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Well-Being Monitoring Within Human-Environment Interactions: A Systematic Review

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Abstract

The systematic literature review analyzes well-being monitoring through the lens of human-environment interaction to identify the criteria impacting well-being, data sources, and models used to characterize well-being processes. The study addresses two research questions: How are human-environment interactions related to well-being? What is the influence of the spatial dimension on well-being monitoring? Reviewing 73 relevant articles, the authors of the study have found that the dominant approach is anthropocentric, emphasizing ecosystems as services for human well-being, while holistic and ecocentric perspectives are underrepresented. Furthermore, there is a significant lack of quantitative and causal research, especially concerning the feedback loop from human well-being to environmental well-being. Studies are mainly focused on the national or regional level, neglecting the local scale, dynamic models, and the use of modern technologies like satellite imagery. These findings underscore the need to integrate systems thinking and environmental monitoring competencies into sustainability education to better prepare future generations to address complex human-environment challenges.

Keywords: Human-environment interactions, monitoring, sustainability education, well-being.

Introduction

The profound and multifaceted challenges of the 21st century from climate change to social inequality underscore the critical need to reorient education towards sustainability. This task requires a deeper understanding of the complex, systemic relationships between human societies and the natural environment. To contribute to this discourse, the study presents a systematic literature review on well-being monitoring through the lens of human-environment interaction. The research aims to identify how current academic work conceptualizes this relationship and to reveal gaps that, when addressed, can help shape a more meaningful and actionable approach to sustainability education.

The well-being of people in interaction with their environment is receiving increasing global attention. The 2030 Agenda for Sustainable Development aims to improve quality of life, reduce environmental degradation, and ensure long-term sustainability

(United Nations, 2015; Bundela & Pandey, 2022). The core challenge is to maintain a safe and just operating space (Hjalsted et al., 2021) that respects both environmental and social boundaries. Climate change and related environmental challenges impact nearly every country, and although the EU has made climate action and adaptation priorities, progress remains insufficient to meet the 2030 and 2050 goals (European Commission, n.d.; European Environmental Agency, n.d.; Sicard et al., 2021). Human well-being, as defined by the Organisation for Economic Co-operation and Development (OECD), includes aspects such as income, health, education, environmental quality, civic engagement, and subjective life satisfaction (OECD, 2020).

However, human activities such as burning fossil fuels, deforestation and intensive agriculture are increasingly influencing the climate and the earth's temperature (European Commission, n.d.). This results in air pollution, drought, biodiversity loss, and rising sea levels, which in turn threaten human well-being (Athanasiou et al., 2020; Davison et al., 2021; Fernandez-Anez, et al., 2021; Hermoso et al., 2022; Igini, 2022; Khomenko et al., 2021; Markonis et al., 2021; Methorst et al., 2021; Nicholls et al., 2021; Senf et al., 2020; Vieira et al., 2023; World Health Organization. Regional Office for Europe, 2021). The OECD emphasizes that human well-being depends on natural resources, which include natural assets (e.g., stocks of natural resources, land cover, and species biodiversity) as well as ecosystems and their services (e.g., oceans, forests, soil, and the atmosphere). Thus, human well-being refers not only to man-made and financial assets, the skills and future health of individuals, and social norms, but also to the sustainability of natural resources (OECD, 2020). The well-being of people and the natural environment must be considered in their mutual interactions. These interactions are shaped by ethical worldviews – anthropocentric (human-centered), biocentric (life-centered), and ecocentric (ecosystem-centered) – that influence environmental attitudes and actions (Liu et al., 2016; Rülke et al., 2020; Thompson & Barton, 1994).

There is a growing interest in understanding local and regional development in terms of its contribution to well-being (Sági & Engelberth, 2018; Tomaney, 2017). It is essential to associate well-being measurements with a local geographical area (e.g., village, community level) in order to be able to analyze the factors affecting the well-being of the people and environment of the given place (Costanza et al., 2016; Fioramonti et al., 2022; Marino & Tebala, 2022; McGregor et al., 2017; OECD, 2020; Veneri & Murtin, 2019).

To improve both the well-being of the environment and the well-being of people, it is necessary to monitor how human-environment interaction affects overall well-being. The well-being monitoring process would help manage processes that would increase the positive impact of various factors on well-being and reduce the risk of negative impacts. A well-being-based society should develop tools to monitor all contributors to human and environmental well-being (Fioramonti et al., 2022). Human-environment interaction is a complex system due to the fact both human society and the environment have many elements and processes.

To maximize the well-being of both humans and the natural environment, further research is needed to understand how human-nature interactions work and, subsequently, how to improve well-being of humans and environment (Brymer et al., 2019). Several reviews have addressed human well-being from different points of view, such as the impact of physical activities, the importance of educational institutions or the workplace, and the well-being of teachers or children, or residents (Hascher & Waber, 2021; Konu & Rimpelä, 2002; Nielsen et al., 2017; Pollard & Lee, 2003; Raj, 2016). No review has concentrated specifically on human-environment interactions and well-being monitoring.

The aim of the study is to conduct a literature review on the concept of human-environment interactions and well-being monitoring to highlight criteria impacting well-being, and the data sources and models used to characterize well-being processes. The focus of well-being research is on the interaction between people and the environment, with the geospatial dimension considered essential. The study analyzes how the following research questions are taken into account in the literature:

RQ1: How are human-environment interactions connected to well-being?

RQ2: What is the influence of the spatial dimension on well-being monitoring?

To answer the research questions, the following tasks have been put forward:

(1) to categorize articles according to the type of human-environment interactions, the focus of well-being, and the philosophy of environmental ethics;

(2) to determine what type of methods, models, factors, and data sources are indicated to assess several aspects of well-being;

(3) to determine the scale of research and spatial dimension usage in well-being evaluation and monitoring.

This review also contributes to teacher education for sustainability by offering insight into how environmental complexity and well-being dynamics can be taught. Embedding systems thinking, spatial literacy, and place-based methodologies in teacher education is crucial for preparing educators to address sustainability challenges in contextually relevant and pedagogically effective ways.

The insights gained from this systematic review serve as a catalyst for a deeper inquiry, aligning with the principles of action research. This paper moves beyond a mere presentation of findings; it uses these results to reflect on our personal and professional experiences as researchers and to explore how these academic gaps can be addressed to foster greater professional mastery for teachers and more sustainable choices in every individual's actions. By critically examining the limitations of the existing literature, the study seeks to provide a foundation for a more holistic, transdisciplinary, and personally meaningful understanding of sustainability in education. The research aligns with the United Nations Educational, Scientific and Cultural Organization university twinning and networking scheme (UNESCO UNITWIN) Chair's mission by addressing gaps in sustainability education, particularly the need for ecocentric pedagogies and systems thinking in teacher training (United Nations Educational, Scientific and Cultural [UNESCO], 2022; Wals & Benavot, 2017).

Methods

The systematic review was conducted in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Page et al., 2021) and recommendations for conducting a systematic review from Khan et al. (2003). The technological roadmap and detailed description of methods are presented in Appendix D. The review process, running from January 2023 to February 2025, involved eight researchers, with one acting as a senior advisor.

Between January and November 2023, the research team clarified the research problem and developed two guiding research questions: RQ1: "How are human-environment interactions connected to well-being?"; RQ2: "What is the influence of the spatial dimension on well-being monitoring?"

The selection of articles was based on the presence of terms from four distinct groups in their title, abstract, or keywords: (I) well-being, (II) human-environment interaction, (III) spatial dimension, and (IV) monitoring (Figure 1). The careful work of creating search terms was more than just a technical task. It was the first time working together to set the limits of the study, and this process demonstrated how complex and interconnected the topics of well-being and the environment truly were (Figure 1).

Figure 1

Search String for Human-Environment Interaction and Well-Being Monitoring Records

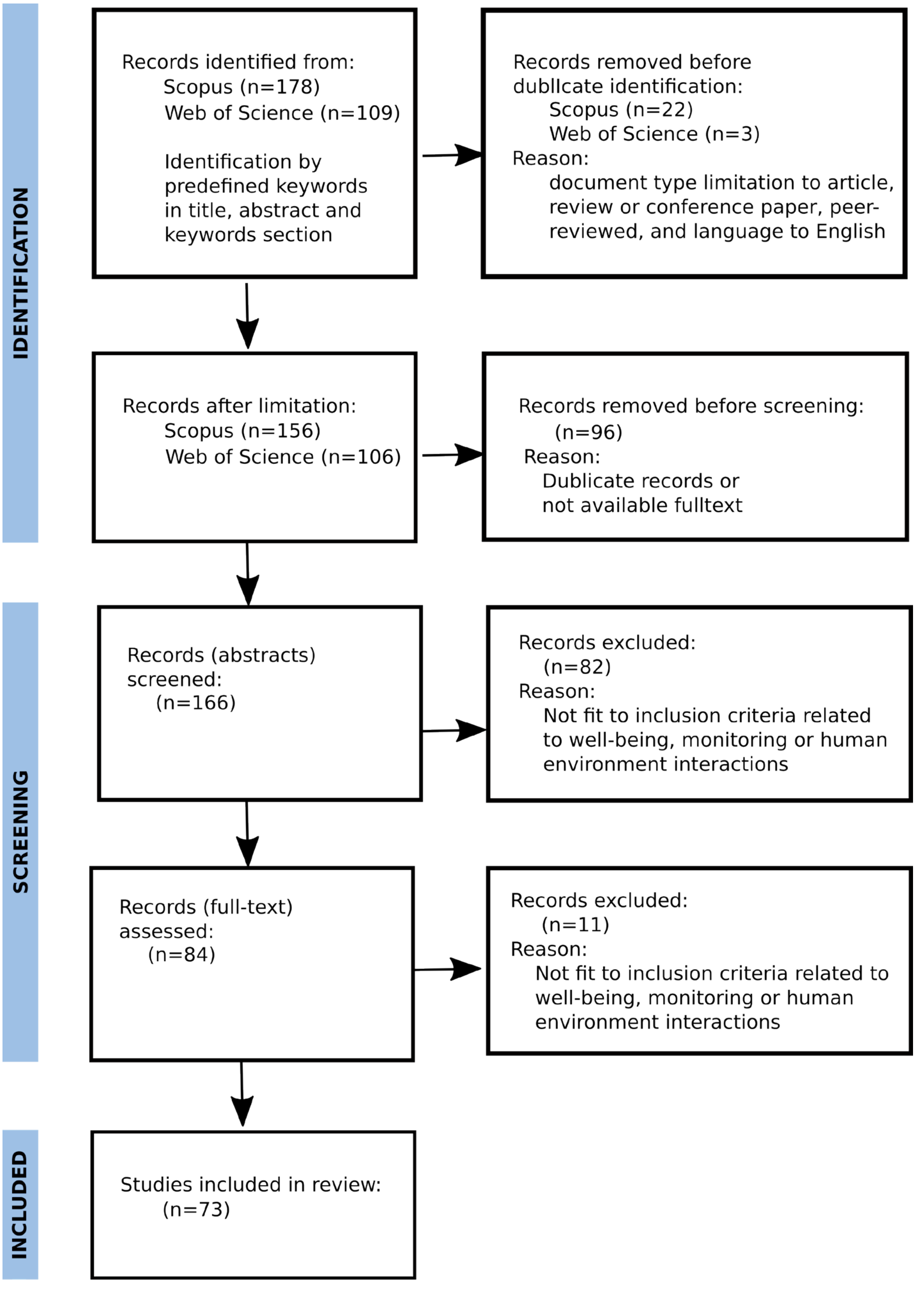
```
Keywords (TITLE-ABS-KEY):
( well-being OR wellbeing )
AND ( spatial OR geospatial OR geographic* )
AND ( "human environment" OR "human-environment" OR
"human ecosystem" OR "human nature" OR "human-na-
ture" OR "social ecological" OR "social-ecological"
OR "socio-ecological" )
AND ( monitor* OR measur* OR evaluat* OR indicat*)
```

Inclusion criteria were the following: articles addressing (1) human or environmental well-being, (2) monitoring or evaluation of well-being, and (3) well-being in the context of human-environment interaction. As exclusion criteria, the following filters were used: (1) limitation to article, review or conference paper; (2) language to English; (3) peer-reviewed documents.

Figure 2

Flow Diagram for Systematic Review Including Databases Searches

Note: The number of records is presented according to the search process in March 2024 and January 2025.



Literature search was conducted in Scopus and Web of Science in December 2023, March 2024, and January 2025 (Figure 2). This resulted in 73 articles selected for an in-depth analysis (Appendix A: List of Articles Reviewed). The process of double-checking these results, where each article was reviewed independently by two researchers, was a critical lesson in academic rigor and a test of the researchers' shared understanding of the research criteria.

The research team drew up the list of questions to collect information from full-text articles (Appendix B: Detailed Questionnaire). From January to March 2024 and again in February 2025, data were coded using a shared Google Docs file. Each article was reviewed independently by two researchers. This process transformed a vast body of literature into structured, analyzable data, which then became the basis for the insights of the study. From March to June 2024, the results were interpreted and a systematic review report was drawn up. In February 2025, the interpretation of the findings was refined based on the additionally selected records.

The methodological approach, while robust and transparent, was also a specific experience of action research. The iterative process of refining the research questions and search string was a firsthand lesson in the fluidity and complexity of defining "well-being" and "human-environment interactions". Working as a team of eight researchers required continuous articulation of individual understandings of the research context and alignment with a shared framework. This collaborative effort was not just about following guidelines but about fostering a shared, personally meaningful understanding of the subject matter, a process which mirrors the goals of reorienting education towards sustainability.

Results

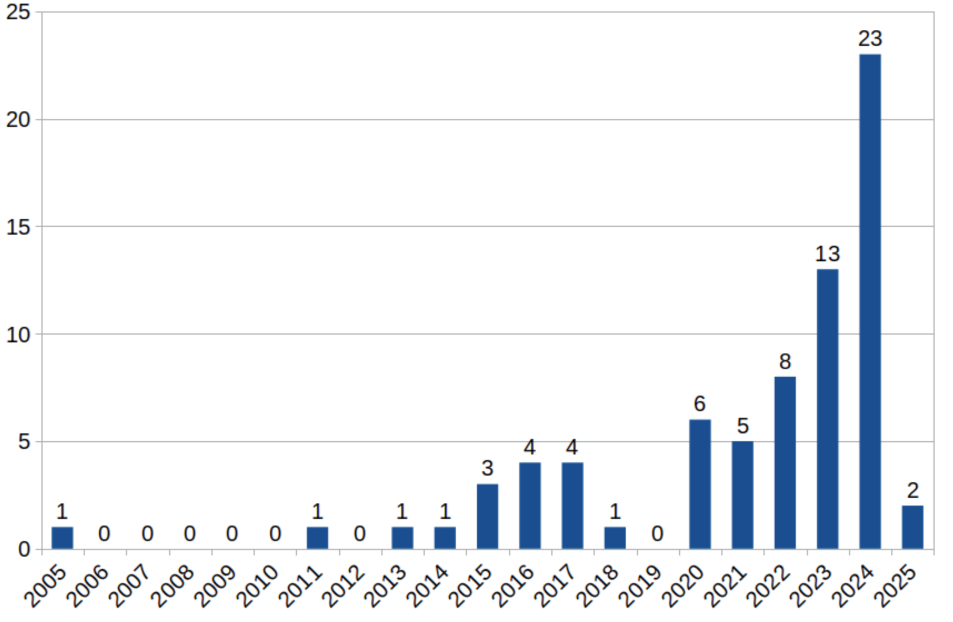
The process of conducting the systematic review yielded both the synthesis of existing knowledge and a deeper understanding of the current state of human-environment interaction research. The section presents the key findings, providing a foundation for a broader discussion on how these insights can be applied to reorienting education for sustainability.

An Overview of the Selected Publications

The review analyzed 73 papers, with 7% being systematic reviews and 93% original studies.

