Integrated framework of rural landscape research: based on the global perspective

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Abstract
Context In recent years, rural landscapes have played an increasingly important role in the fields of tourism, cultural heritage and ecology. Rural landscape research (RLR), which is characterized by diversity and complexity, has attracted more and more attention from researchers. Objectives This study integrated the main research contents of RLR in the past 30 years by arranging the relevant research results and analyzing the research progress of RLR in order to understand the development trend of RLR, the distribution of research power, research hotspots and frontal research. Methods 3740 relevant literatures from 1931 to 2020 were filtrated from the WoS Core Collection Database. Those papers were quantitatively data mined and qualitatively summarized by using Bibliometrics software for mapping and analysis. Results (1) The number of articles related to RLR increased exponentially over time. The average citations per paper increased fastest from 2002 to 2005. According to the characteristics of the number of articles and the average citations per paper, RLR can be divided into three stages from 1990 to 2020: the first stage is from 1990 to 1999; the second stage is from 2000 to 2008; the third stage is from 2009 to 2020. The second stage of RLR has attracted the most international attention among three stages. (2) According to the results of research strength analysis, Europe has a great influence in RLR. The Common Agricultural Policy and the European Landscape Convention are the main driving forces for the change of rural landscape in Europe. (3) At present, the five hotspots of RLR are rural landscape planning and management, cultural ecosystem services, urban-rural conflict, the sustainable development of rural cultural heritage landscape and the impact of landscape structure on habitat. Conclusions Rural landscape research was originally developed based on geography and ecology but has now developed to a comprehensive research direction of multidisciplinary and multi-methods with social, economic, culture and other elements. At present, the object of RLR covers the ecological landscape, production landscape, and cultural landscape of rural landscape system; the content of RLR has shifted from static pattern of rural landscape to dynamic evolution process, urban-rural conflict, cultural ecosystem service and multifunctional landscape trade-off; the research paradigm of RLR has changed from single dimension to multi-dimensional, and combined with “3S” technology and various landscape ecological model software.
The correlation and mechanism should be studied between the rural landscape multifunctionality based on the perspective of multidisciplinary research and rural landscape system in the future, and carry out dynamic monitoring and trend simulation, so as to clarify the thinking and paths of rural landscape multi-functional trade-off and guide the sustainable development of rural areas.

**Keywords** Rural landscape research · Bibliometrics · Co-word analysis · Thematic evolution

**Introduction**

In 2000, the European Landscape Convention provided a clear and broad definition of landscape: “Landscape refers to an area perceived by human beings, characterized by the interaction of nature with human factors”. Only areas inhabited by humans can have culture, and cultural landscape generally refers to areas that have been transformed by human activities. Jones (1988; 1991) considered the rural landscape as cultural landscape that transform nature for agricultural purposes, rather than natural landscape formed by geological, climatic and biological factors. Rural landscapes have varying degrees of cultural character, many of which are now considered to contain valuable cultural heritage values (Tieskens et al. 2017; Oteros-rozas et al. 2017). Therefore, RLR began with the study of cultural landscape. Cultural landscape with the emergence of primitive agriculture, the earliest development of human society agriculture has become a cultural source, also known as agricultural cultural landscape. Early European scholars defined rural landscape more in favour of agricultural landscape (Turner 1990) or cultural landscape (van Berkel and Verburg 2014). With the development of RLR, European geographers found that rural areas, including culture, economy, society, population, nature and other factors reflected in the rural landscape. Therefore, rural cultural landscape was extended to rural landscape, and RLR was transformed into interdisciplinary landscape research (Antrop 2013; Antrop and Eetvelde 2017).

Regarding the definition of rural landscape, scholars have defined rural landscape from the perspectives of geography, landscape ecology, rural tourism and so on, and each discipline has used appropriate definitions, concepts and methods (Table 1). Historical geographers focused on the temporal dimension and causes of the landscape, and its significance as a heritage. Humanistic geographers focused on the landscape as psychological and social constructs with important symbolic significance, as well as vehicles of narrative and symbolic value (Cosgrove 2003). Tourismists focus on the scenery. Landscape ecologists focused on the relationship between spatial patterns of land use and ecological processes, using landscape metrics for quantitative modeling.

Rural landscapes are fully, diverse and closely linked to local natural resources, political and economic policies, social structures and cultural awareness, which contribute to changes in the rural landscape and lead to the diversity and complexity of RLR (Wu et al. 2020). The diversity of RLR is due to the comprehensive performance of economic, human, social and natural phenomena in rural areas, so that the rural landscape has many functions of production (mainly agricultural production) (Díaz et al. 2015), emotion (local sense) (Birnbaum et al. 2021), aesthetics (unique aesthetic value) (Arriaza et al. 2004; Tieskens et al. 2018), history and culture (monuments, places of worship, local traditions) (García-Moruno et al. 2010; Torreggiani and Tassinari 2012), tourism (providing space for leisure and entertainment) (Gao and Wu 2017; Salvatore et al. 2018), environment (habitats for some plants and animals) (Hartel et al. 2010). Complexity is due to the multiple meanings of the rural landscape to society (Bieling et al. 2014). For example, for rural residents, the rural landscape is a means of making a living; for urban residents, rural landscape is natural, even wild, with the function of relaxation and recovery (Kupidura et al. 2014).

