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Socio-Techniques of Rural Transformation and Smart Village for Sustainable Development: A Bibliometric Approach

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ABSTRACT

This study aims to identify the relationship between rural transformation and smart villages with sustainable development. The Scopus database for 2007 to 2024 and the bibliometric approach (R-package) were selected to identify the distribution of published articles, variable relationships, authors, citations, countries, and topic trends. The study results show that proper rural transformation will accelerate the process of achieving sustainable rural development. A village-scale resilience evaluation framework is needed as a new systematic review of rural transformation to accelerate, based on several dimensions. Meanwhile, smart villages with the support of digital technology play a role as drivers for achieving sustainable development. Global contributions to rural transformation studies are dominated by developed countries (China, Australia, Germany, and Italy), while smart village studies are in demand by both developed and developing countries. The results of this study contribute theoretical insight into the interconnection between rural transformation and smart villages towards sustainable development, so that the direction of sustainable development research can combine the two concepts. Practically, this study provides an overview for planners and policymakers in developing rural areas through a combination of both study concepts, so that the target of achieving sustainable development at the micro level of the region can be achieved.

1. INTRODUCTION

Rural transformation is part of a global path or mechanism. Rural transformation is defined as the structural change of the economy from the primary to secondary and tertiary sectors, society, and the environment that leads to economic growth with a culture increasingly similar to urban agglomeration [1, 2]. The influence of rural self-development on urbanization and industrialization brings three types of rural transformation mechanisms, which include endogenous, exogenous, and endogenous/exogenous combinations [3]. Rural transformation is reflected in changes in traditional economic structures, socio-cultural shifts in communities, and infrastructure development in rural areas [4, 5]. With rural transformation, job and business opportunities that suit local conditions will be more open [6]. Rural development is a dynamic process in various contexts, so rural transformation requires the role of residents and external actors to inspire [7]. Contemporary rural development is characterized by the development of rural transformation that focuses on geography, sociology, and economics [2, 8, 9].

Rural transformation is an effort to accelerate development in rural areas. Improving the socio-economy and livelihoods of traditional villages requires the development of rural transformation [10]. The development of appropriate rural transformation will have an impact both on the rural regional system and on rural-urban relations [11]. The development of rural transformation is a response to industrialization and urbanization, as well as the interaction of rural and urban population flows in economic development [12]. The process of migration and industrialization brings about the welfare effects of rural transformation [13]. Further studies [3, 14, 15] said important factors in rural transformation include population, land, industry, ecology, wages, and urbanization. The digital era has influenced the technology-based rural transformation model. The development of technology brings changes in every aspect of life, such as the economy, business, education, and social [16]. Several villages are transformed into smart villages with the use of digital technology.

Smart villages are one of the options for rural development

in the era of digitalization. Smart village is defined as a local community with digital technology and innovation, so there is an improvement in the standard of public services with better local resources [17]. The concept of smart villages is to improve the welfare of traditional rural areas by using digital technology to consider the needs and abilities of the population [17, 18]. In line with this, the study [19] described a smart village as an innovative approach to village-level sustainable development planning based on human resources that leads to economic sector development and is supported by appropriate technology and high technology. Clearly the study [20] mentioned that sustainable development can be facilitated through the concept of smart villages. As a derivative of the concept of smart city, the concept of smart villages has elements that include the environment, people, quality of life, management, mobility, economy, research, and innovation. Although the concept of smart villages is considered a relatively new initiative, it can respond to economic and territorial gaps [21, 22] and address the challenges in the era of disruption in the development of balanced, economically, socially, and environmentally sustainable villages.

Rural development focusing on economic, social, and environmental balance will encourage the achievement of sustainable development goals. The concept of sustainable development in rural areas was initially centered on the agricultural sector, but later shifted to a more holistic and inclusive [20]. The rural sustainable development index comprises population, economic, social, and environmental dimensions [21-23]. Village revitalization through improving urban-rural connectivity through "smart" is important for village communities to be more adaptive and resilient [24] to achieve sustainable rural development. Sustainable development will create prosperity for humans while preserving nature.

Nevertheless, only some countries are transforming in rural areas. Rural transformation has been identified as having been carried out in Western Europe, North America, Israel, China, India, the Philippines, Zimbabwe, and Ecuador from the end of the 20th century to the beginning of the 21st century [11]. Further the study [11] mentioned that China has focused on significantly improving the welfare of rural communities with three indicator systems, which include the level of rural development, the level of rural transformation, and the level of urban-rural coordination. Rural transformation in Indonesia can affect the rural population's quality with the support of digitalization and information technology, such as integrated agricultural models [4, 25]. Meanwhile, rural transformation in Spain has reduced urban and rural disparities [24]. Poland's Rural transformation focuses on food systems to support sustainable development [26].

Rural areas with traditional development patterns are mainly in a disadvantaged condition. Disadvantaged areas generally have poor infrastructure with low-quality services, thus losing investment attractiveness [27]. Some rural areas in Poland are left behind due to poor internet access [17]. Similar conditions prevailed in some regions of Iran, prompting local governments to build information technology centers to expand the accessibility of disadvantaged communities during rural development [28]. Infrastructure development that suits the needs of local communities in disadvantaged areas will increase productivity [29] thus attracting inward investment.