Figure 3

Number of Publications per Year



Publications spanned from 2005 to 2025, peaking in 2024 (n=23) and 2023 (n=13) (Figure 3). The rapid increase in the number of studies in recent years is a clear indication that well-being in the context of human-environment interaction is an increasingly urgent topic on the global research agenda. Research on environmental and human well-being is a global effort due to the worldwide importance of environmental sustainability and its impact on human quality of life (Figure 4). A majority of studies were conducted in Asian countries (34; 35.8%), with a significant portion carried out in China (14; 41.2%), followed by European countries (28; 29.5%), North America (12; 12.6%), South America and Africa (7 each; 7.4%), and Australia (2; 2.1%). Key contributors included Sweden (5 studies), Italy, and India (4 each). This geographical distribution suggests that regions facing rapid urbanization and industrialization are particularly motivated to investigate these complex relationships, offering a critical resource for sustainability education globally.

Figure 4

The Distribution of Studies Across Countries and the Number of Publications per Country

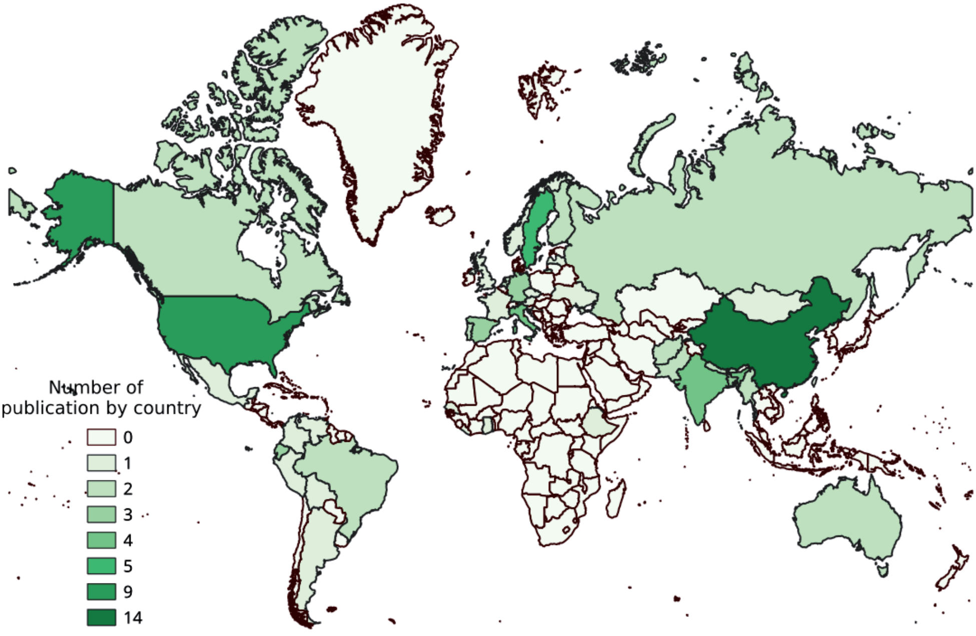
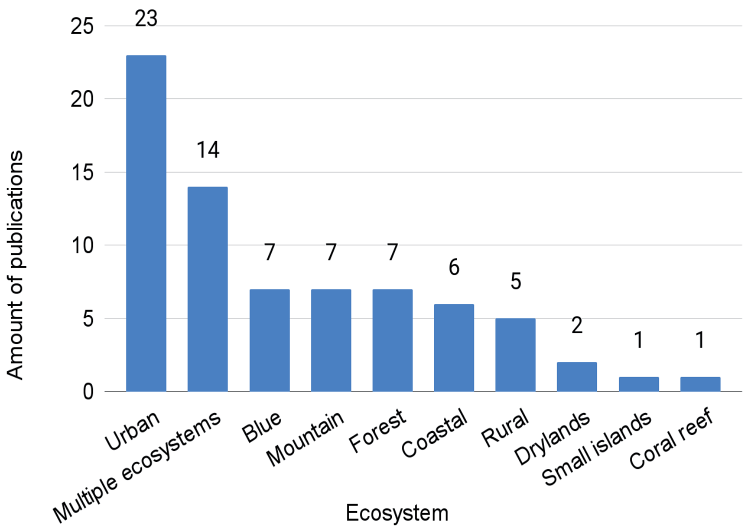


Figure 5

Ecosystem Types Covered in the Assessed Studies



From the socio-ecological system perspective, urban socio-ecological systems were the most studied (n=23), followed by blue, mountain, and forest ecosystems (each n=7) (Figure 5). Coastal ecosystems were examined in 6 studies, rural ecosystems in 5, and drylands in 2. Small islands and coral reefs each had 1 study. The "multiple ecosystems" category includes cases where an administrative territory or region is considered a whole, combining various ecosystems. For instance, a study on the relationship between human well-being and ecosystem services in Mainland China examines 2,842 counties, encompassing different ecosystems such as forests, urban areas, wetlands, grasslands, and others (Liu et al., 2022b). The strong focus on urban environments reflects a broader societal concern for well-being in densely populated areas, a key challenge for sustainable development.

Responses to Research Question 1

RQ1: *How are human-environment interactions connected to well-being?*

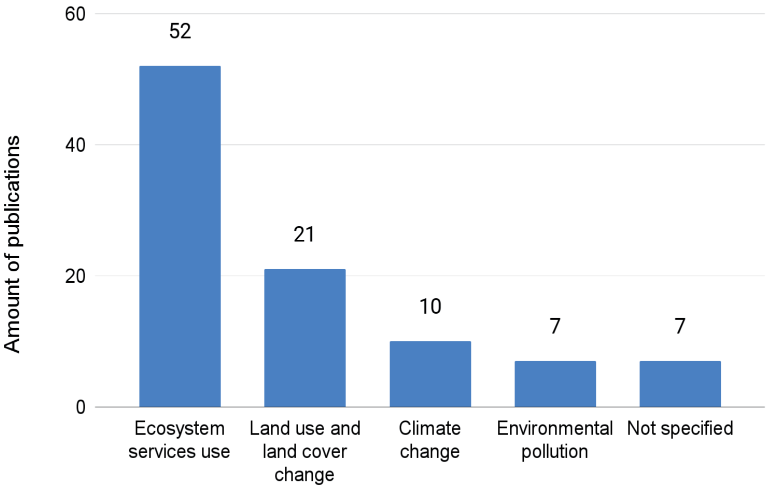
Human-Environment Interactions

In the reviewed articles, human-environment interaction is described as the dynamic and reciprocal relationship between humans and their surrounding environment. This encompasses how humans engage with, modify, and are influenced by the natural world, including ecosystems, land use and land cover changes, climate, and natural resources. Notably, many articles address multiple types of human-environment interactions within a single study.

For their survival and well-being, humans depend on natural resources such as water, air, soil, minerals, energy, and biodiversity. Among the reviewed papers, 52 articles explore human-environment interactions related to the extraction, use, and management of these resources, as well as the ways in which these resources contribute to regulatory or cultural ecosystem services for humans (Figure 6). 21 articles reflect human-environment interactions through land use and land cover changes, 10 articles are related to interactions driven by climate change, and 7 articles analyze human-environment interactions in the context of environmental pollution.

Figure 6

Types of Human-Environment Interactions and the Corresponding Number of Articles

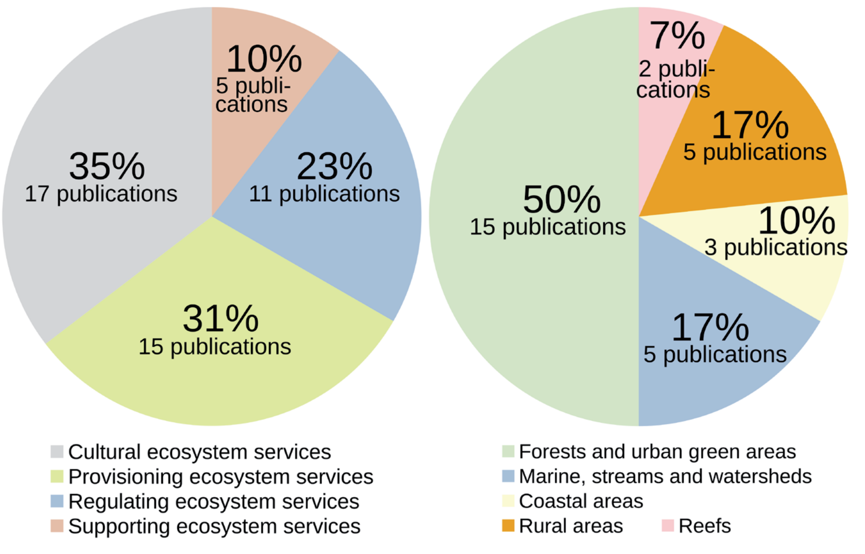


While many articles discuss provisioning, regulating, and cultural ecosystem services collectively (Carilla et al., 2024), others focus on specific services (Figure 7a; Appendix C, Table C.1). For example, Liu et al. (2022a) analyzed multiple services (provisioning, cultural, regulating) and their spatial variations.

Cultural Ecosystem Services (CES): A majority (17; 35%) highlight CES, particularly in urban/suburban forests and green spaces, emphasizing recreation (Capecchi et al., 2021; Chai-Allah et al., 2023; Liepa et al., 2023; Liu et al., 2022b; Samuelsson et al., 2019; Wang & Chen, 2024), a sense of place (Vigl et al., 2021), scenic beauty (Bhatt et al., 2024; Maass et al., 2005; Schwantes et al., 2024; Svoray et al., 2018), cognitive development (Beichler, 2015; Santos Vieira et al., 2021; Sharma-Brymer et al., 2024), and foster social cohesion (Duku et al., 2022).

Provisioning Services are featured in 15 articles (31%), including freshwater (Duku et al., 2022; Liu et al., 2024; Stankiewicz et al., 2023; Yi et al., 2024), energy (Newman et al., 2020), and food (Cai et al., 2024; Duku et al., 2022; Liepa et al., 2023; Schwantes et al., 2024). Additionally, agricultural (Adams et al., 2016; Sitotaw et al., 2024), pastoral goods (Maass et al., 2005), and forest wood (Angelstam et al., 2022; Bhatt et al., 2024; Liu et al., 2022b) are highlighted as key resources for business and biomass production.

Figure 7
Distribution of Ecosystem Services



(a) By service type (b) By ecosystem type

Regulating Services are examined in 11 articles (25%) (Bhatt et al., 2024; Schwantes et al., 2024; Sitotaw et al., 2024), covering climate regulation (Duku et al., 2022; Liepa et al., 2023; Liu et al., 2024; Yi et al., 2024), flood control (Duku et al., 2022), soil retention (Cai et al., 2024; Liu et al., 2022b; Liu et al., 2024; Yi et al., 2024), and bioregulation (Maass et al., 2005). Urban residents prioritized CES, while rural residents valued provisioning services more than regulating services (Liepa et al., 2023).

Supporting Services are addressed in 5 studies (10%) (Cai et al., 2024; Carilla et al., 2024), with habitat quality being the most recognized (Bhatt et al., 2024; Liu et al., 2024; Yi et al., 2024).

Some articles analyze ecosystem services through specific ecosystems rather than service types (Figure 7b; Table C.1).

Forest Ecosystems: 15 articles (50%) examine forests (Aguilar et al., 2024; Bhatt et al., 2024), urban trees (Thapa et al., 2024; Zhu et al., 2022), and parks (dos Santos Facundes et al., 2024; Li et al., 2025; Zeng et al., 2023), highlighting climate regulation (de Guzman et al., 2022; Klobucar et al., 2021) and cultural benefits (Bonilla-Bedoya et al., 2020a; Bonilla-Bedoya et al., 2020b; Carone et al., 2017; Ferguson et al., 2024; Kajosaari et al., 2024).

Aquatic Ecosystems: Eight studies (27%) focus on marine/coastal systems, emphasizing provisioning services like water (Angermeier et al., 2021; Scown et al., 2017), food (de Alencar et al., 2020), and fisheries or tourism (Bastos et al., 2023; Cordero-Penín et al., 2023; Gašparović et al., 2022; Lähde et al., 2024; Peng, 2020).

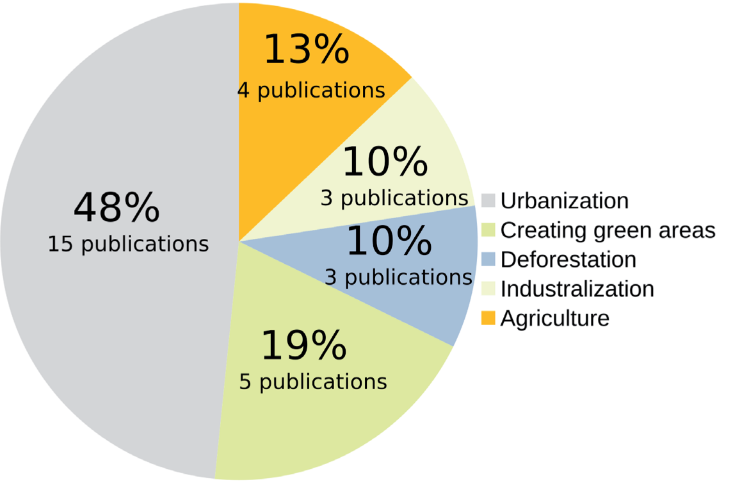
Rural Ecosystems and Reef Ecosystems: Agricultural production (Castillo-Eguskitza et al., 2017; Sietz et al., 2011; Wang et al., 2023a; Wang et al., 2023b) and coral reefs (Bartelet et al., 2023; Cobacho et al., 2020) are also studied.

It is noteworthy that not all articles emphasize the positive impact of ecosystems on human well-being. Negative impacts, such as allergies (Rai & Singh, 2020) or invasive species (Mungi et al., 2023) are noted (Vaz et al., 2017; Von Döhren & Haase, 2015).

Studies analyze human-environment interactions through urbanization, deforestation, industrialization, and agriculture, which drive land cover changes and reduce ecosystem services (Figure 8; Table C.2). In some cases, the articles address multiple types of land use modifications simultaneously, such as urbanization combined with industrialization, the provision of green areas, or deforestation.

Figure 8

Drivers of Land Use and Land Cover Change and the Corresponding Number of Articles



Urbanization: 15 articles (48%) address urban challenges (Bastos et al., 2023; Beichler, 2015; Bonilla-Bedoya et al., 2020a; Bonilla-Bedoya et al., 2020b; de Guzman et al., 2022; Dennis & James, 2016; Gašparović et al., 2022; Kajosaari et al., 2024; Klobucar et al., 2021; Liu et al., 2022a; Zhu et al., 2022).

Creating green areas: Five articles (19%) specifically discuss the provision of green areas and the ecosystem services they deliver (Beichler, 2015; de Guzman et al., 2022; Dennis & James, 2016; Kajosaari et al., 2024; Klobucar et al., 2021)

Deforestation: Three studies (10%) examine impacts on landscapes (Angelstam et al., 2022) and urban climate regulation (Bonilla-Bedoya et al., 2020a; Bonilla-Bedoya et al., 2020b).

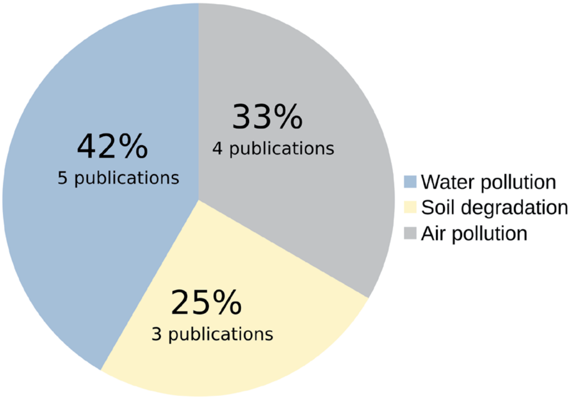
Agriculture: Four articles (13%) analyze vegetation changes over time caused by agriculture in specific regions or land-use changes for farming systems (Herrmann et al., 2014; Kohler et al., 2017; Lamchin et al., 2022; Sietz et al., 2011).

Industrialization: Three studies (10%) link industrialization to pollution and resource depletion (Bastos et al., 2023; Liu et al., 2022a; Zhu et al., 2022).

Land use changes frequently cause air, water, and soil pollution (Figure 9; Table C.3).

Figure 9

Environmental Pollution and the Corresponding Number of Articles



Water pollution (5 articles, 42%): Industrial activities in coastal areas degrade water quality (Bastos et al., 2023; O'Rourke et al., 2024), while urban studies monitor pollution through citizen science (Stankiewicz et al., 2023).

