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Systematic Review

Integrating Land Use, Ecosystem Service, and Human Well-Being: A Systematic Review

Mengxue Liu [1,2,3], Hejie Wei [4], Xiaobin Dong [1,2,3,*], Xue-Chao Wang [1,2,3], Bingyu Zhao [2] and Ying Zhang [1,2,3]

1 State Key Laboratory of Earth Surface Processes and Resource Ecology, Beijing Normal University, Beijing 100875, China; mengxueliu@mail.bnu.edu.cn (M.L.); xcwang@bnu.edu.cn (X.-C.W.); zhangying19@mail.bnu.edu.cn (Y.Z.)
2 Faculty of Geographical Science, Beijing Normal University, Beijing 100875, China; bingyuzhao@mail.bnu.edu.cn
3 College of Resources Science and Technology, Beijing Normal University, Beijing 100875, China
4 College of Resources and Environmental Sciences, Henan Agricultural University, Zhengzhou 450002, China; hjwei@henau.edu.cn
* Correspondence: xbdong@bnu.edu.cn

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Abstract: Global change, population growth, and urbanization have been exerting a severe influence on the environment, including the social system and ecosystem. To find solutions based on nature, clarifying the complicated mechanisms and feedback among land use/land cover changes, ecosystem services, and human well-being, is increasingly crucial. However, the in-depth linkages among these three elements have not been clearly and systematically illustrated, present research paths have not been summarized well, and the future research trends on this topic have not been reasonably discussed. In this sense, the purpose of this paper is to provide an insight into how land use/land cover changes, ecosystem services, and human well-being are linked, as well as their relationships, interacting ways, applications in solving ecological and socioeconomic problems, and to reveal their future research trends. Here, we use a systematic literature review of the peer-reviewed literature to conclude the state of the art and the progress, emphasize the hotspot, and reveal the future trend of the nexus among the three aspects. Results show that (1) ecosystem services are generally altered by the changes in land use type, spatial pattern, and intensity; (2) the nexus among land use change, ecosystem services, and human well-being is usually used for supporting poverty alleviation, ecosystem health, biodiversity conservation, and sustainable development; (3) future research on land use/land cover changes, ecosystem services, and human well-being should mainly focus on strengthening multiscale correlation, driving force analysis, the correlation among different group characteristics, land use types and ecosystem service preferences, and the impact of climate change on ecosystem services and human well-being. This study provides an enhanced understanding of the nexus among the three aspects and a reference for future studies to mitigate the relevant problems.

Keywords: land use/land cover change; ecosystem services; human well-being; relationships

1. Introduction

With the intensification of global human activities and resource consumption, environmental and ecological problems, which have been seriously influencing the stability of the ecosystem and social system, have been drawing increasing attention worldwide [1–3].

Ecosystem services represent the various benefits that humans acquire from the ecosystem. Controversies regarding the classification of ecosystem services have occurred. Ecosystem services are usually classified in four categories from the perspective of function: provision, supporting, regulating, and cultural services. Although this classification method is relatively mature, the classification does not distinguish between the intermediate process and the final service. As a result, double counting problems will occur in service accounting. In the Conceptual Framework of the UK National Ecosystem Assessment (NEA), an ecosystem is defined by its structure and processes. The final ecosystem services are the last link in the chain of natural processes, contributing to human well-being which can reduce the risk of double counting errors [4]. The Millennium Ecosystem Assessment (MA) [5] revealed that 60% of the world's ecosystem services (15 out of 24) were degraded or unsustainable; the 2019 Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) Global Assessment Report [6] indicated that 78% of the benefits (14 of 18 categories) that humans derive from nature are exhibiting a rapid decline, and land use, population, economy, technology, and other human activities are important driving factors. Land use/Land cover change (LUCC) is a generic term for land use and land cover. Land use is the collective name, including, for example, the economic forests and the firewood forests, indicating the development, operation, and the use of land resources in achieving certain economic, social, and ecological benefits; it emphasizes social and economic attributes. Land cover, including, for example, the temperate forests and deciduous forests, represents properties of the Earth's terrestrial surface and immediate subsurface parts which contain biota, soil, surface and groundwater, and human structures. It emphasizes the natural state [7]. Although the land use and land cover review the land type from two different perspectives, they actually refer to the same objects in many cases. Therefore, when conducting land cover and land use surveys and research work, the two are often considered together to establish a unified classification system and are collectively referred to as the land use/land cover classification system. LUCC, as an important manifestation of human activities, can exert considerable effects on both Earth's surface structure and regional climate [8], consequently influencing hydrological resources [9], soil [10], biodiversity [11], and biogeochemical cycles [12]. LUCC has impacts on the structure and function of the entire ecosystem [13], which directly influences the condition and integrity of the ecosystem, and ultimately affects the quantity and quality of ecosystem services. Furthermore, ecosystem services are the basis of natural environmental conditions that humans rely on for survival; they are formed by ecosystems and ecological processes, and their changes can impact all the components of human well-being in direct or indirect ways [14,15].

The ecosystem network is complex and sophisticated [16]. Faced with unprecedented environmental pressures worldwide, humans have begun to seek nature-based solutions [17]. They hope that the ecosystem can solve ecological and environmental problems through self-regulation and feedback. However, the interaction of a large number of complex elements, processes, and structures in the ecosystem makes it extremely difficult to clarify these difficult relationships. In the past, the launches of the Global Land Project [18] and Future Earth have made the line of "LUCC–Ecosystem Services–Human Well-being" clear. This conceptual framework has linked driver changes, ecosystem services, and human well-being so that the assessment of LUCC can be used as an interface between the analysis of ecosystems and human well-being. Clarifying this relationship can effectively reveal the internal interactions between humans and natural systems, improve our understanding of ecosystem service processes and mechanisms, and help us comprehend regional ecological environment changes. It is helpful to formulate and implement land use planning and ecological protection policies [19]. It also has important scientific significance for promoting regional sustainable development [20].

Most previous research has focused on the relationships between LUCC and ecosystem services [21,22] or the relationship between ecosystem services and human well-being [23,24]. Several pieces of the literature [25,26] have researched the impact of LUCC on the structure and function of ecosystems and ecosystem services. Research in this field is relatively mature, but existing mechanistic studies are not dicussed in-depth enough [27]. The research on the relationship between ecosystem services and human well-being have focused on the spatiotemporal changes within each other. Nevertheless, LUCC, ecosystem services, and human well-being have a multilevel, complex, and nonlinear relationship, and they are affected by multiple factors. It is increasingly crucial to identify the linkages among these three aspects, summarize the present research paths, and discuss future trends.

The purpose of this systematic literature review work is to improve our understanding of the current scientific knowledge and research works regarding LUCC, ecosystem services, and human well-being, and to clarify the complex relationship among LUCC, ecosystem services, and human well-being based on the "LUCC–Ecosystem Services–Human Well-being" framework, pointing the way forward for future research works. Though the topic of "LUCC-Ecosystem Services-Human Well-being" is multi-interdisciplinary, this review focuses on addressing the following questions: (1) To describe the main pathways, methods and limitations in studying the relationships between LUCC and ecosystem services; (2) To identify the human well-being and how human well-being links with ecosystem services, intending to solve problems; (3) To present how LUCC, ecosystem services, and human well-being are linked and discussed in future research trends. By summarizing existing research and discussing future research trends, this paper will provide insight comprehension and promote the research and application of the relationships among LUCC, ecosystem services, and human well-being, which is critical for decision makers in seeking nature-based solutions and achieving sustainable development.

2. Materials and Methods

2.1. Development in the Topic of "LUCC–Ecosystem Services–Human Well-Being"

To show the development of the main line of "LUCC–ecosystem services–human well-being", we count the events related to the theme of LUCC, ecosystem services, and human well-being, and the result is shown in Figure 1. First, Constanze [28] and Daily [29] led the wave of worldwide assessment of ecosystem service value in 1997. After the launch of the Global Land Project, scholars have focused on LUCC and ecosystem services. MA creatively proposed a framework for ecosystem services and human well-being, building a bridge for scholars to explore the interaction of the natural ecosystem and socioeconomic system. Planetary Boundaries, SDGs, and Nature-Based Solutions have not explicitly mentioned the comprehensive research of "LUCC, ecosystem services and human well-being" but they integrated this theme in their study. The Future Earth was apparently the first to propose the theme of "LUCC, ecosystem services, and human well-being" as their first topic. Therefore, the development of "LUCC, ecosystem services and human well-being" has shown the significance and necessity of studying this theme.

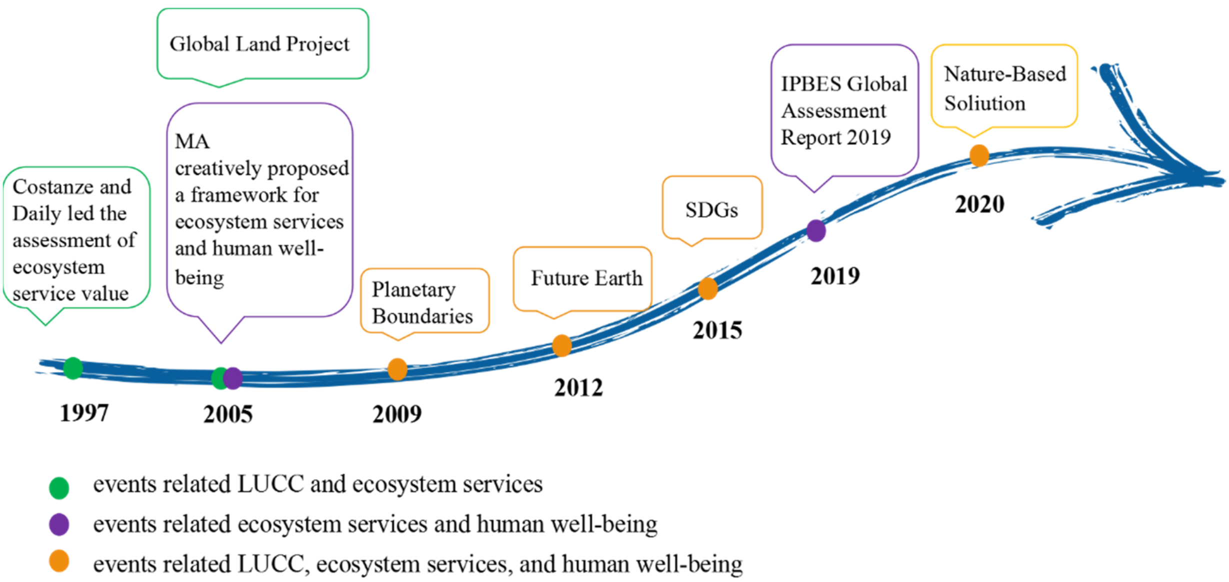


Figure 1. Events in the theme of LUCC, ecosystem services, and human well-being.