Since the twentieth century, the natural and cultural aspects of rural landscapes have attracted increasing attention from researchers, planners and policy makers (Antrop 2004). However, modern rural landscapes are at risk of abandonment and degradation, such changes are the role of many factors, urbanization, globalization, transportation and natural disasters are considered to be the main driving force of rural landscape changes, especially urbanization is considered to be the biggest driver of rural landscape changes (Wu 2014). First, urbanization occupies rural land, leaving rural land use facing problems such as agricultural...
The concept of rural landscape | Subject perspective | References
---|---|---
The rural landscape is cultural landscape that transform nature for agricultural purpose, rather than natural landscape formed by geological, climatic and biological factors | Geography | Jones (1988, 1991)
The rural landscape is a mosaic of a variety of landscape patches, providing species with a variety of broken spatial grid representation of living habitat, including grasslands, woodlands, arable land, roads and hedges | Landscape ecology | Turner (1990)
The rural landscape is one with unique and identifiable structures that reflect a clear relationship between the constituent elements | Landscape aesthetics | Antrop (1997)
The rural landscape is managed through local adaptation and historical traditional agricultural techniques, families and ways of life | Geography | van Berkel and Verburg (2014)
In addition to providing food, feed and fiber production, the rural landscape offers a wide range of ecosystem services, the most common of which are recreation and tourism, as well as cultural heritage and aesthetic functions, often summarized as cultural services | Rural tourism | van Zanten et al. (2014)
Rural landscapes provide a variety of landscape services (LS) that directly or indirectly meet human needs, such as food production, pollination, water regulation or recreation | Landscape ecology | Zasada et al. (2017)
Rural landscape not only provides private good types of goods, but also provides a wide range of public good types of services, which constitute an important socio-economic asset of the rural economy | Social economics | Schaller et al. (2018)
The rural landscape is the result of the interaction between natural elements and human activities in time and space. It is a non-renewable resource that provides information about the overall state of the environment | Geographic information science | Statuto et al. (2018), Picuno et al. (2019)
The traditional rural landscape refers to the concentrated area which is closely related to agriculture geographically and functionally | Geography | Feng et al. (2020)
bibliometric analysis of the current state of research in this field is not sufficient. The bibliometric tool is a new method of literature review, which can be used by software to automatically screen and determine the literature that needs to be read, and the basic situation of a research field can be reflected by drawing knowledge map and cooperative network. Wu et al. (2020) used CiteSpace to visualize and quantify 7581 existing RLR articles on the WoS, but this article focuses only on the study of agricultural landscape and is not systematically integrated from the cultural landscape, agricultural landscape, and agrarian landscape of rural landscape and incorporated into an analytical framework.

In view of the above considerations, this paper uses the bibliometric tool to quantitatively analyze and summarize the relevant literature of RLR. The main purpose of the research is two: first, to understand the basic overview and development trend of RLR, as well as the distribution of research forces such as relevant authors, academic journals, research institutions and countries; second, to identify the hotspots of RLR, as well as their core scientific problems. The structure of this paper is as follows: section “Data sources and research methods” introduces data sources and research methods; section “A review of quantitative research” analyzes the number of articles, authors, periodicals, institutions and countries of RLR from the perspective of quantitative analysis; section “A review of qualitative research” analyzes the hotspots and frontier changes of RLR research in the past 30 years from the perspective of qualitative analysis; “Conclusions” section summarizes the overall situation and problems of RLR, and “Discussion” discusses the key research areas of RLR that need to be improved in the future.

Data sources and research methods

Data sources

This paper uses the WoS Core Collection Database as the literature database. The retrieval words were “Rural landscape” or “Countryside landscape” or “Village landscape” or “Cultural landscape” or “Agricultural landscape” or “Agrarian landscape”. The retrieval method was title retrieval, the restriction document type was “Article” and “Review”, and the restriction language was “English”. The first rural landscape research literature was recorded in 1931. In order to prevent the omission of important early studies, we set the time span for data retrieval from 1931 to 2020. A total of 4007 articles were obtained (data retrieval time: 11 October 2021). After manually eliminating the articles not in the field of RLR, a total of 3740 relevant articles were finally obtained. This paper conducts a bibliometric analysis of RLR based on these 3740 retrieved articles.

Research methods

Bibliometrix is a free open source scientific bibliometric software developed by Aria and Cuccurullo (2017) in the R language environment. It is used by entering the Biblioshiny command on the R language program to launch an interactive web page. Bibliometrix can import literature information from WoS, Scopus, Dimensions, PubMed and other bibliographic databases, statistically analyse relevant scientific literature indices, conduct cooccurrence, cocitation, coupling, cooperative analysis, etc., and finally visualize the results. This paper uses the bibliometric tools Bibliometrix, from qualitative and quantitative perspectives, this paper analyses the annual number of published articles, research strength (authors, institutions, countries), research keywords and topics. The trend of RLR is analysed from multiple perspectives (cooccurrence analysis, cluster analysis and frontal analysis), and the future development trend of RLR is discussed at the end of the paper. The research steps of bibliometric analysis and scientific mapping are shown in Fig. 1.

A review of quantitative research

Analysis of article publication and citation

Figure 2 shows the change in the number of articles and the average citations per paper in RLR over the past 30 years. From the bar chart, the number of articles in RLR is a curve of exponential growth over time. From the line chart, the average citations per paper increased fastest from 2002 to 2005. According to the characteristics of the number of articles and the average citations per paper, RLR can be divided into three stages from 1990 to 2020: The first stage is from
1990 to 1999, the average annual article is only 23.1, the average annual citation is 776.2, this stage is the embryonic stage of RLR, the number of articles and the number of citations are low. The second stage is from 2000 to 2008, the average annual article is 76.6, the average annual citation is 4395.8, this stage is the golden stage of RLR, the number of articles is rising, and the number of citations is higher. The third stage is from 2009 to 2020, the average annual article is 238.9, the average annual citation is 3827.5, in this stage, the number of articles continue to rise, but the number of citations began to decline.