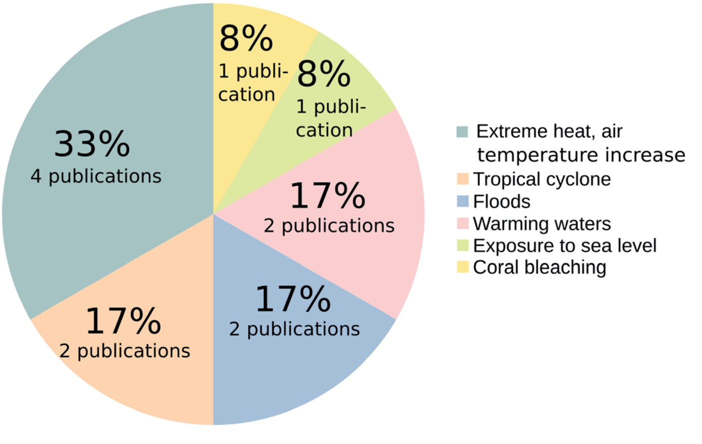
Air pollution (4 articles, 33%): Research in China (Zhang et al., 2024) and Latin America (Bonilla-Bedoya et al., 2021) links urbanization to atmospheric pollutants.

Soil degradation (3 articles, 25%): Agricultural impacts include ecosystem function loss in Burkina Faso (Sietz et al., 2011).

In China, researchers commonly simultaneously examine air, water, and soil pollution (Liu et al., 2022a; Zhu et al., 2022).

Figure 10

Types of Climate Change Hazards and the Corresponding Number of Articles

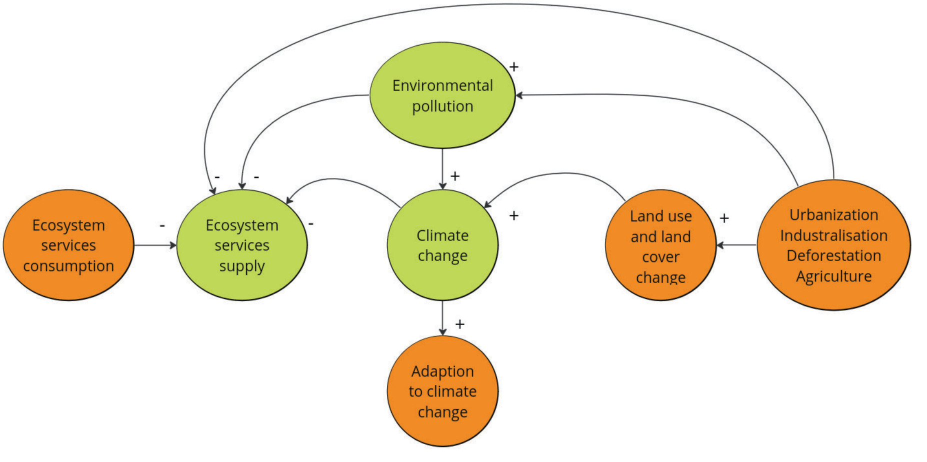


Human activities driving climate change (Figure 10; Table C.4) include fossil fuel use and deforestation, leading to: (1) **extreme heat** (4 articles, 33%), i.e., rising temperatures impact urban and natural systems (de Guzman et al., 2022; Klobucar et al., 2021; Lamchin et al., 2022; Tilman et al., 2024); (2) **flooding** (2 articles, 17%) that is linked to land-use changes (Klobucar et al., 2021; Lamchin et al., 2022); (3) **storms (2 articles, 17%)**, i.e., increased intensity affects coastal ecosystems (Sajjad et al., 2019); (4) **ocean changes (4 articles, 33%)**, i.e., warming (Bartelet et al., 2023; Tilman et al., 2024) and sea level rise (Newman et al., 2020) threaten reefs (Cobacho et al., 2020).

Figure 11

Relations of Human-Environment Interactions Based on the Reviewed Articles

Note: Human components (such as urbanization, industrialization etc.) are highlighted in orange color, and environment components are highlighted in green color.



The analysis reveals a consistent pattern: urbanization and industrialization drive both pollution and climate change, reducing ecosystem services (Figure 11). Key relationships in the causal loop diagram (Haraldsson, 2004) include: (1) Positive links: Urbanization, industrialization, deforestation and agriculture intensify land-use changes; (2) Negative links: Climate change degrades ecosystem services. This framework clarifies feedback loops between human activities (orange nodes) and environmental impacts (green nodes).

Use of the Term "Well-Being" in the Reviewed Articles

The term "human well-being" predominates in the literature, with four studies using alternative phrasings: "health of an urban community" (Carone et al., 2017); "well-being and prosperity of societies" (Cobacho et al., 2020); "well-being of urban residents" (Klobucar et al., 2021); "well-being of the nomads" (Lamchin et al., 2022). Only one study (Stankiewicz et al., 2023) addresses human well-being without explicitly using the term.

"Environmental well-being" appears just once in the reviewed articles. Other studies, which are not included in this review (Bakar et al., 2015; Khan et al., 2022; Rigley et al., 2023) employ it to describe environmental sustainability.

The reviewed literature prefers alternative terms. Ecosystem-focused terminology is used: “ecological well-being” (Zhu et al., 2022); “ecosystem well-being/health” (Angermeier et al., 2021; de Alencar et al., 2020; Stankiewicz et al., 2023); “stream health” (Angermeier et al., 2021). The reviewed article use quality/sustainability metrics: “environmental health/quality” (Burger et al., 2022; Gašparović et al., 2022; Liu et al., 2022a; Sietz et al., 2011; Wang et al., 2023a); “habitat quality” (Wang et al., 2023a); “environmental sustainability” (Angelstam et al., 2022; Castillo-Eguskitza et al., 2017; de Alencar et al., 2020; Gašparović et al., 2022; Klobucar et al., 2021; Newman et al., 2020); “air quality” (Bonilla-Bedoya et al., 2021; de Guzman et al., 2022; Vigl et al., 2021; “water quality” (Scown et al., 2017; Wang et al., 2023a), “quality of the ecosystem” (Mungi et al., 2023); “habitat quality” (Wang et al., 2023a; Zhu et al., 2022), “sustainable use of natural resources” (Sietz et al., 2011).

Methods and Data Sources for Assessing Well-Being Components and Their Interconnections

Both human well-being and environmental well-being are shaped by the interaction between humans and nature. Depending on human activities and environmental processes, these interactions can have either positive or negative effects.

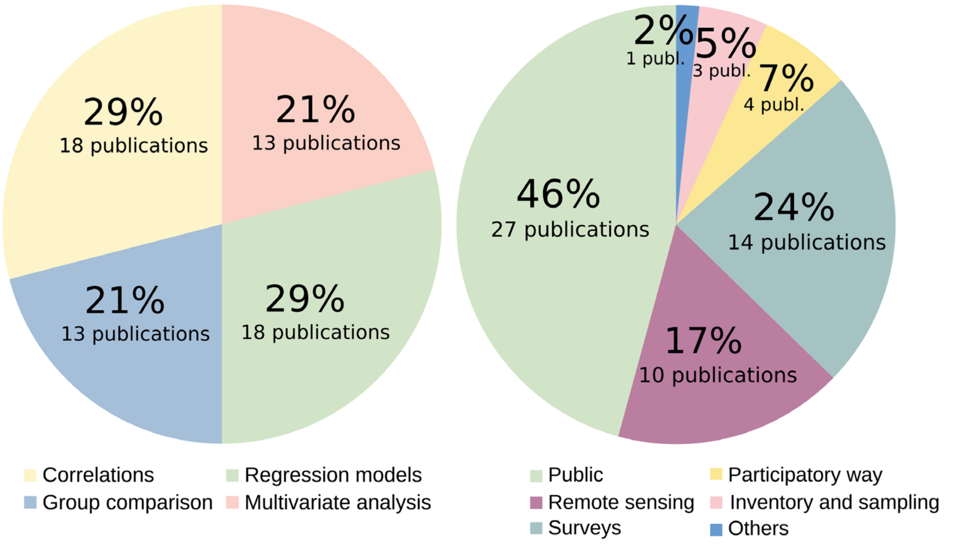
To assess the impact of human-environmental interactions (HEIs) on well-being, the study examined which attributes were measured and how well-being was assessed in academic publications. Among the 73 reviewed articles, 37 employed empirical measurements, primarily using statistical methods (Figure 12a; Tables C.5–C.6). A critical finding of the analysis is the dominant use of statistical methods, particularly regression and correlation analyses (18 studies each), which identify associations but do not necessarily establish causation. This highlights a significant gap in the literature regarding dynamic models and a more comprehensive, holistic understanding of the causal relationships between human activity and well-being.

The most frequently used analysis methods are regression modeling and correlation tests, each appearing in 18 studies (29%).

Regression modeling examples include linear regression (Bonilla-Bedoya et al., 2021; Capecchi et al., 2021; Dennis & James, 2016; Klobuchar, et al. 2021; Wang et al., 2023a), time series linear regression (Herrmann et al., 2014), logistic regression (Bonilla-Bedoya et al., 2020b; Ferguson et al., 2024; Thapa et al., 2024), spatial multiple linear regression (Scown et al., 2017), subset and threshold regression (Li et al., 2025; Zhu et al., 2022), and geographically weighted regression (Liu et al., 2022a; Wang et al., 2023a).

Figure 12

Statistical Analysis Methods and Data Sources for Analyzing Well-Being Components and Their Interconnections



(a) Statistical analysis methods (b) Data sources

Similarly, **correlation tests**, such as Pearson's correlation (Beichler, 2015; Bonilla-Bedoya et al., 2021; Chen et al., 2023; Liu et al., 2024; Molari at el., 2024; Mungi et al., 2023; Sietz et al., 2011; Thapa et al., 2024; Zeng et al., 2023), Spearman's rho (Angermeier et al., 2021; Liu et al., 2024; Scown et al., 2017; Yi et al., 2024), binary correlation with the Phi coefficient (Chai-Allah et al., 2023), and spatial autocorrelation (Sajjad et al., 2019; Liu et al., 2022b; Svoray et al., 2018), are equally prevalent.

Group comparison and multivariate analysis techniques are also commonly used, each appearing in 13 studies (21%). **Group comparison** methods include t-tests (Herrmann et al., 2014), ANOVA for comparing multiple groups (Bonilla-Bedoya et al., 2021; Capecchi et al., 2021; Castillo-Eguskitza et al., 2017; Dennis & James, 2016; Duku et al., 2022; Klobuchar, et al. 2021; Molari at el., 2024), the Kruskal-Wallis test for non-parametric data (Beichler, 2015; Santos Vieira et al., 2021; Thapa et al., 2024), and Dagum Gini coefficient calculations (Zhang et al., 2024). The Wilcoxon test is also used to compare social-ecological indicators across clusters (Liu et al., 2022b).

Multivariate analysis techniques, such as clustering or classification (Bonilla-Bedoya et al., 2020b; dos Santos Facundes et al., 2024; Santos Vieira et al., 2021; Wang et al., 2023b; Liu et al., 2022b; Zhang et al., 2024; Zeng et al., 2023), principal component analysis (Castillo-Eguskitza et al., 2017; Sietz et al., 2011), and factor analysis (Bonilla-Bedoya et al., 2020a; Duku et al., 2022; Ferguson et al., 2024; Santos Vieira et al., 2021) are similarly prominent.

Other methods include Super-SBM models (Zhu et al., 2022), InVEST models (Bastos et al., 2023; Cai et al., 2024; Liu et al., 2024; Wang et al., 2023a; Yi et al., 2024), and text mining using the Word2vec technique (Chai-Allah et al., 2023; Li et al., 2025). Spatial clustering was analyzed using Getis-Ord Gi* statistics (Liepa et al., 2023), while social media data and AI were used to assess cultural ecosystem services. For example, Santos Vieira et al. (2021) analyzed 21,789 Flickr photos along the Brazilian coastline, and Vigl et al. (2021) studied 640,000 photo tags from the Dolomites to map public appreciation for aesthetic, recreational, and cultural values, offering tools for sustainable environmental management and landscape planning.

The research team has observed that 27 studies (46%) rely on publicly available databases to quantitatively assess well-being and explore relationships between its components (Figure 12b; Table C.7). Examples of such data sources include standardized well-being indicators – the Human Well-being Index (Angermeier et al., 2021; Scown et al., 2017), national statistical yearbooks (Zhu et al., 2022; Zhang et al., 2024); user-generated data – geotagged photos from Flickr (Santos Vieira et al., 2021; Svoray et al., 2018); the public eBird database (Chen et al., 2023), the Wikiloc portal with outdoor trails data (Chai-Allah, et al., 2023); environmental monitoring systems – the European Nature Information System (Castillo-Eguskitza et al., 2017), the Malmö geodatabase (Klobuchar, et al., 2021), and other similar databases.

Remote sensing methods are employed in 17% of studies (10 papers): images from Landsat sensors (Bonilla-Bedoya et al., 2020a; Bonilla-Bedoya et al., 2020b; Bonilla-Bedoya et al., 2021; Li et al., 2025), or Normalized Difference Vegetation Index (NDVI) data (Herrmann et al., 2014; Sajjad et al., 2019; Wang et al., 2023a) are used.

Some studies collect their own data, obtained through surveys or interviews (14; 24%), sampling and inventory (3; 5%), or participatory methods (4; 7%). It should be noted that there are studies where the data have been obtained by performing electroencephalography measurements on research participants or by placing participants in a virtual reality environment (1; 2%).

Measurements of HEI Impact on Human and Environmental Well-Being

HEI Impact on Environmental Well-Being

Environmental well-being, influenced by land-use changes, climate change, or ecosystem service consumption, is assessed in 16 publications (Table C.8). These articles focus on the quality of ecosystem services (Bonilla-Bedoya et al., 2020b; Cai et al., 2024; Junker et al., 2015; Kajosaari et al., 2024; Klobuchar, et al. 2021; Liu et al., 2024; Santos Vieira et al., 2021; Scown et al., 2017; Sietz et al., 2011; Yi et al., 2024), habitat quality (Bastos et al., 2023; Bonilla-Bedoya et al., 2021; Mungi et al., 2023; Wang et al., 2023a), biodiversity (Dennis & James, 2016), as well as environmental degradation due to natural hazards (Sajjad et al., 2019).

HEI Impact on Quality and Provision of Ecosystem Services (11 publications)

Human activities significantly influence ecosystem services through land-use changes and resource consumption. Watershed quality depends on hydrological functions, using spatial multiple linear regression, a total of 77% of the variance in the mean county watershed quality index can be explained by belonging to ecoregion, industry dependence, and governance by state (Scown et al., 2017). Sietz et al. (2011) quantified the most important dimensions including poverty, water scarcity, soil degradation, natural agro-constraints, and isolation. However, not all dimensions were correlated, the highest correlation coefficients were between isolation (road density) and the severity of human-induced soil degradation (-0.33) and natural agro-constraints (agro-potential) (0.55). Another direction is the provision of ecosystem services in an urban environment, such as planting trees and shrubs in private areas, which can also enhance the well-being of urban residents. Klobuchar et al. (2021) found that potential plantable space of private houses and house age positively correlated with planted area, but years of residence negatively correlated with the likelihood of tree planting. In their study, Dennis and James (2016) indicate that the biodiversity in urban green areas is influenced by volunteers; according to the linear regression analysis, site volunteer input accounted for 93% of the variation in site biodiversity potential. Bonilla-Bedoya et al. (2020a) indicate factors that influence the conversion of forests and green areas into urban environments. For example, according to the spatial binomial logistic regression model, the following predictors increase the probability of urban processes – built-up land, consumption of drinking water, and sewerage indicators. Kajosaari et al. (2024) investigated the characteristics of urban green areas that contributed to their perceived quality among local populations, concluding that the relationship between area characteristics and perceived quality was rarely linear. While the presence of blue elements and higher forest biodiversity significantly improved perceptions of urban green area quality, their absence did not necessarily lead to negative perceptions. Junker et al. (2015) analyzed the data using generalized linear models and found that different measures of socio-economic conditions could have opposing effects on wildlife population. On the one hand, chimpanzee density was spatially linked to a lack of education and a limited supply of fish protein. On the other hand, areas with better economic and infrastructure development reduced large mammal species richness compared to less developed areas.