The era of digitalization has not been fully utilized for development in rural areas. Some villages experience significant challenges, such as vulnerability to external shocks [30] affecting the economy, society, and the environment. Rural development is a multilevel, multi-actor, and multifaceted process [11] So an integrated set of all elements is required. The concept of smart villages is the most promising option in the digital era [31] because it can integrate rural development initiatives to increase income and quality of life and strengthen the local community [20].

Economic, social, and environmental disparities are still development problems in rural areas. A critical challenge in sustainable development is the inequality of rural and urban welfare [32, 33] mentioned that the determinant of economic growth is greatly influenced by income inequality. In Indonesia, inequality in access to basic services is a crucial problem because two out of five households in rural areas do not have access to sanitation, widening the rural-urban gap [34]. In line with this, Tunisia's rural and urban energy gap has implications for sustainable development in the region [32]. The target of achieving sustainable development in rural areas is a big task for the welfare of rural communities and nature conservation efforts.

For this, Knowledge insights on rural transformation and smart villages are needed to respond to digital era development. Although rural transformation and smart villages were introduced before the 2000s, research interest in rural transformation and smart villages for sustainable development has only increased since the last decade (2015-2024). Smart village studies still highlight a lot of disciplinary backgrounds and geographical contexts, so there is little involvement in the literature with other debates around rural and sustainable development [35]. Scopus data sources said that since the emergence of the concept of sustainable development in 1929, the number of documents on sustainable development research has reached more than 230 thousand in the last decade. Meanwhile, the number of research studies on rural and village transformation related to sustainable development is far below that. It shows that there is a vast potential gap for the development of research on rural transformation and smart villages for sustainable development.

The bibliometric approach with the Scopus database was chosen to uncover emerging trends in the performance of the scientific literature, author productivity, and the most significant linkages between publications [36-38]. The extensive and broad coverage of the Scopus dataset and meta-analysis studies with qualitative and quantitative techniques allows for evaluating research collaborations across organizations and countries [39-41]. The citation analysis and word together analysis in this paper used R software, as the R package and the Shiny application can create flowcharts per the PRISMA 2020 standard, with optimal digital interactivity [41]. Based on this background, this article aims to organize knowledge on the study of rural transformation and fragmented smart villages to provide a new perspective on how rural transformation and smart villages play a role in sustainable development. To that end, performance and scientific analyses are needed to measure research trends in both fields and observe the interrelationships among elements, so that the evolution and intellectual structure of developments in both fields can be captured. This article contributes to the future of rural development by combining the two concepts in sustainable rural development.

2. METHOD

Scopus's broad multidisciplinary scope is one of the most popular reasons for choosing the Scopus database in bibliometric analysis [41, 42]. Scopus is generally considered to have a wider selection of journals than the Web of Science [43, 44]. Thus, using the Scopus database would be very relevant for the scientific studies that emerged in the early 2000s, such as rural transformation and smart villages.

Bibliometric analysis techniques are defined in two categories. First, performance analysis assesses the contributions of various components within a specific domain of study [38, 45]. The performance analysis in this paper was conducted to measure the field of research through the annual scientific production and number of published documents, by identifying the most relevant keywords and conducting citation analysis. Second, scientific analysis or mapping investigates the relationship between research elements [38, 40, 45]. The techniques include citation analysis, co-citation analysis, bibliographic merging, co-word analysis, and co-authorship [38, 39].

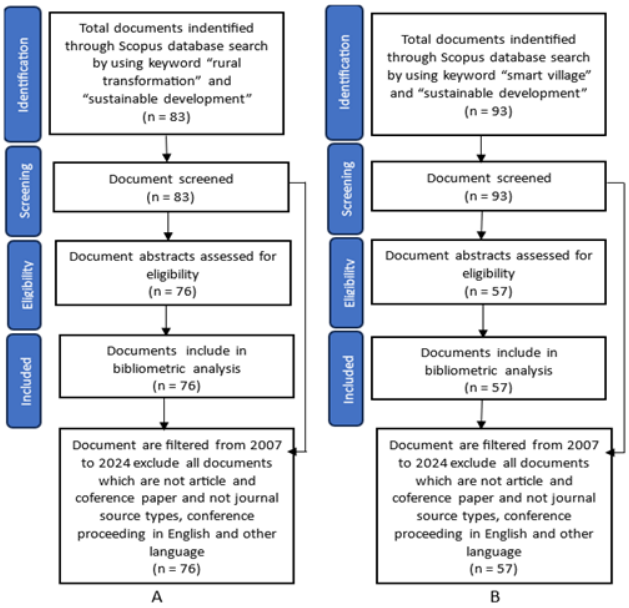


Figure 1. Process of article selection

Science mapping by highlighting state collaboration networks, confiscation analysis, and word analysis in this paper using R software and PRISMA's Systematic Literature Review (SLR). The PRISMA procedure describes the mapping of the literature on rural transformation and smart villages to sustainable development, as presented in Figure 1. The difference in the year of the first appearance of literature on rural transformation and smart village studies underlies the difference in the analysis year between the two. The determination of relevant keywords for this study was based on a literature review and was confirmed by experts in related fields. A literature search using the keywords "rural transformation" AND "*sustainable development"* yielded 83 documents from 2007 to 2024. These documents were sorted using a bibliometric approach, excluding documents that were not articles or conference papers and did not originate from journals or conference proceedings, resulting in 76 eligible documents. Meanwhile, searches using the keywords "*smart village"* AND "*sustainable development"* yielded 93 documents. These documents are narrowed down to 57 eligible documents. These findings suggest that the keywords in Figure 1 receive greater academic attention and scrutiny from academics. Indirectly, academics emphasize that rural transformation is closely related to sustainable development. Selected literature documents using bibliometric approaches, including articles and conference papers. Literature sources include journals and conference proceedings, while the languages spoken are English, Chinese, Russian, German, and Italian. The publication period is from 2007 to 2024.