A article is highly cited indicates that the research has a great enlightenment effect on the subsequent related research, so the emergence of highly cited article will promote the progress of subsequent research to a certain extent. In order to analyze the impact of highly cited articles on RLR, this paper summarizes the contribution of highly cited articles in RLR (Table 2).

Fig. 1 The steps of Bibliometric analysis and science mapping

Fig. 2 The number of articles and the average citations per paper on rural landscape research from 1990 to 2020
Analysis of academic journals

The continuous development of RLR cannot be separated from the support of some important academic journals that have made great contributions to RLR. Table 3 lists the top 10 journals in terms of the number of articles on rural landscapes. These journals published 909 articles on rural landscapes, accounting for 24.19% of the total literature in this field, which means that a series of academic journals focusing on rural landscapes are concentrated in this research field. The journals listed are all SCI and SSCI journals of high quality, with an average impact factor of 4.325, indicating that international mainstream academic circles are paying increasing attention to the field of RLR.

Analysis of relevant authors

Figure 3 shows the author’s bubble chart, the bubble size reflects the number of articles, the bubble transparency reflects the total citations per year. The picture shows 20 of the most influential authors in the field of RLR, of whom Burel and Baudry began RLR earlier, and their articles were cited on average, indicating that their articles had a great impact on subsequent studies. From the point of view of their respective countries, these scholars are from European

### Table 2 The contribution of highly cited articles in rural landscape research

| Article                        | Contribution                                                                 |
|-------------------------------|-----------------------------------------------------------------------------|
| Gesler (1992)                  | This article use the extended significance of landscape concepts obtained from “new” cultural geography, this article explores why certain places or situations are considered therapeutic |
| Kleijn et al. (2001)           | The article presents a study to assess the contribution of the Agro-Environment Programme to the conservation of biodiversity in the intensive use of the Dutch agricultural landscape |
| Antrop (2004)                  | This article discusses the main stages and trends of urbanization in Europe and how it affects the actual rural landscape, as illustrated by a number of case studies in the vicinity of major cities and remote rural areas |
| Williams et al. (2004)         | This article provides some preliminary data to compare the biodiversity of different freshwater ecosystems in the lowland agricultural landscape |
| Arriaza et al. (2004)          | This article proposes a method to evaluate the quality of agricultural landscape through direct and indirect techniques of landscape value |
| Tschernke et al. (2005)        | This article understands the negative and positive impact of agricultural land use on biodiversity conservation and its relationship with ecosystem services from a landscape perspective |
| Antrop (2005)                  | This article argues that the landscape of the past cannot be reproduced, but the management of the traditional landscape in the past provides valuable knowledge for the more sustainable planning and management of the landscape in the future |
| Bianchi et al. (2006)          | This article tests the hypothesis that natural pest control is enhanced in complex plaque landscapes with a high proportion of non-crop habitats compared to simple large-scale landscapes with fewer non-crop habitats |
| Billeter et al. (2008)         | This article investigates the relationship between species abundance in several groups and the link between biodiversity and landscape structure and management |
| Fahrig et al. (2011)           | This article proposes that the biodiversity of agricultural landscapes can be increased by converting some productive land into more natural land. |
| Duro et al. (2012)             | This article makes recommendations in the field of operational mapping of agricultural landscapes, with the aim of mapping and monitoring the agricultural environment in general using medium-spatial resolution Earth observation imagery |

**TC** total article citations

1. Gesler (1992) 569 | Social Science & Medicine
2. Kleijn et al. (2001) 453 | Nature
3. Antrop (2004) 868 | Landscape and Urban Planning
4. Williams et al. (2004) 555 | Biological Conservation
5. Arriaza et al. (2004) 388 | Landscape and Urban Planning
6. Tschernke et al. (2005) 2400 | Ecology Letters
7. Antrop (2005) 776 | Landscape and Urban Planning
8. Bianchi et al. (2006) 1032 | Proceedings of The Royal Society B-Biological Sciences
9. Billeter et al. (2008) 419 | Journal of Applied Ecology
10. Fahrig et al. (2011) 830 | Ecology Letters
11. Duro et al. (2012) 519 | Remote Sensing of Environment
countries, it can be seen that European scholars have long attached importance to RLR, and the subsequent research has a greater impact. An important point in time is that after 2005 the RLR appeared in full bloom.

In order to understand the author’s cooperative communication, this paper then produces the author’s cooperative network diagram (Fig. 4). According to Fig. 4, the main scholars engaged in RLR can be divided into 6 teams, each team’s focus on RLR is shown in Table 4. Team 1 focuses on quantitative approaches to cultural ecosystem services. Team 2 focuses on conservation strategies for ecosystem services. Team 3 is committed to improving the artificial landscape to make it more natural for animal habitats. Team 4 and Team 5 are studying biodiversity, unlike Team 4, which focuses on the impact of landscape structure on biodiversity, and Team 5, which focuses on the impact of agricultural