Cultural ecosystem services (CES) are also important contributors to human well-being, for example, through spiritual enrichment, cognitive development, recreation, and aesthetic experiences. Santos Vieira et al. (2021), using the Kruskal-Wallis test, concluded that the counts and richness of CES were higher in areas with higher protection compared to unprotected areas.

HEI Impact on Habitat Quality (4 publications)

Pollution and land cover changes directly impact habitats. Bastos et al. (2023) conclude that coastal habitats face pollution from industrial activities. Bonilla-Bedoya et al. (2021) used linear regression models to explain (with $r^2 > 0.6$) the spatiotemporal variation in the amounts of air pollutants (CO, $PM_{2.5}$, and O_3). They concluded that both land cover and an increase in forest and impervious cover significantly explain (< 0.001) the variation in the amounts of these three pollutants. Mungi et al. (2023) used the maximum entropy (MaxEnt) method to assess habitat suitability for selected invasive plants in India and noted that the drivers differed for each species. Wang et al. (2023) concluded that habitat quality was positively influenced by fractional vegetation cover and soil moisture content, but negatively influenced by the proportion of cultivated land and proportion of built-up land.

HEI Impact on Ecosystem Resilience (1 publication)

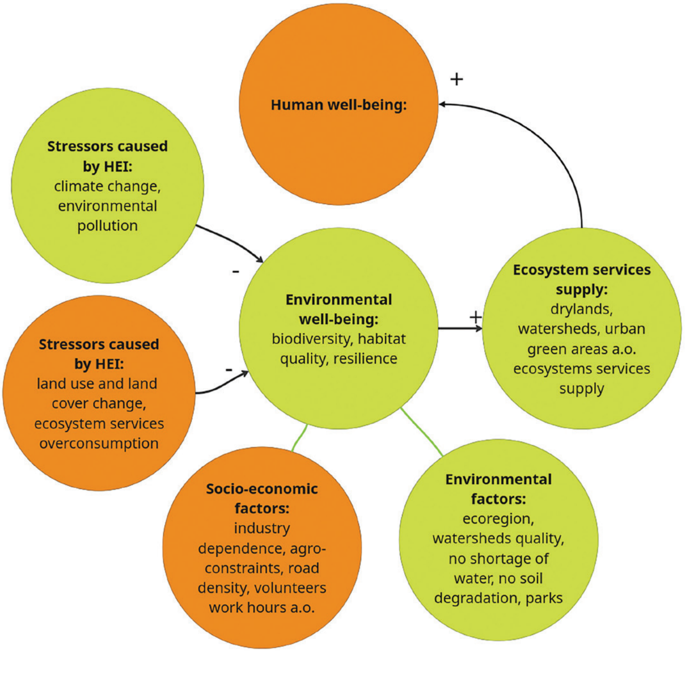
Climate change initiates natural hazards that also affect human well-being. Sajjad et al. (2019) assessed ecosystem resilience to typhoon-induced destruction. Ecological dimension indicators (e.g., parks and forests) contribute positively to resilience, whereas urban areas contribute negatively; tourist flows can contribute to the economic growth of communities that can lead to widened opportunities to invest more in public safety through local fiscal expenditure. A negative relationship between native population size and resilience was found – ares with larger native populations provided fewer opportunities for the non-native population to migrate into these areas.

Figure 13 presents the analysis of the reviewed articles on the impact of human-environmental interactions on environmental well-being, their relationship to human well-being, and related factors. The black lines represent causations, they are not quantitatively related, but their theoretical existence is indicated in the examined studies. Moreover, the plus sign (+) denotes an increasing effect, and the minus sign (-) denotes a reducing effect. Green lines represent quantitative indicators that appear in the reviewed studies, but whose causation is not precisely determined by the studies, so mutual effects with arrows is not indicated. Thus, Figure 13 shows that environmental well-being characterized by biodiversity, habitat quality and resilience is related to socio-economic factors, such as dependence on industry, agro-constraints, road density, invested volunteer work, etc., and environmental factors such as ecoregion, watersheds quality, water availability, soil degradation, and availability of green areas.

Figure 13

Environmental Well-Being and Relations with Environmental and Socio-Economic Factors

Note: The green lines represent relations between quantitative indicators. The black lines represent theoretical causations. Human components are highlighted in orange, and environment components are highlighted in green.



HEI Impact on Human Well-Being

Human well-being measurements have been conducted in 22 publications (Table C.9), with a focus on how ecosystem service consumption and land use and land cover changes impact well-being.

HEI Impact on Subjective Well-Being (satisfaction with CES and living in restoring areas)

In the reviewed articles, subjective well-being is characterized by happiness (Wang et al., 2023b) or, more specifically, by a person's happy facial expressions in photographs (Svoray et al., 2018), as well as by satisfaction with the CES supply (Beichler, 2015; Ferguson et al., 2024; Li et al., 2025; Molari at el., 2024; Zeng et al., 2023). The review of the selected articles has revealed that there have been studies that refer to the city of Ecuador, in which no relationship between urban green areas or forests and subjective well-being has been discovered (Bonilla-Bedoya et al., 2020a).

HEI Impact on Health (forests, mountains, urban green areas and biodiversity)

The second dimension of human well-being is attributed to human health and quality of life. In the studies of the reviewed articles, human health is characterized by such measurable attributes as stress level (Capecchi et al., 2021) and perceived restoration (Bonilla-Bedoya et al., 2020a; Chai-Allah et al., 2023), life expectancy, age-specific mortality risk, cause-specific mortality rate (Chen et al., 2023), and obesity prevalence (Angermeier et al., 2021). Some of these studies conclude that forests and mountainous areas have beneficial effects on human health. For example, Capecchi et al. (2021) calculated the potential of different types of forests for stress recovery and concluded that although all types of forests caused less stress compared to the urban environment, the type of forest was important. The deciduous category has a lower suitability value than conifers, in particular in winter time. Additionally, coppices are perceived less favorably than high forests. The third aspect studied is the hilliness of the territory. The authors concluded that the suitability of forests for stress reduction value was indirectly proportional to altitude in both winter and summer. Chen et al. (2023) claim that human health is related to the biodiversity of the surrounding area, for example, the biodiversity of rare species of birds. Their study uses Pearson's correlation test and although the correlations are statistically significant they are very weak. For example, the correlation between regional rarefied species richness of birds and life expectancy at the county level is $r = 0.18$ ($p < 0{\cdot}001$), while the correlation with the percentage increase in life expectancy is $r = 0.17$ ($p < 0{\cdot}001$). Rarefied species richness of birds was negatively correlated with the majority of cause-specific deaths, for example, for cardiovascular diseases $r = -0.242$.

HEI Impact on Human Livelihoods by Living in Protected Areas or Greening Areas

Another key aspect of a person's well-being is their income and livelihood. Research on how income and livelihoods are affected by HEI presents mixed outcomes. Herrmann et al. (2014) found better well-being in communities less focused on environmental quality, while Castillo-Eguskitza et al. (2017) noted that protected areas boosted sustainability and local quality of life. Dos Santos Facundes et al. (2024) warned that urban greening in vulnerable areas might displace residents and worsen inequities. Thapa et al. (2024) added that land ownership in megacities was positively linked to tree cover and urban greening.

HEI Impact on Comprehensive Human Well-Being by Ecoregion (Environmental Conditions), Industry-Dependence, State, and Ecosystem Quality

Scown et al. (2017) assessed human well-being using an indicator that reflects the availability of social, economic, and ecosystem services within a given area. In this study, spatial multiple linear regression was used and, as a result, a total of 31% of the variance in the county's human well-being was explained by ecoregion (environmental conditions), industry-dependence, and state. Additionally, this study looked for relationships between average human well-being indicators at the county level and watershed quality. Correlations between county average human well-being and watershed quality were weak, and Spearman's rank correlation coefficients ρ were less than 0.2.

Duku et al. (2022) observed that provisional ($\beta = 0.55$; $p \leq 0.001$) and cultural ($\beta = 0.374$; $p \leq 0.05$) ecosystem services had a significant positive relationship with human well-being. However, the relationship between regulating ecosystem services and human well-being was significantly strong but reversed ($\beta = -0.87$; $p \leq 0.001$).

Analyzing the correlations of human well-being and ecosystem services (ES-HWB) in China, Liu at al. (2022a) concluded that there were three types of clusters (regions): (1) positive correlation, (2) negative correlation, and (3) no correlation. In addition, they found that a positive ES-HWB relationship was found mainly in socio-economically underdeveloped (rural or agricultural) regions with low ES production levels; a negative ES-HWB relationship occurred mostly in intermediately developed regions with abundant non-food ES; and ES and HWB had no relationships in socio-economically well-developed (intensive agriculture/urbanized) societies with ample provisioning ES.

Zhang et al. (2024) concluded that economic, social, and technological factors positively contributed to increasing well-being levels, while ecological effects, such as SO_2 pollution, had a negative impact. Their analysis employed the entropy method, Dagum Gini coefficient, and Logarithmic Mean Divisia Index (LMDI) decomposition to assess these influences.

Zhu et al. (2022) came up with an algorithm how to measure the efficiency with which natural resources and the ecological environment were transformed into a corresponding level of human well-being – economic growth, social equality (income of rural residents/income of urban residents), universal education health, favorable environment (green park space, air quality rate); they also concluded that for cities at different hierarchy levels, the effect of technological progress on the efficiency of well-being performance is different. High-level cities had a higher level of development and pursued green and high-quality development.

Figure 14

Human Well-Being and Relations with Environmental and Socio-Economic Factors

Note: Green lines represent relations between quantitative indicators. Human components are highlighted in orange, and environment components are highlighted in green.

Figure 14 presents the interrelationships between quantitative indicators of human well-being and other indicators, such as environmental well-being, environmental factors, and socio-economic factors. It should be noted that causations are not indicated, because the examined articles often used correlation analyses or group comparisons rather than causal designs.

Responses to Research Question 2

RQ2*: What is the influence of the spatial dimension on well-being monitoring?*

The section presents results to highlight the role of spatial dimension in the reviewed literature. It is worth noting that this issue has been less addressed than that of the previous research question.

Geographical Scale

The majority of studies (46) were conducted at a regional scale, covering parts of one or more countries. Examples include research on forests (Aguilar et al., 2024;

Bhatt et al., 2024), coastal areas (Bastos et al., 2023; Santos Vieira et al., 2021; Sajjad et al., 2019), islands (Cordero-Penín et al., 2023; Newman et al., 2020), or mountain regions (Carilla et al., 2024; Wang et al., 2023b) that cross several countries. Additionally, 16 studies focused on the city scale or specific urban areas (Bonilla-Bedoya et al., 2020a; Bonilla-Bedoya et al., 2021; Dennis, & James, 2016; dos Santos Facundes et al., 2024; Kajosaari et al., 2024; Klobuchar, et al. 2021; Li et al., 2025; Zeng et al., 2023), while four studies examined national or global scales (Angelucci & Radogna, 2024; Mungi et al., 2023; Sietz et al., 2011; Wang et al., 2023a). In several articles, the geographical scale was not explicitly defined. A more detailed evaluation was performed on the 37 studies in which well-being indicators were quantitatively measured (Table C.10; Table C.11). The overwhelming focus on regional and city-scale research indicates a clear need for expanding well-being monitoring at the local and community levels, where interventions and educational efforts are most effective.

Temporal Scale

Ten environmental and 17 human well-being observations were collected only at one specific moment in time, as snapshots, rather than as continuous, long-term series of observations. For example, for the habitat quality assessment, the risk of water pollution in coastal industrialized areas is determined as a one-time measure, rather than a permanent long-term measurement (Bastos et al., 2023). Another example is the study of the counts and richness of Cultural Ecosystem services measured at a single point in time (Santos Vieira et al., 2021). Svoray et al. (2018) study the geographic locations where people have happy facial expressions in photographs, and this study also reflects a specific moment in time. Five environmental and three human well-being measures are dynamical as they change over time. For example, the study has assessed habitat quality and shown changes for the period from 2000 to 2020 (Wang et al., 2023a). In the study on the typhoon destructive potential for coastal regions of China, the study period was from 1980 to 2014, which allowed observing short-term geographical changes in typhoons (Sajjad et al., 2019). To study the spatial representation of people's perceptions of changes in vegetation cover and NDVI trends, data for the period from 1982 to 2008 were used (Herrmann et al., 2014). The heavy reliance on "snapshot" studies, as opposed to dynamic, longitudinal ones, presents a major challenge for understanding the complex feedback loops between human and environmental well-being over time. This gap in the literature is a key area for future research and a significant consideration for educators developing sustainability curricula.

Monitoring Spatial Variations

Results from 14 environmental and 15 human well-being studies are linked to geographic location, showing differences between different areas. For example, Scown et al. (2017) identified disparities (high and low levels) in the quality of surface watershed ecosystems and human well-being at the county level (US). Bonilla-Bedoya et al. (2021) presented the spatial variations in air pollution in the urban gradient of the Quito Metropolitan District. Sietz et al. (2011) revealed the spatial distribution of the typical vulnerability patterns. A cluster analysis revealed a set of seven typical vulnerability patterns showing combinations of distinct indicators (poverty, water stress, soil degradation, natural agro-constraints, and isolation). The study by Bonilla-Bedoya et al. (2020a) found the probable urbanization distribution in the Metropolitan District of Quito. Bastos et al. (2023) noted spatial variations in risk across the Ria de Aveiro's marine, coastal, estuarine, and freshwater habitats. Spatial variations have also been discovered in studies on human well-being. For example, Beichler (2015) shows in his study which geographic areas are the ones where people are most satisfied with the CES supply. The research by Capecchi et al. (2021) shows the distribution of forest suitability for stress level reduction. Bonilla-Bedoya et al. (2020a) observe the spatial variations of people's perceived restoration and subjective well-being according to the origins of the respondents. Zhu et al. (2022) examined the spatial distribution of ecological well-being performance in China. Duku et al. (2022) published spatial variation maps of three human well-being levels across Ghana's coastal areas. Liu et al. (2022a) found that the local-scale relationship between ecosystem services and human well-being had spatial heterogeneity, varying from positive to negative or no correlations across broad regions.

Monitoring the Spatial Distribution of Impacting Factors

Among the reviewed papers, ten environmental and four human well-being studies show the spatial distribution of both well-being measurements and their influencing factors. Thus, for example, in the study on habitat quality, the distribution of high-risk water pollution stressors selected in the region of Aveiro is specified (Bastos et al., 2023). The study on biodiversity monitoring indicates not only the distribution of the most vulnerable habitats, but also the distribution of high-concern invasive plants at a national scale in India (Mungi et al., 2023). In a study on human health and perceived restoration in nature, Bonilla-Bedoya et al. (2020a) reflect the following distributions: land cover, density of green areas and urban forests in the census blocks, local spatial dissimilarity, local spatial isolation, population density, and socio-economic disparity (poor and non-poor). The study on air pollution presents the spatial distribution of land cover influencing air quality (Bonilla-Bedoya et al. 2021). Kajosaari et al. (2024) present both probabilities of positive or negative perceptions of urban green space quality and spatial distribution of availability of urban green space in Espoo. Liu et al. (2022a) conclude that the variations and spatial patterns of the ecosystem services and human well-being relationships are influenced by several social-ecological factors, e.g., population density and land cover compositions.

Discussion

The section synthesizes the key insights emerged from the systematic review, highlighting three primary themes: conceptual unclarity in defining well-being and human-environment interactions, the challenge of establishing causal relationships, and the critical importance of the spatial and temporal dimensions in well-being monitoring. The findings are relevant not only for environmental science but also *carry significant implications* for teacher education for sustainability, as educators play a central role in equipping future generations with *the knowledge, values, and critical thinking skills required to address* sustainability challenges.

The review process prompted the interdisciplinary research team to confront the prevalence of human-centered thinking in sustainability literature. While not all members specialize in environmental studies, it has been collectively recognized how this dominant perspective shapes education research. Discussions have revealed that even academic frameworks positioning nature as "service-provider" inadvertently narrow sustainability discourse. This realization now informs how the research team members, as education researchers, approach sustainability – emphasizing its systemic nature beyond utilitarian benefits. Through the systematic review, the research team has gained a deeper appreciation for the conceptual inconsistencies and methodological gaps that currently characterize the field. This experience underscores the research team's conviction that a more holistic and integrated approach is essential to advancing both research and pedagogy.