2.2. Systematic Search and Literature Selection

To identify relevant studies, a systematic methodology [30] was adopted. The method consisted of three stages: (1) determine the research questions to define the study scope; (2) conduct a systematic search using keywords; (3) analyze and report the results in detail.

The objective of this review is to address how LUCC, ecosystem services, and human well-being are linked, and what the future research trends are. However, when we used 'land use change' OR 'land cover change' as the first search, then 'ecosystem services' as the second search, and 'human well-being' as the final search, 167 papers were found, but there were only 8 papers where the relationships among LUCC, ecosystem services, and human well-being were explicitly discussed. The number of relevant results using the above methodology was rare to conduct this study. In these cases, additional intelligent search approaches were utilized. We divided the study into three research parts: (1) the relationship between LUCC and ecosystem services; (2) the relationship between ecosystem services and human well-being; (3) the relationship among LUCC, ecosystem services, and human well-being. Then, we summarized the relationships based on the results.

In order to determine the scope of the research, this paper presents related research questions as followed.

The main research questions of the relationship between LUCC and ecosystem services are:

1. What are the present research paths in linking LUCC and ecosystem services?
2. What are the main methods to measure the relationship between LUCC and ecosystem services?
3. What are the current challenges in studying the relationships between LUCC and ecosystem services?

The main research questions of the relationship between ecosystem services and human well-being are:

1. What is the connotation of human well-being?
2. What are evaluation indicators to measure human well-being?
3. What is the state of the art in studying the relationships between ecosystem services and human well-being?
4. What are the current challenges in studying the relationships between ecosystem services and human well-being?

The main research questions of the relationship among LUCC, ecosystem services, and human well-being are:

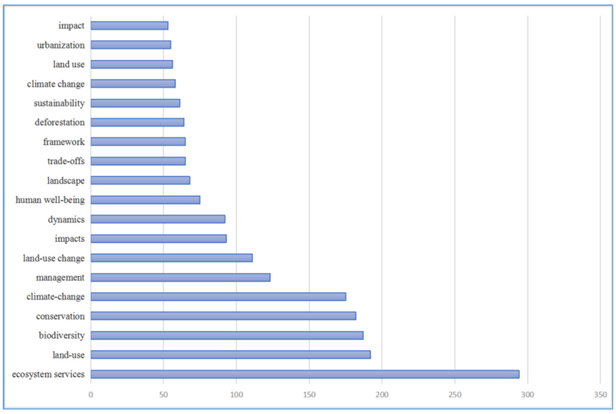
1. How are LUCC, ecosystem services, and human well-being linked?
2. What are the future research trends?

The search was conducted through the Web of Science. The search time range was the maximum time range of the database. Only the paper published in a scientific peer-review journal was selected, and the paper should be written in the English language. The keywords must exist either in title, keywords, or abstract. Papers that were not accessible were not included in this review. In addition, reference lists were scanned for other relevant articles. When conducting the first part of the search of LUCC and ecosystem services, 'land use change' OR 'land cover change' AND 'ecosystem services' were employed. Then, 4536 papers were found on this topic. Due to the extensive research conducted in this topic and many reviews having summarized this topic from different perspectives [22,31,32], we only selected the 50 most representative papers in studying the relationships between LUCC and ecosystem services, according to our experience in this field to conduct our review. 'ecosystem services' AND 'human well-being' were used to conduct the second part of the search of ecosystem services and human well-being; then 2511 papers were obtained. Only 81 papers met the objectives. When conducting the third part of the research, 'land use change' OR 'land cover change' was the first search, then 'ecosystem services' was the second search, and 'human well-being' was the final research. We obtained 167 papers, but the papers which definitely described the relationships among LUCC, ecosystem services, and human well-being were only 8. This reflects the limited number of research in revealing the relationships among LUCC, ecosystem services, and human well-being, despite the large number of studies mentioning LUCC and ecosystem services or ecosystem services and human well-being. A descriptive analysis of the results was performed in the results section.

2.3. An Overview of the Keyword Search

To enrich the analysis, we utilized the visualization techniques to conduct word frequency analysis. Word frequency analysis, also known as the content clouds, can summarize the contents of a document by depicting the words which would be larger as they appear more often within the cloud. We collect all related papers in LUCC, ecosystem services, and human well-being to conduct a literature survey. The keywords of these papers were counted and are shown in Figure 2a; the larger the font is, the higher the frequency of a keyword is. Keywords with a frequency larger than 50 were counted in Figure 2b. As shown in Figure 2, aside from the topics in the keywords, these papers also focused on "biodiversity", "conservation", "climate change", and "management", in which the frequency was higher than 100. It shows the fields where scholars used such topics to contribute to. Following closely were the keywords "impacts" and "dynamic", suggesting the common perspective used to explore the relationship among LUCC, ecosystem services, and human well-being. "Trade-off" and "framework" were the most common method to study LUCC, ecosystem services, and human well-being. Moreover, "deforestation" and "urbanization" were two popular topics in studying the relationship among LUCC, ecosystem services, and human well-being.

(a)



(b)

Figure 2. (**a**) Tag cloud of the keywords related to "LUCC–ecosystem services–human well-being", where a larger font denotes a higher frequency; (**b**) count of keywords with a frequency larger than 50.

3. Results

3.1. LUCC and Ecosystem Services

LUCC is the most direct present of human activities [33]. The changes in the utilization way, structure, composition, pattern, and spatial configuration of land use can affect ecological processes, such as soil erosion, cycle of matter, and biogeochemical cycle, ultimately affecting ecosystem services [34]. The change degree of ecosystem services depends on specific land use practices. LUCC and ecosystem services are media for comprehending the dynamic and complicated relationship between social and natural systems. The impacts of LUCC on ecosystem services occur mainly in three ways: changing biodiversity [35], ecosystem processes [36], and habitats [37]. LUCC and ecosystem services have a complex relationship with feedback and adjustments. LUCC can directly change the structure and function of the ecosystem. The evaluation results of ecosystem services can offer theoretical support for the land use-related policy setting. Understanding the impact of LUCC on ecosystem services allows for clarifying the process of LUCC and accurately assessing ecosystem services, which will help formulate and implement land use planning and ecological conservation policies.

Many studies have been designed for demonstrating the relationship between LUCC and ecosystem services. The study scale ranges from global and national to regional [38,39], and the study cases include ecologically fragile areas [40] and developed regions [41]. The use of LUCC to evaluate ecosystem services mainly focuses on (1) the adoption of data to analyze historical changes in ecosystem services [42,43], and (2) the prediction of future changes in ecosystem services under different land use change scenarios [44,45]. A quantitative analysis of the impact of LUCC on ecosystem services is a key step in building a bridge between land management and ecosystem services. The relationships between the two elements can be summarized into three categories: (1) changing ecosystem services through changes in land use types; (2) changing ecosystem services through changes in land use spatial patterns; (3) changing ecosystem services through changes in land use intensity. After reviewing related research in studying the relationships between LUCC and ecosystem services, the relationship between LUCC and ecosystem services was summarized and visualized in Figure 3.

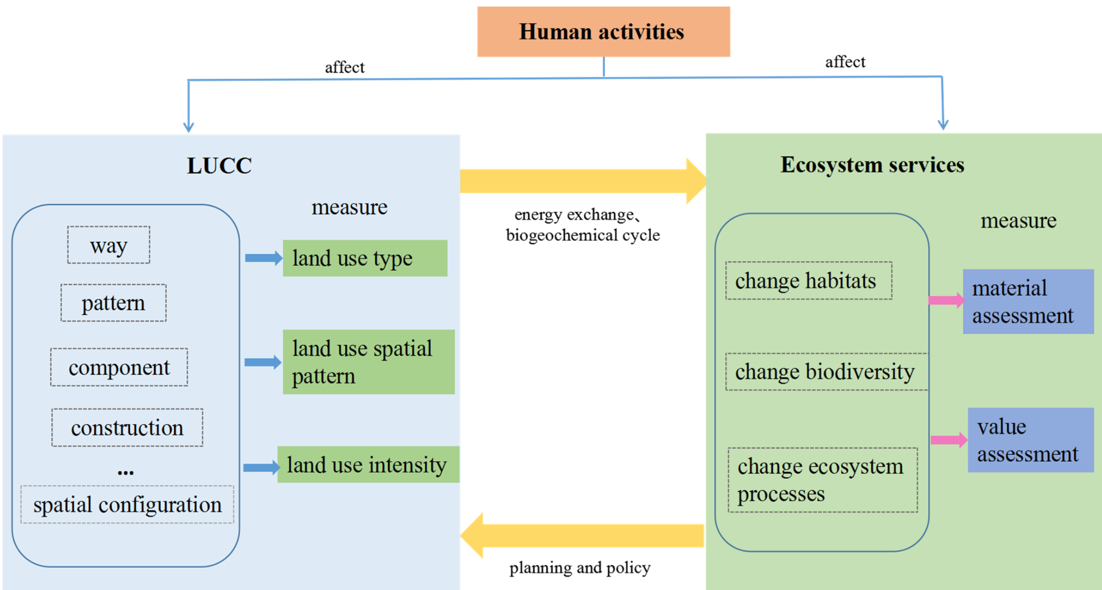


Figure 3. Relationship between LUCC and ecosystem services.

