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Review of Digital Village Research Based on Bibliometrics and Web Mapping Analysis

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Abstract: Digital Village (DV) is a new rural development framework that aims to promote the digital transformation of rural industry, culture, governance, public services, environmental protection and other fields through digital technological innovation and the implementation of diversified application scenarios, and to promote, activate and strengthen various functional effects, so as to accelerate the restructuring of the rural socio-economic development model and promote the comprehensive upgrading of rural areas. DV construction is considered and widely proven to be an important path and future opportunity for rural revitalization and sustainable development, and has garnered significant academic interest. In this study, bibliometric methods were used to systematically sort out and deeply analyze the relevant research results. DV research results have grown rapidly in the recent 10 years, showing significant interdisciplinary research characteristics, and research hotspots focusing on industrial development, digital transformation and development, sustainable agricultural development, environmental protection, and technological innovation and application. The prevailing trend in research has undergone a transition, progressing from the application of digital technology in agriculture to the digital transformation in rural development and finally to the impact of DV construction on the economy, society, and the environment. Studies in developed countries have focused on innovation of digital technology and the digital divide, while those in developing countries have focused on rural poverty reduction and revitalization by digital technology introduction, and the potential risks during the DV transformation process.

Keywords: Digital economy; Digital village; Rural revitalization; Sustainable development; Bibliometric analysis

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1. Introduction

Digital Village (DV) is a framework for rural development, which mainly refers to relying on the development of

digital economy, taking data-based elements as the basis, informatization network platform as the carrier, digital infrastructure and digital technology innovation and application as the driving force, and promoting the digitization of rural industry, culture, governance, public service, environmental protection and other fields, so as to accelerate the reconstruction of rural socio-economic development mode and promote the transformation, upgrading and comprehensive modernization of rural socio-economic development model [1–4].

DV plays a significant role in promoting agricultural upgrading, production business model innovation, governance, and service level improvement, farmers' income growth, and quality of life improvement. For example, the application of digital technology in the whole process of agricultural production is conducive to increasing crop yields, improving crop quality, increasing resource utilization efficiency, and reducing input costs and environmental impacts [5–6]. The construction of digital governance platforms reduces the cost of publicizing, revising, and maintaining rural governance rules, improves the efficiency of supplying and adapting the rules, and improves the operational efficiency of monitoring, punishing, and conflict resolution mechanisms. As a result, DV has been recognized as an important pathway and future opportunity to achieve sustainable agricultural and rural development and has attracted the interest of many sectors globally [7–8].

DV, also known as "Smart Village", generally refers to villages that maximize the use of ICT, social innovation, and digital solutions to improve income and quality of life, public service levels, and resource efficiency for the benefit of local people and businesses. It is a multi-dimensional research field that incorporates elements of sustainable development in rural areas, such as improving production efficiency, protecting environmental resources, and enhancing community morale [9].

As an integrated system encompassing technological, economic, social, and environmental dimensions, DV studies are gradually attracting academics' attention from a range of disciplines.

Researchers have already employed the bibliometric approach to gain insight into the study of smart villages nowadays, focusing on different topics (agriculture, ecological effects, IT technology, etc.), or different regions (China, Indonesia, Africa, etc.) [10–16]. Some studies employed a single keyword, like "Smart agriculture" and "Smart Village", which is also inadequate for encompassing all studies related to DV [17–18]. The authors anticipate that future bibliometric analyses of DVs will employ a more comprehensive range of analytical methods to investigate the evolution of research trends, characteristics, hot topics, and progress in this field. This will facilitate a more nuanced understanding of future research directions.

Accordingly, from the perspective of bibliometric analysis, this paper presents a systematic compilation of research related to DVs. This is intended to facilitate a comprehensive understanding of DV research progress and provide scholars, builders, and managers involved in DVs with a broad global perspective and ideas for further learning. The remaining sections of this paper are organized as follows: Section 2 provides the materials and methods; Section 3 provides the research results; Sections 4 and 5 present a discussion and the conclusions, respectively.

2. Materials and methods

Web of Science (WoS) is a highly regarded citation data platform comprising the Science Citation Index Expanded (SCIE) and Social Science Citation Index (SSCI) databases. It encompasses various interdisciplinary, comprehensive, and influential international academic journals. The authors conducted this study through a regular bibliometric analysis method, which included data collection, cleaning, and analysis (**Figure 1**).