The Dominant "Anthropocentric" Approach and Personal Reflections on Sustainability

The systematic review has examined articles addressing both human and environmental well-being. The analysis confirms that the dominant framing is anthropocentric – ecosystems and nature are often conceptualized primarily as resources or service providers for human benefit (Bartelet et al., 2023; Beichler, 2016; Bonilla-Bedoya et al., 2020a; Bonilla-Bedoya et al., 2020b; Capecchi et al., 2021; Carone et al., 2017; Chai-Allah et al., 2023; Cobacho et al., 2020). In contrast, holistic or ecocentric perspectives – where humans are viewed as integral components of ecosystems – are rarely central to the research design. While many articles recognize that environmental well-being is essential to sustaining human well-being (Chen et al., 2023; de Guzman et al., 2022; Duku et al., 2022), their primary focus often remains on improving human outcomes (Bastos et al., 2023; Castillo-Eguskitz et al., 2017; Cordero-Penín et al., 2023). This reflects a persistent anthropocentric bias, where environmental well-being is instrumentalized rather than valued intrinsically.

This anthropocentric bias is a critical point for reflection in sustainability education, where nature is frequently framed through a utilitarian lens. A more balanced, transdisciplinary approach would emphasize ecosystem-centered pedagogy that promotes a deeper understanding of interdependence, ecological ethics, and the intrinsic value of nature (Salīte et al., 2024). Such an approach has the potential to foster a robust biospheric consciousness and align with research indicating that a shift in educational paradigms is needed to improve environmental sustainability (Ferreira & Pitarma, 2021; Wals & Benavot 2017).

From a personal perspective, conducting this study has deepened the research team's understanding of sustainability beyond a simple definition of "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 2015). The research team has recognized sustainability not merely as a set of policies or technological fixes, but as a profoundly ethical and relational concept. The overwhelming anthropocentric bias in the literature reviewed has become, for the research team, a powerful wake-up call. It has highlighted how deeply ingrained the idea of human dominance is in the collective scientific and societal worldview. This research process has become a journey of personal reflection, forcing the research team to confront personal assumptions and biases about the human place in the natural world. True sustainability, as the research team now understands, requires a paradigm shift – moving from a perspective in which humanity manages nature for human benefit to one in which people see themselves as an inseparable part of a complex, interconnected web of life. The authors acknowledge that conducting this review has reinforced their commitment to embedding sustainability in educational contexts. The authors believe that this shift must be cultivated through education, equipping future generations with not only technical knowledge but also an ecocentric worldview that values the intrinsic well-being of the planet. The process has not only deepened the research team's understanding of holistic sustainability perspectives but also underscored the responsibility of educators and researchers to act as role models in aligning educational practice with planetary well-being.

Confusing Concepts and Definitions of Human and Environmental Well-Being and Their Misleading Interactions

A finding of this review is the lack of consensus around a single, coherent definition of well-being across the literature. Well-being is interpreted through multiple frameworks. Cambridge Dictionary (2022) defines well-being as "the state of feeling healthy and happy". The UK's What Works Centre for Wellbeing emphasizes subjective dimensions such as life satisfaction and emotional experience (Muller et al., 2021). According to the Organization for Economic Cooperation and Development (OECD) (2020), well-being consists of three domains: material conditions (e.g., income, housing), quality of life (e.g., health, education, and environmental quality), and subjective well-being (e.g., life satisfaction). Most reviewed articles align with this framework, focusing on subjective well-being, health, and economic aspects. While the OECD definitions for human well-being are available, definitions for environmental well-being could not be identified. In addition, it should be emphasized that the term "environmental well-being" is used in only one article, while other articles use terms referring to environmental quality or health. The authors contend that this terminological preference underscores an anthropocentric approach, where the priority is placed on human well-being and its direct relationship with the environment, rather than on the intrinsic value of the environment itself. The systematic review has identified three aspects of environmental well-being: (1) ecosystem health providing biodiversity and avoiding vulnerability (Bonilla-Bedoya et al., 2020b; Dennis & James, 2016; Junker et al., 2015; Kajosaari et al., 2024; Klobuchar et al. 2021; Santos Vieira et al., 2021; Scown et al., 2017; Sietz et al., 2011); (2) habitat quality (Bastos et al., 2023; Bonilla-Bedoya et al., 2021; Mungi et al., 2023; Wang et al., 2023a); (3) ecosystem resilience (Sajjad et al., 2019). Environmental well-being is also related to sustainability (Angelstam et al., 2022; Castillo-Eguskitza et al., 2017; de Alencar et al., 2020; Gašparović et al., 2022; Klobucar et al., 2021; Newman et al., 2020). The United Nations defines sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987). To ensure the sustainability of living things, environmental well-being must be congruent with sustained disease resistance, good nutrition, and the persistence of species-appropriate population dynamics. However, considering the limited number of systematic review articles, the authors of the present study believe that the concept of environmental well-being needs to be further explored and discussed in the future.

Similarly, the concept of human-environment interaction is used inconsistently. Articles portray humans as: (1) consumers of ecosystem services (Aguilar et al., 2024; Bhatt et al., 2024; Cai et al., 2024; Duku et al., 2022; Ferguson et al., 2024; Liepa et al., 2023; Liu et al., 2022b; Maass et al., 2005; Samuelsson et al., 2019); (2) modifiers of the environment (Bastos et al., 2023; Beichler, 2015; Bonilla-Bedoya et al., 2020a; Bonilla-Bedoya et al., 2020b; Carilla et al., 2024; de Guzman et al., 2022; Dennis & James, 2016; Kajosaari et al., 2024; Liu et al., 2022a; Zeng et al., 2023; Zhu et al., 2022); (3) subjects affected by natural hazards (Bartelet et al., 2023; Sajjad et al., 2019; Klobucar et al., 2021; Lamchin et al., 2022).

Two approaches dominate: first, research focuses on improving access to ecosystem services (e.g., green spaces) (Beichler, 2015; de Guzman et al., 2022; Dennis & James, 2016; Kajosaari et al., 2024; Klobucar et al., 2021; Molari et al., 2024; Zeng et al., 2023); second, studies seek to identify which services most enhance well-being.

However, activities like urbanization (Bonilla-Bedoya et al., 2020a; Liu et al., 2022a; Thapa et al., 2024), industrialization (Bastos et al., 2023; Liu et al., 2022a), rural development (Kohler et al., 2017), and forest management (Angelstam et al., 2022) often prioritize economic benefits. These activities drive land-use changes that lead to the degradation and reduced availability of essential ecosystem services.

Natural hazards affect humans' lives in the following ways: increased air and water temperatures lead to rising sea levels and higher wind speeds (Bartelet et al., 2023; Newman et al., 2020; Sajjad et al., 2019). This reduces the ecosystem services available to humans. People need to find solutions to adapt to the new conditions to maintain livelihood and quality of life (Cobacho et al., 2020).

This lack of conceptual clarity can mislead both scientific interpretation and educational practice. Clear, context-sensitive definitions are essential, particularly in sustainability-oriented teacher education, where students must be able to navigate the complexity and ambiguity inherent in environmental discourse (McFarlane & Ogazon, 2011; Ram et al., 2025).

Uncertainty in Quantitative Relationships Between Human/ Environmental Well-Being and Influencing Factors

Many studies rely on statistical associations rather than methods that reveal causality, limiting an understanding of what truly influences well-being. Additionally, in some studies, the quantitative relationships revealed for well-being-related variables are weak or non-existent. For instance, Scown et al. (2017) reported very weak correlations ($\rho < 0.2$) between watershed quality and human well-being indicators. Similarly, Chen et al. (2023) found statistically significant but weak correlations, e.g., between bird species richness and life expectancy ($r = 0.18$; $p < 0{\cdot}001$). These examples illustrate that correlation alone may not capture the complex dynamics of human-environment relationships. Human-environment relationships are complex and not very often subject to linearity. Therefore, it is necessary to look for other more effective ways to determine the relationships, including causal relationships. The use of correlations has weaknesses and limitations. The obtained correlations do not indicate a causal relationship; the authors of the articles themselves point out this deficiency (Angermeier et al., 2021).

Moreover, findings across studies are often contradictory. Some report that CES and green areas impact subjective well-being (Beichler, 2015; Molari et al., 2024; Svoray et al., 2018; Wang et al., 2023b; Zeng et al., 2023); while others find no significant effect, for example, no relationship between urban green areas or forests and subjective well-being has been discovered (Bonilla-Bedoya et al., 2020a).

Studies also diverge on whether improving environmental conditions leads to improved human well-being. For example, Herrmann et al. (2014) have concluded that the livelihood and well-being variables evolve more positively in communities that do not care about the quality of the environment (non-greening communities). Also, Duku et al. (2022) have concluded that human well-being and regulatory ecosystem services are inversely correlated, the higher human well-being is rated, the lower the indicators for such ecosystem services that control the level of air, land, and water pollution. On the other hand, Castillo-Eguskitza et al. (2017) state that the protected area fulfills its sustainability goal and enhances the local population's quality of life. The fact that there is no clear connection between human and environmental well-being is also evidenced by other articles excluded from the systematic review.

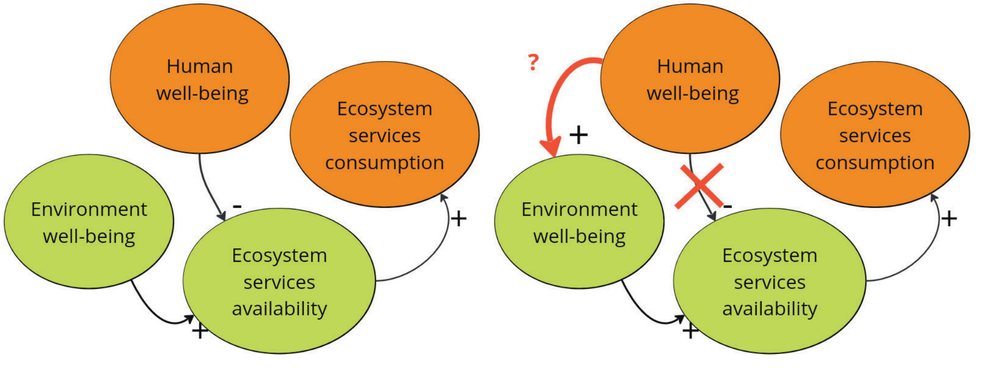
Larger-scale analyses reinforce this ambiguity. Van de Kerk and Manuel (2012) observed an average negative correlation between Human Well-being (HW) and Environmental Well-being (EW) across 151 countries. Also, Ulman et al. (2020) analyzed the effects of human well-being on environmental well-being and concluded that a high level of HW has a negative influence on the level of EW (path coef =−0.585, Sig =0.000), indicating a tendency to decrease its level. However, Ulman et al. (2020) conducted a separate analysis of countries with factor-driven economies and innovation-driven economies and concluded that the influence of HW on EW is negative in factor-driven economies with path coef =−0.787 and Sig =0.000 and positive in innovation-driven economies with path coef =0.588 and Sig =0.003.

Given that human-environment interactions form a complex and dynamic system, the authors of the present study conclude that the dominant use of statistical methods is inadequate for fully capturing these linkages. While some articles have begun to apply AI and machine learning techniques (Li et al., 2025; Liu et al., 2024; Santos Vieira et al., 2021; Vigl et al., 2021), their use is not widespread. Therefore, the authors of the present study assert that future research must prioritize advanced methodologies, including dynamic modeling and machine learning, to better quantify and, most importantly, identify causalities between human and environmental well-being. Notably, the systematic review emphasizes the critical absence of a feedback loop from human well-being to environmental well-being in the existing literature – an essential mechanism for ensuring long-term environmental sustainability. Figure 15 provides a conceptual perspective, illustrating the current situation and the desired future state, highlighting where quantitative causation studies are most needed to complete this feedback loop.

Figure 15

A Conceptual Perspective on Human-Environment Interactions and the Causal Relationships of Well-Being

Note: Black lines are conclusions about theoretical links from the reviewed literature, red lines are the ones where quantitative causation studies are needed. Human components are highlighted in orange, and environment components are highlighted in green.



(a) Current situation (b) Desired future situation

Embedding systems thinking and basic modeling into sustainability education can help students understand these interdependencies and develop skills to work with complexity (Dias et al., 2022; Iliško et al., 2017; Salīte et al., 2024). A major gap identified is the limited number of studies that establish quantitative or causal links between human or environmental well-being and influencing factors. While statistical analysis is common, few studies explore dynamic or feedback-driven models. This presents a challenge and an opportunity for education. Embedding these approaches in training helps future educators critically assess the interconnected nature of ecological, social, and economic systems. As Zandvliet and Paul (2023) argue, ecological problems cannot be fully understood or solved without acknowledging the irrationalities and complexities within our current societal systems.

Spatial Dimension of Well-Being Monitoring

The present analysis underscores the essential, often underexplored, role of the spatial and temporal dimensions in well-being monitoring. The spatial dimension allows for targeted, place-based interventions, which are crucial for enhancing quality of life and addressing disparities. Monitoring well-being means regularly collecting, analyzing, and using data to manage human-environment interactions, enhance positive outcomes, and reduce risks (BetterEvaluation, 2022).

Spatial variations affect access to essential services and resources (Beichler, 2015; dos Santos Facundes et al., 2024; Duku et al., 2022; Zhu et al. 2022). Well-being monitoring in different locations helps identify disparities in access to healthcare, education, employment opportunities, social services, and ecosystem services (Bonilla-Bedoya et al. 2020a; Capecchi et al., 2021; Duku et al., 2022). This information guides the allocation of resources to address these disparities, ultimately enhancing well-being (Liu et al., 2022b; Santos Vieira et al., 2021). Spatial analysis considers the quality of the environment within different geographical areas (Bastos et al., 2023; Mungi et al., 2023; Scown et al., 2017). Monitoring environmental factors, such as air quality (Bonilla-Bedoya et al., 2021) and water quality (Sietz et al., 2011), green spaces (dos Santos Facundes et al., 2024; Kajosaari et al., 2024; Thapa et al., 2024), land cover (Herrmann et al., 2014), and exposure to pollution, helps in understanding how the environment impacts residents' well-being. Spatial dimensions aid in identifying and addressing disparities to improve overall well-being. This spatial lens is also essential for effective policymaking (Bonilla-Bedoya et al., 2020b; Bonilla-Bedoya et al., 2021; Duku et al., 2022; Sajjad et al., 2019; Svoray et al., 2018; Wang et al., 2023b; Zhu et al., 2022) and for education. In sustainability education, spatial awareness enables learners to connect abstract concepts to real-life challenges, as engaging students in localized, field-based activities and spatial tasks enhances their environmental literacy and connection to place (Saraiva et al., 2024).

Scales of Monitoring

The systematic review has revealed a significant imbalance in the scale of monitoring. A limited number of researchers focus on conducting studies at the local level (Bonilla-Bedoya et al., 2020b; Dennis, & James, 2016; dos Santos Facundes et al., 2024; Kajosaari et al., 2024; Klobuchar, et al. 2021). Most research projects are conducted at the regional level, not measured for small territories (local scale) (Angermeier et al., 2021; Bastos et al., 2023; Beichler, 2015; Bonilla-Bedoya et al., 2020a; Capecchi et al., 2021; Castillo-Eguskitza et al., 2017; Chen et al., 2023; Duku et al., 2022; Herrmann et al., 2014; Sajjad et al., 2019; Santos Vieira et al., 2021; Svoray et al., 2018; Thapa et al., 2024; Wang et al., 2023b; Zhang et al., 2024). While monitoring well-being at various scales is important for a comprehensive understanding, the local scale is particularly significant due to its contextual relevance, ability to identify community-specific needs, and the potential for tailored, impactful interventions that directly improve the well-being of the community (Bonilla-Bedoya et al., 2020b; Dennis, & James, 2016; Fry et al., 2017; Kajosaari et al., 2024). The choice of monitoring scale should align with research goals and available resources.