3.1.1. Effect of Land Use Type Changes on Ecosystem Services

The type of land use directly determines the value of ecosystem services, and different allocation methods for land use affect the distribution and migration of soil nutrients. In addition, their benefits to carbon sequestration are different, resulting in diverse ecosystem services [46]. The literature [47] indicates that the reduction in land use/cover with a higher coefficient of value is often the main reason for the reduction in the value of regional ecosystem services. Land use conversion matrixes and dynamics are the most used methods to study the effect of land use changes on ecosystem services. On the basis of historical land use data, research has established an ecological value matrix related to land use changes to understand the trade-offs among ecosystem services caused by land use changes [42]. The literature [48] studied how land use dynamics changed the ecosystem service value in the Ethiopian Highlands from 1973–2012.

Numerous research concentrated on long-term studies on this topic such as MA mainly concentrated on 10 interval years during 50 years, and UK NEA also mainly considered 10 interval years during 60 years [49]. Although they were committed to long-term change monitoring, they were based on sparse time-series data and ignored intra-annual and annual changes by gradual change and mutation of land use (such as forest fire and flood). Few works have studied the influence of LUCC on ecosystem services with long-term and dense time-series data. For example, the research [50] applied an equivalent factor of ecosystem services and long time-series data of a 1 year interval to explore the impact of land transformation processes on ecosystem services from 1985–2016. The study [51] applied Spectral mixture analysis with Landsat time-series data to understand the impact of land transformation processes on ecosystem services of a 1 year interval from 1987–2007. Satellite data can record long observation information of Earth's surface, and they are efficient data sources for assessing the current spatial extent and ecosystem condition and services. Therefore, dense time-series satellite data combing with new methods is a trend to identify the spatiotemporal dynamic impact of LUCC on ecosystem services.

In general, denser time-series monitoring is seen less in the study of the spatiotemporal dynamic impact of LUCC on ecosystem services. Moreover, clearly defining how much land use change, climate change, and other human activities have caused variations in ecosystem services is difficult. Lastly, most research have concentrated on the correlation between the land conversion matrix and ecosystem service value, and ignored the relationship between their spatial distributions.

3.1.2. Effect of Land Use Spatial Pattern on Ecosystem Services

The spatial pattern of land use, such as changes in habitat area and landscape fragmentation, inevitably affects or restricts the movement of species in the landscape, the migration of water and nutrients, soil erosion and other ecosystem processes, and the population dynamics and biodiversity in the landscape. That is, the spatial pattern of land use affects ecosystem services [52]. Many studies have used landscape indexes to explore the relationship between land use and ecosystem services. The study [53] has evaluated the influence of LUCC in Chile's temperate forests from 1986 to 2011 on the spatial pattern of habitat diversity in primary forests and concluded that the loss of ecosystem services could be determined by the interaction among area loss, patch number increase, and diversity loss. The study [54] assessed the impact of interactions of LUCC dynamics and ecosystem services supply in the European Alps. The results indicated that the ecosystem services capacity in complex agroecological mountainous areas was extremely sensitive to long-term landscape dynamics. The study [55] adopted ten landscape indexes and nine ecosystem services to analyze the correlation and constructed a multiple linear regression model to explore the characteristics and relationship between the two in urban and rural gradients.

The interaction of landscape pattern evolution on ecosystem services is a very complex process; research on the driving forces of landscape pattern changes is the basis for a complete understanding of the relationship between human activities and the changes of landscape patterns [56]. Therefore, the research of the driving mechanism is necessary for studying landscape pattern changes and ecosystem services. Moreover, there is no comprehensive study that considered all kinds of ecosystem services with landscape pattern changes.

3.1.3. Effect of Land Use Intensity on Ecosystem Services

Human investment in and use of various land resources are different. The most direct manifestation is the change in land use intensity. Land use intensity represents the intensity of the impact of human activities on the terrestrial ecosystem. The larger the value is, the stronger the impact human activities will be. In general, urban land owns the largest value of land use intensity [57]. Land use intensity not only impacts ecosystem structure and function in a region but is also an important driving force for the change in ecosystem service functions. Studies have suggested that increasing in land use intensity will enhance the trade-off between supply and regulation services [58]. When the land use intensity exceeds a certain threshold, it will cause an excessive loss of water, soil, and nutrients, which will reduce the food supply capacity and affect human food security and well-being. The tipping point, a specific type of threshold, refers to a series of states of a system where further disturbances will lead to fast changing and prevent the system from restoring the previous condition [59]. Tipping points can be early-warning signals for critical transitions in studying land use intensity and ecosystem services. With the intensifying of land use, the stakeholders usually ignore the gradual process before a tipping point is reached [60]. For example, the use of fire as a land management tool resulted in a tipping point between agriculture and more sustainable land use practices in the Brazilian Amazon [61]. Therefore, it is urgent to empower decision makers with the knowledge of tipping points. However, identifying tipping points in land use is also a challenge [62]. In addition, the increase in land use intensity will increase the fragmentation of the landscape and increase ecological sensitivity. Xu et al. [63] demonstrated the different responses of land use intensity, ecosystem services, and human well-being in rural China. The results indicated that the land use intensity increase in the study area was positively correlated with provision services, living well-being, and negatively correlated with regulating services. The literature [64] built the networks among biodiversity, ecosystem services, and ecosystem functions to explore how land use intensity changes the relationship among the three.

Although land use intensity can reflect the effect of human activities, the mechanism of how ecosystem services respond to land use intensity remains unclear. This issue reduces our ability to predict how different land use scenarios affect the supply of ecosystem services.

3.1.4. Methods for Measuring the Relationship between LUCC and Ecosystem Services

With regard to studying the relationship between LUCC and ecosystem services, the most common methods are the InVEST model, principal component analysis, sensitivity analysis, logistic analysis, grey prediction model, Markov model, and Mann–Kendall test. Other methods, such as ecosystem service index, energy analysis, and scenario simulation, are also used in studies. Some studies [65–67] have used the life cycle assessment (LCA) method to evaluate the relationship between LUCC and ecosystem services, and the core of this method is the calculation of characteristic factors. Many studies [68,69] have used remote sensing data and GIS-based models to test the effect of LUCC on ecosystem services to solve the social system–ecosystem interaction problem. Landsat data and the InVEST model were employed to explore the influence of LUCC on the ecosystem services of the Koshi River Basin from 1996 to 2016 [70]. On the basis of Landsat and climate data from 1990 to 2010, Fu et al. studied the influence of LUCC and climate change on ecosystem services in the Altai of China [71]. However, most of the papers did not use a single method but a collection of several different methods. This study regards ten papers as examples and counts the methods used. The results are shown in Table 1. Scenario simulation method and remote sensing data and GIS-based models are the most used methods in measuring the relationships between LUCC and ecosystem services.

Table 1. Examples of methods exploring the relationships between LUCC and ecosystem services.

References	Methods											
	the InVEST Model	**Ecosystem Services Index Method**	**Remote Sensing Data and GIS-Based Models**	**Scenario Simulation Method**	**the Markov Model**	**Principal Component Analysis**	**Sensitivity Analysis**	**Logistic Analysis**	**the Grey Prediction Model**	**the Mann-Kendall Test**	**Energy Analysis Method**	**the Life Cycle Assessment (LCA) Method**
[72]	√			√								
[73]			√			√						
[45]				√			√					
[74]			√					√				
[75]				√					√			
[76]			√	√	√							
[77]												
[78]	√	√		√	√			√				
[79]										√	√	
[80]												√
Application	assessing ecosystem services		acquiring historical/future LUCC data and related analysis methods			exploring the relationship between LUCC and ecosystem services					calculations of daily monetary flows of ecosystem processes based on the concept of energy	assessing the value of ecosystem services and human well-being in economic units

In addition, there is no reliable and widely accepted method available for ecosystem service verification. Existing ecosystem service evaluation methods have not yet formed a complete set of evaluation theories and index systems. Different evaluation methods have distinct calculation models, parameter determination, and ecosystem service classification, and their evaluation results often have large differences. Even if the evaluation of the same ecosystem is done, the evaluation results may remarkably differ, resulting in the inability to compare the results of different studies.

3.1.5. Scale Effect

The scale issue is an inevitable problem in the study of geography. Regarding the research on LUCC and ecosystem services, on a global scale, among the studies we have reviewed, most of the research have concentrated on linking the detection of the forest, arable land, and wetland change and soil processes, climate change, and biodiversity and then conducted scenario analysis and prediction on the global land change. On a regional scale, research has mainly explained the impact of LUCC on the distribution and changes in key ecosystem services and then developed land and ecological decision support tools that are suitable for regional development; LUCC has the most direct and evident impact on ecosystem services on a local scale. Most studies we have reviewed on a local scale [81,82] have concentrated on the driving and response relationship between LUCC and ecosystem services to adjust the way of land resource utilization and promote the sustainable development of regions.

When studying the relationship between LUCC and ecosystem services, we conclude three main issues after reviewing. First, LUCC has dominant spatial scales, as well as ecosystem service generation, supply and demand, consumption, and impact ranges. Therefore, the characteristic scales of LUCC are often inconsistent with the characteristic scales of ecosystem services, resulting in the scale complexity of research. Second, the sensitivity of different types of ecosystem services to scales is also different; choosing to model a scale is a complicated issue. Third, the optimal scale for modeling ecosystem services is inconsistent with the optimal scale for studying ecological processes and regional issues. Hence, the trade-off among observing, modeling, process, and other scales is also one of the main limitations of research. These scale issues were summarized in Figure 4.