3. RESULT AND DISCUSSION

3.1 Publication trends

Tables 1-2 depict information regarding the literature under review. Bibliometric data show that rural transformation studies are increasing, with the highest number of articles in 2020 and 2023 and the highest citations in 2007. Meanwhile, the smart village study was first published in 2016, with an increasing trend and the highest number of articles in 2018, 2023, and 2024. Based on the analysis results (Figure 2(a)), the rural transformation study comprised 76 documents from 48 publications, showing a significant annual growth rate of 16.79%. The average age of these documents is about 4.38 years, accompanied by an average of 15.97 citations. The dataset comprised 227 contributing authors, 11 individual papers, and an average of 3.61 co-authors per document. As many as 17.11% of the documents are by international authors. The multidisciplinary nature of the literature is seen in the dataset with 437 plus keywords and 305 author keywords.

Table 1. Main information about the "rural transformation" review corpus

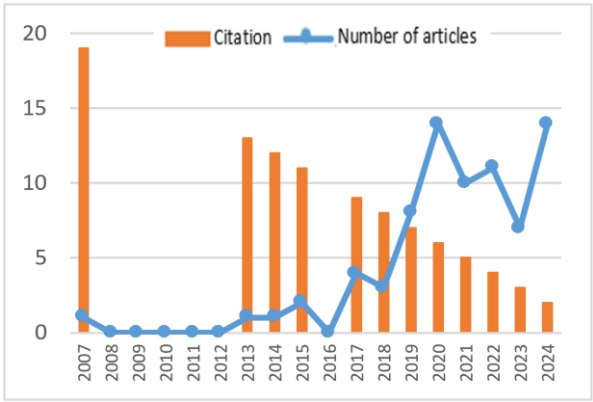
General Discussion	Results
Timespan	2007:2024
Sources	48
Documents	76
Annual Growth Rate %	16.79
Document Average Age	4.38
Average citations per doc	15.97
Total authors	227
International co-authorships %	17.11

Table 2. Main information about the "smart village" review corpus

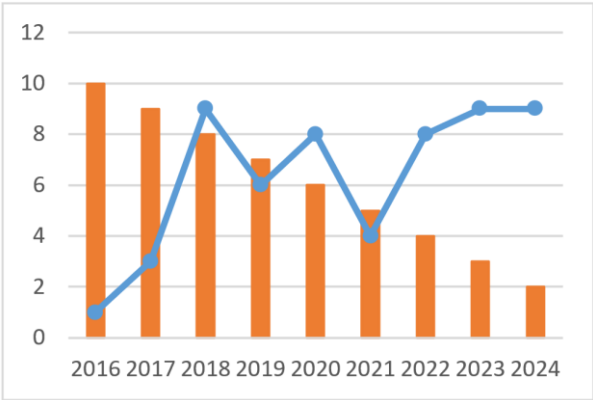
General Discussion	Results
Timespan	2016:2024
Sources	47
Documents	57
Annual Growth Rate %	31.61
Document Average Age	4.19
Average citations per doc	25
Total authors	161
International co-authorships %	24.56

Meanwhile, the smart village bibliometric data from 2016 to 2024 (Figure 2(b)) consists of 57 documents from 47 sources with a significant annual growth rate of 31.61%. These documents have a relatively new average age of 4.19 years, receiving an average of 25 citations. The dataset involved 161 contributing authors, including seven documents written by a single author, and showed an average of 3.09 co-authors per document collaboration. As many as 24.56% of the documents

are by international authors. The multidisciplinary nature of the literature is seen in the dataset with 344 plus keywords and 221 author keywords. Interest in smart village research and rural transformation to sustainable development has increased over the past decade (2015-2024). Research on smart villages primarily emphasizes disciplinary background and geographic context, resulting in minimal engagement with broader discussions about rural and sustainable development.



(a) Rural transformation



(b) Smart village

Figure 2. Scientific production and average annual citations

Although Muth has introduced publications related to rural transformation through the Conference on African Local Institutions and Rural Transformation: Lincoln University, Pennsylvania, 20–21 April 1967, the publication of Rural Transformation to sustainable development only appeared in 2007. Allina-Pisano wrote this article titled Rural transformation in Ukraine: A sustainable model? The study [46] explains economic reforms in rural areas of Ukraine through collective agricultural restructuring and privatization of agricultural land. The transformation of collective agriculture in Ukraine is carried out through two steps. First, reorganize collectives to create a form of personal ownership and management. Second, allocating land to create smaller private farms. The transformation carried out in the region has implications for villagers' new property rights and has also impacted sustainable development in Ukraine. Meanwhile, the smart village publication was introduced in 2002 through an article by the study [47] titled Designing a DNA for adaptive architecture: A new built environment for social sustainability. The publication of smart villages related to sustainable development has just been introduced by the study [48] with the article title Ending energy poverty, one solar grid at a time [Spectral lines]. Smart villages were introduced by connecting the concept of SDGs through the fulfillment of smart electricity for poverty eradication (SDG 1).