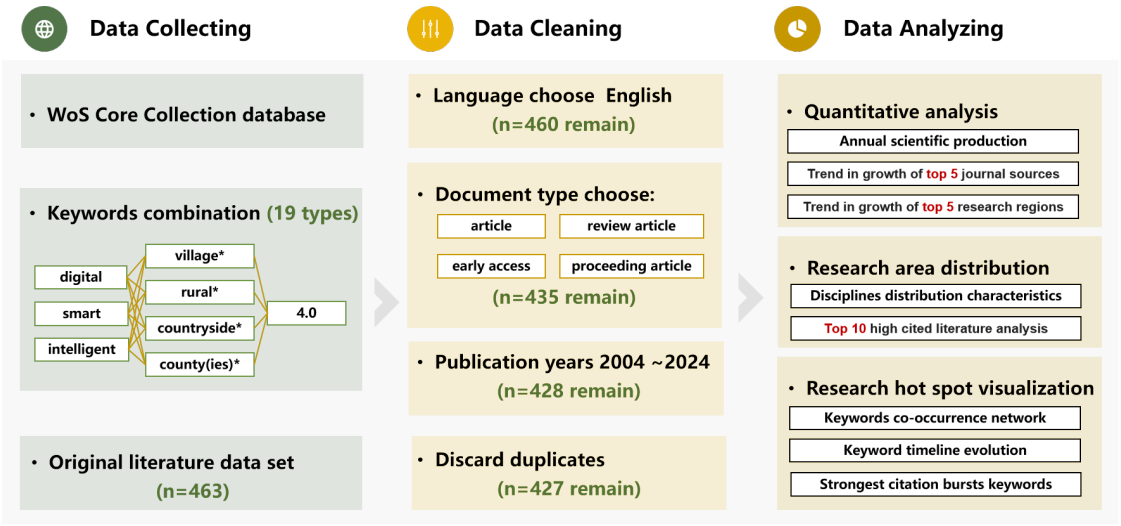

Figure 1. Data collection workflow and research design ("n" represents the number of literatures selected in this study)

Data collecting: In the WoS core collection database, the keywords were chosen by the formula TS=("digital village*" OR "smart village*" OR "intelligent village*" OR "village 4.0" OR "digital rural*" OR "smart rural*" OR "intelligent rural*" OR "rural 4.0" OR "digital countryside*" OR "smart countryside*" OR "intelligent countryside*" OR "countryside 4.0" OR "digital county*" OR "smart county*" OR "intelligent county*" OR "county 4.0" OR "digital counties" OR "smart counties" OR "intelligent counties"). 463 publications were found under the mentioned 19 types of keyword combination (articles from 1984 to 2024 were collected) on 20 October 2024. The outcomes were exported to "complete records and cited references" and saved in text format.

Data cleaning: To make the data comparable and concrete, some papers were cleaned or removed [12–13]. Firstly, this work excluded non-English articles (3 publications are excluded) and only considered English articles to ensure data comparability. Secondly, we choose academic research papers, including articles, review articles, early access, and proceeding articles. In contrast, editorial material, book reviews, letters, corrections, meeting abstracts, and retracted publications are excluded (25 publications are excluded). Thirdly, the authors focus on the recent 20 years of research, so articles published before 2004 are excluded (7 publications are excluded). Finally, discard duplicates and check out (1 publication is excluded). Thus, there are 427 publications remaining in the final analysis article data set.

Data analysis: The research of DV was reviewed and analyzed in three principal aspects. Firstly, the authors conducted a quantitative analysis of the research lineage, including annual scientific production development, trends in growth in the top 10 regions, and journal resources. Secondly, the distribution of study areas is examined, the distribution characteristics are discussed, and the top 10 highly cited papers are reviewed and analyzed. Thirdly, visualization of the evolution of research hot spots includes keywords co-occurrence network, keyword timeline evolution, and the strongest citation bursts of keywords. Software packages such as VOSviewer version 1.6.20 (https://www.vosviewer.com/, accessed on 25 November 2022) and CiteSpace version 6.3.R3 (64-bit) Advanced (https://citespace.podia.com/, accessed on 27 June 2024) are valuable tools used for analyzing large amounts of data in this paper. A preliminary statistical literature analysis was performed using a unique open-source R-tool, Bibliometrix, to analyze regions' and sources' production over time. This was done to visualize the textual data on DV research (https://www.bibliometrix.org/, accessed on 27 June 2024).

3. Results

3.1. Quantitative analysis of the literature

3.1.1. Annual trends in the number of publications

The amount of published research in the DV field can indicate the level of research focus and progress in the area. **Figure 2** illustrates a fluctuating upward trend in the quantity of published papers in this field from 2004 to 2024.