Similarly, a temporal gap exists, with few studies tracking well-being over time (Bonilla-Bedoya et al., 2021; Castillo-Eguskitza et al., 2017; Herrmann et al., 2014; Liu et al., 2024; Sajjad et al., 2019; Wang et al., 2023a; Yi et al., 2024; Zhang et al., 2024), limiting the potential for tracking change or causality. Most data are collected at a single time point, which constrains an understanding of dynamic trends (Angermeier et al., 2021; Bastos et al., 2023; Beichler, 2015; Bonilla-Bedoya et al., 2020b; Cai et al., 2024; Dennis & James, 2016; Duku et al., 2022; Kajosaari et al., 2024; Liu et al., 2022b; Mungi et al., 2023; Santos Vieira et al., 2021; Scown et al., 2017; Svoray et al., 2018; Thapa et al., 2024; Zhu et al., 2022).

From a sustainability education perspective, fostering understanding of both spatial and temporal dimensions helps students and future educators recognize the layered and evolving nature of environmental and social issues. Embedding these elements in teacher education encourages place-based learning and systems thinking (Abdallah, 2025; Zandvliet & Paul, 2023; Wanchana et al., 2020). Localized data is crucial to understanding disparities and enabling community-level interventions. This supports the integration of place-based education and geospatial thinking into sustainability pedagogy. Educators can use such approaches to connect abstract sustainability goals with learners' everyday environments, fostering stronger place identity and stewardship.

Traditionally, data is captured through surveys of householders (Wang et al., 2023a; Duku et al., 2022; Junker et al., 2015), forest attendees (Capecchi et al., 2021; Liepa et al., 2023), residential property owners (Klobuchar et al., 2021), and field experts (Bastos et al., 2023; Bonilla-Bedoya et al., 2020a). There is an issue of incomplete country coverage, incomplete time series, and untimely data (Junker et al., 2015; Wang et al., 2023b). Surveys can be time-consuming, expensive, and labor-intensive (Tingzon et al., 2019). Therefore, it is necessary to look for data sources where there are no problems with access and use, and the data is regularly updated.

Satellite data has significant but underused potential for assessing well-being at local scales (Jean et al., 2016; Yeh et al., 2020). It can reflect land-use intensity and agricultural trends not visible in survey data (Burke & Lobell, 2017; Kubitza et al., 2020; Lobell et al., 2020; Nguyen et al., 2020; Viana et al., 2019).

The Potential of Satellite Data

Despite these benefits, few reviewed studies utilize satellite or remote sensing data (Bonilla-Bedoya et al., 2020a; Bonilla-Bedoya et al., 2020b; Bonilla-Bedoya et al., 2021; dos Santos Facundes et al., 2024; Herrmann et al., 2014; Li et al., 2025; Mungi et al., 2023; Sajjad et al., 2019; Thapa et al., 2024; Wang et al., 2023a), and some highlight issues, such as weak correlation between satellite-observed and perceived environmental changes (Herrmann et al., 2014). Hargreaves & Watmough (2020) argue that satellite-based monitoring of well-being is still emerging and requires new methodologies. Bonilla-Bedoya et al. (2020a) also stress the need for fine-scale, socio-ecologically informed spatial-temporal indicators. These findings indicate an opportunity to expand satellite data integration both in research and education. In educational contexts, however, satellite data use remains limited due to technical, motivational, and informational barriers (Asimakopoulou et al., 2023). Sustainability education would benefit from incorporating remote sensing into curricula, improving students' digital literacy and analytical skills (Danaher et al., 2021).

Limitations of the Systematic Review

The systematic review has several limitations that should be considered. First, the findings have been constrained by the scope of the search strategy, which has focused on a specific set of keywords and databases. While comprehensive, this approach may have inadvertently omitted relevant literature from related disciplines, such as sociology, public health, or economics, that also addresses human-environment interactions. The review is limited to studies published in indexed academic databases, potentially excluding relevant grey literature and non-English sources. Second, as a qualitative synthesis of existing literature, this review does not allow for a quantitative meta-analysis of results. Methodological diversity among the included studies has posed challenges for direct comparison. The authors of the present study, therefore, rely on a narrative approach to highlight trends and inconsistencies. Third, the synthesis has been influenced by the interdisciplinary backgrounds of the authors, which, while enriching interpretation, may also introduce subjective bias. Finally, the limitations identified within the reviewed articles themselves – such as the prevalent reliance on correlational data, single time-point analyses, and a dominant regional scale – are inherent limitations of the findings. The research conclusions are a direct reflection of the current state of the field, highlighting persistent gaps that require further empirical and methodological exploration to advance the understanding of well-being in the context of human-environment dynamics.

Conclusions and Implications for Sustainability Education

The systematic review has examined human-environment well-being monitoring and identified factors influencing well-being, as well as the data sources and methods used to characterize well-being processes. The focus of the well-being research has been from the perspective of interaction between people and the environment. The study has addressed two research questions: How do human-environment interactions are connected to well-being? What is the influence of the spatial dimension on well-being monitoring? Using the predefined keywords, the study has identified 73 relevant articles for the systematic review.

Based on the analysis, it is possible to draw the main conclusions provided below. (1) The dominant approach across studies is anthropocentric – ecosystems and nature are mainly viewed as tools or services for human benefit. Holistic or ecocentric frameworks, where humans are embedded within ecosystems, are rarely the primary research focus. (2) There is a lack of research that establishes quantitative or causal links between well-being and its influencing factors. While statistical methods are common, there is notable potential to apply dynamic models and explore empirical causation. Notably, links between human-environment interactions and their impact on both human and environmental well-being remain underexplored. 3) Most studies focus on national or regional scales, with limited attention to small-scale (local) well-being monitoring. 4) The articles lack perspective on the local scale, dynamical models, and satellite data usage.

The review has also identified key challenges and gaps in the current research on human and environmental well-being interactions. These findings are valuable for researchers, policymakers, and educators aiming to improve sustainability outcomes.

Based on the gaps identified, the authors of the present study recommend the following future areas for research and practice: (1) Expand local-scale research using geolocalized well-being factors; (2) Explore approaches related to dynamic data modelling and causal analysis; (3) Identify new approaches based on technologies for well-being data collection and analysis such as satellite imaging analysis; 4) Develop methods to establish a feedback loop between human well-being and environmental well-being; (5) Assess the limitations of well-being models in socio-ecological system context; (6) Identify the challenges of well-being research extension towards well-being models upgrade with data from different online information systems.

The research findings present clear implications for teacher education for sustainability. The authors of the present study advocate for integrating dynamic modeling and satellite data analysis into teacher training, equipping educators to address sustainability challenges with both technical and ethical competence. While these methods show theoretical promise based on the review findings, their implementation would require careful adaptation to different educational contexts. The challenge is to train future educators to transcend the dominant anthropocentric view by incorporating ecocentric pedagogies and a systems-thinking approach. This involves teaching them to critically analyze the conceptual inconsistencies they will encounter in academic literature and media, and to understand that a truly sustainable future requires valuing the environment intrinsically. Furthermore, to prepare students for the complexities of real-world environmental challenges, educators must be equipped with the skills to integrate local, place-based learning with dynamic, data-driven analysis. This includes the effective use of emerging technologies like satellite data and dynamic models to move from a static understanding of problems to a dynamic and predictive one. Ultimately, this will empower a new generation of learners to not only understand sustainability but to actively and effectively contribute to it. Future studies should prioritise longitudinal, participatory action research involving teacher educators and learners in co-creating sustainability curricula. Expanding research to underrepresented cultural contexts and incorporating non-English scholarship could enhance inclusivity. The research findings underscore the urgency of reforming teacher education to include ecocentric frameworks, systems thinking, and geospatial technologies, fostering a generation of educators who can navigate the complexities of sustainability.

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References

Abdallah, A. K. (2025). Local to global: Place-based learning in sustainability education. In E. M. Alqodsi & A. K. Abdallah (Eds.), *Legal Frameworks and Educational Strategies for Sustainable Development* (pp. 233–260). IGI Global. https://doi.org/10.4018/979-8-3693-2987-0.ch013

Adams, H., Adger, W. N., Ahmad, S., Ahmed, A., Begum, D., Lázár, A. N., Matthews, Z., Rahman, M. M., & Streatfield, P. K. (2016). Spatial and temporal dynamics of multidimensional well-being, livelihoods and ecosystem services in coastal Bangladesh. *Scientific Data,* *3*, 160094. https://doi.org/10.1038/sdata.2016.94

Aguilar, F. X., Lautrup, M., Kim, D., Tangen, A. C., Rautiainen, A., Brownell, H., López, L. N., Stratton, A. D. H., Glasenapp, S., Korth, S. M., Sjølie, H. K., & Bredahl Jacobsen, J. (2024). Inherently spatial: Data and analytical insights for the identification of forest socio-ecological hotspots. *Silva Fennica, 58*(5), 24053. https://doi.org/10.14214/sf.24053

Angelstam, P., Asplund, B., Bastian, O., Engelmark, O., Fedoriak, M., Grunewald, K., Ibisch, P. L., Lindvall, P., Manton, M., Nilsson, M., Nilsson, S. B., Roberntz, P., Shkaruba, A., Skoog, P., Soloviy, I., Svoboda, M., Teplyakov, V., Tivell, A., Westholm, E., ... Öster, L. (2022). Tradition as asset or burden for transitions from forests as cropping systems to multifunctional forest landscapes: Sweden as a case study. *Forest Ecology and Management, 505*, Article 119895. https://doi.org/10.1016/j.foreco.2021.119895

Angermeier, P. L., Krometis, L. A., Stern, M. J., & Hemby, T. L. (2021). Exploring relationships among stream health, human well-being, and demographics in Virginia, USA. *Ecological Indicators, 121*, 107194. https://doi.org/10.1016/j.ecolind.2020.107194

Asimakopoulou, P., Nastos, P., Vassilakis, E., Antonarakou, A., Hatzaki, M., Katsigianni, O., Papamatthaiou, M., & Kontoes, C. (2023). Climate change education through Earth observation: An approach for EO newcomers in schools. *Sustainability*, *15*(19), 14454. https://doi.org/10.3390/su151914454

Athanasiou, P., van Dongeren, A., Giardino, A., Vousdoukas, M. I., Ranasinghe, R., & Kwadijk, J. (2020). Uncertainties in projections of sandy beach erosion due to sea level rise: An analysis at the European scale. *Scientific reports*, *10*(1), 11895. https://doi.org/10.1038/s41598-020-68576-0

Bakar, A. A., Osman, M. M., Bachok, S., Ibrahim, M., & Mohamed, M. Z. (2015). Modelling economic wellbeing and social wellbeing for sustainability: A theoretical concept. *Procedia Environmental Sciences*, *28*, 286–296. https://doi.org/10.1016/j.proenv.2015.07.037

Bartelet, H. A., Barnes, M. L., & Cumming, G. S. (2023). Microeconomic adaptation to severe climate disturbances on Australian coral reefs. *Ambio, 52*(2), 285–299. https://doi.org/10.1007/s13280-022-01798-w

Bastos, M. I., Roebeling, P. C., Alves, F. L., Villasante, S., & Magalhães Filho, L. (2023). High risk water pollution hazards affecting Aveiro coastal lagoon (Portugal) – A habitat risk assessment using InVEST. *Ecological Informatics, 76*, Article 102144. https://doi.org/10.1016/j.ecoinf.2023.102144

Beichler, S. A. (2015). Exploring the link between supply and demand of cultural ecosystem services – Towards an integrated vulnerability assessment. *International Journal of Biodiversity Science, Ecosystem Services & Management, 11*(3), 250–263. https://doi.org/10.1080/21513732.2015.1059891

Better Evaluation. (n.d.). *Monitoring*. Retrieved November 4, 2023, from https://www.betterevaluation.org/methods-approaches/themes/monitoring

Bhatt, H., Verma, D., Jugran, H. P., Kumar, V., & Pandey, R. (2024). Community perception about ecosystem services assessment from forests managed under different regimes in Hindu Kush Himalaya. *Environmental and Sustainability Indicators, 24*, 100463. https://doi.org/10.1016/j.indic.2024.100463

Bonilla-Bedoya, S., Estrella, A., Santos, F., & Herrera, M. A. (2020a). Forests and urban green areas as tools to address the challenges of sustainability in Latin American urban socio-ecological systems. *Applied Geography, 125*, Article 102343. https://doi.org/10.1016/j.apgeog.2020.102343

Bonilla-Bedoya, S., Mora, A., Vaca, A., Estrella, A., & Herrera, M. Á. (2020b). Modelling the relationship between urban expansion processes and urban forest characteristics: An application to the Metropolitan District of Quito. *Computers, Environment and Urban Systems, 79*, Article 101420. https://doi.org/10.1016/j.compenvurbsys.2019.101420

Bonilla-Bedoya, S., Zalakeviciute, R., Coronel, D. M., Durango-Cordero, J., Molina, J. R., Macedo-Pezzopane, J. E., & Herrera, M. Á. (2021). Spatiotemporal variation of forest cover and its relation to air quality in urban Andean socio-ecological systems. *Urban Forestry & Urban Greening, 59*, Article 127008. https://doi.org/10.1016/j.ufug.2021.127008

Brymer, E., Freeman, E., & Richardson, M. (2019). One health: The well-being impacts of human-nature relationships. *Frontiers in Psychology*, *10*, 1611. https://doi.org/10.3389/fpsyg.2019.01611

Bundela, A. K., & Pandey, K. K. (2022). The United Nations General Assembly passes historic resolution to beat plastic pollution. *Anthropocene Science, 1*(2), 332–336. https://doi.org/10.1007/s44177-022-00021-5

Burger, J., Gochfeld, M., Kosson, D. S., Brown, K. G., Salisbury, J., Greenberg, M., & Jeitner, C. (2022). Combining ecological, eco-cultural, and environmental justice parameters to create Eco-EJ indicators to monitor cultural and environmental justices for diverse communities around contaminated sites. *Environmental Monitoring and Assessment, 194*(3), Article 177. https://doi.org/10.1007/s10661-021-09535-8

Burke, M., & Lobell, D. B. (2017). Satellite-based assessment of yield variation and its determinants in smallholder African systems. *Proceedings of the National Academy of Sciences, 114*(9), 2189–2194. https://doi.org/10.1073/pnas.1616919114

Cai, Y., Li, H., & Li, W. (2024). Optimization of a "social-ecological" system pattern from the perspective of ecosystem service supply and demand: A case study of Jilin Province. *Land, 13*(10), 1716. https://doi.org/10.3390/land13101716

Carilla, J., Grau, R., Acosta, O. O., Malizia, A., Ceballos, S., Llambí, L. D., Piquer-Rodríguez, M., Zarbá, L., Flores, S., Cuesta, F., Luna, T. O., Ferreira, W., Tovar, C., Jimenez, Y., Hurtado, A. B. M., Nagy, L. O., Buscardo, E., Wallem, P., Breuer, P., ... Aráoz, E. (2024). ROSA: An Andean network of social–ecological observatories. *Mountain Research and Development, 44*(4), A1–A10. https://doi.org/10.1659/mrd.2023.00048

Capecchi, I., Grilli, G., Barbierato, E., & Sacchelli, S. (2021). A spatial multi-criteria decision support system for stress recovery-oriented forest management. In A. Bisello, D. Vettorato, D. Ludlow, & C. Baranzelli (Eds.), *Smart and sustainable planning for cities and regions: Results of SSPCR 2019—Open access contributions* (pp. 171–184). Springer. https://doi.org/10.1007/978-3-030-57764-3_12

Carone, P., De Toro, P., & Franciosa, A. (2017). Evaluation of urban processes on health in historic urban landscape approach: Experimentation in the metropolitan area of Naples (Italy). *Quality Innovation Prosperity, 21*(1), 202–222. https://doi.org/10.12776/qip.v21i1.793

Castillo-Eguskitza, N., Rescia, A. J., & Onaindia, M. (2017). Urdaibai biosphere reserve

(Biscay, Spain): Conservation against development? *Science of the Total Environment, 592*, 124–133. https://doi.org/10.1016/j.scitotenv.2017.03.076

Chai-allah, A., Fox, N., Günther, F., Bentayeb, F., Brunschwig, G., Bimonte, S., & Joly, F. (2023). Mining crowdsourced text to capture hikers' perceptions associated with landscape features and outdoor physical activities. *Ecological Informatics, 78*, Article 102332. https://doi.org/10.1016/j.ecoinf.2023.102332