3.2 Publication source

Based on 76 articles published in Scopus, the top ten most published sources of rural transformation studies include "Land", with A total of 7 articles, followed by "Sustainability (Switzerland)" with six articles. A strong focus and coverage on sustainability topics. While "Ecological Indicator, Habitat International, IOP Conference Series Earth and Environment SCI, Journal of Rural Studies, Progress in Geography" have three articles each. "Applied Geography, Development (Basingstoke), Dili Xuebaq/Acta Geographica Sinica" published two articles. These journals cover various fields, including environment, rural, geography, sustainability, development, and the earth, describing the cross-cutting nature of rural transformation research. This distribution provides insight into how researchers can publish their work by considering leading journals and the potential for interdisciplinary collaboration.

Meanwhile, of the 57 articles about smart villages published by Scopus, the most were published by "Sustainability (Switzerland)", eight articles. "Frontiers in Eviromental Science, IOP Conference Series: Earth and Enviromental SCI, IOP International Series: Materials Science and Engine" 2 articles each. Meanwhile, "10Th International Conference on ICT for Smart SOC, 2017 IEEE Conference on Technologies for Sustainability, ACM International Conference Proceeding Series, ACTA Scientiarium Polonorum, Adminitratio Locorum, Africa Journal of Hospitality, Tourism and Leiser, Agricultural Systems" 1 article each. Most of the articles in Scopus are sourced from conferences, and a few journal articles still discuss smart villages, so there are still enormous gaps for smart village research that can be filled.

3.3 The variable relationship between transformation and smart villages to sustainable development

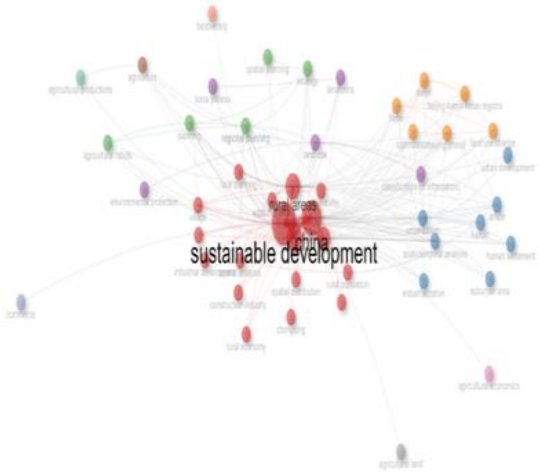
Figure 3 visualizes the network between keywords in both studies. Nodes in the network represent keywords. The more frequently a keyword appears, the larger the node, and vice versa. The frequency with which keywords co-occur affects line thickness. Based on co-occurrence analysis, there are three central criteria: betweenness-centralization shows how dependent other nodes are on a particular node; closeness-centralization shows access effectiveness; and "PageRank" shows the significance score of each node. In the rural transformation study, the PageRank values for "sustainable development" and "China" were the highest, as were the betweenness centrality and closeness centrality values (Table 3). Both became components of Cluster 1. The study of rural transformation and sustainable development is formed from the simultaneous emergence of the keyword "sustainable development", "China", "rural development", "rural area", "sustainaibility", "rural population", dan "village", "agglomeration", "spatial analysis", "industrial development", "spatial distribution"," agricultural production"," rural economy", "rural planning", "adaptive management", "chongqing", "construction industry" from cluster 1 (red). It shows that development in rural areas is designed to achieve sustainable development [49]. The transition from rural development to sustainability and resilience of rural areas can be accelerated through rural transformation [50]. Rural transformation has been proven to reduce poverty and achieve

the first goal of sustainable development [51]. Rural transformation through Internet of Things (IoT) [18, 52] can be done to increase agricultural production so that a better rural economy is achieved.

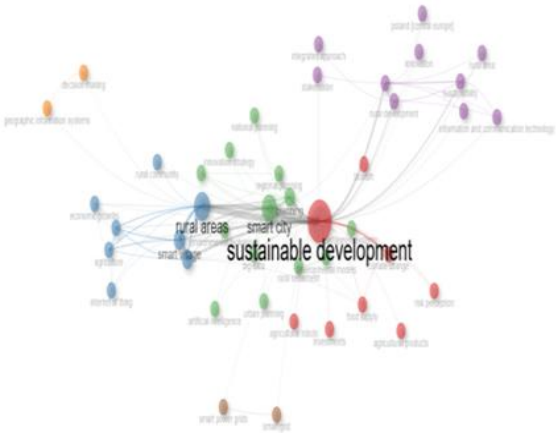
Cluster 2 (blue) is composed of the simultaneous occurrence of the keywords "urbanization", "spatiotemporal analysis"," industrialization"," human", "human settlement", "suburban area", and "urban development". Massive urbanization in some countries of the world has had an impact on depopulation and population ageing in rural areas [52, 53]. Therefore, village revitalization is significant for village attractiveness strategies and solutions to urbanization problems and rural-urban gaps [50, 54, 55]. Rural transformation in many regions of the world is carried out to overcome urbanization and rural-urban gaps [56, 57]. Rural transformation as part of urban development can be carried out through smart villages [17]. Cluster 3 (green) is composed of keywords "planning", "regional planning", "ecology", "agricultural robots", and "spatial planning". Through proper spatial planning, land use will increase agricultural production [58] while still paying attention to ecological sustainability [59, 60]. Cluster 4 (purple) is composed of the keywords "land use", "loess plateau", "enviromental protection", "landforms", "classification (of information)". Meanwhile, keywords "China", "Beijing (China)", "hebei", "tianjin", "optimization", "land use change", and "beijing-tianjin-hebei regions" were included in cluster 5 (orange). Scopus data set noted that over the past decade, China has been the country that has conducted the most research in this field, followed by Australia, Germany, and Italy.

