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Review

Land Use Transitions: Progress, Challenges and Prospects

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Abstract: The study of land use transition has generally become an important breakthrough point to deeply understand the human-land interaction and reveal major socio-economic development issues and related environmental effects. Attempting to provide scientific support for sustainable land use and environmental management, this review systematically analyzes the overall picture, development trends, key fields and hot topics of land use transition research in the past two decades from a comprehensive perspective, which incorporates two complementary parts including the systematic quantitative literature review (based on CiteSpace) and the traditional literature review. The results reveal that: a. current research presents three characteristics, i.e., focusing on complex social issues, driven by realistic demand, and research branches becoming clearer and more systematic; b. there are four key fields and hot topics in land use transition research, i.e., i. theories and hypothesis of land use transition; ii. measuring land use transition; iii. the impacts of land use transition on "social-economic-ecological" system; iv. drivers and regulation of land use transition. However, challenges remain, current land use transition research is still to some extent fragmented, and it should be enriched by integrating with land system science. The dominant morphology biased should be redressed by underlining the recessive morphology transition process. Meanwhile, new techniques and methods are necessary to observe, track, monitor and model the recessive attributes. Finally, distant drivers of land use transition should not be ignored in this rapidly globalizing world.

Keywords: land use transition; land use morphology; land system science; literature review; CiteSpace; progress and prospects

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1. Introduction

Land is the spatial carrier of anthropogenic activities, the most basic production factor of socio-economic development, and the most fundamental survival resource for urban and rural residents. Since the end of the 20th century, increasing intensive land use activities have become an important factor affecting global sustainable growth. On the one hand, over-exploitation and uncontrolled utilization of land resources in areas with higher natural suitability has brought huge challenges to regional sustainability. On the other hand, farmland abandonment in marginal areas has brought about a greater threat to food security [1–3]. A series of problems such as increased pressure on agricultural land, soil pollution and decreased biodiversity caused by high-intensity land use have brought about many difficulties to the development, management and sustainable use of land resources, and also attracted wide attention [4]. Land use faces the challenge of how to address the relations between meeting human needs and maintaining the long-term ability of the biosphere to provide goods and services [5].

At present, the world is experiencing major changes, which are intertwined with epidemic such as the COVID-19. Climate change poses severe threats to human survival [6].

As the leading sources of greenhouse gas emissions, land use transition (LUT) has greatly challenged the functions of ecosystems, thus having an important impact on climate change [7]. How to take effective measures to deal with resource exhaustion and the impact of human activities on the environment, ensure food security and further understand the feedback relationship between the natural environment and human society, has become an important issue that needs to be solved urgently [8]. LUT research helps to provide comprehensive information for decision-makers in land use planning and environmental management, and has important practical significance for coordinating regional social, economic and ecological development goals. In recent years, the research projects and related papers concerning LUT have shown a rapid growth trend, but the comprehensive and systematic bibliometric analysis is still insufficient. Scholars' focus on LUT research is constantly changing and adjusting. Therefore, it is necessary to clarify the research focus of different periods and the network relations of the hot topics. Several questions should be answered:

(1) What is the general trend of LUT research?
(2) What are the distinguishing stage characteristics and hot topics of LUT research?
(3) What are the major fields of LUT research?
(4) What are the challenges and future directions of LUT research?

2. Data and Methods

The literature data in this paper comes from the core collection of the Web of Science database (http://apps.webofknowledge.com/, accessed on 20 March 2021). Web of Science is an important database for obtaining global academic information. It includes more than 13,000 authoritative and high-impact academic journals around the world, covering fields such as natural science, engineering technology, biomedical science, social science, art and humanities, with data dating back to 1900. Web of Science catalogs references cited in this paper. With a unique citation index, users can easily retrieve their citation and trace the origin and history of a research document by using an article, a patent number, a conference document, a journal or a book as the search term.

This paper analyzes the knowledge graph by CiteSpace. CiteSpace is a data mining and visualization analysis software jointly developed by Professor Chen Chaomei from the School of Information Science and Technology of Drexel University and WISE Laboratory of Dalian University of Technology. The software can dig the underlying information and intuitively present relevant information and the interrelationships between information entities through a visual knowledge map by extracting and analyzing the subject information such as keywords, topics, authors and institutions. This software also shows the development trend of a discipline or knowledge field in a certain period through the convergence of relevant information, and reveals the development status of scientific knowledge in this field. It is widely used in information science, economics, sociology and many other fields [9]. The search prerequisites of LUT research are set as follows: "TS = land use transition", with TS as the theme, time spans 1900–2021, the language is English, and the literature type is article. There are 8700 records were retrieved, and 8564 records remain after eliminating the literature that is not related to the research subject, the earliest year is 1987. Based on Citespace.5.6.R3, we set the parameters: the cutting time is set as 1a (year), the threshold positioning is Top 50; the node type determines the purpose of CiteSpace analysis, so we select keyword in node types. Co-occurrence analysis helps us understand the hot topics, topic distribution and subject arrangement [9]. Keyword co-occurrence analysis is an effective tool of analyzing the keywords provided by the authors in the data set. Relying on keyword co-occurrence analysis of 8564 records related to LUT, the literature was macroscopically visualized and the network map was obtained, and the research progress of LUT was discussed.

This review consists of two complementary parts: the systematic quantitative literature review (Section 3) and the traditional literature review (Section 4). Systematic quantitative literature review uses a large amount of literature analysis, to explore the critical path and knowledge inflection point of the evolution of the subject field, so as to help scholars quickly understand the relevant situation of the field. However, there are still some defects in this method. It is unable to review the previous studies in a more deeply way and clarify the research context of different branches. Therefore, based on the systematic quantitative literature review, this article further carries out traditional literature review in order to better understand the research of LUT.

3. Statistical Analysis of Literatures Concerning LUT Research

3.1. An Overview of LUT Research

The number and trends of published literatures concerning LUT research from 1987 to 2020 were analyzed (Figure 1). We found that the number of literatures in this field has shown a fluctuating upward trend, and the number of published papers showed a rapid upward trend after 2013. According to the number of annual publications, the research on LUT can be roughly divided into two stages: (1) Slow growth stage (1987–2006). Research on LUT has been developed from scratch, and some developed countries have begun to devote themselves to related research on forest transition. (2) Rapid development stage (2007–present). Research on LUT has gradually received attention, the number of papers related to the subject of LUT has increased rapidly, and scholars have carried out a series of researches from different disciplines and perspectives with a variety of methods and technical means.