Chen, Y., Zhao, P., Xu, Q., Qu, B., Li, D., Clement, S., & Li, L. (2023). Relating biodiversity with health disparities of human population: An ecological study across the United States. *One Health, 16*, Article 100548. https://doi.org/10.1016/j.onehlt.2023.100548

Cobacho, S. P., Wanke, S., Konstantinou, Z., & El Serafy, G. (2020). Impacts of shellfish reef management on the provision of ecosystem services resulting from climate change in the Dutch Wadden Sea. *Marine Policy, 119*, Article 104058. https://doi.org/10.1016/j.marpol.2020.104058

Cordero-Penín, V., Abramic, A., García-Mendoza, A., Otero-Ferrer, F., & Haroun, R. (2023). Mapping marine ecosystem services potential across an oceanic archipelago: Applicability and limitations for decision-making. *Ecosystem Services, 60*, Article 101517. https://doi.org/10.1016/j.ecoser.2023.101517

Costanza, R., Daly, L., Fioramonti, L., Giovannini, E., Kubiszewski, I., Mortensen, L. F., Pickett, K. E., Ragnarsdottir, K. V., De Vogli, R., & Wilkinson, R. (2016). Modelling and measuring sustainable wellbeing in connection with the UN Sustainable Development Goals. *Ecological Economics*, *130*, 350-355. http://dx.doi.org/10.1016/j.ecolecon.2016.07.009

Danaher, M., Wu, J., & Hewson, M. (2021). Sustainability: A regional Australian experience of educating secondary geography teachers. *Education Sciences*, *11*(3), 126. https://doi.org/10.3390/educsci11030126

Davison, S. M. C., White, M. P., Pahl, S., Taylor, T., Fielding, K., Roberts, B. R., Economou, T., McMeel, O., Kellett, P., & Fleming, L. E. (2021). Public concern about, and desire for research into, the human health effects of marine plastic pollution: Results from a 15-country survey across Europe and Australia. *Global Environmental Change*, *69*, 102309. https://doi.org/10.1016/j.gloenvcha.2021.102309

de Alencar, N. M. P., Le Tissier, M., Paterson, S. K., & Newton, A. (2020). Circles of coastal sustainability: A framework for coastal management. *Sustainability, 12*(12), Article 4886. https://doi.org/10.3390/su12124886

de Guzman, E. B., Escobedo, F. J., & O'Leary, R. (2022). A socio-ecological approach to align tree stewardship programs with public health benefits in marginalized neighborhoods in Los Angeles, USA. *Frontiers in Sustainable Cities, 4*, Article 944182. https://doi.org/10.3389/frsc.2022.944182

Dennis, M., & James, P. (2016). User participation in urban green commons: Exploring the links between access, voluntarism, biodiversity and well being. *Urban Forestry & Urban Greening, 15*, 22–31. https://doi.org/10.1016/j.ufug.2015.11.009

Dias, B. G., da Silva Onevetch, R. T., dos Santos, J. A. R., & da Cunha Lopes, G. (2022). Competences for sustainable development goals: The challenge in business administration education. *Journal of Teacher Education for Sustainability*, *24*(1), 73-86. https://doi.org/10.2478/jtes-2022-0006 dos Santos Facundes, A., Rodriguez Chuma, V. J. U., & Mustin, K. (2024). Urban green space exposure is low and unequally distributed in an Amazonian metropolis. *Environmental Conservation, 51*(3), 168–178. https://doi.org/10.1017/S0376892924000092

Duku, E., Mattah, P. A. D., & Angnuureng, D. B. (2022). Assessment of wetland ecosystem services and human wellbeing nexus in sub-Saharan Africa: Empirical evidence from a socio-ecological landscape of Ghana. *Environmental and Sustainability Indicators, 15*, Article 100186. https://doi.org/10.1016/j.indic.2022.100186

European Commission. (n.d.). *Causes of climate change*. Retrieved December 4, 2023, from https://climate.ec.europa.eu/climate-change/causes-climate-change_en

European Environment Agency. (n.d.). *State of Europe's environment*. European Environment Agency. Retrieved December 12, 2023, from https://www.eea.europa.eu/

Ferguson, L. A., Ferguson, M. D., Rodrigues, K., Evensen, D., Caraynoff, A. R., Persson, K., Porter, J. B., & Eisenhaure, S. (2024). The role of health and wellbeing in shaping local park experiences during the COVID-19 pandemic. *Journal of Outdoor Recreation and Tourism, 46*, Article 100739. https://doi.org/10.1016/j.jort.2024.100739

Fernandez-Anez, N., Krasovskiy, A., Müller, M., Vacik, H., Baetens, J., Hukić, E., Kapovic Solomun, M., Atanassova, I., Glushkova, M., Bogunovic, I., Fajkovic, H., Djuma, H., Boustras, G., Adamek, M., Devetter, M., Hrabalikova, M., Huska, D., Martínez Barroso, P., Vaverkova, M. D., … Cerdà, A. (2021). Current wildland fire patterns and challenges in Europe: A synthesis of national perspectives. *Air, Soil and Water Research*, *14*, 11786221211028185. https://doi.org/10.1177/11786221211028185

Ferreira, M. E., & Pitarma, R. (2021). Enhancing ecocentric environmental attitudes: An experience of science teaching to inspire students to value trees. *Journal of Teacher Education for Sustainability*, *23*(1), 132-149. https://doi.org/10.2478/jtes-2021-0010

Fioramonti, L., Coscieme, L., Costanza, R., Kubiszewski, I., Trebeck, K., Wallis, S., Roberts, D., Mortensen, L. F., Pickett, K., Wilkinson, R., Ragnarsdottir, K. V., McGlade, J., Lovins, H., & De Vogli, R. (2022). Wellbeing economy: An effective paradigm to mainstream post-growth policies? *Ecological Economics, 192*, 107261. https://doi.org/10.1016/j.ecolecon.2021.107261

Fry, B. P., Agarwala, M., Atkinson, G., Clements, T., Homewood, K., Mourato, S., Rowcliffe, J. M., Wallace, G., & Milner-Gulland, E. J. (2017). Monitoring local well-being in environmental interventions: A consideration of practical trade-offs. *Oryx*, *51*(1), 68-76. https://doi.org/10.1017/S003060531500112X

Gašparović, S., Sopina, A., & Zeneral, A. (2022). Impacts of Zagreb's urban development on dynamic changes in stream landscapes from mid-twentieth century. *Land, 11*(5), Article 692. https://doi.org/10.3390/land11050692

Haraldsson, H. V. (2004). *Introduction to systems thinking and causal loop diagrams* (5th rev. ed.; Report No. 1:2004). Department of Chemical Engineering, Lund University. https://www.researchgate.net/publication/258261003_Introduction_to_system_thinking_and_causal_loop_diagrams

Hargreaves, P. K., & Watmough, G. R. (2020). Satellite Earth observation of socioeconomic conditions for improved poverty reporting. In M. Collins (Ed.), *Proceedings of SPIE: Space, satellites, and sustainability* (Vol. 11527, 1152708). SPIE.

https://doi.org/10.1117/12.2570831

Hascher, T., & Waber, J. (2021). Teacher well-being: A systematic review of the research literature from the year 2000–2019. *Educational Research Review*, *34*, 100411. https://doi.org/10.1016/j.edurev.2021.100411

Herrmann, S. M., Sall, I., & Sy, O. (2014). People and pixels in the Sahel: A study linking coarse-resolution remote sensing observations to land users' perceptions of their changing environment in Senegal. *Ecology and Society, 19*(3), Article 29. https://doi.org/10.5751/ES-06710-190329

Hermoso, V., Carvalho, S. B., Giakoumi, S., Goldsborough, D., Katsanevakis, S., Leontiou, S., Markantonatou, V., Rumes, B., Vogiatzakis, I. N., & Yates, K. L. (2022). The EU Biodiversity Strategy for 2030: Opportunities and challenges on the path towards biodiversity recovery. *Environmental Science & Policy*, *127*, 263–271. https://doi.org/10.1016/j.envsci.2021.10.028

Hjalsted, A. W., Laurent, A., Andersen, M. M., Olsen, K. H., Ryberg, M., & Hauschild, M. (2021). Sharing the safe operating space: Exploring ethical allocation principles to operationalize the planetary boundaries and assess absolute sustainability at individual and industrial sector levels. *Journal of Industrial Ecology*, *25*(1), 6–19. https://doi.org/10.1111/jiec.13050

Igini, M. (2022). Top 6 Environmental Issues in Europe in 2024, *Earth.org.* https://earth.org/environmental-issues-in-europe/

Iliško, D., Oļehnoviča, E., Ostrovska, I., Akmene, V., & Salīte, I. (2017). Meeting the challenges of ESD competency-based curriculum in a vocational school setting. *Discourse and Communication for Sustainable Education*, 8(2), 103113. https://doi.org/10.1515/dcse-2017-0019

Jean, N., Burke, M., Xie, M., Davis, W. M., Lobell, D. B., & Ermon, S. (2016). Combining satellite imagery and machine learning to predict poverty. *Science*, *353*(6301), 790–794. https://doi.org/10.1126/science.aaf7894

Junker, J., Boesch, C., Mundry, R., Stephens, C., Lormie, M., Tweh, C., & Kühl, H. S. (2015). Education and access to fish but not economic development predict chimpanzee and mammal occurrence in West Africa. *Biological Conservation, 182*, 27–35. https://doi.org/10.1016/j.biocon.2014.11.034

Kajosaari, A., Hasanzadeh, K., Fagerholm, N., Nummi, P., Kuusisto-Hjort, P., & Kyttä, M. (2024). Predicting context-sensitive urban green space quality to support urban green infrastructure planning. *Landscape and Urban Planning, 242*, Article 104952. https://doi.org/10.1016/j.landurbplan.2023.104952

Khan, K. S., Kunz, R., Kleijnen, J., & Antes, G. (2003). Five steps to conducting a systematic review. *Journal of the Royal Society of Medicine, 96*(3), 118–121. https://doi.org/10.1177/014107680309600304

Khan, S., Murshed, M., Ozturk, I., & Khudoykulov, K. (2022). The roles of energy efficiency improvement, renewable electricity production, and financial inclusion in stimulating environmental sustainability in the Next Eleven countries. *Renewable Energy*, *193*, 1164–1176. https://doi.org/10.1016/j.renene.2022.05.065

Khomenko, S., Cirach, M., Pereira-Barboza, E., Mueller, N., Barrera-Gómez, J., Rojas-Rueda, D., de Hoogh, K., Hoek, G., & Nieuwenhuijsen, M. (2021). Premature mortality due to air pollution in European cities: A health impact assessment. *The Lancet Planetary Health, 5*(3), e121–e134. https://doi.org/10.1016/S2542-5196(20)30272-2

Klobucar, B., Östberg, J., Wiström, B., & Jansson, M. (2021). Residential urban trees—Socio-ecological factors affecting tree and shrub abundance in the city of Malmö, Sweden. *Urban Forestry & Urban Greening, 62*, Article 127118. https://doi.org/10.1016/j.ufug.2021.127118

Konu, A., & Rimpelä, M. (2002). Well-being in schools: a conceptual model. *Health promotion international*, 17(1), 79–87. https://doi.org/10.1093/heapro/17.1.79

Kohler, M., Stotten, R., Steinbacher, M., Leitinger, G., Tasser, E., Schirpke, U., Tappeiner, U., & Schermer, M. (2017). Participative spatial scenario analysis for alpine ecosystems. *Environmental Management, 60*(4), 679–692. https://doi.org/10.1007/s00267-017-0903-7

Kubitza, C., Krishna, V. V., Schulthess, U., & Jain, M. (2020). Estimating adoption and impacts of agricultural management practices in developing countries using satellite data. A scoping review. *Agronomy for Sustainable Development*, 40, 1–21. https://doi.org/10.1007/s13593-020-0610-2

Lamchin, M., Lee, W. K., & Wang, S. W. (2022). Multi-temporal analysis of past and future land-cover changes of the Third Pole. *Land, 11*(12), Article 2227. https://doi.org/10.3390/land11122227

Lähde, E., Pohja-Mykrä, M., & Schreck, J. (2024). Co-creation of socio-ecological systems knowledge to adopt an Ecosystem-based Approach and Land-Sea Interactions in maritime spatial planning. *Marine Policy, 163*, Article 106079. https://doi.org/10.1016/j.marpol.2024.106079

Li, J., Fu, J., Gao, J., Zhou, R., Zhao, Z., Yang, P., & Yi, Y. (2025). How do urban green space attributes affect visitation and satisfaction? An empirical study based on multisource data. *Cities, 156*, Article 105543. https://doi.org/10.1016/j.cities.2024.105543

Liepa, L., Rendenieks, Z., Jansons, Ā., Miezīte, O., & Dubrovskis, E. (2023). Mapping forest ecosystem service supply in two case studies in Latvia. *Applied Geography, 155*, Article 102969. https://doi.org/10.1016/j.apgeog.2023.102969

Liu, X., Liu, G., Yang, Z., Chen, B., & Ulgiati, S. (2016). Comparing national environmental and economic performances through emergy sustainability indicators: Moving environmental ethics beyond anthropocentrism toward ecocentrism. *Renewable and Sustainable Energy Reviews*, *58*, 1532-1542. https://doi.org/10.1016/j.rser.2015.12.188

Liu, H., Liu, H., & Cheng, Y. (2022a). Illustrating the multi-stakeholder perceptions of environmental pollution based on big data: Lessons from China. *Regional Sustainability, 3*(1), 12–26. https://doi.org/10.1016/j.regsus.2022.03.003

Liu, L., Fang, X., & Wu, J. (2022b). How does the local-scale relationship between ecosystem services and human wellbeing vary across broad regions? *Science of the Total Environment, 816*, Article 151493. https://doi.org/10.1016/j.scitotenv.2021.151493

Liu, Y., Liu, Z., Zhang, X., Zhang, B., Shi, J., Liu, A., Chang, S., Yang, Y., & Wang, Y. (2024). Spatially explicit priority optimization of land ecosystem services in the ecologically fragile region. *Land Use Policy, 147*, Article 107356. https://doi.org/10.1016/j.landusepol.2024.107356

Lobell, D. B., Azzari, G., Burke, M., Gourlay, S., Jin, Z., Kilic, T., & Murray, S. (2020). Eyes in the sky, boots on the ground: Assessing satellite-and ground-based approaches to crop yield measurement and analysis. *American Journal of Agricultural Economics*, *102*(1), 202–219. https://doi.org/10.1093/ajae/aaz051

Marino, D., & Tebala, D. (2022). Rural areas and well-being in EU Countries+ UK: A taxonomy and a cluster analysis. *Sustainability*, *14*(22), 15213. https://doi.org/10.3390/su142215213

Markonis, Y., Kumar, R., Hanel, M., Rakovec, O., Máca, P., & AghaKouchak, A. (2021). The rise of compound warm-season droughts in Europe. *Science Advances*, *7*(6), eabb9668. https://doi.org/10.1126/sciadv.abb9668

Maass, J. M., Balvanera, P., Castillo, A., Daily, G. C., Mooney, H. A., Ehrlich, P., Quesada, M., Miranda, A., Jaramillo, V. J., García-Oliva, F., Martínez-Yrízar, A., Cotler, H., López-Blanco, J., Pérez-Jiménez, A., Búrquez, A., Tinoco, C., Ceballos, G., Barraza, L., Ayala, R., & Sarukhán, J. (2005). Ecosystem services of tropical dry forests: Insights from long-term ecological and social research on the Pacific Coast of Mexico. *Ecology and Society, 10*(1), Article 17. https://doi.org/10.5751/ES-01219-100117

McFarlane, D. A., & Ogazon, A. G. (2011). The challenges of sustainability education. *Journal of Multidisciplinary Research, 3*(3), 81–107.