Table 3. Keywords-based cluster "rural transformation" study

Node	Betweenness	Closeness	PageRank
Cluster 1			
sustainable development	555,462834	0,0212766	0,14831633
china	183,90363	0,0178571 4	0,10776191
rural development	46,1407045	0,0151515 2	0,07238473
rural area	28,6756756	0,0140845 1	0,05470988
rural areas	60,035192	0,0153846 2	0,06758932
sustainability	0,10101141	0,0116279 1	0,01838259
rural population	0,29388738	0,0116279 1	0,01708421
village	0,27076045	0,0116279 1	0,0159878
agglomeration	0,14109058	0,0116279 1	0,01434835
spatial analysis	0,24561142	0,0117647 1	0,01692362
industrial development	0	0,0109890 1	0,00682655
spatial distribution	0	0,0111111 1	0,00992837
agricultural production	0	0,0109890 1	0,00734405
rural economy	0	0,0109890 1	0,00630415
rural planning	0	0,0112359 6	0,008848
adaptive management	0	0,0109890 1	0,00630415
chongqing	0	0,0108695 7	0,00527074
construction industry	0	0,0113636 4	0,00937174
Cluster 2			
urbanization	9,67988971	0,0129870 1	0,03172941
spatiotemporal analysis	2,52164181	0,0123456 8	0,02686048
article	0,12468072	0,0117647 1	0,01455203
industrialization	0	0,0113636 4	0,01163469
human	0,12468072	0,0117647 1	0,01455203
human settlement	0	0,0112359 6	0,00838339
suburban area	0	0,0109890 1	0,00633267
urban development	0	0,0109890 1	0,00634045
Cluster 3			
planning	0,67846401	0,0117647 1	0,0242042
regional planning	3,72206346	0,0125	0,03123713
ecology	0,44557011	0,0116279 1	0,01384998
agricultural robots	0,03149606	0,0113636 4	0,0110867
spatial planning	0	0,0109890 1	0,00650086
Cluster 4			
land use	8,80079271	0,0128205 1	0,02970852
loess plateau	0,03030303	0,0111111 1	0,00926746
environmental protection	0	0,0108695 7	0,00591343
landforms	0,12541806	0,0112359 6	0,00992409
classification (of information)	0	0,0111111 1	0,00741897
Cluster 5			
hebei	0,94950142	0,0120481 9	0,02136748
beijing [china]	3,88060073	0,0126582 3	0,02753627
tianjin	0,91257153	0,0120481 9	0,01975678
optimization	0,0693883	0,0116279 1	0,01425801
land use change	0	0,0113636 4	0,01018911
beijing-tianjin-hebei regions	0	0,0113636 4	0,00958085
Clusters 6-11			
agriculture	0,63253968	0,0113636 4	0,01145225
agricultural economics	0	0,0107526 9	0,00423574
agricultural land	0	0,0107526 9	0,00423574
agricultural productions	0	0,0108695 7	0,00573334
biodiversity	0	0,0107526 9	0,00423574
commerce	0	0,0107526 9	0,00423574



(a) Rural transformation



(b) Smart village

Figure 3. Variable relationships

In the smart village study, the PageRank values for "sustainable development" and "climate change" were the highest, as were the betweenness centrality and closeness centrality values (Table 4). Both became components of Cluster 1. The study of smart villages and sustainable development shows the linkage of keywords in the network, as presented in Figure 3. Cluster 1 (red) is formed by the simultaneous occurrence of the keywords "sustainable development", "climate change", "food supply", "agricultural products", "agricultural robots", "investments", "risk perception", and" tourism". The concept of sustainable development is very closely related to rural development as a means of improving the quality of life of rural communities [61, 62]. Sustainable development is a response to climate change conditions that affect the resilience of a region. One of the forms of this response is implemented through the climate smart village (CSA) [60, 63-65]. CSA has been shown to significantly impact increasing farmers' income and productivity [66], and AI-powered smart agriculture is influencing sustainable rural development [67]. Cluster 2 (blue) is formed by the simultaneous occurrence of the keywords "rural areas", "smart village", "economics", "agriculture", "Internet of Things", "rural community", "economic growth". Smart villages are a model of sustainable development that drives rural development [68-70].