### Table 3  Top 10 academic journals in the field of rural landscape research

| Journal                                           | Articles | Percentage occupied (%) | Impact factor (2020) |
|---------------------------------------------------|----------|-------------------------|----------------------|
| Agriculture, Ecosystems & Environment             | 185      | 4.95                    | 5.567                |
| Landscape and Urban Planning                      | 149      | 3.98                    | 6.142                |
| Landscape Ecology                                 | 123      | 3.29                    | 3.848                |
| Biological Conservation                           | 87       | 2.33                    | 5.990                |
| Sustainability                                    | 79       | 2.12                    | 3.251                |
| Land Use Policy                                   | 77       | 2.06                    | 5.398                |
| Landscape Research                                | 71       | 1.90                    | 1.806                |
| Ecological Indicators                             | 52       | 1.39                    | 4.958                |
| Biodiversity and Conservation                     | 44       | 1.18                    | 3.549                |
| PLoS ONE                                           | 44       | 1.18                    | 2.740                |

**Fig. 3** Authors’ production over time in the field of rural landscape research (N.Articles number of articles; TCpy total citations per year)
Table 4 The focus of TOP scholars and their team to rural landscape research

| Team | Members | Focus | Representative articles |
|------|---------|-------|-------------------------|
| 1    | Plieninger T; Primdahl T; Verburg PH; Bieling C; Kizos T | The team is working on ways to quantify cultural ecosystem services, complementing the biophysical and market value of ecosystem services to more comprehensively describe the value of different ecosystem services in research and practice | Bieling and Plieninger (2013), van Berkel and Verburg (2014), Plieninger et al. (2014), van Zanten et al. (2014), Plieninger et al. (2015), Oteros-Rozas et al. (2017) |
| 2    | Fischer J; Hanspach J; Hartel T | The team is committed to developing conservation strategies for ecosystem services and protecting wildlife | Hartel et al. (2010), Hartel et al. (2014), Dorrestein et al. (2014), Hanspach et al. (2016), Dorrestein et al. (2017), Shumi et al. (2018), Velten et al. (2018) |
| 3    | Lindenmayer DB; Driscoll DA | The team is working to improve the artificial landscape to make it more in line with animal habitats | Hazell et al. (2001), Hazell et al. (2004), Pulsford et al. (2017), Pulsford et al. (2018), Pulsford et al. (2019) |
| 4    | Burel F; Baudry J; Billeter R; Herzog F | The team’s findings suggest that rural landscape management should focus on land use intensity and habitat connectivity to improve the diversity of agricultural landscapes | Burel and Baudry (2005), Hendrickx et al. (2007), Bailey et al. (2007), Fahrig et al. (2011), Favre-Bac et al. (2017) |
| 5    | Liira J; Tscharntke T; Cousins SAO; Verheyen K | The team demonstrated the negative impact of agricultural land use on biodiversity conservation, with agricultural intensification reducing biodiversity in farmland in the past | Tscharntke et al. (2005), Flohre et al. (2011), Guerrero et al. (2012), Winqvist et al. (2014), Gayer et al. (2019) |
| 6    | Statuto D; Picuno P | The team demonstrated that analyzing geographic information from historical maps in GIS is a powerful tool for more informed decision-making and management of rural landscapes | Tortora et al. (2015), Statuto et al. (2016), Statuto et al. (2017), Statuto et al. (2018), Picuno et al. (2019) |
intensification on biodiversity. Team 6’s research began in 2015 and used new techniques in geography such as GIS.

Analysis of research institutions

This paper counts the top ten research institutions with the largest number of RLR papers published internationally (Table 5). Stockholm University in Sweden is the largest research institution for RLR. Ten research institutions published a total of 521 papers, accounting for 13.96% of the total number of papers, which is relatively small. Most research institutions belong to European countries and the United States, indicating that the main scientific forces of RLR are in European countries and the United States.

Analysis of representative country

In order to analyze the degree of investment in RLR in various countries, this paper draws the country scientific production in the field of RLR (Fig. 5). The United States has the most RLR, followed by Germany, France, Australia, the United Kingdom and China. In order to analyze cooperation and exchanges between countries, this paper draws a network of cooperation between the 10 countries with the most research on rural landscapes (Fig. 6). Two conclusions can be drawn from the figure: (1) The United States, the United Kingdom, Germany has a lot of cooperation and exchanges with other countries; (2) There are more opportunities for cooperation and exchange in RLR among European countries.

European countries have far more articles on rural landscapes than any other continent, especially the European Union. The reason for the large number of rural landscape studies carried out in EU countries is their social background, according to statistics, 90% of the total area of the EU is in rural areas, more than half of the EU population lives in rural areas, in addition, rural areas bear the EU to ensure food safety, rural employment and life, urban leisure tourism, resources and environmental protection, cultural heritage and development of important functions, is an important support for the achievement of sustainable development strategic objectives (Jones 2011; Agnoletti 2014).

After the end of World War II, European countries adopted land consolidation policies to increase agricultural production, and the large-scale application of synthetic fertilizers and mechanization allowed poor and unstable soils to be cultivated intensively. After the 1950s, the intensification and expansion of agriculture changed the agricultural landscape throughout Europe (van Zanten et al. 2014), the homogenization of the agricultural landscape is serious (Vliet et al. 2015). With the attention of the government and researchers, the analysis of the function, change and development of rural landscape has always been an important part of RLR in Europe (Palang et al. 2005). In the course of the historical process of rural landscape change in Europe, two important policies have played a great role in promoting it. The first is the Common Agricultural Policy (CAP). CAP aims to increase farmers’ productive capacity and promote the intensification and expansion of agriculture (Sutcliffe et al. 2013; Pedroli et al. 2016). At the same time, the decline in agricultural profitability has led to farmland abandonment in marginal agricultural areas (Kuemmerle et al. 2008; Verburg et al. 2009; Renwick et al.