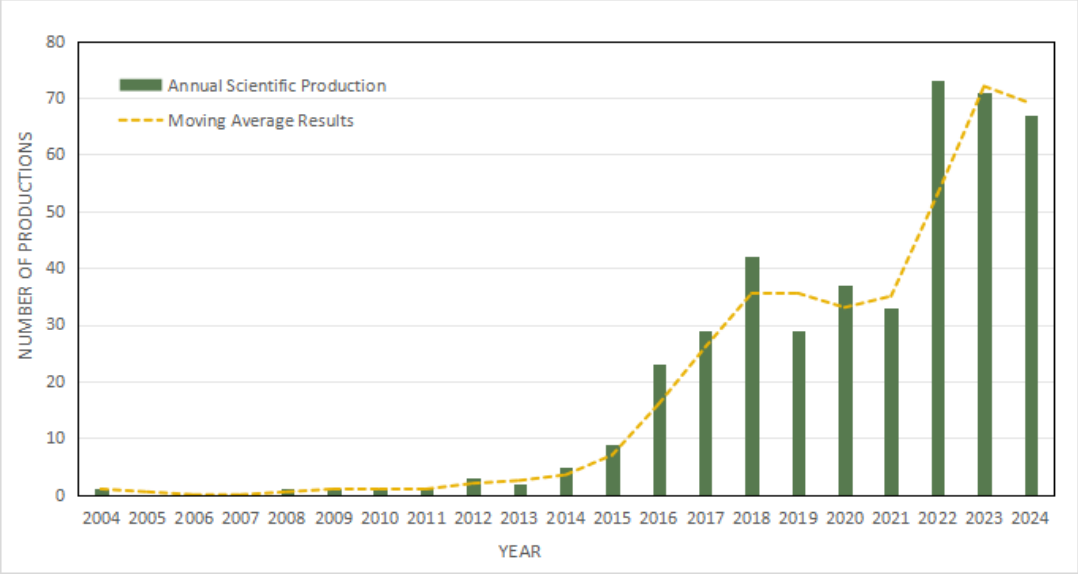

Figure 2. Annual publication trend of DV from 2004 to 2024

This study divides the development trends in the relevant fields into four periods for in-depth analysis: 2004 to 2012, 2013 to 2018, 2019 to 2021, and 2022 to 2024. Between 2004 and 2012, research growth was relatively slow, and the number of published papers was small, totalling eight, accounting for 1.87% of the total published volume. This phenomenon can be attributed to the fact that the DV was still in the initial stage of development and had not yet been fully developed. From 2013 to 2018, the number of papers in the field of DV has increased significantly, and the number of publications has increased dramatically. 110 papers were published during this period, accounting for 25.7% of the total. This growth has been driven by advances in digital technology, which has boosted rural development. From 2019 to 2021, the research showed a balanced fluctuation state, and the number of papers published remained relatively stable. 102 papers were published, accounting for 23.8 % of the total papers published, with an average of 34 papers published annually. The research results at this stage may have been affected by the COVID-19 epidemic on the construction and development process of DVs, which led to a slowdown in the advancement of research work. From 2022 to 2024, the number of papers increased rapidly, with a total of 208 articles published, accounting for 48.6% of the total publications. This indicates that research in this field has entered a new round of rapid growth.

3.1.2. Map of the top 10 research geographical papers

In international academia, the quantity of published papers is often regarded as a critical indicator of a country's importance and influence in a particular field of research. As shown in **Figure 3**, Asian countries comprise three of the top nine countries in the world, including China, India, and Indonesia. Among the countries of the Americas, the United States is unique.

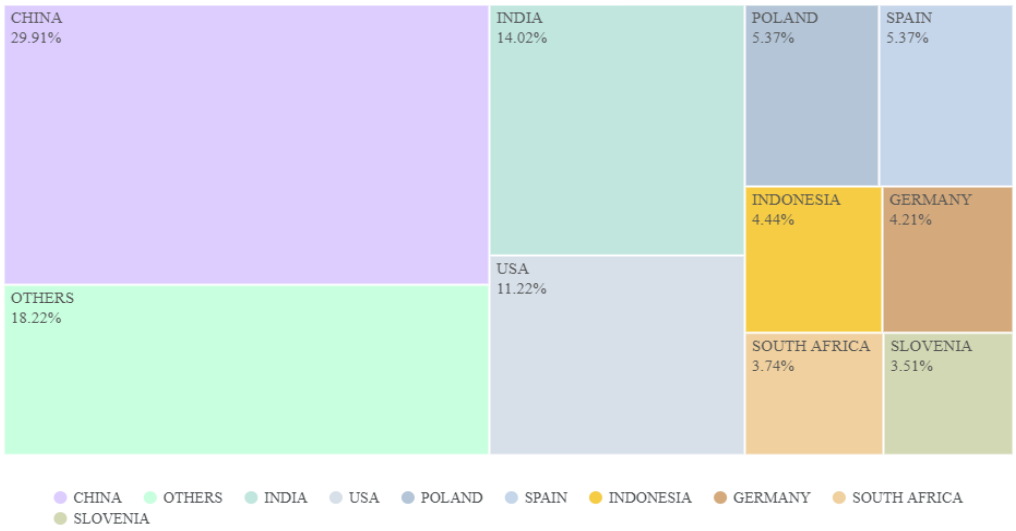

Figure 3. Map of the top 10 research geographical papers

Among European countries, Poland, Spain, Germany, and Slovenia performed well; South Africa is the only African country on the list. Asian countries accounted for 43.93% of the global research output in the DV, with China topping the list with 128 publications, followed by India with 60. This data highlights the research activity and importance in the field of DV construction in Asia, reflecting the urgent need for DV empowerment in the vast rural areas of Asia. In Europe, four countries, Poland, Spain, Germany, and Slovenia, have similar research output in this field, with about 20 papers per country, accounting for 18.46% of the global total, which indicates the robust research strength of developed countries in the field of DV research. The United States, as the only country in the Americas to make the list, has 48 papers accounting for 11.22% of the global total, a phenomenon closely related to its advanced status in science and technology. In contrast, South Africa in Africa has only 16 papers, accounting for 3.74%, but its participation in the field of DV research must be addressed. In addition, documents from other countries not listed accounted for 18.22%, indicating that there is still significant development space and potential in DV research.