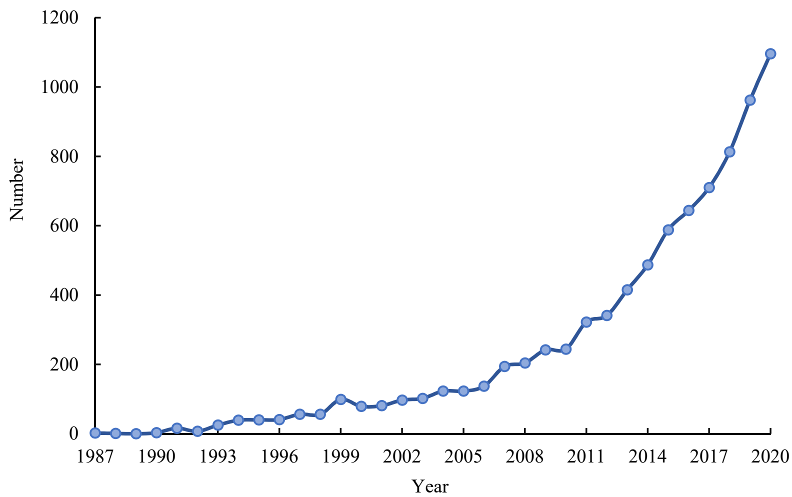

Figure 1. Number of literatures concerning LUT research from 1987 to 2020.

According to data from Web of Science, by the end of 2020, the top three countries with the number of publications on LUT research are USA (2982), China (1496) and Germany (844), followed by UK, Australia, Canada, Netherlands, France, Spain and Italy (Table 1). Research on LUT has attracted widespread attention in various fields. Statistical analysis shows that research results related to LUT have been published in more than 1600 SCI/SSCI indexed journals, covering multiple disciplines and fields such as geography, environmental science, ecology, sociology, economics and urban planning. The top 10 journals with publication volume are: *Land Use Policy, Sustainability, Remote Sensing of Environment*, *Remote Sensing*, *Science of the Total Environment*, *Land*, *Plos One*, *Applied Geography*, *Landscape and Urban Planning* and *Environmental Research Letters* (Figure 2).

Table 1. Major countries publishing articles concerning LUT.

Rank	Country	Number of Articles	Centrality [a]
1	USA	2982	0.32
2	China	1496	0.03
3	Germany	844	0.19
4	UK	727	0.14
5	Australia	563	0.16
6	Canada	515	0.17
7	Netherlands	454	0.1
8	France	435	0.14
9	Spain	358	0.08
10	Italy	350	0.05

Note: [a] Centrality is an indicator to measure the importance of nodes in the network [10]. The larger the value of centrality is, the more the number of publications cooperated with other countries.

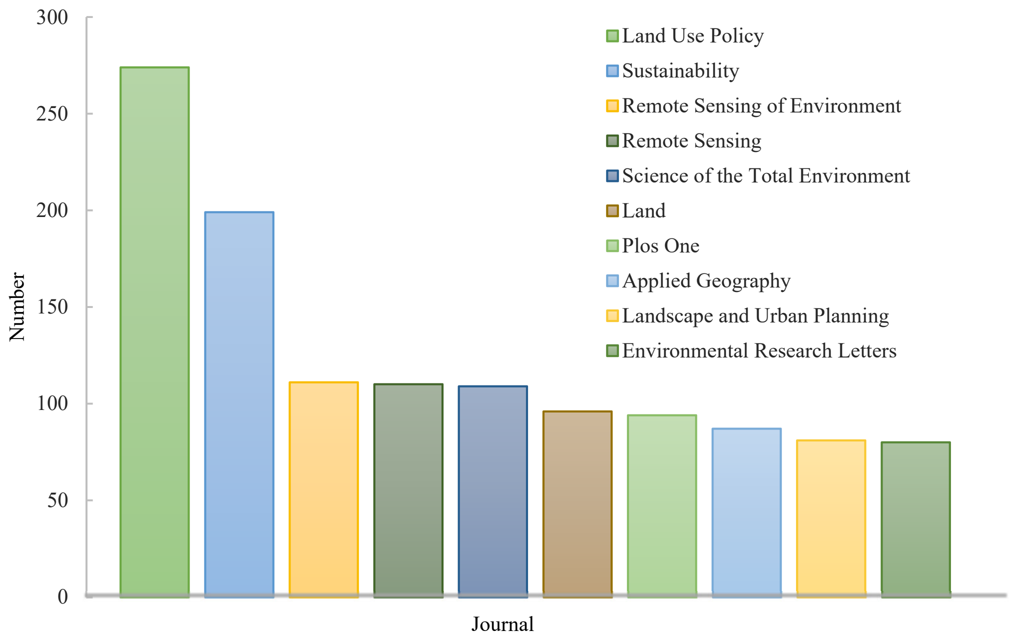

Figure 2. The top 10 journals with publication number concerning LUT during 1987–2020.

3.2. Evolving Research Hot Topics

3.2.1. Analysis of Keywords and Hot Topics Distribution

CiteSpace provides three visualizations methods: cluster view, timeline view and time-zone view. Among them, the timeline view focuses on delineating the relationship between clusters and the historical span of literature in a certain cluster. Based on CiteSpace, the key-words and hot topics related to LUT research since 2000 (few literatures on LUT previous to this) were analyzed. CiteSpace provides two indicators, modularity Q (Q) and weighted mean silhouette (S), based on the network structure and the definition of clustering. It can be used as a basis for us to judge the effect of atlas rendering. Generally speaking, Q value is generally within the interval of (0, 1), and $Q > 0.3$ means that the community structure divided is significant. Weighted mean silhouette means the homogeneity of the cluster. The higher the value is, the more consistent the members in the cluster will be. $S > 0.7$, means that the clustering is efficient and compelling [9]. The result showed the modularity Q and weighted mean silhouette of the cluster analysis are 0.6333 and 0.7154, respectively, indicating that the model clustering results are scientific and reasonable. Finally, the timeline map of LUT research from 2000 to 2020 was obtained (Figure 3). Related research hot topics can be roughly divided into 11 categories, i.e., LUT, land change, rural development, fallow management, circulation, shifting cultivation, change detection, habitat, land-use change, rural poverty alleviation and grassland traditional management. There are 10 keywords with a frequency of more than 30, i.e., dynamics, impact, China, deforestation, pattern, forest transition, cover change, urbanization, land use and model. Through the analysis of high-frequency words, it is found that the keywords of LUT research cover a wide range, and there are obvious differences in the research focus and hot topics at different stages. In general, it can be divided into the following three stages:

(1) Slow growth stage (2000–2007): This stage focuses on forest transition and land use change caused by large-scale deforestation due to population growth and agricultural expansion, as well as the impact of LUT on climate change, landscape, ecosystem, grassland management and agriculture policy.

(2) Fluctuant rising stage (2008–2012): At this stage, research on LUT has gradually attracted attention. The research focuses on land use change under the context of globalization, and the impact of farmland abandonment, grassland degradation and other factors on land use management and sustainable regional development.

(3) Rapid development stage (2013–present): Related research pays more attention to LUT and its resources and environmental effects in the process of globalization and rapid urbanization. Measuring methods and models of LUT have been explored extensively. At this stage, land abandonment and farmers' livelihood changes brought about by farmland and rural housing land transition have arisen the attention on the issues of ecosystem service changes.

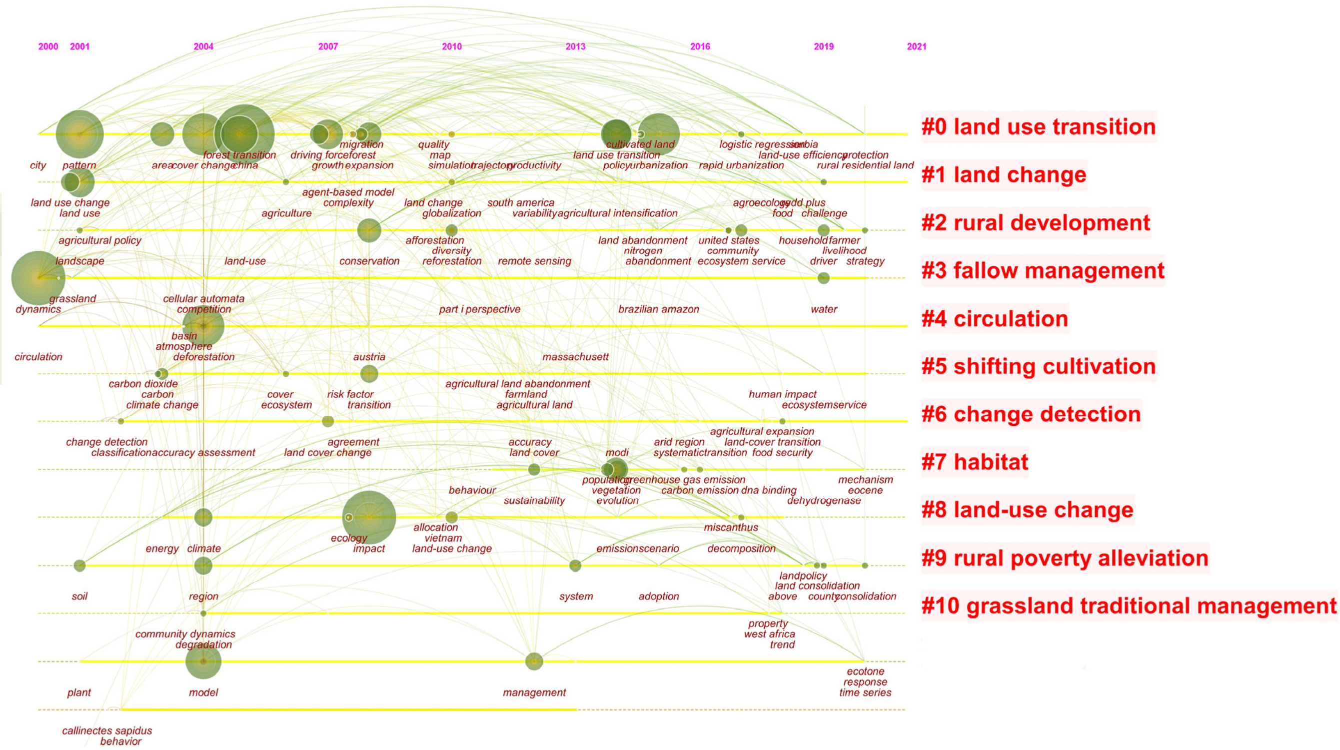

Figure 3. Timeline map of LUT research.

3.2.2. Burst Words Analysis

The keywords emergence degree can be used to explore the words with high frequency changes in a certain period of time from a large number of subject words, thereby reflecting the change of research hot topics during that period. Burst words represent the phenomenon that the keywords to be investigated transition in a short period of time. Burst words can detect words with a high frequency change rate in a certain period of time from a large number of subject words by investigating word frequency, emphasizing sudden change. Burst terms detection in CiteSpace was used to detect the emergent keywords in the LUT research from 2000 to 2020, and 25 emergent words were detected (Table 2). It can be seen from Table 2 that at different stages, there are obvious differences in research focus and hot topics areas. Before 2010, there were relatively few research on LUT, mostly focusing on the impact of grassland degradation and deforestation on ecosystems, as well as the spatio-temporal evolution characteristics of LUT and simulation studies. After 2010, the direction of LUT research has become more diverse, the frequency of hot topics has increased and more attentions have been paid to the research on complex issues caused by LUT. From 2010 to 2017, research topics such as land-change, transition-matrix, management, land-cover change and land-use change received more attentions. From 2017 to 2020, relevant research pays more attention to the impact of urbanization expansion and globalization on LUT. Among them, the spatio-temporal evolution of land-use change process, driving factors and its impacts on regional sustainability have become hot topics.

Table 2. Top 25 keywords with the strongest citation bursts during 2000–2020.

