] Key Laboratory of Environmental Change and Natural Disasters of Chinese Ministry of Education, Beijing Normal University, Beijing 100875, China

[4] Academy of Disaster Reduction and Emergency Management, Ministry of Emergency Management and Ministry of Education, Beijing 100875, China