3.2. Research field and analysis of highly cited articles

3.2.1. Characteristics of Research Areas

The publications of DV research are classified into different research fields. As shown in **Table 1**, the field of DV research is mainly focused on Environmental Sciences Ecology (112), Engineering (110), Computer Science (95), Science Technology Other Topics (89), Telecommunications (35), Energy Fuels (31), Agriculture (29), Public Administration (26), Business Economics (24), Social Sciences Other Topics (18). Environmental sciences, ecology, energy, social sciences, and technology science are the main categories of DV research, whether from the source of publications or the subject categories distributed in the research field. It is worth noting that according to the classification of research fields, the total number of articles published in these fields reached 569, significantly more than the 428 collected, which reflects the significant interdisciplinary characteristics of the DV research field.

Table 1. The main research fields of DV

Research areas	Record count
Environmental sciences ecology	112
Engineering	110
Computer science	95
Science technology, and other topics	89
Telecommunications	35
Energy fuels	31
Agriculture	29
Public administration	26
Business economics	24
Social sciences and other topics	18

3.2.2. Analysis of the top 10 highly cited papers

This study analyzed the ten most frequently cited papers in the DV field (**Table 2**). These highly cited academic papers reflect the quality and academic influence of the corresponding publications. According to the Web of Science platform journal citation report standards, these highly cited papers are from 2017 to 2022. The top ten journals include Sustainability, Journal of Rural Studies, Computers & Electrical Engineering, IEEE Access, Ecology and Society, and Energies. The top ten highly cited papers discuss the interaction between smart villages, digital villages, artificial intelligence, and rural construction from multiple perspectives. For example, seven of these ten papers focus on the theme of smart and digital villages. Among them, the most cited paper, the first, published by Lytras and Visvizi in Sustainability in 2018, profoundly explores the basic principles of smart cities and smart villages and their interrelationships. The second highly cited paper was published by Naldi et al. in the Journal of Rural Studies in 2015 and was cited 203 times. It proposed indicators of smart rural development and discussed the correlation of these indicators in future empirical research. The other three papers focus on artificial intelligence and rural construction. For example, the third highly cited paper was published by Saba et al. in Computers & Electrical Engineering in 2022, focusing on the application of the Internet of Things in smart rural construction. It is worth noting that before 2017, there were no highly cited scientific papers in the field of DV research, which indicates that DV research has begun to receive extensive attention from the academic community since 2017. In addition, the relevant research results are mainly published in environmental sciences, ecology, engineering, computer science, science and technology, other topics, and other fields.

Table 2. Top 10 highly cited scientific papers in DV research

No.	Title	Authors	Total citations	Journal source
1	Who Uses Smart City Services and What to Make of It: Toward Interdisciplinary Smart Cities Research [19]	Lytras, M. D.; Visvizi, A.	206	Sustainability
2	What is smart rural development? [20]	Naldi, L.; Nilsson, P.; Westlund, H., et al.	203	Journal of Rural Studies
3	Anomaly-based intrusion detection system for IoT networks through a deep learning model [21]	Saba, T.; Rehman, A.; Sadad, T., et al.	125	Computers & Electrical Engineering

Table 1 (Continued)

No.	Title	Authors	Total citations	Journal source
4	Neutrosophic Multi-Criteria Decision Making Approach for IoT-Based Enterprises [22]	Nabeeh, N. A.; Abdel-Basset, M.; El-Ghareeb, H. A., et al.	118	IEEE Access
5	The climate-smart village approach: framework of an integrative strategy for scaling up adaptation options in agriculture [23]	Aggarwal, P. K.; Jarvis, A.; Campbell, B. M., et al.	115	Ecology and Society
6	Smart Villages: Comprehensive Review of Initiatives and Practices [9]	Zavratnik, V.; Kos, A.; Duh, E. S.	111	Sustainability
7	Energy Sustainability in Smart Cities: Artificial Intelligence, Smart Monitoring, and Optimization of Energy Consumption [24]	Chui, K. T.; Lytras, M. D.; Visvizi, A.	109	Energies
8	Smart rural futures: Will rural areas be left behind in the 4th industrial revolution? [25]	Cowie, P.; Townsend, L.; Salemink, K.	102	Journal of Rural Studies
9	An Integrated Neutrosophic-TOPSIS Approach and Its Application to Personnel Selection: A New Trend in Brain Processing Brain Analysis [26]	Nabeeh, N. A.; Smarandache, F.; Abdel-Basset, M., et al.	101	IEEE Access
10	A review of the rural-digital policy agenda from a community resilience perspective [27]	Roberts, E.; Anderson, B. A.; Skerratt, S., et al.	97	Journal of Rural Studies

3.3. Visual analysis of research hotspots

3.3.1. Bibliographic coupling analysis combined with systematic literature review

The bibliometric analysis method was used to analyze the keywords of DV research in the core collection of WOS. It uses CiteSpace and Excel software to visualize the information and intuitively show DV research's trends and essential characteristics. The overlap diagram in **Figure 4a** shows its current development, and the articles in this cluster were published in the last five years, namely, 2020–2024. The total number of identified keywords that appear once or more is 82, divided into 7 clusters.