Keywords	Year	Strength [a]	Begin	End	2000–2020 [b]
vegetation	2000	14.51	2000	2007	
evolution	2000	7.01	2000	2007	
simulation	2000	15.47	2000	2011	
record	2000	9.2	2000	2014	
ecosystem	2000	11.03	2002	2010	
fire	2000	8.45	2002	2011	
pasture	2000	7.41	2004	2011	
grassland	2000	8.67	2005	2009	
deforestation	2000	7.32	2007	2008	
forest transition	2000	7.17	2008	2013	
land-change	2000	15.71	2010	2010	
transition-matrix	2000	3.22	2010	2010	
management	2000	3.3	2012	2018	
carbon stock	2000	7.42	2014	2017	
land cover change	2000	3.44	2015	2016	
land-use change	2000	3.35	2015	2017	
expansion	2000	3.62	2017	2020	
sustainable development	2000	9.74	2018	2019	
land use transition	2000	4.11	2018	2020	
life cycle assessment	2000	7.05	2018	2020	
urbanization	2000	6.39	2018	2020	
ecosystem service	2000	11.36	2019	2020	
renewable energy	2000	9.2	2019	2020	
politics	2000	7.51	2019	2020	
consolidation	2000	7.45	2019	2020	

Note: [a] Strength is an indicator to measure the degree of a burst event. The larger the value is, the more active the keyword is in the research field. [b] The red line indicates the year with active burst words, and the green line indicates the year with inactive burst words.

3.2.3. Analysis of Institutional Cooperation Network

The institutional cooperation network map can show us how the various institutions are connected, as well as the contribution of each institution in the field of LUT research, which helps us identify researchers and institutions that deserve attention. Through analyzing the major research institutions and cooperation networks of LUT research, we found that LUT research has received extensive attentions in 88 countries and 420 research institutions all over the world (Figure 4). Universities and scientific research institutes have relatively close ties and cooperation. There are 47 institutions with more than 40 articles. The Chinese Academy of Sciences occupies a central position in the cooperation network in the field of LUT research, with University of Maryland, Beijing Normal University, University of Wisconsin, National Aeronautics and Space Administration, Colorado State University, Humboldt University, University of Copenhagen and Peking University, as the linkage of the network. In addition, Wageningen University, Michigan State University, University of Amsterdam, Arizona State University, Columbia University, Stanford University, Yale University and other research institutes have also published more fruitful works.

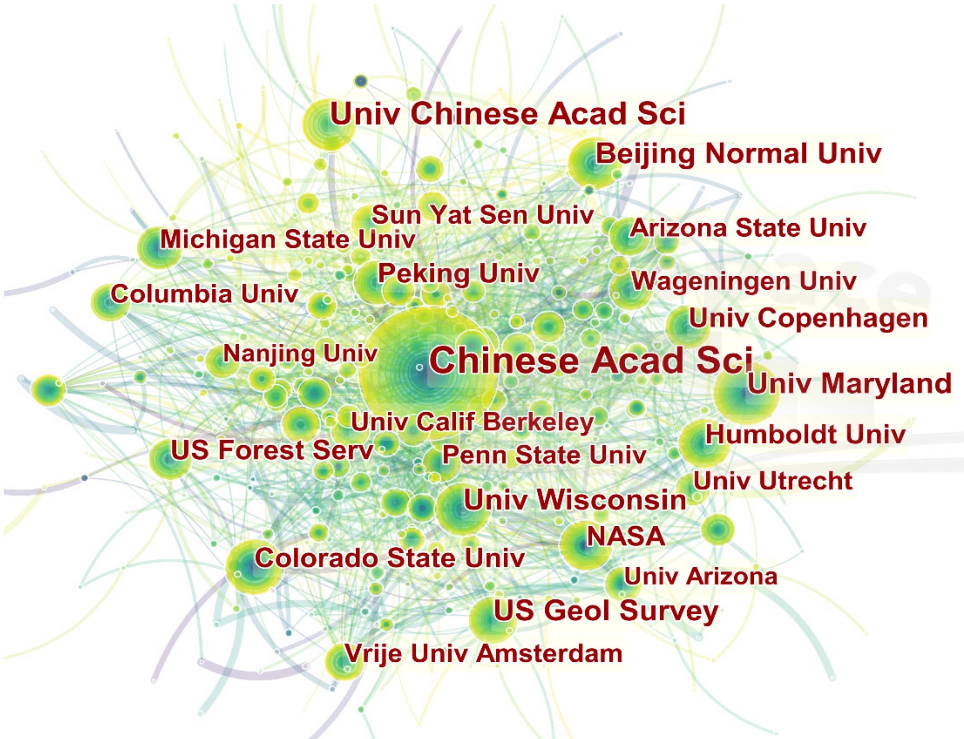

Figure 4. Institutional cooperation network map of LUT research.

4. Key Fields and Hot Topics of LUT Research

4.1. Theories and Hypothesis of LUT

Due to population growth, the global demand for food has accelerated the transformation of natural ecosystems into agricultural land. However, in some developed countries with diversified livelihood strategies, forest coverage has also increased. The latter trend is referred to as the forest transition, which is defined as the transition from net deforestation to net forest coverage increase [11]. In the early 1990s, Mather pioneered the forest transition hypothesis [12,13]. In 1995, Grainger proposed the concept of LUT from the perspective of land use morphology changes in forestry countries. He assumed that most forestry countries have to go through some stages of development: continuous deforestation and increased forest land until a new balance is reached between the forestry and agricultural sectors [14,15]. Forested land can even increase again due to self-regeneration and artificial afforestation. This turning point is what Mather calls forest transition, that is, at this point, the national forestry cover stops decreasing and starts to increase. In 2005, Foley constructed a stage model of LUT, suggesting that land may undergo five stages of transformation from natural ecosystems such as forests to territorial reclamation, subsistence agriculture and smallholder management, gradual intensification and intensive use [5]. Due to differences in the historical, social, economic conditions and ecological environment of different regions, the speed and stage of LUT are also different, and they are subject to socio-economic levels and national policies.