Although scholars have conducted a large number of studies on LUCC and ecosystem services globally [83] and regionally [84], ongoing studies that can comprehensively consider the effects of different scales remain limited. The literature [85] studied the effect of different LUCC scales on the assessment of ecosystem services. This study selected stock model, dynamic flow model, and ecological model to the research. The stock model refers to an ecosystem service assessing by static stock, such as the carbon storage model. The dynamic flow model represents a model that solves a dynamic system, which dynamic flows rely on the exact representation of landscape patterns, such as the sediment delivery model. The ecological model addresses a complex ecological system that contains both stocks and dynamic flows, such as the pollination model. The results show that the ecosystem services by stock estimates are the most sensitive to scale aggregation, and the ecosystem services by dynamic flow models are the most sensitive to spatial scale. The ecosystem services by ecological process models involving stock estimates and dynamic flow models are sensitive to scale aggregation and spatial scale. The literature [86] studied the scale effect between LUCC and ecosystem services. The results indicated that the error of land use will affect the results of LUCC as the scale widens, and the sensitivity of various ecosystem services to land use errors is also different.

In future research, the scale selection, difference, correlation, and effect of the impact of LUCC on ecosystem services should be discussed in-depth, and objective standards should be established to measure the uncertainty of scale conversion [87].

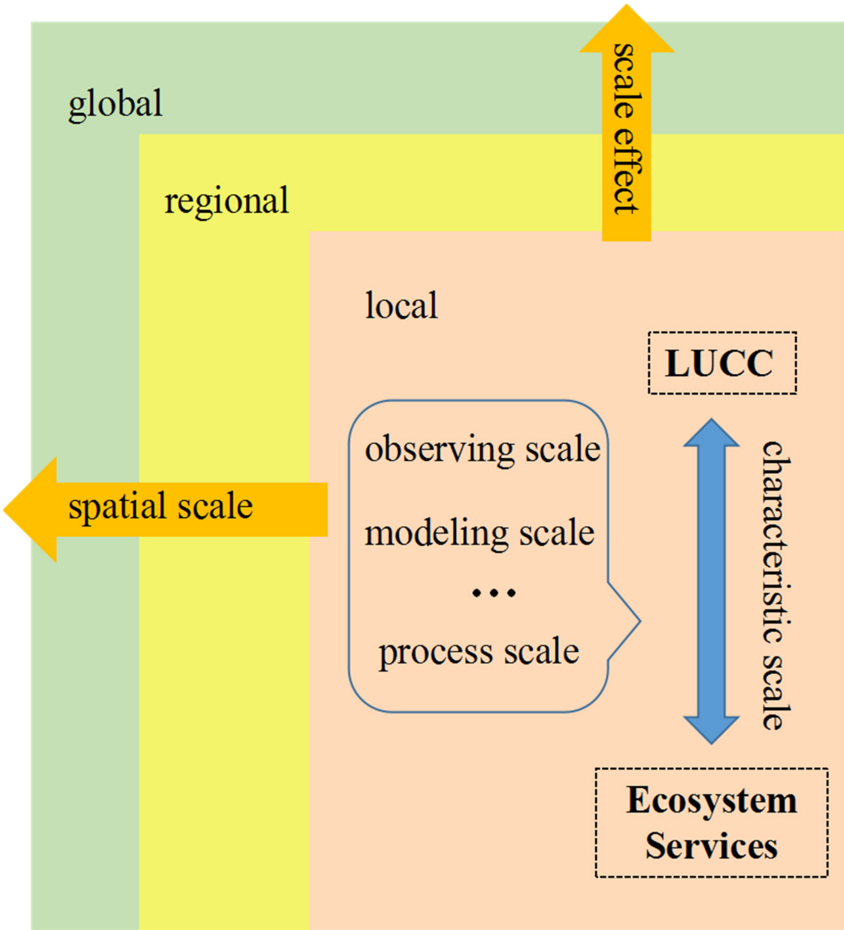


Figure 4. Scale issues in studying the relationship of LUCC and ecosystem services.

3.1.6. The Combined Effects of LUCC and Climate Change to Ecosystem Services

LUCC is the major driving factor in affecting ecosystem services, climate change, as another important driving factor, can influence the structure, composition, process, and distribution of ecosystems [88]. One the one hand, rising temperature, decreasing precipitation, and greenhouse gas emissions can change ecosystem services; on the other hand, climate change also can result in land use change, and that in turn shapes ecosystem services. Therefore, most previous studies concentrated on the changes of ecosystem services under the combined effects of land use and climate change [89–91]. With the in-depth research on the driving mechanism of ecosystem services, a few studies have begun to distinguish the respective impacts of climate change and LUCC on ecosystem services [92]. They mainly adopted scenario analyses and conducted at regional scales. For example, the study used scenario analysis to explore the separated effects of climate change and LUCC on carbon sequestration, water yield, and soil conservation services in the karst landscape, and results show that changes in carbon sequestration and water yield were mainly dominated by LUCC while soil conservation was mainly dominated by climate change [93].

LUCC and climate change jointly shape ecosystem services. Due to the complex interactions between LUCC and climate change [94], it is difficult to separate the impacts on ecosystem service changes of LUCC and climate change completely. New methods and frameworks need to be developed in distinguishing the impacts of LUCC and climate change on ecosystem services. Before that, we need to treat LUCC and climate change comprehensively in studies to provide comprehensive and scientific support for decision making and policy formulation.

3.2. Ecosystem Services and Human Well-Being

3.2.1. Connotation and Evaluation Indicators of Human Well-Being

Human well-being is a concept comprising the aspects of anthropology, economics, psychology, sociology, and other social sciences. On the basis of different research backgrounds and purposes, scholars in diverse research fields select various elements to construct the concept of well-being. This paper summarizes the different concepts of well-being in Table 2. In accordance with the different concepts of well-being, research has proposed various evaluation indicators of human well-being. At this stage, evaluation indicators of human well-being can roughly be divided into subjective well-being [95], objective well-being, and the combination of subjective and objective well-being. The relative details are shown in Table 3. Given that human well-being is influenced by natural, socioeconomic, and cultural factors [96], the evaluation indicators of human well-being are diverse. However, these indicators focus on the economic and social dimensions of human well-being, and the environmental factors of human well-being are unclear. Relatively few indicators are available to measure spiritual, cultural, and subjective well-being [97].

Table 2. Concept of well-being.

Year	Concept	Reference
1781	Classical utilitarianism in Bentham's position believes that well-being is the satisfaction of the utility or preference of the consumption of goods. It is the favourite and most favourable mental state, which can be evaluated by people's happiness or satisfaction.	[98]
1990	The Human Development Report issued by the United Nations in 1990 selected life span (determined by life expectancy at birth), knowledge (calculated by adult literacy rate and average years of education), and ability to obtain required resources (measured by the purchasing power evaluation of GDP per capita based on US dollars), and other indicators to measure human well-being.	[99]
1993	Sen noted that well-being is a function of feasibility. A person's feasibility refers to the combination of various possible functional activities that the person can achieve.	[100]
1997	Dodds believed that well-being has four basic connotations: (1) Human well-being is regarded as a state of mind. (2) Well-being is regarded as a state of the world, which includes satisfaction with people's preferences and basic needs. (3) Well-being is regarded as human abilities. (4) Satisfaction with well-being is regarded as a basic need.	[101]
2003	Cummins and others believed that human well-being is a concept that generally measures people's life satisfaction, including seven major areas: satisfaction with living standards, health, life achievement, interpersonal relationships, safety, community connections, and future safety.	[102]
2005	MA is an activity and state that people consider valuable. It is a concept based on experience. It defines the components of human well-being as safety, the basic material needs for maintaining a high-quality life, health, good social relations, and freedom of choice and action. The five aspects are similar to Maslow's demand theory.	[103]
2009	The Commission on the Measurement of Economic Performance and Social Progress believed that human well-being has eight key dimensions: (1) material standard of living (income, consumption, and wealth), (2) health, (3) education, (4) personal activities, (5) policy and government, (6) social relations, (7) social and physical environmental conditions (present and future), and (8) physical and economic insecurity.	[104]
2010	The concept of human well-being is abstracted to a process and an outcome in three interacting dimensions, which is the objective material circumstances of a person, subjective evaluation of people's goals and the processes they engage in, and a relational component, respectively.	[105]
2011	Hall believed that human well-being includes health, knowledge, work, good material conditions, self-determination, interpersonal relationships, and living conditions. Under certain conditions, human well-being is also divided into personal and social well-being.	[106]

Table 2. *Cont.*

Year	Concept	Reference
2012	Summers believed that human well-being consists of basic human needs, economic needs, environmental needs, and subjective happiness.	[23]
2015	Human well-being includes objective material of living conditions and subjective assessment of surroundings. The objective material of living conditions cover livelihoods, health, income, housing, and the environment.	[107]
2019	Psychological well-being is an indispensable part of well-being, which contains happiness, hedonic and eudaimonic, self-actualization, resilience, healthy relationships, cognitive functioning, and a lack of mental distress. It is usually affected by culture services.	[108]
2021	Human well-being contains subjective well-being and objective well-being. Subjective refers to affective and cognitive evaluations of the extent to which life is going well. Objective well-being refers to the evaluation of the extent to which social and physical needs are met.	[109]

Table 3. Evaluation indicators of human well-being.