| Institution                          | Number of articles | Country    |
|-------------------------------------|--------------------|------------|
| Stockholm University                | 61                 | Sweden     |
| University of Wisconsin System      | 60                 | US         |
| The Australian National University  | 55                 | Australia  |
| Michigan State University           | 55                 | US         |
| Swedish University of Agricultural Sciences | 54              | Sweden     |
| Iowa State University               | 52                 | US         |
| Lund University                     | 49                 | Sweden     |
| Wageningen University & Research    | 48                 | Netherlands|
| Ghent University                    | 47                 | Belgium    |
| University of Copenhagen            | 46                 | Denmark    |
Since the 1990s, the globalization of commodity markets and CAP reform have further exacerbated agricultural intensification and expansion, resulting in land abandonment in vulnerable areas (van Zanten et al. 2014). To sum up, although CAP has improved farmers’ production efficiency and promoted agricultural scale operation, the damage to the rural landscape is serious.

The second is the European Landscape Convention (ELC). In 2000, the European Commission issued the ELC to promote landscape conservation, management and planning, and to organize international cooperation on landscape issues, making a significant contribution to the protection of the European rural landscape (Pinto-Correia et al. 2006; Plieninger et al. 2014; Görka 2018). In addition, the ELC proposes that landscapes are important for personal and social well-being, both in urban and rural areas, in outstanding landscapes and everyday landscapes (Oteros-Rozas et al. 2017). The European rural landscape has become a model of modern rural development and has been widely used as an indispensable reference to the alliances and organizations of European countries in RLR, in addition, the formulation and promulgation of conventions and policies play an important role in the protection and development of rural landscapes (Agnoletti 2014; Estel et al. 2015; Pedroli et al. 2016).

A review of qualitative research

Keywords cooccurrence network analysis

Because keywords are the core summary of a paper, there must be some correlation between the keywords in the same paper, and this correlation can be expressed by the frequency of cooccurrence. It is generally believed that the more frequently two
keywords appear in the same literature, the closer the relationship between these two topics is. This paper uses the Co-occurrence Network module of Bibilioshiny to make a keyword cooccurrence network, and only extract the 40 keywords with the highest occurrence frequency into the co-word network to obtain the keyword cooccurrence map (Fig. 7). Each node represents the corresponding keyword, and the size of the node reflects the frequency of keyword occurrence. The two keywords of the line represent that they are related, and the thickness of the line reflects whether the theme content is closely related or distant.

**High-frequency keyword cluster analysis**

In order to analyze the hotspots of RLR, this paper does clustering analysis of high-frequency keywords (Fig. 8), the final 40 keywords form 5 clusters, Fig. 8 the darker the color of the Chinese block, the longer the frequency of the occurrence of the keyword is higher. The five clusters formed by keyword clustering represent five hotspots of RLR. The most frequently used keywords in the five clusters are Agricultural landscape, Agricultural, Rural landscape, Cultural landscape, and Fragmentation.

There are 5 hotspots in RLR, and the core scientific problems in these five research fields are analyzed below.

Cluster 1 mainly studied rural landscape planning and management to conserve biodiversity in intensive agricultural landscapes. The main keywords are: Agricultural landscape, Biodiversity, Ecosystem services, Conservation, Landscape ecology, Landscape planning, Agricultural intensification, Biodiversity conservation, Landscape management, and Agroecosystems. Several studies have shown that agricultural intensification is the main cause of the decline in biodiversity in rural agricultural landscapes (Balzan et al. 2017). The intensification and specialization of agriculture has led to a single farming pattern (cultivation, fertilization, irrigation and pesticide use) in rural agriculture, which has dramatically altered the ecosystems in which local organisms interact and threaten biodiversity significantly. With the transformation of rural landscape from the unique function of agricultural production to the multi-functional of...
nature conservation, environmental protection, beautification and production, landscape planning has aroused the interest of researchers. Pacione (2013) and Tudor et al. (2014) point out that landscape planning is critical to successfully resolving various types of landscape conflicts and protecting specific landscapes. In theory, systematic landscape planning can find a balance between multi-functional rural landscape, while achieving food security, landscape development and biodiversity conservation (Jackson et al. 2012; Schlesinger et al. 2016; De Montis et al. 2016).

Cluster 2 mainly studied Cultural Ecosystem Services (CES). The main keywords are: Agriculture, Landscape, Land use, Species richness, Cultural ecosystem services, Water quality, Diversity, and Birds. The agricultural landscape is a hot spot for ecosystem services and plays an important role in improving human well-being (Pinto-Correia et al. 2006; Solymosi 2011). However, the current study of ecosystem services places too much emphasis on the easy-to-quantify minority services, and few people pay attention to the cultural services of the landscape. Cultural ecosystem services refer to the intangible benefits that people derive from ecosystems through spiritual enrichment, cognitive development, reflection, entertainment, and aesthetic experiences (MEA 2005). How to quantify cultural ecosystem services precisely is a core scientific issue in this field (Plieninger et al. 2015; Oteros-Rozas et al. 2017).