Cluster 3 (green) is composed of keywords "smart city", "planning", "big data", "regional planning", "rural settlement", "urban growth", "artificial intelligence", "developmental models", "environmental technology", "innovation strategy", "national planning", "settlement systems", "urban planning". The keyword "smart city" formed from the simultaneous occurrence of "planing" and "big data". It shows that smart cities are part of regional planning and are inseparable from general planning [19]. Big data through IoT is an important catalyst for the development of rural areas and economic improvement in the agricultural sector [71, 72] through smart economy and smart agriculture in rural areas [64, 73, 74]. Meanwhile, smart cities are the basic concept of smart villages [55] closely related to sustainability and rural development, which is the purpose of the smart village. Cluster 4 (purple) is composed of the keywords "rural development", "village", "sustainability", "information and communication technology", "integrated approach", "rural area", "innovation", "poland [central europe]", "population decline", "stakeholder". Cluster 5 (orange) is composed of the emergence of the keywords "decision making" and "smart power grids".

Table 4. Keywords-based cluster “smart village” study

Node	Betweenness	Closeness	PageRank
Cluster 1			
sustainable development	637,091367	0,02173913	0,18199887
climate change	1,65485312	0,01282051	0,02374922
food supply	0	0,01234568	0,01458229
agricultural products	0	0,01149425	0,00579731
agricultural robots	0	0,01149425	0,00579731
investments	0	0,01149425	0,00579731
risk perception	0	0,01162791	0,00817224
tourism	0	0,01149425	0,00579731
Cluster 2			
rural areas	122,195453	0,01515152	0,08452602
smart village	13,1979858	0,01369863	0,04973338
economics	9,66430444	0,01388889	0,04742002
agriculture	3,31916944	0,01282051	0,02691754
Internet of Things	3,31916944	0,01282051	0,02691754
rural community	0	0,01204819	0,00887648
economic growths	0	0,01265823	0,01599162
Internet of Thing	0	0,00961538	0,01166733
Cluster 3			
smart city	52,4461822	0,01470588	0,07442776
planning	20,0342037	0,01388889	0,0478912
big data	0	0,0125	0,01743881
regional planning	1,00484504	0,01282051	0,02270265
rural settlement	1,93436193	0,01298701	0,02092017
urban growth	0,0625	0,01219512	0,01539918
artificial intelligence	0	0,01176471	0,00787153

developmental models	0	0,01282051	0,01634902
environmental technology	0	0,01190476	0,00988688
innovation strategy	0	0,00934579	0,00765015
national planning	0	0,01190476	0,01015514
settlement systems	0	0,01162791	0,00816827
urban planning	0	0,01176471	0,00787153
Cluster 4			
rural development	2,77727273	0,01219512	0,02784963
village	7,60799118	0,01282051	0,03951181
sustainability	1,69034091	0,01219512	0,02948253
information and communication technology	0	0,01190476	0,01582883
integrated approach	0	0,01162791	0,00842756
rural area	0	0,01176471	0,01319859
innovation	0	0,01162791	0,00828509
poland [central europe]	0	0,01162791	0,00842756
population decline	0	0,01176471	0,01079111
stakeholder	0	0,01162791	0,00828509
Clusters 5 and 6			
decision making	0	0,00943396	0,00963678
geographic information systems	0	0,00943396	0,00963678
smart grid	0	0,01162791	0,01008228
smart power grids	0	0,01162791	0,01008228

Based on the author keyword analysis (Figure 4(a)) of the rural transformation study to sustainable development, it is known that the most common words are "rural transformation" with 19 words, "sustainable development" with 12 words, "rural revitalization" with eight words, "China" with 35 words, "rural areas" and "poverty reduction" with three words each. Meanwhile, the study of smart villages for sustainable development (Figure 4(b)) found that the most common words that appeared were "smart village" and "smart villages" with 22 and 12 words, "sustainable development" with nine words, "smart cities" with six words, and "rural areas" with four words. It shows that the study of rural and smart village transformation to sustainable development is a topic that attracts much academic interest.

(a) Rural transformation

(b) Smart village

Figure 4. Word cloud

3.4 Geographical origin

A literature review shows significant geographical patterns in rural transformation and smart village research for sustainable development. China dominated the rural transformation study with a frequency of 137, followed by Australia, Germany, and Italy with a frequency of 5 each. Meanwhile, the smart village study was dominated by Indonesia with a frequency of 24, followed by China with a frequency of 16, India with a frequency of 12, and the USA with a frequency of 11. China and Poland were the strongest countries in the discourse of the two studies (Figures 5 and 6, Tables 5 and 6).