Human activities have modified the natural environment considerably. As the population grows, growing demand for food makes more land is needed to expand food production, which intensifies land-use and land-cover changes (LUCC) [16–18]. To gain better understanding of land-use and land-cover changes and of the physical and human driving forces behind these processes, LUCC project was cosponsored [19]. LUT is one of the manifestations of LUCC, and is also an important research content of GLP. Scholars have carried out research on the conceptual connotation, theoretical models, measurement methods, driving mechanism and environmental effects of LUT [20–24]. Long theorized land use transitions by developing and expanding the concept and connotations of land use morphology as dominant morphology and recessive morphology [23]. The dominant morphology refers to the land use structure of a certain region over a certain period of time, with features such as the quantity (area and proportion) and spatial pattern of land use types. While the recessive morphology includes the land use features in the aspects of quality (nutrient, pollution and degradation), property rights (state-owed and collective-owed), management mode (individual, joint-stock system and transfer and large-scale management), input (capital, technology and labor), output (yield, output value and input-output ratio) and function (production, living, ecology and culture). Accordingly, the concept of LUT was further developed as the changes in land use morphologies, including dominant morphology and recessive morphology, of a certain region over a certain period of time driven by socio-economic change and innovation, and it usually corresponds to the transformation of the socio-economic development stage [23,25]. Long put forward the theoretical model of regional land use transitions, i.e., as the socio-economic development, the competition/trade-off between different land use types presents a decreasing trend, and finally achieves a stable equilibria [25,26].

Based on the special socio-economic, socio-ecological and physical conditions, some scholars probed the research theoretical framework and hypotheses of LUT [27–32]. Qu and Long (2018), based on existing researches and the Environmental Kuznets Curve, put forward a theoretical hypothesis of the interactive mechanism among the land use transitions, the economic effect, the environmental effect and the land use management. Finding that there was a one-way Granger causality from urban construction land use transitions to economic development and environmental pollution, respectively, and no significant Granger causality was found from land use management to economic development or environmental pollution [33]. Some scholars supported that LUT refers to any change in land use systems from one state to another one, land use change is non-linear and different parts of the world are in different transition stages, depending on their history, social and economic conditions and ecological context [32,34].

4.2. Measuring LUT

The selection of land use morphology indicators and the measurement of its transition process are the premise and basis for analyzing the characteristics of LUT. The extension of land use morphology brings about opportunities and challenges as the qualitative aspect of land use transitions is reflected by the changes of recessive land use morphology, which is difficult to be measured or represented [35,36]. The research on the dominant morphology of land use is an important prerequisite for the recessive morphology research. The dominant and recessive morphologies are coupled to construct the characterization index of LUT, and various methods are used to quantify LUT. Comprehensive measurement helps to explore the characteristics and regularities of LUT from multiple perspectives and levels. Accordingly, Long put forward three innovative integrated approaches to study land use transitions: one is the multidisciplinary research framework for recessive LUT which involves disciplines including geography, management, economics and sociology [23]; another is the horizontal comparison research method with space to exchange for time [25]; the other is the transect research method based on the key gradient factor of regional socio-economic development [37]. Tsai used interactive LUT agent-based model by endogenizing the interactions of socio-ecological feedbacks and socio-economic factors in a generalizable model to simulate changes in land use caused by farmers' decision-making behaviors, and the recursive effects of land use changes on farmers' decision-making behaviors, and explored the conditions for forest transition in different scenarios [38]. Some scholars have used land satellite images and GIS to explore the trajectory of long-term series of forest cover changes, reveal the main driving paths of forest transition, and analyze the impact of forest transition on ecosystem products and services [39–41].

Through literature review, it is found that since the end of the 20th century, related research has shifted from focusing on single-dimensional LUT to multi-dimensional one [42–44]. At present, scholars are conducting research on the measurement, simulation, spatial differentiation characteristics and influence factors of LUT based on remote sensing data, national statistics data and survey data [45–49]. The measurement methods include classification and regression tree (CART) models, interactive land use transition agent-based model (ILUTABM), global land-use model (GLM), system of environmental-economic accounting (SEEA), center of gravity model, cold/hot spots analysis and other methods [22,50–58] (Table 3). At the same time, methods such as structural analysis, questionnaire interviews and the spatial econometric model have also been gradually applied to related researches. Abundant data sources and multiple models provide a variety of ideas for the measurement of LUT, and also provide scientific support for the research of LUT caused by socio-ecological feedback under the background of globalization. However, current researches focus on the measurement of the dominant morphology transformation of land use, while the measurement of the recessive morphology transformation of land use and its impact on "social-economic-ecological" still need to be further explored.

Table 3. Characterization and measurement methods of LUT.

Data [a]	Methods	Object/Research Question	Reference
Remote sensing data	Classification and regression tree (CART) models	Land use transitions in unsustainable arid agro-ecosystems	Romo et al., 2014 [41]; Bonilla-Moheno and Aide, 2020 [50]
	Cellular automata models	Rules relate LUCC variables to the observed historical changes	Roodposhti et al., 2019 [51]
	Land-use transfer matrix	Regional land use type conversion	Liu and Long, 2016 [22]; Quintero-Gallego et al., 2018 [52]
	Interactive land use transition agent-based model (ILUTABM)	Simulates the land use changes resulting from farmers' decision	Tsai et al., 2019 [56]
Statistics data	Global land-use model (GLM); earth system models (ESMs)	Harmonization of land-use scenarios	Hurtt et al., 2020, 2011 [47,57]
	Transect research method	Rural housing land transition	Long et al., 2007 [37]
	Land use change (LUC) models, Dyna-CLUE model	Assessment Land use change modelling accuracy	Lü et al., 2020 [54]
	System of environmental-economic accounting (SEEA)	Land cover account	Wentland et al., 2020 [48]; Weber, 2007 [49]
Survey data	Ethnographic fieldwork	How customary land tenure systems mediate transformations of land use and livelihoods	Rignall and Kusunose, 2018 [58]
	Decoupling index model and balance index model	Coupling relationship of land use transition between cultivated land and rural residential land in China	Qu et al., 2019 [55]

Note: [a] Measuring LUT is highly depended on the data sources, which is an important criterion and perspective for the classification of the techniques of measuring LUT. Therefore, we divided the measurement methods of LUT into three types based on data sources, i.e., remote sensing data, statistics data and survey data.