Category	Indicators	Reference	Characteristic
Objective human well-being	Gross domestic product (GDP) Physical quality of life index (PQoL) Human development index (HDI) Human welfare index (HWI) National well-being Index (NWI) Affect balance scale	[110] [111] [112] [113] [114] [115]	Objective well-being refers to the material and social attributes that affect personal and social well-being, including wealth, education, health, and facilities. Objective well-being mainly uses measurable social or economic indicators to reflect the degree to which human needs are met.
Objective well-being	Personal welfare index Satisfaction with life scale The scale of positive and negative experiences Quality of life scale Personal well-being index Pemberton happiness index Happy planet index	[116] [117] [118] [119] [120] [121] [122]	Subjective well-being believes that well-being is determined by people's attitudes of likes and dislikes and depends on inner feelings and situational experiences. It focuses more on the individual's evaluation of his situation and his subjective feelings.
The combination of subjective and objective well-being	Human well-being index system	[123]	It is a comprehensive measurement of subjective-objective well-being. Given that human well-being is multidimensional, hierarchical, and regional, the principles of scientificity, comprehensiveness, hierarchy, and operability should be followed when constructing the index system of human well-being.

3.2.2. Research Progress on Ecosystem Services and Human Well-Being

(1) Frameworks linking ecosystem services and human well-being

Several interdisciplinary research projects have explored how humans can transform and interact in social ecosystems to improve human well-being. However, most of them are based on the framework of ecosystem services and human well-being. This paper summarizes frameworks in Table 4. A framework can help comprehend the linkages between ecosystem services and human well-being [124], but most existing frameworks have not been applied to empirical studies [125]. In addition, some important issues such as social inequality, preference of different groups, classification needs and results, and system and governance are often ignored within these frameworks.

(2) Research hotspots on the relationship between ecosystem services and human well-being

Table 4. Research frameworks on linking ecosystem services and human well-being.

Frameworks	Contents	Merits and Demerits	References
MEA	It links four types of ecosystem services (provision, regulating, supporting, and cultural) with five components of well-being (safety, achieving good life, health, good social relations, and freedom of choice and action).	The MEA framework believes that a one-way relationship exists between ecosystem services and human well-being. The potential for analyzing this connection is limited, and issues related to social differentiation and political economy are ignored.	[103]
Sustainable Livelihood Framework (SLF)	SLF is an influential framework that conceptualizes livelihood based on the following five aspects: environment, conditions, and trends; livelihood resources; institutional processes and organizational structures; livelihood strategies; sustainable livelihood outcomes.	The focus of the framework is livelihood instead of human well-being.	[126]
Cascade Model for Ecosystem Services	The framework is transformed into causality through the conceptualization of the links among biophysical structures, processes, functions, services, benefits, and values.	This framework shows that the contribution of ES to human well-being occurs through different steps. It emphasizes social and ecological interaction, in which human behavior regulates ES through mechanisms, factors, and feedback. The framework has been widely used. It has been further developed to include the socioeconomic processes that interfere with each cascading step and the role of management, governance, or sociopolitical context.	[127]

At the research spatial scale, most research on ecosystems and human well-being has concentrated on national and subnational scales, whereas research on city and community scales is relatively rare. In terms of the study area, marine, urban, and agricultural environments have been more heavily studied, whereas fewer case studies in forests, wetlands, and fisheries have been considered. In terms of application, the integration of ecosystem services and human well-being into sustainable management is a new mode for researchers, managers, and policy makers [128]. Ecosystem services and human well-being are being used in studies related to poverty alleviation [129,130], environmental protection [131], biodiversity [132], and sustainable development [133].

1 Poverty alleviation

Poverty is not only a decline in income but also the restriction of human development and choice and the decline or exploitation of well-being [134]. In the contrast, improving ecosystem services (mainly referring to provision services) is generally believed to help alleviate poverty, especially in rural areas of developing countries [135,136]. Therefore, the degradation of ecosystem services is also considered to have an adverse effect on human well-being, which undermines efforts to reduce poverty.

After reviewing related research in ecosystem services, human well-being, and poverty allevation, a research framework for studying ecosystem services, human well-being, and poverty alleviation was developed (Figure 5). Ecosystem services and human well-being are committed to poverty alleviation, which contains poverty prevention and reduction [137]. Poverty prevention refers to the practice of supporting the livelihood of people living above the poverty line by strengthening ecosystem services. Generally, ecosystem services potentially contribute to poverty alleviation through four modes: ① providing basic support for livelihood, ② obtaining economic compensation by providing ecosystem services, ③ selling ecological service products through market transactions, and ④ ecological migration due to deterioration of ecosystem services.

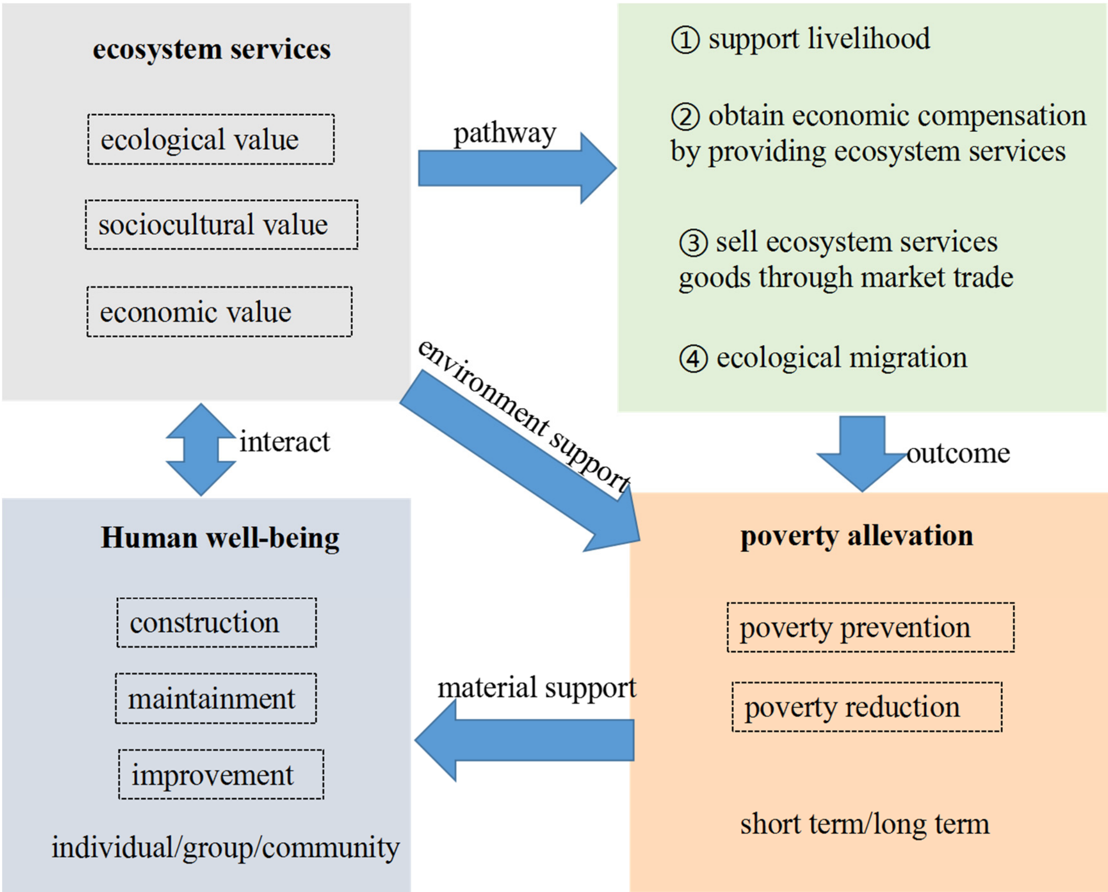


Figure 5. Framework of ecosystem services, human well-being, and poverty alleviation.

Existing research has explored the links among poverty, ecosystem services, and human well-being and identified ten key components and determinants that are essential to poverty alleviation [138]. The literature [139] explored the link between livelihood-supporting ecosystem services and human well-being in poor areas and proposed methods to improve livelihood and alleviate poverty. On the basis of the empirical understanding of family well-being and poverty trajectories, the literature [140] concluded that the benefits of natural resources and ecosystem services are definitely related to stable income and multidimensional well-being. The literature [129] comprehensively analyzed the key issues on coastal ecosystem services and human well-being in developing countries and the key poverty alleviation mechanism that might have been overlooked before.

However, few studies have examined the relationship between ecosystem services and poverty at the macro level, and most have ignored the distribution of impacts; thus, this approach is insufficient to determine which groups actually benefit.

2 Ecosystem health

Ecosystem health performs an increasely important role in improving subjective well-being. Bad environmental conditions may damage human body health and psychological helath [108], reduce the possibility of environment-friendly behavior, and further deteriorate the ecosystem [141]. Enhancing the health of the ecosystem can improve people's well-being. For example, the species diversity of birds and the coverage of vegetation are related to growth in well-being [142]. The study [143] developed river health assessment standards by considering ecosystems and human demand. The study [144] explored the response of ecosystem health and human well-being on a watershed scale. The results showed that with the change in LUCC, the health of the ecosystem exhibited a downward trend, and that human well-being had increased exponentially. The study [145] constructed the Yellow River health assessment framework on three spatial scales, used the Happy River Index to integrate trends in river health and human well-being, and provided suggestions for improving human well-being in the Yellow River region.

Ecosystem health assessment is mostly conducted by constructing indicators based on ecosystem processes. The purpose of ecosystem health is not to diagnose ecosystem diseases, but to define the expected state of the ecosystem and determine the limits of the ecosystem. The concepts of ecosystem health, assessment, and application fields are mature, but the research of ecosystem health integrated with human well-being, such as linked human needs and well-being, economic development, and human threats is relatively rare. This kind of research can provide an effective basis for regional sustainable development and environmental management.

3 Biodiversity

Biodiversity generally includes gene, species, ecosystem, and landscape diversities. The assessment of biodiversity and ecosystem services is an important basis for ecosystem management and decision making, and biodiversity and ecosystem services are closely related to human well-being [146]. Biodiversity generally has a positive impact on ecosystem services. Research has shown that a positive correlation exists between biodiversity index and ecosystem service supply [147]. The continuous loss of biodiversity has caused the deterioration of ecosystem services, thereby increasing ecosystem vulnerability and affecting human well-being [148,149]. Biodiversity can cope with the risk of ecosystem service degradation and indirectly increase human well-being. People whose production and lives depend directly on ecosystem services (farmers, herders, fishermen, etc.) are severely impacted by biodiversity loss.