Table 5. Summary of transformation practices from the five most frequently researched countries

No.	Country	Rural Transformation Practices
1	China	Modern agriculture, village restructuring and revitalization, village development mode innovation, primary sector transformation, technology application, industry transformation, agribusiness expansion, agricultural modernization, local industrialization, agricultural digitalization, institutional reform and innovation, economic restructuring with E-commerce, agricultural product streaming, green transformation of agricultural industry, governance innovation
2	Australia	Transformation of the cultural industry in coastal areas
3	Germany	Transformation of biosphere reserve governance
4	Italy	The use of remote sensing for urban planning landscape patterns
5	Poland	Demographic transformation, economic transformation, functional transformation, land use transformation

Table 6. Summary of transformation practices from the five most frequently researched countries

No.	Country	Smart Village Practices
1	Indonesia	Smart agriculture, digital villages, smart economy, smart governance
2	China	Climate-smart villages, culture-smart villages, smart infrastructure, governance digitalization, living digitalization, infrastructural digitalization, rural elderly care with smart technology
3	India	Smart agriculture, smart farming, smart lighting, climate-smart farming, e-government services, rural off-grid power generation, rural drinking water technology
4	USA	Telemedicine, agricultural sensor technology, village government online platform
5	Poland	Smart agriculture, smart transportation, smart energy

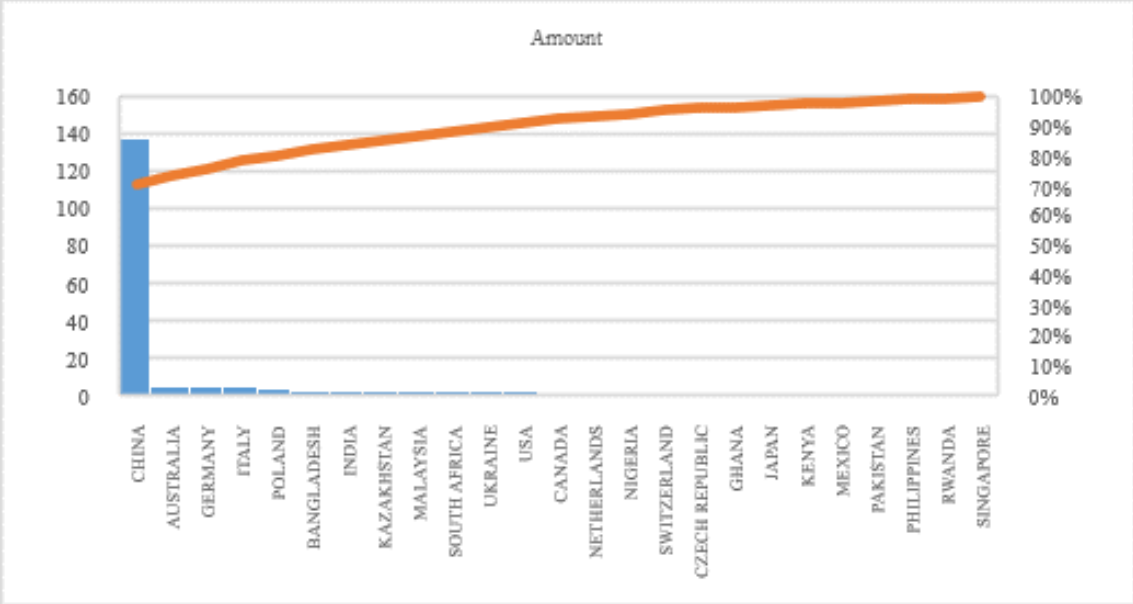


Figure 5. Number of publications of rural transformation studies per country

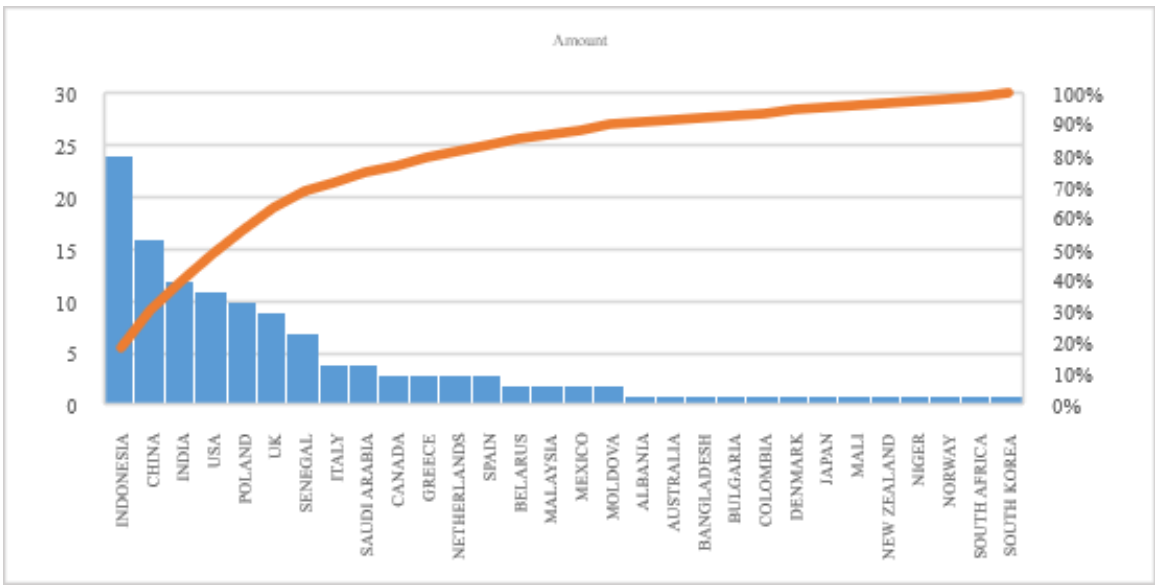


Figure 6. Number of publications on smart village studies per country

3.5 Impact and visibility of publications

An analysis of influential academic publications in rural transformation research and smart villages focuses on the most cited articles in the dataset. Tables 7 and 8 show the ten articles with the most citations, accompanied by total citations (TC) and average citations per year. This research includes important articles that significantly changed academic thinking about rural transformation and smart villages.