Cluster 1 (red): This cluster represents the latest research direction of DV in the current academic and industrial circles. This cluster has 17 core keywords, covering a wide range of research fields and practical applications. Among them, the areas that people pay special attention to include "digital village, areas, divide, China, e-commerce, information-technology, big-data, health", etc. These keywords reflect the current hot spots of DV technology development, and JP reveals critical social and economic development issues. Through the in-depth study of these keywords, researchers can better understand the impact of DV transformation on different regions and fields. Especially in a big country such as China, how to use e-commerce, information technology, and big data to narrow the gap between urban and rural areas, improve public health, and promote the all-around development of the economy and society.

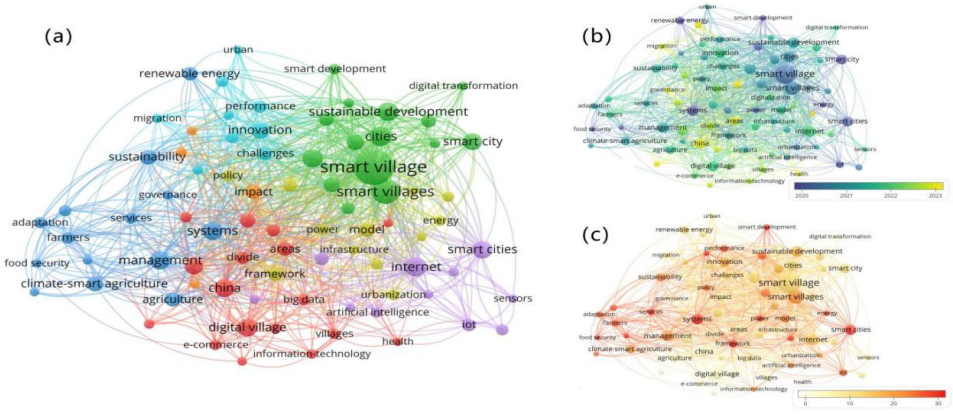

Figure 4. a visualizes the analysis of co-occurrences by overlapping keywords in DV research; b is the time trend of keywords; c is the number of citations of keywords

Cluster 2 (green): This represents the oldest cluster in the field of DV research, which covers 15 core keywords. Among these keywords, particular attention is paid to "cities, digital transformation, diversification, growth, smart village, smart city, sustainable development, digital transformation, rural areas, rural development." These words reflect the main research direction of DV and reveal society's current focus on the challenges and opportunities faced by urban and rural development. By exploring these keywords in depth, researchers and policymakers can better understand how to promote the intelligent development of cities in the digital wave while ensuring sustainable progress in rural areas to achieve comprehensive digital transformation and economic growth.

Cluster 3 (blue): In the field of DV research, it is the hot spot that is most concerned with. This cluster covers 14 core keywords. People have shown great interest in "adaptation, agriculture, climate-smart villages, farmers, food security, governance, management, systems, sustainability." These research directions cover not only all aspects of DV production but also the social, economic, and environmental factors associated with it, aiming to promote the sustainable development of agriculture, ensure farmers' livelihoods and food safety, and address the challenges posed by climate change. Through an in-depth study of these areas, researchers hope to find effective strategies and solutions to achieve the long-term stability of DV and sustainable development of the environment.

Group 4 (yellow): Like Group 1, this group is relatively new in this field, including 12 core keywords. The research focus of this group mainly focuses on "carbon emission, energy, framework, infrastructure, policy, power, rural revitalization, urbanization", and so on. These keywords cover essential topics in the current development of DV, reflecting the concerns of the group of researchers on environmental protection, sustainable development, and socio-economic transformation. Through discussion of these core keywords, this group of researchers is committed to proposing innovative solutions and strategies to cope with global climate change, energy crisis, and unbalanced urban and rural development. Their research results provide theoretical support for academia and practical references for policymakers and practitioners.

Cluster 5 (purple): The fifth most significant cluster in DV research is a high-profile research cluster covering 11 core keywords. This cluster focuses on several cutting-edge technology fields, including "artificial intelligence, digital rural construction, IoT, sensors, technology, internet, smart cities, smart rural" and so on. These keywords represent the current hot spot of DV technology development and reflect the extensive research interest and in-depth exploration of the cluster in promoting scientific and technological innovation and application. DV is

committed to promoting technological progress and practical application in related fields to achieve remarkable results in digital transformation and intelligent upgrading.

Cluster 6 (turquoise colour): This group has attracted much attention in the research field and has a high research heat. It covers nine core keywords that have attracted wide attention and discussion in academic and practical applications. This group focuses on the following aspects: "challenges, communities, digital economy, entrepreneurship, innovation, migration, perspective, urban", and so on. These keywords not only cover the current hot issues of DV development but also involve the potential trends of future development. Through the in-depth study of these keywords, researchers can better understand the complexity and diversity of the current DV and provide helpful guidance and suggestions for future development.

Cluster 7 (orange): The number of core keywords is relatively small, including only four. These keywords include "dynamics, gender, impact, investments." The cluster focuses on the fields and research directions covered by these keywords. Through in-depth discussion and analysis of these keywords, researchers can better understand DV-related domain dynamics, gender differences, influencing factors, and investment strategies. This cluster's research results will positively impact the promotion of academic development and practical application of DV-related fields.