4.3. The Impacts of LUT on "Social-Economic-Ecological" System

4.3.1. Impacts of LUT on Social Development

LUT is the result of the interaction between natural environmental conditions and socio-economic factors. Influential factors of LUT include endogenous socio-ecological forces and exogenous socio-economic factors [32]. On the one hand, various land use issues are related to the rapid urban-rural transformation development, which has significant impacts on land use policies [59–61]. On the other hand, socio-economic system and policies, especially those that related to land resources management, are important external factors that play a vital role in shaping land use morphology [62,63].

Considering the regions that LUT takes place, it can be divided into two counterparts-urban area and rural area. Urban LUT is a process of the expansion of construction land and reduction of cultivated land and forestland in the process of urbanization. Farmland transition and rural housing land transition are two crucial contents of rural LUT [64–66]. Against the context of globalization, marketization and urbanization, the growing foreign direct investment and tertiary industry accelerates the expansion of urban construction land, which encroaches on vast farmland and drives the changes of household livelihood and population flow, and, finally, induces the alteration of land use structure [67,68]. In view of rural regions, the variation of regional land use morphology is tightly associated with rural transformation development, and at the same time, is constrained by system vicissitude and national strategy [58,69]. The strategy to alleviate the pressure on land resources in some areas is to move production activities from one area to another [70], and it is not a sustainable way. Therefore, some scholars proposed sustainable land management scheme to assess the risk of land consolidation and agricultural development, reconcile environmental and agricultural policies, and to solve the problems of grassland abandonment and low land use efficiency [71,72].

4.3.2. Impacts of LUT on Economic Growth

LUT is motivated by socio-economic changes. Due to the extensive exchange of energy, material, and information flows between the internal and external urban-rural territorial system, the main bodies of land use are more sensitive to the economic and social responses. Decisions relating to economic development demand often directly or indirectly change the supply of land services, thereby triggering the transformation of land use structure and functions [63]. With the increase of population, in order to meet people's various demands for land in production and living, productive land around the world has been extensively developed and converted [73]. Regarding competition for productive land, different scholars have different views, Malthusian believes that the stock of suitable land is finite, continuous development will lead to a shortage of productive land, which will have a negative impact on welfare. Ricardian reckoned that it becomes economically feasible to bring marginal land into use as prices of land-based commodities increase, but it comes at ever increasing economic, environmental and social costs. The economic impact of LUT is not directly proportional to the area loss, but is affected by the combined effects of soil capacity, dryland crop combination and local economic factors [74]. Due to the changes in socio-economic factors, such as the decline in soil quality, the increase in the opportunity cost of farming, the outmigration of rural labor, the adjustment of agricultural policies, and the reform of the land system, etc., land abandonment has become one of the important trends of global land use changes and it is crucial for agricultural production and landscape planning [1,52,75]. In response to the negative effects of LUT on rural economic development, Ojoyi pointed out that extra employment opportunities and livelihood support activities should be created to minimize dependence on natural resources [7]. Some scholars believe that through rural land use planning and advanced technologies, agglomerated economic production can be formed, which promotes the transition from the fragmented use of land under the subsistence agriculture model to the large-scale management under the intensive farm model, so as to reduce deforestation and relieve land pressure and improve land use efficiency [5,76–78].

Rural reform and development have always been the hot-spot issues of LUT, which function as the tool of regulating land use and promoting socio-economic development [33]. The internal driving force of LUT comes from the trade-offs and games between different stakeholders, which is manifested in the conflict of land use patterns. Driven by conflicts, the structure and function of land use are continuously adjusted to adapt to the new balance requirements, and, finally, LUT is realized through land services supply [4,79]. Farmland use is a complex process of rural agricultural economic reproduction and natural reproduction. The transition of cultivated land use has an important impact on the rural natural landscape and socio-economic development [53,80]. Especially in the context of ecological civilization construction and national food security, research on the mutual feedback mechanism of farmland transition and food security, and its impacts on farmers' livelihoods, rural industrial development and rural transformation development have received widespread attention [24,81].

4.3.3. Impacts of LUT on Ecosystem Services

At present, research on LUT and its environmental effects is mainly implemented by using GIS techniques, ecosystem service value assessment, landscape pattern index and ecological environment index, at the scales of regional, drainage basin, provincial, prefecture-level city, county level and township level. In the process of socio-economic development, the impacts of LUT on eco-environment have become one of the research priorities of global change research. The corresponding research contents range from atmospheric composition to terrestrial ecosystem [82–84], which generally can be divided into three aspects: (1) the impacts of LUT on atmospheric environment, water environment, soil environment, vegetation and biodiversity; (2) the impacts on overall ecosystem service; (3) the landscape ecological pattern responses, and the coupling relations between land use structure and land use multifunctionality [85–87].

Land development is revenue-oriented, the increase in human activities and commercial space is mainly at the expense of forest-covered ecosystems, farmland and pasture [19,88–90]. How to deal with the trade-offs between the value derived from new land uses and the cost of lost ecosystem services has become a very important proposition. The rapid transformation and fragmentation of land cover may lead to a series of problems such as biodiversity loss, land degradation, water quality decline, insufficient food supply, extinction of wildlife and environmental degradation [91–95]. Faced with the trade-off between environmental protection and food security, some scholars have proposed ecological plans for cropland reforestation and urban green projects through the production of commodities with high income and price elasticity to alleviate the pressure on the ecological environment caused by over-development of land resources [86,96]. In order to alleviate the pressure on grassland areas caused by the transformation of grassland to cultivated land, the EU sets minimum standards for the protection of the ratio of permanent grassland to protect the ecological value of grassland [97].

4.4. Drivers and Regulation of LUT

4.4.1. Research on the Driving Factors of LUT

In most cases, LUT is a random process [5]. Carrying out research on the driving factors of LUT will help scientifically regulate the quantity and quality of regional land resources, and is of great significance to regional land use planning, regional ecological environmental protection, mitigating global climate change and vegetation restoration strategies [7,98,99]. From the perspective of the land system, the driving factors of LUT can be divided into endogenous driving forces and external driving forces. The interaction and mutual influence of various factors have a comprehensive and complex impacts on urban-rural development and land use. On the one hand, with population growth, people's demand for productive land and residential land has increased. Urban land and agricultural land have largely replaced other land, and were limited by the location [100–102]. On the other hand, with socio-economic development, global power has become the main determinant of LUT. Facing the pressure of population growth and extreme poverty, national markets and policies created opportunities and constraints for new land uses [103–105].