Previous research have indicated two links among biodiversity, ecosystem services, and human well-being. One is the view of human development: humans use existing ecological products and values to improve human well-being, which often leads to a decline in ecosystem services. The other is the view of protection: biodiversity is the cornerstone of providing human well-being. Biodiversity causes the improvement of ecosystem services, thereby improving human well-being [146]. Scholars have conducted a series of studies based on this view. The study [150] used the DPISR model to explore the socioeconomic impact on biodiversity, ecosystem services, and human well-being in China. The study [151] established a conceptual framework for biodiversity assets, ecosystem functions, ecosystem stability, and ecosystem services. The results showed that biodiversity assets and ecosystem service flows affect human well-being. After reviewing realted research in this topic, a research framework was summarized for the study of biodiversity ecosystem services, and human well-being. The results are shown in Figure 6.

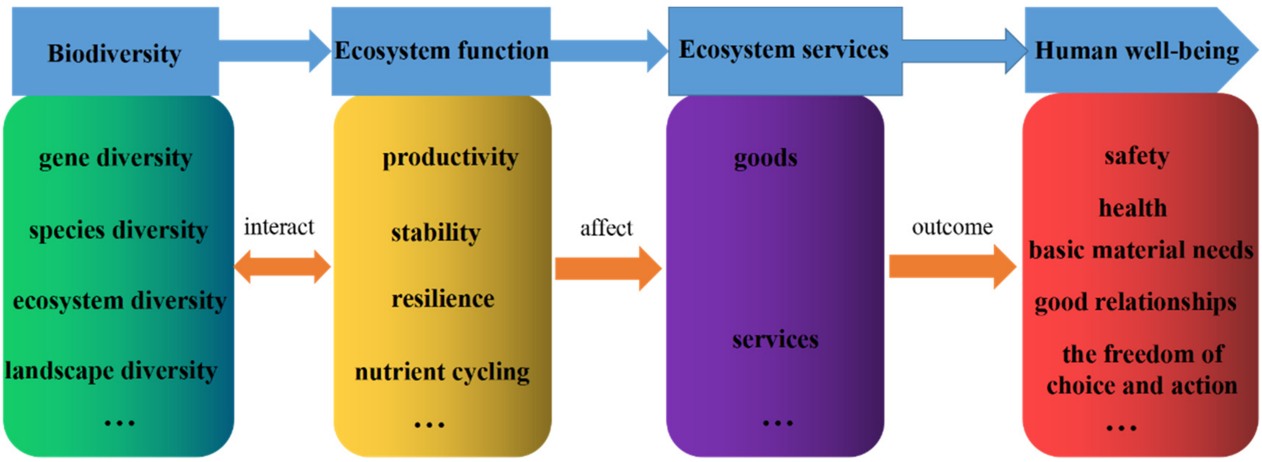


Figure 6. The framework of biodiversity, ecosystem services, and human well-being.

Biodiversity is related to ecosystem services through various forms of operating mechanisms at different spatial scales. However, given that the relationship among biodiversity, ecosystem services, and human well-being is uncertain, the connection of biodiversity with ecosystem services and human well-being has not yet been studied in global hotspots [152]. Therefore, the characterization of the cascading characteristics of biodiversity, ecosystem services, and human well-being should be strengthened in the future.

4 Sustainable development

The ultimate goals of sustainable development are to solve environmental problems and to improve human well-being [153]. Sustainability science focuses on the relationship between ecosystem services and human well-being and discusses the impacts of biodiversity, ecosystem processes, and socioeconomic factors, such as climate and land use change, on the two. Among the 17 goals of sustainable development, most are closely related to ecosystem services and human well-being [154].

The study [155] emphasized that the core objective of sustainable science is to consider ecosystem services, human well-being, and sustainable development comprehensively. In other words, sustainable science focuses on the interactions of humans and the environment [156]. The adaptability, vulnerability, and resilience of human and natural systems are crucial to sustainable development but are still challenges in ongoing studies. In addition, the framework of ecosystem services and human well-being encapsulates sustainable development in three aspects: society, economy, and environment. The literature [157] explored the relationship between ecosystem services and sustainable development indicators under the background of the COVID-19 pandemic. The results showed that ecosystem services were beneficial to all sustainable development goals, and human pressure had led to decreased ecosystem services. The literature [158] studied ecosystem services and local human well-being from the perspective of sustainable palm oil production. The production of palm oil has increased the income of residents and improved human well-being. However, the negative impact of palm oil production on the local society is considerable.

The relationship among sustainable development, ecosystem services, and human well-being was summarized and visualized in Figure 7 after sorting and extracting from related research. In addition, some limitations of ongoing research in this topic were summarized. First, many countries have been collecting data and analyses to assess the changing characteristics of their domestic sustainable development processes, but they have not paid attention to the synergy/trade-offs in the implementation of the Sustainable Development Goals. Moreover, the literature has systematically compared the United Nations Sustainable Development Goals with the regional dimensions of human well-being and found an overlap between the regional concepts of human well-being and the global Sustainable Development Goals and substantial gaps between them [159]. Therefore, when realizing the Sustainable Development Goals, studying the continuity and distinction between human well-being and the Sustainable Development Goals in a region is crucial. Second, further study should focus on the trade-offs between human well-being and the natural system. Last but not least, how society guides and manages the transformation of human and natural systems to sustainability is still a core issue needed to be solved.

5 Natural capital

Natural capital can be defined as a stock of materials or information that can directly or indirectly provide human beings with various ecosystem services [160]. Natural capital is an important issue in linking ecosystem services and human well-being. Ecosystem services are included in four types of capital systems: natural capital, built capital, human capital, and social capital when it comes to the conceptual framework of capital in economics. However, natural capital cannot directly transition into human well-being, it must combine with the other three capital to generate ecosystem service flow.

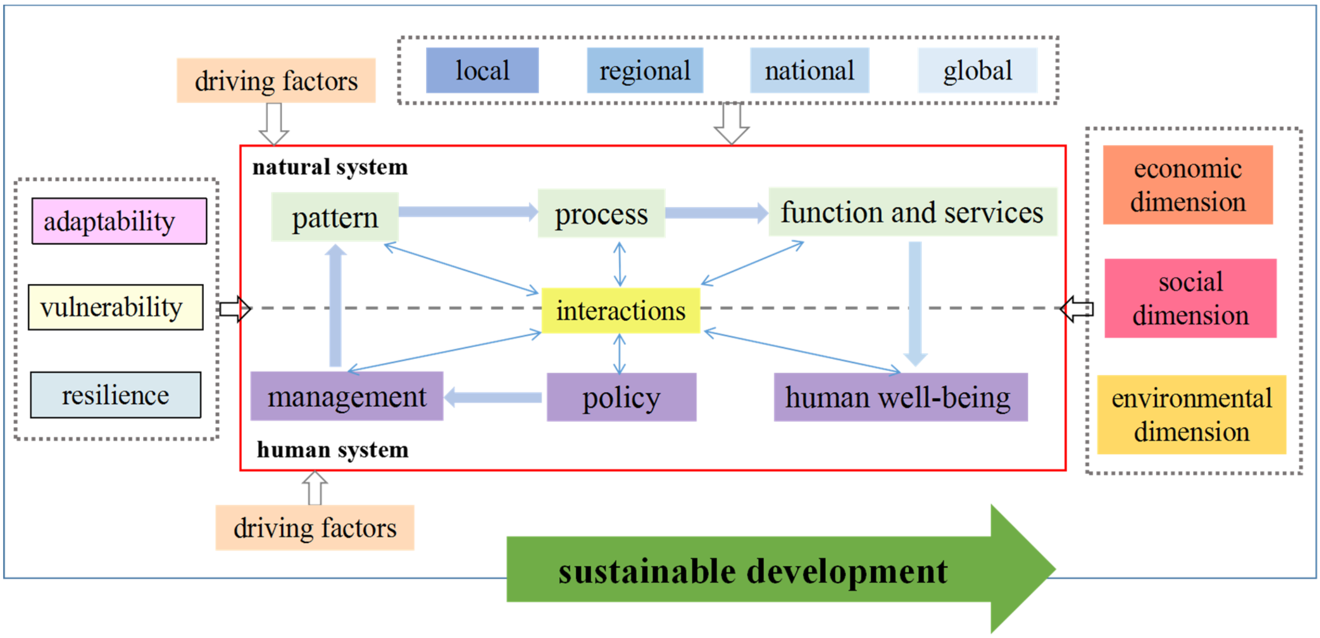


Figure 7. Relationships among ecosystem services, human well-being, and sustainable development.

There has been considerable development in natural capital in linking ecosystem services and human well-being [161–163]. The study [164] investigated the preferences of residents in Japan for natural capital-based and produced capital-based ecosystem services. The results show a stronger preference for natural capital-based ecosystem services, which indicates natural capital-based ecosystem services are beneficial to human well-being. Natural capital is also used in poverty alleviation. The study's results [165] show that the lower the area of ecological assets, the higher the economic poverty is in most countries in the Qinling-Dabashan region. Therefore, taking ecological asset management into regional poverty alleviation is necessary.

Natural capital not only supports the life system on earth but also links ecosystem services and human well-being. Therefore, it is urgent to integrate the values of natural capital into major development decisions.