Figure 4b shows the overlap of the keyword co-occurrence network. The use of colour represents the average year of literature. Specifically, purple corresponds to 2020, blue to 2021, green to 2022, and yellow to 2023. In this way, the authors can intuitively observe the overlap of research at different time stages in the network, analyze its development dynamics and the formation of research groups, and accordingly determine the possible direction of future research. According to the detailed analysis of **Figure 4b**, cluster 2 was formed earlier in the research group, and its average publication year is 2020. Cluster 1 shows a new research trend, with an average publication year of 2023. This phenomenon reveals the shift of research interest from the focus on digital villages, digital transformation, and rural development to the emerging fields of big data, information technology, innovative health, and e-commerce.

In addition, **Figure 4c** shows the citation frequency of each keyword. Through careful observation and analysis, the authors can find that the citation frequency of cluster 3 is significantly higher than that of other clusters, ranking first. This phenomenon shows that researchers have paid more significant attention to the social, economic, and environmental factors related to DV production. Their research objectives are mainly focused on promoting the sustainable development of agriculture, ensuring farmers' livelihoods and food safety, and actively responding to the challenges posed by climate change. Keywords such as "dynamics, gender, impact, investments" in cluster 7 have received less attention, which may be because these aspects have not attracted enough attention or the related research results are relatively few.

3.3.2. DV research theme evolution analysis

This study conducted a cluster analysis of keywords and summarized the top 16 cluster tags on the scale. These labels are, in order: 0 smart village, #1 rural areas, #2 smart villages, #3 smart cities, #4 climate-smart agriculture, #5 social empowerment, #6 cost benefit, #7 digital technologies, #8 renewable energy, #9 qualitative comparative analysis, #10 digital village, #11 transformative governance, #12 multithreading, #13 social networking archaeology, #14 sexual education, #15 multi-criteria decision making. The numbers in the cluster label indicate that the amount of literature included decreases from small to large. Research on urban green space carbon storage mainly focuses on smart villages, rural areas, smart cities, and the ecological environment. By displaying 16

cluster words in a period (**Figure 5**), from the distribution of high-frequency keywords in different periods, as time goes by, new topics continue to emerge in the research field, and the depth and breadth of the research also increase.

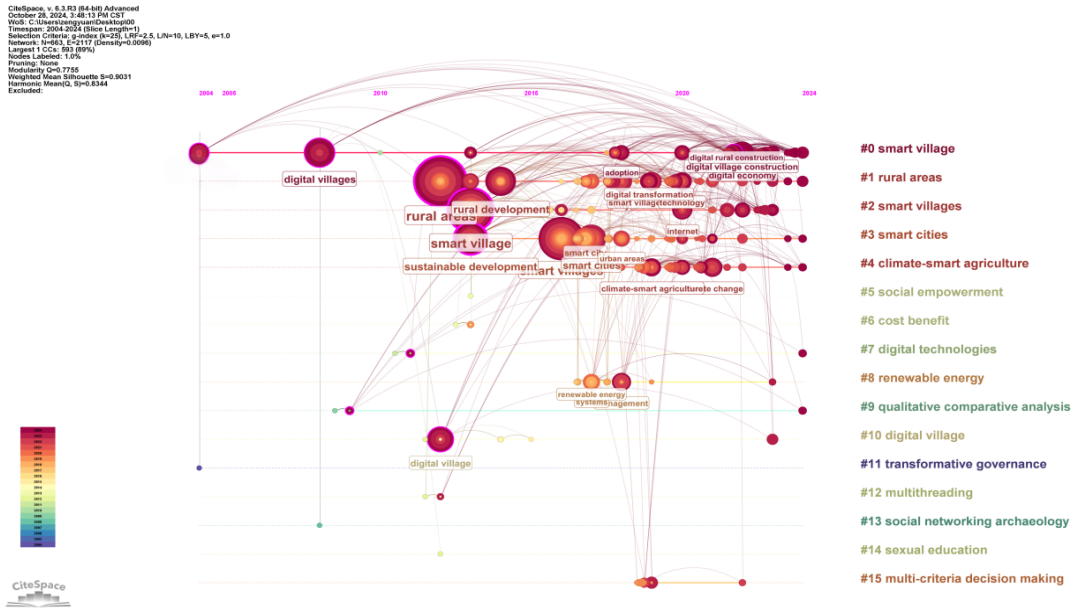

Figure 5. DV research topic word timeline view

DV research can be divided into three stages according to the timeline. From 2004 to 2010, the early stage mainly focused on digital villages, the concept of digital villages. The focus of research in this period is to use digital tools and technologies to optimize the agricultural production process, thereby improving the efficiency and quality of agricultural production. This is the initial stage of DV research, mainly focusing on applying digital technology to the farm field to achieve modernization and intelligence in agricultural production.

From 2010 to 2020, it has been in a rapid development period of DV research, and it is also the period with the most significant amount of literature. During this period, researchers mainly focused on rural areas, rural development, sustainable development, climate-smart agriculture change, digital transformation, etc. The research content covers many aspects, including but not limited to the status quo and challenges of rural areas, the strategies and models of rural development, the path and practice of sustainable development, the transformation of climate-smart agriculture, and the impact of digital transformation on rural social and economic structure.