In general, LUT is the result of the combined effect of endogenous socio-ecological feedback and exogenous socio-economic factors [106]. The intense flows of information, capital, commodities and people generated by the increasing interactions in this globalized world greatly influence the land use patterns, which highlights the forces of the remote markets [107]. The driving forces of LUT are related and heterogeneous in different time and space dimensions, and are affected by many complex factors such as nature, politics, economy, and culture [50,108]. Natural factors include natural disasters, endowment discrepancy and climate change; socio-economic factors incorporates globalization, urbanization, marketization, demand for agricultural products, agricultural production activities and population growth; political factors consist of national policies, land consolidation and land resource management systems.

4.4.2. Research on Optimal Regulation of LUT

At present, the root cause of many issues arise from LUT is the contradiction between socio-economic advancement and environmental protection, which results from the fact that, in most cases, economic growth is at the expense of environmental sustainability [77]. How to deal with the relationship between the social and economic benefits and resources and environmental benefits is the key to optimal regulation of LUT. Through literature review, it is found that the optimization and regulation of LUT is mainly realized through engineering and technological means, and policy and system innovation. The main cause of LUT lies in the fact that rural land has been intensively occupied by urban construction land. In terms of the regulation of LUT, it is necessary to change the way in which the external system of the rural area affects the internal system, promoting the free flow of urban and rural elements [109–111]. Land use planning and land consolidation are important engineering techniques to optimize and control the LUT. Rural land use planning is a way to ensure the best use of land. By evaluating and balancing the trade-offs between different social, economic and environmental goals, it discusses how to adjust the land use structure through spatial planning, so as to achieve the optimal land use status and promote the transformation of land use from single-function oriented to multifunctional land use [112–115]. As a policy tool to optimize the structure of land use and improve the efficiency of land use, land consolidation has the dual attributes of engineering projects and policy measures [72,116,117].

In response to the problems induced by LUT, relevant management departments have formulated a series of policy interventions to promote the sustainable use of land resources. Such as America's Endangered Species Act (ESA) and National Environmental Protection Act (NEPA), and land retirement programs and production subsidies, China's "1.8 billion mu red line" and "Grain for Green Policy", and Morocco's Customary land tenure [29–31]. France has adopted environmental policies aimed at the conservation of natural habitats and wildlife, and Cameroon enacted national forest law, which provided the legal basis for the implementation of a land use zoning [8,75,118,119]. It is possible to design alternative land-use management strategies to fight desertification processes [70]. Customary land tenure is essential for regulating land use and farmers' livelihoods and ensuring economic growth [69]. In addition, applications of dynamic land use classification have also been highly recognized. In order to facilitate the targeted implementation of land management strategy, some scholars divided territorial space into rural protection area, suburban coordination area, urban agglomeration area, restricted development area and conditional construction area, and propose corresponding management measures and policies according to the characteristics of each specific area to regulate land use activities and address the relationship between economic development and environmental protection [87,120].

5. Challenges and Prospects

The above analysis reveals that there still exists some drawbacks on LUT research that should be further improved. By reviewing the literature regarding the impacts of LUT on social and economic development, and the ecosystem services, we found that these literatures are quantitative biased, which mostly rely on the new approaches, especially the remote-sensing techniques. Researchers have intensively used the geographic information systems to map and quantify the impacts of LUT on ecosystem service values. However, this review of studies reveals a distinct paucity of the comprehensive research underlining both natural and human dimensions of land use activities. A complex systems approach can aid in organizing ideas regarding complex land use process relating to the corresponding policy/institution design, utilization behavior, socio-economic and environmental impacts. Therefore, it is necessary to examine the process and its consequences under the guidance of land system science. Besides, although land use change has been studied at a wide range of spatial and temporal scales, there is currently insufficient research into the LUT at the broadest-scale. Local or regional forces undoubtedly influence the LUT process, while the global driver cannot be ignored. Globalization has been an indispensable factor reshaping land use morphology, and land systems should be understood and modeled as open systems with large flows of goods, people and capital that connect local land use with global-scale factors [121].

5.1. LUT Research under the Guidance of Land System Science

Land system science provides a theoretical guidance for integrated LUT research. Current LUT research is to some extent fragmented, merely focusing on certain single land use type, e.g., farmland, forestland, rural housing land, etc. These studies have examined the process, patterns, mechanisms and impacts of land use transitions at the local and regional scale, and, have produced synthesized findings from individual case studies, as well as have generalized our understanding of LUT process [122]. However, only focusing on the one dimension or some key elements of land system cannot meet the demands of the research on LUT as land system not only represents the terrestrial components of the Earth system, but also encompasses all processes and activities related to the human use of land [123,124]. It is acknowledged that the architecture of land system is human–natural coupled, and requires to be studied from an integrated way. Land system research therefore has become an ideal tool to cope with the complexity of LUT. As a comprehensive concept, LUT is fully embodied in the trending variation of land use morphology, which is a so inclusive term that incorporates both dominant morphology (quantity involving area and proportion, spatial pattern of land use types, etc.) and recessive morphology (quality involving nutrient, pollution and degradation, and property rights involving state-owed, collective-owed, etc.). Thus, albeit LUT and land system are different concepts, they all attempt to provide a systematic understanding of land use. Land system science aims to improve the observation, monitoring, understanding, modelling and sustainability of land system and its changes [124,125]. LUT research should be proceeded within the research framework of land system science [126], and requires improved understanding and theorizing of the changes of land use morphologies as a highly dynamic and connected complex system transition process [127].