McGregor, A., Aguilar, A. M., & Lockhart, V. (2017). Environmentally smart design: Designing for social wellbeing across the city and in the workplace. *Architectural Design*, *87*(2), 48–55. https://doi.org/10.1002/ad.2152

Methorst, J., Rehdanz, K., Mueller, T., Hansjürgens, B., Bonn, A., & Böhning-Gaese, K. (2021). The importance of species diversity for human well-being in Europe. *Ecological Economics*, *181*, 106917. https://doi.org/10.1016/j.ecolecon.2020.106917

Molari, M., Dominici, L., Manso, M., Silva, C. M., & Comino, E. (2024). A socio-ecological approach to investigate the perception of green walls in cities: A comparative analysis of case studies in Turin and Lisbon. *Nature-Based Solutions, 6*, Article 100175. https://doi.org/10.1016/j.nbsj.2024.100175

Mungi, N. A., Qureshi, Q., & Jhala, Y. V. (2023). Distribution, drivers and restoration priorities of plant invasions in India. *Journal of Applied Ecology, 60*(11), 2400–2412. https://doi.org/10.1111/1365-2664.14506

Newman, R. J. S., Capitani, C., Courtney-Mustaphi, C., Thorn, J. P. R., Kariuki, R., Enns, C., & Marchant, R. (2020). Integrating insights from social-ecological interactions into sustainable land use change scenarios for small islands in the western Indian Ocean. *Sustainability, 12*(4), Article 1340. https://doi.org/10.3390/su12041340

Nielsen, K., Nielsen, M. B., Ogbonnaya, C., Känsälä, M., Saari, E., & Isaksson, K. (2017). Workplace resources to improve both employee well-being and performance: A systematic review and meta-analysis. *Work & Stress*, *31*(2), 101–120. https://doi.org/10.1080/02678373.2017.1304463

Nguyen, T. T., Hoang, T. D., Pham, M. T., Vu, T. T., Nguyen, T. H., Huynh, Q. T., & Jo, J. (2020). Monitoring agriculture areas with satellite images and deep learning. *Applied Soft Computing*, *95*, 106565. https://doi.org/10.1016/j.asoc.2020.106565

Nicholls, R. J., Lincke, D., Hinkel, J., Brown, S., Vafeidis, A. T., Meyssignac, B., Hanson, S., E., Merkens. J.-L., & Fang, J. (2021). A global analysis of subsidence, relative sea-level change and coastal flood exposure. *Nature Climate Change*, *11*(4), 338–342. https://doi.org/10.1038/s41558-021-00993-z

Organization for Economic Cooperation and Development. (2020). *How's Life? 2020: Measuring well-being*. OECD Publishing. https://doi.org/10.1787/9870c393-en

O'Rourke, R., Dunn, L., Taylor, D., O'Sullivan, A., & Donatuto, J. (2024). You say "natural resources," we say part of our community health: Using Indigenous health indicators to evaluate Coast Salish priorities when the environment is polluted. *Environmental Justice*. Advance online publication. https://doi.org/10.1089/env.2024.0035

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ, 372*, Article n71. https://doi.org/10.1136/bmj.n71

Peng, L.-P. (2020). Understanding human–nature connections through landscape socialization. *International Journal of Environmental Research and Public Health, 17*(20), Article 7593. https://doi.org/10.3390/ijerph17207593

Pollard, E. L., & Lee, P. D. (2003). Child well-being: A systematic review of the literature. *Social Indicators Research, 61*, 59–78. https://doi.org/10.1023/A:1021284215801

Rai, P. K., & Singh, J. S. (2020). Invasive alien plant species: Their impact on environment, ecosystem services and human health. *Ecological Indicators*, *111*, 106020. https://doi.org/10.1016/j.ecolind.2020.106020

Raj, K. S. (2016). Well-being in residency: A systematic review. *Journal of Graduate Medical Education*, *8*(5), 674–684. https://doi.org/10.4300/JGME-D-15-00764.1

Ram, S. A., Tihanyi, D., MacLean, H. L., & Posen, I. D. (2025). Crafting a definition of sustainability for engineering education and applying it to assess curriculum. *Sustainability Science and Technology*, *2*(2), 024004. https://doi.org/10.1088/2977-3504/adcf28

Rigley, E., Chapman, A., Evers, C., & McNeill, W. (2023). Anthropocentrism and environmental wellbeing in AI ethics standards: A scoping review and discussion. *AI*, *4*(4), 844–874. https://doi.org/10.3390/ai4040043

Rülke, J., Rieckmann, M., Nzau, J. M., & Teucher, M. (2020). How ecocentrism and anthropocentrism influence human–environment relationships in a Kenyan biodiversity hotspot. *Sustainability*, *12*(19), 8213. https://doi.org/10.3390/su12198213

Sági, J., & Engelberth, I. (2018). Regional development and well-being of regions in Hungary. *Polgári Szemle (Civic Review), 14*(Special Issue), 184–194. https://doi.org/10.24307/psz.2018.0412

Sajjad, M., Li, Y., Li, Y., Chan, J. C. L., & Khalid, S. (2019). Integrating typhoon destructive potential and social-ecological systems toward resilient coastal communities. *Earth's Future, 7*(7), 805–818. https://doi.org/10.1029/2019EF001226

Santos Vieira, F. A., Santos, D. T. V., Bragagnolo, C., Campos-Silva, J. V., Correia, R. A. H., Jepson, P., Malhado, A. C. M., & Ladle, R. J. (2021). Social media data reveals multiple cultural services along the 8,500 kilometers of Brazilian coastline. *Ocean & Coastal Management, 214*, Article 105918.

https://doi.org/10.1016/j.ocecoaman.2021.105918
Salīte, I., Briede, L., Ivanova, O., Świtała, E., & Boče, A. (2024). An evolutionary-ecological perspective in teacher education: A transdisciplinary approach in ecopedagogy. *Journal of Teacher Education for Sustainability, 26*(2), 211–227. https://doi.org/10.2478/jtes-2024-0023
Samuelsson, K., Colding, J., & Barthel, S. (2019). Urban resilience at eye level: Spatial analysis of empirically defined experiential landscapes. *Landscape and Urban Planning, 187*, 70–80. https://doi.org/10.1016/j.landurbplan.2019.03.015
Saraiva, E., Faria, F., Ferreira, C., & Azevedo, M. M. (2024). Education for sustainability through field activities and game-based tasks. *Journal of Teacher Education for Sustainability*, *26*(1), 119–140. https://doi.org/10.2478/jtes-2024-0008
Schwantes, A. M., Firkowski, C. R., Affinito, F., Rodriguez, P. S., Fortin, M.-J., & Gonzalez, A. (2024). Monitoring ecosystem services with essential ecosystem service variables. *Frontiers in Ecology and the Environment, 22*(8), Article e2792. https://doi.org/10.1002/fee.2792
Scown, M. W., Flotemersch, J. E., Spanbauer, T. L., Eason, T., Garmestani, A., & Chaffin, B. C. (2017). People and water: Exploring the social-ecological condition of watersheds of the United States. *Elementa: Science of the Anthropocene, 5*, Article 64. https://doi.org/10.1525/elementa.189
Senf, C., Buras, A., Zang, C. S., Rammig, A., & Seidl, R. (2020). Excess forest mortality is consistently linked to drought across Europe. *Nature Communications, 11*(1), Article 6200. https://doi.org/10.1038/s41467-020-19924-1
Sicard, P., Agathokleous, E., De Marco, A., Paoletti, E., & Calatayud, V. (2021). Urban population exposure to air pollution in Europe over the last decades. *Environmental Sciences Europe*, *33*(1), 1–12. https://doi.org/10.1186/s12302-020-00450-2
Sietz, D., Lüdeke, M. K. B., & Walther, C. (2011). Categorisation of typical vulnerability patterns in global drylands. *Global Environmental Change, 21*(2), 431–440. https://doi.org/10.1016/j.gloenvcha.2010.11.005
Sitotaw, T. M., Willemen, L., Meshesha, D. T., & Nelson, A. D. (2024). Empirical assessments of small-scale ecosystem service flows in rural mosaic landscapes in the Ethiopian highlands. *Ecosystem Services, 67*, Article 101622. https://doi.org/10.1016/j.ecoser.2024.101622
Sharma-Brymer, V., Brymer, E., Willis, R., & Leach, M. (2024). Synergies of affordances and place-based relationality in Forest School practice: Implications for socio-emotional well-being. *Frontiers in Psychology, 15*, Article 1352374. https://doi.org/10.3389/fpsyg.2024.1352374
Stankiewicz, J., König, A., Pickar, K. A., & Weiss, S. (2023). How certain is good enough? Managing data quality and uncertainty in ordinal citizen science data sets for evidence-based policies on fresh water. *Citizen Science: Theory and Practice, 8*(1), Article 39. https://doi.org/10.5334/cstp.592
Svoray, T., Dorman, M., Shahar, G., & Kloog, I. (2018). Demonstrating the effect of exposure to nature on happy facial expressions via Flickr data: Advantages of non-intrusive social network data analyses and geoinformatics methodologies. *Journal of Environmental Psychology, 58*, 93–100. https://doi.org/10.1016/j.jenvp.2018.07.006

Thapa, P., Torralba, M., Nölke, N., Chowdhury, K., Nagendra, H., & Plieninger, T. (2024). Disentangling associations of human wellbeing with green infrastructure, degree of urbanity, and social factors around an Asian megacity. *Landscape Ecology, 39*(8), Article 152. https://doi.org/10.1007/s10980-024-01937-6

Thompson, S. C. G., & Barton, M. A. (1994). Ecocentric and anthropocentric attitudes toward the environment. *Journal of Environmental Psychology*, *14*(2), 149–157. https://doi.org/10.1016/S0272-4944(05)80168-9

Tilman, A. R., Krueger, E. H., McManus, L. C., & Watson, J. R. (2024). Maintaining human wellbeing as socio-environmental systems undergo regime shifts. *Ecological Economics, 221*(3), Article 108194. https://doi.org/10.1016/j.ecolecon.2024.108194

Tingzon, I., Orden, A., Go, K. T., Sy, S., Sekara, V., Weber, I., Fatehkia, M., García-Herranz, M., & Kim, D. (2019). Mapping poverty in the Philippines using machine learning, satellite imagery, and crowd-sourced geospatial information. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *42*, 425–431. https://doi.org/10.5194/isprs-archives-XLII-4-W19-425-2019

Tomaney, J. (2017). Region and place III: Well-being. *Progress in Human Geography*, *41*(1), 99-107. https://doi.org/10.1177/0309132515601775

Ulman, S.-R., Mihai, C., & Cautisanu, C. (2020). Peculiarities of the relation between human and environmental wellbeing in different stages of national development. *Sustainability, 12*(19), Article 8106. https://doi.org/10.3390/su12198106

United Nations Educational, Scientific and Cultural Organization. (2022). *The UNITWIN/UNESCO Chairs Programme: guidelines and procedures*. UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000380998

United Nations. (2015). *Transforming our world: The 2030 Agenda for Sustainable Development*. United Nations. https://sdgs.un.org/2030agenda

van de Kerk, G., & Manuel, A. (2012). *Are human wellbeing and environmental wellbeing at collision course? The role of good governance and other factors in preventing a collision* (Research paper). Sustainable Society Foundation. https://ssi.wi.th-koeln.de/documents/ssfindex/Research_paper-HW-EW.pdf

Vaz, A. S., Kueffer, C., Kull, C. A., Richardson, D. M., Vicente, J. R., Kühn, I., Schröter, M., Hauck, J., Bonn, A., & Honrado, J. P. (2017). Integrating ecosystem services and disservices: Insights from plant invasions. *Ecosystem Services, 23*, 94–107. https://doi.org/10.1016/j.ecoser.2016.11.017

Viana, C. M., Girão, I., & Rocha, J. (2019). Long-term satellite image time-series for land use/land cover change detection using refined open source data in a rural region. *Remote Sensing*, *11*(9), 1104. https://doi.org/10.3390/rs11091104

Veneri, P., & Murtin, F. (2019). Where are the highest living standards? Measuring well-being and inclusiveness in OECD regions. *Regional Studies*, *53*(5), 657–666. https://doi.org/10.1080/00343404.2018.1463091

Vieira, D. C. S., Borrelli, P., Jahanianfard, D., Benali, A., Scarpa, S., & Panagos, P. (2023). Wildfires in Europe: Burned soils require attention. *Environmental research*, *217*, 114936. https://doi.org/10.1016/j.envres.2022.114936

Vigl, L. E., Marsoner, T., Giombini, V., Pecher, C., Simion, H., Stemle, E., Tasser, E., & Depellegrin, D. (2021). Harnessing artificial intelligence technology and social media data to support cultural ecosystem service assessments. *People and Nature, 3*(3), 673–685. https://doi.org/10.1002/pan3.10199

von Döhren, P., & Haase, D. (2015). Ecosystem disservices research: A review of the state of the art with a focus on cities. *Ecological Indicators, 52*, 490–497. https://doi.org/10.1016/j.ecolind.2014.12.027

Wals, A. E., & Benavot, A. (2017). Can we meet the sustainability challenges? The role of education and lifelong learning. *European Journal of Education*, *52*(4), 404–413. https://doi.org/10.1111/ejed.12250

Wanchana, Y., Inprom, P., Rawang, W., & Ayudhya, A. O. J. N. (2020). Environmental education competency: Enhancing the work of teachers. *Journal of Teacher Education for Sustainability*, *22*(2), 140–152. https://doi.org/10.2478/jtes-2020-0021

Wang, D., Hao, H., Liu, H., Sun, L., & Li, Y. (2023a). Dynamic change of habitat quality and its key driving factors in Ningxia Hui Autonomous Region, China. *Nature Conservation, 53*, 125–155. https://doi.org/10.3897/natureconservation.53.102810

Wang, Y., Liu, Y., Wu, X., Wang, X., Yao, Y., Zhang, Z., & Fu, B. (2023b). Ecological restoration in Tibet optimises the cognitive structures of stakeholders on social-ecological systems. *People and Nature, 5*(5), 1664–1679. https://doi.org/10.1002/pan3.10532

Wang, X., & Chen, S. (2024). Psychometric evaluation of the extended inclusion of nature in self scale in Chinese adults through the Rasch analysis. *People and Nature, 6*(6), 2431–2448. https://doi.org/10.1002/pan3.10726

World Commission on Environment and Development. (1987). *Our common future* (A/42/427). United Nations. https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf

World Health Organization. Regional Office for Europe. (2021). *Nature, biodiversity and health: An overview of interconnections*. World Health Organization. Regional Office for Europe. https://apps.who.int/iris/handle/10665/341376

Yeh, C., Perez, A., Driscoll, A., Azzari, G., Tang, Z., Lobell, D. B., Ermon, S., & Burke, M. (2020). Using publicly available satellite imagery and deep learning to understand economic well-being in Africa. *Nature Communications, 11*, 2583. https://doi.org/10.1038/s41467-020-16185-w

Yi, S., Wang, H., Xie, L., Wang, C., & Huang, X. (2024). Spatio-temporal dynamics and drivers of ecosystem service bundles in the Altay Region: Implications for sustainable land management. *Land, 13*(6), Article 805. https://doi.org/10.3390/land13060805

Zandvliet, D. B., & Paul, A. (2023). Social ecology and environmental diversity in teacher education. *Journal of Teacher Education for Sustainability, 25*(1), 168–181. https://doi.org/10.2478/jtes-2023-0011

Zeng, M., Ma, Q., Gan, K. K., & Chen, Z. (2025). Evaluation of social value in urban parks through implementation of SolVES model in Mianyang People's Park. In B. J. He, D. Prasad, L. Yan, A. Cheshmehzangi, & G. Pignatta (Eds.), *International conference on urban climate, sustainability and urban design (UCSUD 2023)* (Lecture Notes in Civil Engineering, Vol. 559, pp. 402–423). Springer Nature Singapore. https://doi.org/10.1007/978-981-97-8401-1_29

Zhang, Y., Zhong, C., & Wang, Y. (2024). Measurement, spatial differences and driving effects of well-being levels in China. *PLOS ONE, 19*(10), e0311291.

https://doi.org/10.1371/journal.pone.0311291

Zhu, Y., Zhang, R., & Cui, J. (2022). Spatial differentiation and influencing factors in the ecological well-being performance of urban agglomerations in the middle reaches of the Yangtze River: A hierarchical perspective. *International Journal of Environmental Research and Public Health, 19*(19), Article 12867. https://doi.org/10.3390/ijerph191912867

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