Since 2020, DV research has entered a stage of expansion and deepening. During this period, more and more researchers began to pay attention to digital rural construction, digital village construction, and digital economy, making related research gradually increase. They deeply discussed how to use modern information technology, especially the Internet, big data, artificial intelligence, and other means to promote the development of the rural economy, improve the quality of life of rural residents, narrow the gap between urban and rural areas, and promote the implementation of the rural revitalization strategy. In addition, researchers also pay attention to the role of digital rural construction in environmental protection, education popularization, medical improvement, and other aspects, trying to solve a series of problems rural areas face through digital means.

4. Discussion

4.1. Research progress and literature review

Based on the results of bibliometric analysis, this study makes a comprehensive review of the impact of DV and looks forward to the future research trend. The main conclusions are as follows.

Firstly, DV research has shown a rapid and active growth trend in recent years, highly consistent with the international development of digital village construction. For example, especially after 2013, there has been a significant increase in publications related to DV research (2013–2018). The study found that DV research mainly involves the disciplinary fields of computer science, engineering, agriculture, business economics, public administration, social sciences, environmental sciences, etc., which shows a significant interdisciplinary research characteristic.

Secondly, analyzing the top 10 papers with high citations, hot topics mainly focus on industrial development, digital transformation and development, sustainable agricultural development, environmental protection, technological innovation, and applications from multiple fields. From a thematic evolution analysis, Clustering topics include smart village, rural areas, climate-smart agriculture, social empowerment, cost-benefit, digital technologies, renewable energy, digital village, transformative governance, social networking archaeology, and multi-criteria decision making. Keyword cluster analysis of DV research shows that research topics mainly focus on smart village, internet, climate-smart agriculture, management, digital village, sustainable development, renewable energy, big data, etc.

Finally, the authors discuss the evolution trend of DV research in detail, aiming to provide readers with a comprehensive and macro understanding of the perspective. Initially, DV research focused on the application of digital technology in the field of agriculture, and researchers devoted themselves to exploring how to use advanced digital technology to improve agricultural production efficiency and management level. Over time, the focus of DV research has gradually shifted to focus more on rural development and digital transformation issues. Researchers are beginning to explore how digital means can contribute to economic development, social progress, and environmental sustainability in rural areas. Recently, DV research has further focused on the topic of digital village construction. Researchers have begun to comprehensively analyze the impact of digital village construction on multiple dimensions such as economy, society, and environment, and explore how to promote the process of rural digitalization while achieving sustainable economic development, social equity and justice, as well as environmental protection and improvement.

4.2. Identification of regional characteristics of DV research

From the perspective of worldwide experience, different countries, in their respective constraints and institutional environments, promote DV construction in diverse pathways. Moreover, each region is also different in agricultural and rural modernization and digitization due to differences in the stages of development. Developed countries that have already modernized their agriculture and rural areas have focused more on digital infrastructure development, digitization of public services, innovation of digital technologies, and solving digital divide problems. Developing countries that are still pursuing the modernization of agriculture and rural areas focus more on the introduction of digital technologies to change the production and business models and innovate economic activities, and concentrate on poverty reduction and revitalization, digital rural infrastructure construction, and the digital transformation and its impacts. In this study, 4 active DV research regions were selected for discussion: China, the EU, Africa, and India. The characteristics of each of these regions will be examined and discussed.

4.2.1. China

China is the region with the highest volume of digital countryside research (128), representing approximately 30% of the global total. The field of digital countryside research in China has a relatively recent history, with the first studies emerging in 2012. These initial investigations were primarily concentrated in three areas: environmental sciences (44 studies), green sustainable science technology (30 studies), and environmental studies (27 studies). Since then, the pace of research has accelerated significantly (Average under 5 before 2021 and average more than 30 after that).

The development of China's digital countryside is characterized by systematic government-led promotion and comprehensive application in multiple fields [28–35]. China released the Outline of Digital Village Development in 2019, which aims to further explore the huge potential of informatization in rural revitalization, promote the comprehensive upgrading of agriculture, the progress of rural areas, and the comprehensive development of farmers by accelerating the construction of village information infrastructure. Through policy support and financial investment, the government has promoted the construction of network infrastructure in rural areas, smart agriculture, the digitalization of rural governance, and the development of the rural digital economy.

For example, Deqing County in Zhejiang Province has utilized the advantages of geographic information and artificial intelligence industries to promote the integrated reform of the digital countryside, established the overall digital countryside architecture of "1+1+N", and promoted the integrated development of rural e-commerce, digital agricultural parks, and industrial data. This shows that in building the digital countryside, China not only focuses on improving infrastructure but also emphasizes industrial upgrading and governance innovation to achieve comprehensive modernization of the countryside.

4.2.2. EU

The EU has a long history of research on DVs, and the related policy framework has been developed to a considerable extent. This has become an important reference point for many regions engaged in policy research on digital villages [36–38]. The development of DVs in EU countries is characterized by the promotion of digital infrastructure, digitization of public services, and innovation in economic activities in rural areas through policy support and financial investments. The EU has established the "EU Action for Smart Village" (**Figure 6**), which provides a definition and framework for smart villages and highlights supporting policies. The initiative prioritizes rural digital service platforms, innovative ecosystems, and smart rural construction in its rural development goals, ensuring that the agricultural sector and rural areas are closely linked to the digital economy [39–42].