Cluster 3 mainly studied urban-rural conflict, using Geographic Information System (GIS) and Remote Sensing (RS) to study land use change. The main keywords are: Rural landscape, Land use change, GIS, Landscape metrics, Landscape change, Remote sensing, Urbanization, and China. Anth person-made change in land use and land cover is a global phenomenon that has an impact on agricultural production and ecosystem services (Goswami et al. 2020). Urbanization, in particular, has fundamentally changed the nature of ecosystems within, around and even away from urban areas (Chen and Zhou 2018;
Yang et al. 2018; Zou et al. 2019). At present, the rise of new geo-technologies such as GIS and RS is the hope of alleviating urban-rural conflicts. First, satellite remote sensing can collect long-term land-use information for the analysis of structural and functional changes in rural landscapes on a time and spatial scale (Sandker et al. 2010; Statuto et al. 2018; Murray et al. 2018). High-quality images provided by aerial photography have been widely used as the basic tool of the RLR (Moser et al. 2002; Martin-Martin et al. 2013). Second, visual communication, as a “common currency”, is an effective bridge between policy makers and experts (Appleton and Lovett 2003). Using geographic information from historical maps, combined with modern digital mapping and remote sensing imagery, the GIS enables more informed management and decision-making of rural landscapes (Iosifescu-Enescu et al. 2010; Casado-Arzuaga et al. 2014; Statuto et al. 2018).

Cluster 4 mainly studied the sustainable development of rural cultural heritage landscape. The main keywords are: Cultural landscape, Cultural heritage, Sustainability, Heritage, Climate change, Management, and Resilience. Cultural heritage landscape has always been considered a high-value landscape. Centuries of farming, forestry, fishing and pastoral management have shaped the rich and diverse cultural heritage landscape of rural areas (Antrop 2005; Dorresteijn et al. 2017), for example, Honghe Hani Rice Terraces in China (Gao et al. 2021), Italian dry-stone wall terracing (Tucci et al. 2019). These cultural heritage landscapes and traditional agricultural landscapes have important natural, cultural and aesthetic values and make important contributions to local identity (Antrop 1997; Vliet et al. 2015; Stanik et al. 2018). However, these landscapes are susceptible to change (Fischer et al. 2012; Yu et al. 2016), such as, the increase in the opportunity cost of rural labor and population outflow leads to farmland abandonment, and the change of residential space structure leads to the occupation of agricultural land for residential construction (Zhang et al. 2016). How to protect the cultural heritage landscape is an important issue (Ridding et al. 2018; Di Fazio et al. 2018; Gullino et al. 2018). In order to realize the sustainable development of rural cultural heritage landscape, scholars are studying the combination of cultural and historical values and socio-economic trends, such as rural tourism (Feng et al. 2020; Chrastina et al. 2020).
Cluster 5 mainly studied the impact of landscape structure on habitat. The main keywords are: Fragmentation, Landscape structure, Habitat fragmentation, Dispersal, Connectivity, Australia, and Restoration. Agricultural expansion reduces the global range of natural habitats (Wimberly et al. 2018), the disappearance of rivers, streams, ponds, ditches, hedges and habitat islands in rural areas has led to a decrease in the heterogeneity of agricultural landscapes (Tieskens et al. 2017). A fundamental concept of landscape ecology is that landscape heterogeneity affects various ecological responses (Fahrig et al. 2011), for example, the animal movement (Doherty et al. 2019), population persistence (Fraterrigo et al. 2009), species interactions (Reino et al. 2009) and ecosystem services (Wang et al. 2021). Habitat fragmentation and reduced landscape heterogeneity are considered to be major pressures on biodiversity (Opdam and Wascher 2004; Geiger et al. 2010). Studies have demonstrated the importance of improving landscape structures for biodiversity conservation (Van der Zanden et al. 2016; Hass et al. 2018; Uthes et al. 2020). Improving habitat connectivity in agricultural landscapes is an effective way to improve landscape structure and protect biodiversity (Wimberly et al. 2018; Scriven et al. 2019).

**Frontal analysis**

Through the cooccurrence network and cluster analysis of keywords, this paper has a general understanding of the hotspots of RLR, but the development trend and thematic evolution of research content is still unclear, and then, this paper uses R to map the heat map of the annual distribution of keywords (Fig. 9), and Biblioshiny’s Thematic evolution module to visualize the Thematic evolution path of RLR (Fig. 10).

Observing the frequency changes in keywords, Cultural landscape, Agricultural landscape, Agriculture, Landscape, Ecosystem services, Rural landscape,
Land use change, Cultural heritage has been around for nearly five years, and it’s getting more and more frequent. Landscape metrics, Cultural landscape, Landscape planning, Urbanization, Land use have also seen high frequency in recent years. Three time slices were set in the Thematic evolution module, which automatically formed three evolution nodes in 2008, 2014, and 2018. The Thematic evolution path has a single path and differentiation path, and the single path indicates that the research topic has not changed. Compared with a single path, differentiation path is of greater significance to related research. Agricultural landscape (1931–2008), Cultural landscape (1931–2008), Ecosystem services (2009–2020), Land use change (2015–2020), are single research paths. There are three clear frontier research paths in the thematic evolution path map: Agricultural landscape (1931–2008)—Rural landscape (2009–2014)—Agricultural intensification (2015–2020); Cultural landscape (1931–2008)—Biodiversity (2009–2014)—Agriculture landscape (2015–2020); Landscape (1931–2008)—Remote sensing (2009–2014)—Land use change (2015–2020).

Agricultural landscape (1931–2008)—Rural landscape (2009–2014)—Agricultural intensification (2015–2020).