(3) Relationship between ecosystem services and human well-being

1 Trade-off and synergy

The term "trade-off" first appeared in the field of physics to discuss the relationship among signal detectability, accuracy, resolution, and background suppression. Since then, increasing research fields have introduced trade-offs to understand the interactions between things. The trade-off of ecosystem services shows a downward trend of one service with the increase in another service. Owing to the diverse and uneven distribution of ecosystem services and coupled with different human demands, people also have distinct preferences for the choice of ecosystem services. The trade-offs between different ESs also lead to trade-offs in the well-being of different groups. The trade-offs exist not only between ecosystem services and between different beneficiaries of ecosystem services, but also between ecosystem services and human well-being.

The study [166] summarized the cases that discussed the application of ecosystem trade-offs and synergy results to human well-being at different scales and emphasized the three conditions for trade-offs: at least one stakeholder owns the available natural resources; the existence of provision services; at least one stakeholder acts on a local scale. The study [167] explored whether marine-protected areas can synergistically interact with other services (such as fisheries and tourism), which depends on the appropriate development of institutional strength and social capital and provided a number of recommendations to improve human well-being.

Ongoing research on trade-off/synergy mainly focuses on types and formation mechanisms, research methods, analysis tools, scale effects, and uncertainties. Multidisciplinary/interdisciplinary comprehensive research is an important direction for future research on the trade-off/synergy between ecosystem services and human well-being. At the same time, fully clarifying the mechanism of ecosystem structure–process–function–service at different scales from various perspectives, exploring the temporal and spatial dynamics and influencing factors of the trade-off/synergy between ecosystem services and human well-being, and identifying its internal mechanism and possible relationship changes, are of great significance to promote the coordinated development of the natural ecosystem, social economy, and human well-being.

2 Supply, demand, and consumption

The consumption of ecosystem services refers to the consumption, utilization, and occupation of ecological services by human production and life. The continuous supply of ecosystem services is the foundation of the sustainable development of society and nature. Humans consume ecosystem services to meet demands and improve their well-being. The differences in demand in ecosystem services drive the change of ecosystem service management. At the same time, ecosystem management adjusts ecosystem service supply. In addition, the benefits that an individual obtains from ecosystem services depends on complex transmission mechanisms, which involve the material flow, ecosystem service flow, and value flow, and are not automatically and evenly distributed. Their distribution and consumption will be affected by the market, social relations, gender, abilities, rights, and various capitals. The supply-demand-consumption mechanism is a key link in the process of transforming ecosystem services to human well-being and determines the availability of ecosystem services for people. A scientific understanding of the relationship among the supply, demand, and consumption of ecosystem services and human well-being is of great significance for coordinating the relationship between the conservation of ecosystem services and the improvement of human well-being.

The supply, demand, and consumption of ecosystem services are asynchronous, and uncertainty exists in the relationship among them and human well-being. Therefore, many studies are committed to solving this problem. Research [123] explored the links among ecosystem services supply, social demand, and human well-being in the mountain–oasis–desert areas. The results showed that the spatial distribution of social demand of ecosystem services is not completely consistent with biophysical supply, and factors from the supply and demand sides will lead to a mismatch between ecosystem service supply and demand. The research [168] studied the distribution of cooling ecosystem services from the perspective of social supply and demand, and the results showed that urban cooling ecosystem service demand was high in districts with lower socio-economic status ranking, while cooling ecosystem service supply was high in Northern districts with higher socio-economic status. The uncertainty of the relationship among ecosystem service supply, demand, and consumption makes it more difficult to incorporate the relationship among the three into ecosystem management and decision making. Therefore, clarifying the production, transmission, and consumption processes of ecosystem service flows, and in-depth analysis and understanding of the spatial characteristics of ecosystem service supply and consumption are of great significance to the formulation of ecological compensation policies and the conservation of ecosystem functions in specific regions.

Existing research mainly focuses on the relationship between ecosystem services and subjective well-being on a large scale, while quantitative research on the relationship and mechanism of the supply, demand, and consumption of ecosystem services and human well-being on a regional scale should be strengthened. In addition, the quantification of the supply, demand, and consumption of ecosystem services and the research on the spatial pattern of ecosystem services should be improved. For example, within the study area, who consumes ecosystem services, how are they distributed in space, and which aspects of well-being have been improved? To solve this problem, spatiotemporal dynamic simulation of ecosystem service flow should be reinforced.

(4) Scale effects on the study of ecosystem services and human well-being

In the processes of evaluating and measuring the impact of ecosystem services on human well-being, scale is an important analytical perspective. Ecosystem services at different scales have distinct importances to stakeholders at different scales and involve ecological processes at different scales. We summarize four scale issues in this topic. First, the consumption of a specific ecosystem service can be supplied by the ecosystems of multiple scales, and a certain provision service can be consumed by multiple scales of consumers. A study has shown that demand-related activities occur on different scales and will produce cumulative impacts and pressures on other scales [169]. Second, the trade-offs and synergies on one scale are inapplicable to another scale. Third, different time scales will also have an impact on the research on the relationship between ecosystem services and human well-being. We cannot derive the long-term trend of the impact of ecosystem services on human well-being based on short-term data. Lastly, the interactive effects of different scales of ecosystem services will have an important impact on human well-being and focusing on only one study scale will miss the interactive effects.

Therefore, the impact of ecosystem services on human well-being can only be analyzed and judged scientifically on a specific scale. Research [170] used subjective well-being indicators to assess the well-being of cultural services provided by 151 British marine sites to recreational anglers and divers from a large scale. The study [136] used surveys and multilayer linear models to analyze the impact of regional ecosystem services and personal characteristics on subjective well-being on a watershed scale. The literature [171] studied the impact of ecosystem services on human well-being on a neighbourhood scale and found that changes in ecosystem services can fundamentally explain the changes in human well-being, especially education and health well-being. Although quantifying the relationship between them on multiple scales remains challenging, scholars still make unremitting efforts. For example, research has used spatial interpolation to solve the downscaling problem of human well-being [172].

However, it is still a big practical policy challenge when addressing scale issues to balance the national and local benefit, such as infrastructure planning and ecological conservation establishment. Moreover, the distribution-consumption mechanism of the impact of ecosystem service changes on human well-being at different scales has not yet been systematically studied. In the future, when studying the links between ecosystem services and human well-being on multiple scales, a systematic understanding of the spatiotemporal supply, demand, consumption, and flow of ecosystem services is needed.

3.3. Relationships among LUCC, Ecosystem Services, and Human Well-Being

Humans meet their own needs by changing the type, pattern, and intensity of land use, leading to changes in ecosystem types and ecosystem services, affecting major ecological processes, such as material circulation and energy flow [173], and adversely influencing human well-being. Based on previous work, we summarized the relationships among the three, which is shown in Figure 8. The links among LUCC, ES, and human well-being are complex and multifaceted [174]. The ways affecting them can roughly be divided into three types: (1) changes in the resource system; (2) changes in the government system; (3) changes in broader social, economic, and political systems. Based on this, scholars have conducted much research, but research has focused on the impact of LUCC on ecosystem services and human well-being at large and medium scales. Although studies have shown that human-induced land use changes (such as the expansion of industrialized land) are beneficial to the improvement of human well-being, LUCC has uneven and time-lagged effects on human well-being and may not cause an immediate response.

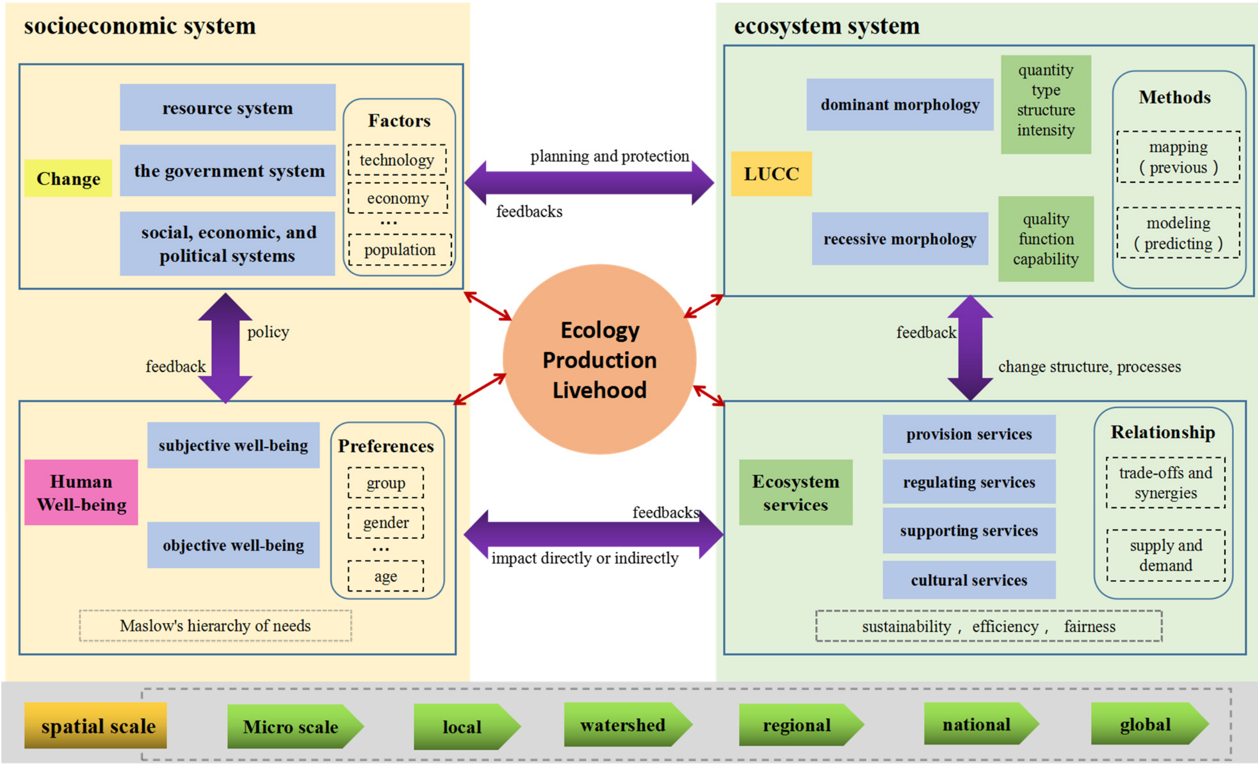


Figure 8. Relationships among LUCC, ecosystem services, and human well-being.