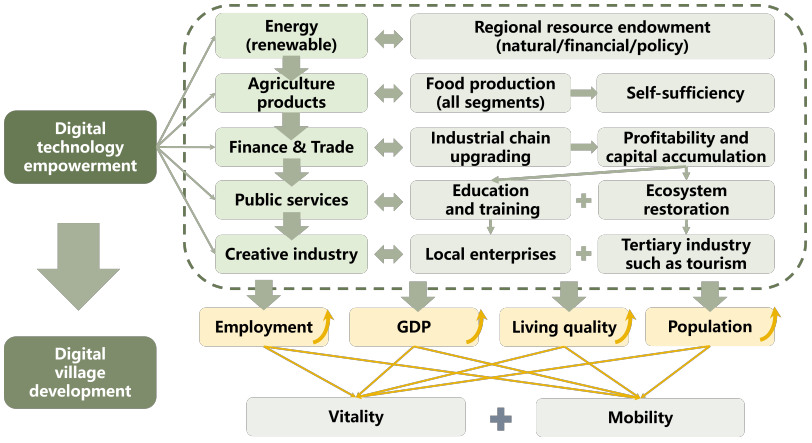

Figure 6. The practice framework of smart villages from EU actions

The EU's DV development, which is more of a solution to the problem of rural exodus, adopts a multidimensional and comprehensive system of institutional development, hoping to support the development of rural industries, especially tourism, through funds and government grants [43–45]. These initiatives are aimed at upgrading digital skills in rural areas, enhancing the capacity of communities to provide digital services, and promoting innovative community-based projects to achieve sustainable economic and social development.

4.2.3. Africa

DV studies in Africa have focused more on the development of infrastructure, such as food, water, electricity, and networks [46–48]. According to the report of Sustainable Development Goals (SDG) in 2024, efforts to end poverty are slowing down, especially in sub-Saharan Africa, Northern Africa, and Western Asia, which indicates that DV, an effective technical method to assist the local infrastructure construction and safeguard people's basic well-being, is urgent and necessary [49–51]. The development of DV in African countries has been characterized by the active utilization of digital technologies to enhance agricultural productivity and market access. Furthermore, there has been a notable degree of collaboration with other regions to expedite the resolution of infrastructure deficiencies and the digital divide.

For example, Ethiopia, through cooperation with Alibaba Group and the United Nations International Trade Centre, has optimized the supply chain and brand story of coffee beans, enabling the sale of otherwise coarse coffee beans at a higher price, thus increasing the income of coffee farmers [52–53]. This case demonstrates how African countries can digitally enhance the value chain of agricultural products and promote farmers' income, thereby boosting the economic development of rural areas.

4.2.4. India

India is particularly focused on the positive role of information and communication technology (ICT) in the development of DVs [54]. It is their intention to facilitate the modernization and digitization of rural areas through the utilization of information technology. This will encompass the construction of precision farms, the implementation of measures to enhance soil and water resources, and the improvement of the digital literacy of the population, with a particular focus on the rural youth demographic [55–56].

Under the Digital India framework, India is promoting DVs across the country as a means of bridging the rural-urban information divide, enhancing rural economic development, and transforming rural governance [57–59]. Government-led digitization projects, such as the Digital India initiative, encompass the informatization and modernization of rural areas [60–61]. The objective is to enhance the digital literacy of rural residents, improve infrastructure, and optimize the efficiency of governance and quality of life through digital services. A case in point is the Indian government's transformation of its village public service centers into mobile Internet access centers in 1,050 pilot villages. This has provided villagers with Internet access through the deployment of free Wi-Fi, thereby enhancing the digitization of rural residents' lives [62]. Furthermore, the Government of India is utilizing the Knowledge and Information Programme (Gyandoot) to facilitate the computerized management of essential demographic information, thereby enhancing the efficiency and service capacity of rural governance offices [63].

5. Conclusion

At present, the research in the field of DV is gradually becoming the focus of the scientific community. In this study, bibliometric methods were used to conduct an in-depth analysis of DV-related research, and 428 related papers included in the core database of WoS were systematically sorted out. The research reveals the trend of the number of papers published in this field and the distribution of journals, analyzes highly cited articles, author groups, and research fields in detail, and identifies the development trends of key terms and topics that appear frequently. The main conclusions of this research are as follows. (1) Recent years have seen a rapid growth in the field of DV research, characterized by significant interdisciplinary research initiatives and research hotspots focusing on industrial development, digital transformation, sustainable agricultural development, environmental protection, and technological innovation and application. (2) The prevailing trend in research has undergone a transition, progressing from the application of digital technology in agriculture to the digital transformation in rural development and finally to the impact of DV construction on the economy, society, and the environment. (3) Studies in developed countries have focused on innovation of digital technology and the digital divide, while those in developing countries have focused on rural poverty reduction and revitalization by digital technology introduction, and the potential risks during the DV transformation process.

Results of this paper provide useful information for professionals and scholars working on DV and digital economy, rural transformational development and restructuring, and rural revitalization. The research results can help researchers quickly familiarize themselves with the research progress of DV, and the most influential journals, authors, or countries. These findings can also help researchers identify relevant research topics, future research directions, and proposed concepts, techniques, and methodologies, enabling them to conduct additional investigations, expand their research interests, or seek academic partnerships.

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