Fuchs et al. (2015) in its analysis of land use and land cover changes in Europe in the twentieth century identified land abandonment, afforestation and agricultural intensification as the most important land change processes. A recent review of the driving forces of landscape change in Europe (Plieninger et al. 2016) also considers “land abandonment and agricultural intensification” to be the most important drivers. As a result of urbanization and technological innovation, fewer people need more agricultural land, and agricultural intensification can improve the efficiency of grain production, however, agricultural intensification only increases production, while ignoring the problem of environmental pollution. Therefore, the development of sustainable intensive agriculture is the development trend of agriculture in the future, and the concept and realization path of sustainable agriculture intensive is the forefront of scholars’ attention.

Cultural landscape (1931–2008)—Biodiversity (2009–2014)—Agriculture landscape (2015–2020).

As rural landscape transformation has a significant impact on biodiversity, cultural identity and landscape identity (Van der Sluis et al. 2019). Scholars study ecosystem services in rural areas, especially cultural ecosystem services. The concept of biocultural diversity has attracted the attention of many scholars.
Biocultural diversity contains and integrates the cultural and biological (and non-biological) aspects of the landscape, referring to the specific link between biodiversity and cultural diversity (Gavin et al. 2015; Rotherham 2015; Bridgewater 2017; Eriksson 2018; Agnoletti and Rotherham 2015) believe that considering biocultural diversity and recognizing the need to protect key habitats that interact with nature may help to resolve some of the contradictions between landscape and conservation.

The change of rural land use from extensive to intensive is accompanied by the loss of biodiversity and the homogenization of landscape in rural areas (Jackson et al. 2012; Nowakowski et al. 2015; Kristensen et al. 2016). Therefore, it is a key issue to promote the balance between agricultural production in agricultural systems and biodiversity conservation in rural landscapes. The solution of land use conflict through GIS and RS is the frontier that scholars are paying attention to.

**An integrated framework for rural landscape research**

Through cluster analysis, it is found that the different functions of rural landscape can be divided into three different landscape types: cultural landscape, ecological landscape and production landscape, and there are complex tradeoffs and synergies between different landscape types. The function of cultural landscape is related not only to the protection of historical heritage, but also to the local sense at the local, regional and national levels, and outstanding cultural landscape can bring considerable tourism benefits to the local area; the function of ecological landscape is to protect ecosystem services and provide human welfare, ecological landscape and production landscape have obvious tradeoffs (Law et al. 2021), but also with cultural landscape has a synergy; the function of production landscape is to live and accumulate production materials for farmers, and a key function of the production landscape is related to food security, food sovereignty and foreign exchange, as well as to increasing agricultural income, rural employment and value-added in rural areas to slow the outflow of people. Because of the tradeoff and synergy between different landscape types, landscape planning in order to develop the high-intensity multifunctionality of rural landscape, need to have a tradeoff of thinking, and adopt an integrated landscape management approach, in a favorable way to strengthen the efficiency of rural landscape planning (Badiani et al. 2017; Israel and Wynberg 2018). Through reasonable and comprehensive landscape planning, the rural landscape develops towards multifunctional and sustainable landscape. Based on the research contents of rural landscapes, an integrated framework diagram of RLR is drawn (Fig. 11).

**Conclusions**

This paper collects and organizes 3740 related articles on rural landscape in the WoS Core Collection Database from 1990 to 2020 as research objects, and systematically combs and analyzes the hotspots, development trends and characteristics of RLR in the world using the bibliometric method, and concludes as follows through quantitative and qualitative analysis:

1. Through quantitative analysis and research, the number and citation of RLR papers, relevant authors, research institutions and the basic situation of the country are obtained. The number of articles related to RLR increased exponentially over time. The average citations per paper increased fastest from 2002 to 2005.
According to the characteristics of the number of articles and the average citations per paper, RLR can be divided into three stages from 1990 to 2020: the first stage is from 1990 to 1999; the second stage is from 2000 to 2008; the third stage is from 2009 to 2020. The second stage of RLR has attracted the most international attention among three stages. European scholars, research institutions and governments attach more importance to rural landscape, which is an important scientific research force in RLR. The main scholars engaged in RLR can be divided into 6 teams, their research direction are: the quantitative method of cultural ecosystem services, ecosystem services protection strategy, improve artificial landscape to make it more in line with natural animal habitats, impacts of landscape structure on biodiversity, impacts of agricultural intensification on biodiversity, the use of GIS and other new geographic technology to make decisions and management of rural landscape. Stockholm University and University of Wisconsin System are the largest research institutions for RLR. The United States and most European countries pay great attention to RLR, the United States, Germany, France is currently the country with the largest number of RLR, which shows that developed countries pay more attention to RLR.

(2) Through the qualitative research and analysis of the keyword cooccurrence network and the thematic evolution path map, the five hotspots and three clear research frontier paths of RLR are extracted. The five hotspots are: rural landscape planning and management, cultural ecosystem services, urban-rural conflict, the sustainable development of rural cultural heritage landscape, the impact of landscape structure on habitat. The three frontal paths are: Agricultural landscape (1931–2008)—Rural landscape (2009–2014)—Agricultural intensification (2015–2020); Cultural landscape (1931–2008)—Biodiversity (2009–2014)—Agriculture landscape (2015–2020); Landscape (1931–2008)—Remote sensing (2009–2014)—Land use change (2015–2020). In recent years, RLR has paid more attention to the protection of cultural heritage landscape, biocultural diversity and landscape planning. RLR, from qualitative landscape narrative analysis to the extensive use of GIS and RS and other techniques for quantitative measurement, to qualitative and quantitative analysis methods for rural landscape multi-dimensional, dynamic and comprehensive research, so that modern RLR presents a complex, multi-dimensional characteristics.