Changes in the natural resource system: The number of studies in this area is relatively large. Study [175] used the equivalent factor method and index system evaluation method to evaluate and describe the relationships among LUCC, ecosystem services, and human well-being based on 3S technology (Global positioning systems, Geography information systems, and Remote sensing) in the Manas River Basin from 2003 to 2013. An evaluation description of the relationships among the three was provided. The results suggested that to achieve sustainable development, existing land use trends must be slowed down. Studies have also been performed from a multiscale perspective. Based on land use data and social statistics, study [176] constructed a multiscale analysis framework of "land use intensity–ecosystem services–human well-being" and discussed the trade-offs of land use intensity–ecosystem services–human well-being at county and township scales. The results showed that the relationship between land use intensity-ecosystem services-human well-being in Anding District from 1990 to 2015 had regional similarities and local differences in townships. The increase in land use intensity improved the provisioning services and well-being of production materials but decreased the regulating and supporting services.

Changes in the government system: Relevant studies have mostly concentrated on the changes in the relationships among the three before and after the implementation of government policies. For example, before and after the government implemented ecological resettlement in the water source area of the middle route of the South–North Water Transfer Project, land use changes caused by resettlement affected the changes in ecosystem services, thereby affecting the changes in the human welfare of stakeholders. Human well-being can be used to judge whether a resettlement design is appropriate. The study [177] divided stakeholders at different spatial scales into farmers, governments, regions, and the world and separated various stakeholders through cascade models and ecosystem service flows. The results showed that ecological migration reduced the well-being of farmers, and that the government should change the subsidy standard for ecological migration. In addition, short-term investment will provide long-term benefits to the government, whereas downstream regions and the world have always benefited in short- and long-term periods. Another research [178] employed a coupling harmonious degree model to explore the relationships among landscape pattern index, ecosystem services, and human well-being in China from 1996–2016, when China was in the economic construction period.

Changes in social, economic, and political systems: Most of the assessments in this field have been based on different scenario simulations. Quintas-Soriano et al. [179] discussed the relationship between social importance and vulnerability of eight key services and components of human well-being under four LUCC scenarios in a Spanish arid ecosystem. The results indicated significant differences in social perceptions between the positive and negative effects of land use types on ecosystem services.

4. Directions for Further Research

The research on the relationship among LUCC, ecosystem services, and human well-being is an important interdisciplinary issue in the field of natural and human systems. Clarifying the difficult relationships among the three can help the decision makers seek nature-based solutions and achieve sustainable development under global climate changes and ecological pressures. However, a considerable gap remains in synthetically understanding the relationships among LUCC, ecosystem services, and human well-being. Therefore, the review was undertaken to clarify how LUCC, ecosystem services, and human well-being are linked, and discussed the future research agenda. By reviewing related studies in the field of "LUCC-ecosystem services-human well-being", we summarize the influencing pathways, common methods, and scale effects in studying the relationship between LUCC and ecosystem services. Subsequently, we conclude frameworks and identify the applications, as well as scale effects, in studying ecosystem services and human well-being. Lastly, we conclude three paths among the three elements at a high level and figure out their relationship to provide a comprehensive understanding of the relationship among the three. However, some issues should be strengthened in future studies to promote its development.

4.1. LUCC and Ecosystem Services

1. More attention needs to be paid to invisible changes in land use and intangible ecosystem services. When studying the relationship between LUCC and ecosystem services, an increasing number of studies have concentrated on the use of complex models to explain how LUCC affects ecosystem services. On the contrary, few studies have explored invisible changes in land use (land use structure, speed, and diversity) and ecosystem services, and the relationship between LUCC and intangible ecosystem services has been minimally studied, which is equally important in researching the interaction between the social system and ecosystem.

2. Unified definition and classification of ecosystem services are needed. To date, disputes remain on the basic definition and classification schemes of ecosystem services in the academic community, which results in the difficulty of clearly defining the ecosystem services themselves and the service generation mechanism and causes a lack of unified evaluation indicators and methods for ecosystem services. Therefore, evaluation results by different methods lack comparability.

3. The issue of scale needs to be emphasized in the process of studying LUCC and ecosystem services. The interaction among ecosystem services changes with temporal and spatial scales. Insufficient research exists on ecological mechanisms at different scales, especially at the microscopic scale, which is an important step to clarify the ecological process and mechanism of how LUCC influences ecosystem services.

4.2. Ecosystem Services and Human Well-Being

(1) The nature of various ecosystem services and their impacts on human well-being are unresolved. The relationship between ecosystem services and human well-being is not a simple one-way linear correlation; rather, it is more of a complex, nonlinear relationship. Human well-being can also affect the supply of ecosystem services through the feedback of the social ecosystem; existing studies also have certain limitations on the understanding of

human well-being because of the sociality of human well-being. Therefore, an in-depth study of the interaction mechanism between ecosystem services and human well-being plays an important role in resolving controversial resource utilization and promoting sustainable development.

(2) The complicated relationship between ecosystem services and multilevel well-being at different temporal and spatial scales needs to be clarified. The internal laws and characteristics of the spatiotemporal changes in ecosystem services are not inconsiderable. The supply of ecosystem services changes over time. The lack of understanding of the spatial structure, spatial flow, and socioeconomic effects of ecosystem services has led to the current discussion of the relationship between the two, mostly focusing on proposing conceptual frameworks and qualitative descriptions. Quantitative relationship studies are lacking, and this information will help understand the complex processes and mechanisms between them further.

(3) The preferences of different groups for ecosystem services and various stakeholders of human well-being need to be focused on in future studies. How the behaviors of different entities affect ecosystem services and the well-being of various stakeholder groups and how the well-being of these stakeholder groups changes over time have spillover effects on other regions. In order to provide credible information to decision makers, these problems should be researched. In addition, few studies have clarified users' preferences and perceptions of ecosystem services, which is useful in policy making.

(4) Knowledge about how governance affects the sustainability, efficiency, and fair value of ecosystem service supply is lacking [180]. Compared with other interventions, few people have investigated the effectiveness of policies based on ecosystem services, which is a new challenge for the government to assess the policy implementation.

4.3. LUCC, Ecosystem Services, and Human Well-Being

(1) Research on the temporal and spatial relationships of LUCC–ecosystem services–human well-being needs to focus on the relationships between scales (local, watershed, regional, and global) and the impacts on ecological processes. Human activities, ecosystem services, and human well-being have a complex relationship on a spatial scale. The spatiotemporal mechanism remains unclear, especially at the microscale. The study of the internal connection of LUCC, ecosystem services, and human well-being from the perspective of biophysical processes should be enhanced. Only when we have a complete understanding of the three elements, can we develop appropriate strategies and determine the management regime.

(2) The analysis of driving forces under different scales among LUCC, ecosystem services, and human well-being needs to be strengthened. Owing to various natural and social factors, such as climate change, land use change, biological invasion, policy, technology, economy, and population, ecosystem services have high temporal and spatial variabilities [181]. Therefore, it brings resistance to the formulation and implementation of ecosystem service management policies. In order to address scale issues and balance national and local benefits in a large project decision, it is necessary to clarify the different driving forces under different scales.

(3) The preferences and perceptions of ecosystem services and human well-being by different groups, genders, and ages have not been correlated with land use types. This result can offer valuable information for comprehending the impacts of various LUCCs on the deterioration or protection of ecosystem services and help governments make decisions [182].

(4) The cumulative effects of climate change on ecosystem services need to be taken into consideration. When studying LUCC–ecosystem services–human well-being, climate change and land use change are closely related in time and space [94], and attention should be paid to the impact of climate change on ecosystem services and human well-being, which can provide enough evidence for comprehensive environmental management.

5. Conclusions

With the changes in the global environment and the impact of human activities, human beings are seeking nature-based solutions. Hence, an increasing number of studies have focused on "LUCC–ecosystem services–human well-being". However, most studies have focused on discovering the relationship between LUCC and ecosystem services, while an increasing number of studies are trying to reveal the complicated relationship between ecosystem services and human well-being. Although previous studies provided valuable information on the relationships between LUCC and ecosystem services, exploring the linkages between ecosystem services and human well-being, the in-depth linkages among these three elements have not been clearly and systematically understood. In this review, we have gone a step further to build up the scientific knowledge among LUCC, ecosystem services, and human well-being, clarify how these three elements are linked, and reveal their future research trends. This paper uses a systematic literature review of the peer-reviewed literature to summarize present research paths, visualize the linkages, and discuss the future research trends on this topic. The main findings of the review are as follows:

(1) Existing research in exploring the relationship between LUCC and human well-being is usually through land use type change, land use spatial pattern change, and land use intensity change. They usually use a collection of several different methods to explore the difficult relationships between LUCC and ecosystem services. In addition, scale effects are still a challenge in current studies.
(2) Although there is no universal indicator of measuring human well-being, different studies build evaluation indicators to measure human well-being according to their understanding of human well-being. Moreover, the study of ecosystem services and human well-being is usually applied in poverty alleviation, ecosystem health, biodiversity, sustainable development, and natural capital.
(3) The ways affecting LUCC, ecosystem services, and human well-being can roughly be divided into three types: resource system change, government system change, and political system change.
(4) The directions of further development on the topic of LUCC–ecosystem services–human well-being are discussed. There is still a lot of space for further improvements. Four issues were listed which are worth addressing in future studies of "LUCC-ecosystem services-human well-being": spatiotemporal scale correlation, driving force analysis under different scales, the correlation among different group characteristics in human well-being, and the impact of climate change on ecosystem services and human well-being.

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