5.2. Attaching Importance to the Transition of Land Tenure Regime

Land tenure regime is one of the important factors affecting the recessive morphology of land use, and its variation and adjustment should be underlined as the existing LUT research is dominant morphology biased. Land system/polices/institutions are instruments of regulating land use activities, and plays a vital role in shaping land use morphology. In reality, LUT is the direct result of human decision-making at multiple scales, with far-reaching consequences for the land use morphology [128]. Policy/institution making is also a human-dominated process, which is complex and intricate. Therefore, to better understand land use transitions, it is necessary to scrutinize the relationships between land tenure regime evolution and the dynamic of land use morphology. Dominant morphology continues to be strongly shaped by policy/institution interventions. It can, therefore, be surmised that land tenure regime not only greatly influences the dominant morphology, but also functions as an ideal analytical lens to examine the regularities of LUT. For instance, China's rural land use system has been reformed and innovated towards an easy-to-transfer policy design [129]. While the scale of land management, input intensity, organization form and other corresponding attributes will change. A better insight into the recessive morphology evolution from the perspective of land tenure regime change is thereby required.

5.3. Overcoming the Challenges of Detecting the Recessive Morphology of Land Use

Innovating the technologies and methods of monitoring and modeling the recessive morphology of land use is needed to provide scientific underpinning for deepening LUT research. The key words and burst words analysis show that "land use change", "eoco-system service", "environmental impacts", etc., attracted more attentions in the past few decades. However, these studies mostly rely on the quantitative variation of land use, neglecting the human domain of land use activities. Understanding the consequences of LUT requires robust documentation on the characteristics of transition process. The observation and monitoring of land dominant morphology now mainly relying on remotely sensed data coupled with field observations and corroborating information describing the social, economic and physical dimensions of land use has achieved good detection results [130]. However, the attributes of the recessive morphology of land use encompass soil quality, property rights, management mode, etc., which are hidden, invisible, intricate and difficult to observe, monitor and quantify. Thus, applying state-of-the-art techniques and innovating new methods for understanding the socio-economic dimensions of LUT is of vital importance. For instance, the big data analysis technique is an effective tool of analyzing the land property information based on the land registration data, which can deal with huge volumes of data. Information technology may be an appropriate means of capturing the capital and information flow between urban and rural regions, and, of course, can be employed into analyzing land investment data. These approaches have been used successfully in different fields of LUT research. Yet it is not enough to reveal a full picture of the process of land use transitions [131]. Improved data, upgraded models and case studies in observation and estimation of LUT impacts, which depend only on exploring advanced techniques, are demanded for seeking a deeper understanding the transition of land recessive morphology.

5.4. Linking Local LUT with Globalization

The keywords (Table 2) and timeline map analysis (Figure 3) indicated that the impact globalization on LUT have been brought into focus. LUT research has a tradition of place-based studies, focusing on local/regional trending transition of the attributes of land use. As globalization proceeds, there are signs that distal interconnections have played an increasingly role in land use activities. Yet scant attention is given to the distant drivers of LUT. The various materials and non-material flows embodied in international trade and online activities generate direct and indirect changes on land use morphology and the affiliated impacts. In order to understand the consequences of international forces on local land use, approaches or methods from information geography are necessary to capture the visible or invisible information of land use. Causes of LUT are not confined to local factors, but incorporates distant influences, such as remote markets, diffusion of technologies and international political forces. Although short-term fluctuation and changes of land use morphology cannot be understood as LUT, the so-called "transition" stems from the accumulation of the progressive changes or refinement of land use morphology. The accumulation of these subtle and major changes will ultimately restructure local land use structure, and result in the transformation of land use functions. The relation between global land use changes and the emergence of new zoonotic diseases is still unclear. A quantitative analysis indicated that human encroachment into wildlife habitats may contribute to the emergence of zoonotic diseases [132]. However, there is not enough research examining its influence on the emergence of zoonotic disease. Understanding these emerging or hidden interactions and feedbacks between distant socio-economic activities and local land use poses theoretical and methodological challenges. The theoretical lenses through which the remote impacts on local LUT can be framed have been insufficiently explored. It is crucial to develop a new generation of multi-scale models and methods to couple local and global LUT processes. As the pandemic raged, interdisciplinary collaborations are urgently needed to advance knowledge on land use implications for zoonotic disease emergence [133].

6. Conclusions

LUT is a locally pervasive and globally significant social-ecological trend. The aims of this article are (1) to investigate the progress of LUT research based on both bibliometric and a systematic review of the literature; (2) to summarize key fields and research hot topics of LUT research; (3) to identify the challenges and suggest potential directions for future research.

We have demonstrated the following:

(1) The annual output of papers has exhibited a general upward trend during 1987–2020. This trend can be interpreted as an indication of the increasing importance of LUT in the research of land system science. Research networks and collaborations including both developing and developed countries have been established, which bring together researchers, practitioners and policymakers from multiple disciplines to work collaboratively on LUT.

(2) Research on LUT is characterized by focusing on complex social issues, driven by realistic demand, and research branch becoming clearer and more systematic. The key fields and hot topics of existing LUT research can be summarized into four aspects: i. theories and hypothesis of LUT; ii. measuring LUT; iii. the impacts of LUT on "social-economic-ecological" system; iv. drivers and regulation of LUT.

(3) The complexity of LUT research requires the diversity of disciplines, methodological approaches and research scales. It has become an interdisciplinary branch of sciences of geography, economics, land management, etc., integrating multiple methods including remote sensing, GIS and mathematical models. The research scale covers multiple levels such as township, region, country and global. Emerging factors continuously bring about both challenges and opportunities to LUT research. Globalization, information technology and other modern techniques complicate LUT process, the mechanism and potential pathways of LUT would be changed. Meanwhile, improvements in related technologies can particularly enhance observing, tracking, monitoring and modeling the recessive morphologies of LUT, thus deepening LUT research.

(4) Research on LUT has still many unresolved fundamental issues. LUT research is "science- and process-centred", theoretical discussions of LUT do not offer enough assistance for regulating and managing land use activities. A focus on local case studies based on contingent factors constrains the theoretical innovation of LUT research. LUT can be apprehended through theoretical generalizations that solves limitations of case studies. LUT theories could benefit from incorporating theories of land system to address the complex interactions, multi-causality and the contextual character of LUT process. Scientific theory on LUT lags behind the research practice. Despite considerable advances in LUT research and related fields, an inclusive theory of LUT or sets of theories have not emerged. Pursuit of the theoretical improvements should also enhance the connections between LUT and global environmental change, resilience and sustainability research, aiming at translating scientific findings on land system into solutions for sustainable land use.

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