In general, the number of RLR has been increasing year by year, and from the study based on geography and ecology to the multidisciplinary and multi-method combination of social and economic development, culture and other elements of comprehensive research direction. At present, RLR takes cultural tourism landscape, ecological landscape, agricultural production landscape and rural landscape planning as its main research objects, and changes from the static pattern of rural landscape to dynamic evolution process, urban-rural conflict, cultural ecosystem service and multi-functional landscape trade-off. In the research paradigm from a single dimension to a multi-dimensional, and combined with “3S” technology, a variety of landscape ecological model software research.

Discussion

Multi-functionality and sustainability of the rural landscape

The concept of “agricultural multi-functionality” was introduced in Agenda 21, adopted by the United Nations Conference on Environment and Development in 1992. It was noted that, in addition to the economic function of producing commodity outputs such as food and fibre, agriculture also had the environmental and social functions of improving the rural environment, protecting biodiversity, developing rural societies and preserving agricultural cultural heritage. The rural landscape is the main resource of agricultural production, providing food, materials and energy to the market. The rural landscape also supports biodiversity and has a unique ecosystem. However, in recent years, the outflow of rural population, the aging of the population and the abandonment of cultivated land have led to the decline of cultivated land production and biodiversity, and the abandonment of cultural heritage. The multi-functionality of rural landscape is defined as a landscape
capable of providing a variety of different ecological, economic and social functions, which means increased synergy and reduced trade-offs between landscape objectives (Reyers et al. 2012; Hart et al. 2016; Israel and Wynberg 2018; Ren et al. 2021). Multi-functional landscapes include a balance between agricultural production, carbon storage and biodiversity. There are strong trade-offs between agriculture and the environment, and there are fewer and fewer opportunities to mitigate them, which, once they cross the threshold, inhibit a sustainable future (Vos and Meekes 1999; Wu 2013; Swaffield et al. 2019). Law et al. (2021) summarize the sustainability of rural landscapes as the occupation and management of areas other than those directly affected by cities without reducing ecosystem services to meet current and future social needs.

There are still some problems in RLR sustainability and multi-functional rural landscape: First, there are more practical studies on multifunctional landscape recognition, planning and management in rural areas, and less theoretical research; Second, there are more evaluations and studies on the main functions of rural landscape, and less evaluation and research on the versatility of landscapes; Third, the relationship between the function of rural landscape and the versatility of landscape is less involved.

Methods of rural landscape research

From the perspective of social-natural coupling system, the internal structure and mechanism between the internal structure and function of the multi-functional system of rural landscape are more complex, and the relationship between the landscape functions of specific areas in rural areas is different in type, and their functional effect on the region is different (Wu 2021). Therefore, from the perspective of multidisciplinary research, from the perspective of rural landscape system, the relationship and mechanism between the multi-functionality of rural landscape, and dynamic monitoring and trend simulation, can help clarify the multi-functional trade-off of rural landscape ideas and paths, guide the sustainable development of rural areas.

The mutual logic of landscape structure and its ecological process is a hot field in landscape ecology and other disciplines (Wu 2019). At present, the research on the dynamic change of landscape pattern and the strategy of agricultural landscape optimization is more in-depth, but the research on the logical relationship and coupling mechanism between agricultural landscape and rural revitalization, urban-rural integration, rural tourism, rotational fallow system, precision poverty alleviation, population migration, farming culture, etc. is still in the exploration stage, especially the dialectical relationship between agricultural culture inheritance and protection and rural landscape change.

Application of new technologies in rural landscape research

In recent years, GIS and RS research methods have played an important role in RLR, combined with the application of new technology methods in space big data mining and the introduction of multidisciplinary research methods to analyze the evolution of rural landscape in different regions at different times, the trend of rural landscape evolution simulation and prediction will be an important development direction. In addition, the impact of rural landscape on local social economy and ecology is profound and diverse, but also the scope of many disciplines, need to integrate the ecology, geography, economics, sociology, culture, management and other disciplines of theory and methods, on the basis of qualitative analysis, quantitative interpretation of the nature and intensity of these effects.

The ancient village has important cultural heritage landscape value, but it is very difficult to explore the cultural village. Yu et al. (2016) surveyed 2555 cultural villages in China, but he also noted that this is just the tip of the iceberg of China’s existing cultural villages. In order to explore the cultural village and make the distribution map of the cultural village, we need to use “3S” technology, namely GIS, RS, GPS.

Strengthen cooperation and exchange in rural landscape research

Because of the different stages of rural and agricultural development, the driving factors of rural landscape change are both similar and different. Human interference, topography, rapid urbanization, rural tourism development, the transformation of agricultural management subjects and changes in the layout of cultivated plants and farming techniques are the main factors leading to changes in rural landscapes in...
developing countries. The rural landscape changes in developed countries in Europe are mainly due to agricultural practice, urbanization process, landscape productivity, land use change, market change, external policy intervention, loss of adaptability and changes in social organization and attitude, different types of farmers’ decision-making, agricultural landscape owner management methods, etc. may have an impact on the rural landscape. With the development of urbanization, these cultural heritage landscapes in rural developing countries are facing similar challenges as those in Europe. Therefore, the exchange of RLR between countries can undoubtedly protect the loss of rural landscape (Ledda et al. 2020). Developing countries in rural development can learn from the European countries’ planning and design of rural landscape, so as to avoid the loss of the value of rural landscape.

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Declarations

Conflict of interest The authors declare no conflict of interest.

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