Ten widely cited articles for rural transformation studies discuss many transformations in the China region. The transformation was related to the agglomeration of industry in rural China. Various cases were raised, ranging from the problem of land use change, land conflicts, and tourism-based economic development. The widely cited article focuses on developing urban-rural transformation by examining the coupling relationship of rural production coordination, living function, and ecology [75]. The same thing is done [76] in

overcoming land use conflicts by paying attention to coordinating human and environmental couplings so that rural transformation towards industry does not cause land conflicts in rural areas. The impact of rural transformation through agglomeration is an interesting topic due to environmental pollution's effects, so it becomes one of the obstacles to sustainable development [77]. Meanwhile, the study [78] focuses on rural transformation through rural tourism development to encourage sustainable development. In general, the rural transformation that has occurred in China has both positive and negative impacts. Transformation without regard to the environment has an impact on environmental sustainability. However, several transformations that have occurred in China have also led to economic, social, and environmental improvements, accelerating the achievement of sustainable development. A new systematic review of rural transformation to accelerate the achievement of sustainable development requires a framework for evaluating village-scale resilience based on several dimensions: resources, morphology, human, environment, and function [75, 76, 79].

Table 7. Top authors' contributions and high-impact articles on rural transformation studies

No.	Article	DOI	TC	AVE. Year
1	Yang Y, 2020, Ecol Indic	10.1016/j.ecolind.2020.106512	248	41,3
2	Ge D, 2020, J Rural Stud	10.1016/j.jrurstud.2020.04.010	110	18,3
3	Tang Q, 2013, Appl Geogr	10.1016/j.apgeog.2013.03.007	88	6,7
4	Ma W, 2018, SCI Total Environ	10.1016/j.scitotenv.2017.09.152	86	10,7
5	Bao W, 2021, J Environ Manage	10.1016/j.jenvman.2021.113168	71	14,2
6	Qin T, 2022, Agric	10.3390/agriculture12020297	60	15
7	Jiang G, 2017, J Clean Prod	10.1016/j.jclepro.2017.04.152	55	6,1
8	Cheng M, 2019, Dili Xuebao/ACTA Geogr Sin	10.11821/dlxb201908007	35	5
9	Li H, 2022, J Clean Prod	10.1016/j.jclepro.2022.132738	32	8
10	Gao C, 2019, Sustainability	10.3390/su11143890	32	4,5

Table 8. Top authors' contributions and high-impact articles on smart village studies

No.	Article	DOI	TC	AVE. Year
1	Lytras MD, 2018, Sustainability	10.3390/su10061998	312	39
2	Visvizi A, 2018, J SCI Technol Policy Manage	10.1108/JSTPM-02-2018-0020	235	29,4
3	Chui KT, 2018, Energies	10.3390/en11112869	171	21,4
4	Adamowicz M, 2020, Sustainability	10.3390/su12166503	85	12,6
5	Aryal JP, 2020, Int J Innov Sustainable Develo	10.1504/IJISD.2020.106243	61	10,2
6	Jagustovicć R, 2019, Agric Syst	10.1016/j.agsy.2018.12.008	59	8,4
7	Zhang X, 2020, Sustainability	10.3390/su122410510	56	9,3
8	Battino S, 2019, Sustainability	10.3390/su11113004	51	7,2
9	Van Gevelt T, 2018, Energy Sustainable Dev	10.1016/j.esd.2018.01.005	50	6
10	Sutriadi R, 2018, Iop Conf Ser Earth Environ Sci	10.1088/1755-1315/202/1/012047	48	6

Smart village articles have a variety of variations, both in the themes raised and in the location of the research. The perspective debate on the concept of "smart" became an article that received many citations. The concept of smart in a smart city is more pragmatic, and there is a normative bias, so a discussion is needed for the prerequisites for interdisciplinary "smart" concepts [80]. Several researchers have introduced nested cluster models to identify "smart" models that are holistic, scalable, and human-centered [81]. The model offered can be applied at the micro, mezzo, and macro levels, so it significantly contributes to the early identification of smart villages. Meanwhile, the study [20] introduced the concept of smart village measurement by calculating the empirical potential of management, quality of life, economy, natural environment, and mobility.

The concept of smart villages is developing in various fields and dimensions. One is smart villages implemented with sustainable energy fulfillment by integrating IoT and urban space concepts [82]. Smart energy, with universal energy access in several regions, has increased rural development [70]. Meanwhile, the studies [83, 84] developed the concept of smart villages with climate-smart agriculture. CSA has been proven to improve climate change adaptation, mitigation, and food security, so that it contributes significantly to achieving sustainable development goals by reducing hunger, reducing land degradation, eradicating poverty, addressing climate change, and promoting gender equality. China defines smart villages as a rural development model utilizing information and communication technology (ICT). This model is applied to underdeveloped villages and is the most appropriate choice in encouraging sustainable rural development [85]. As noted in the study [86], the use of ICT is an innovative breakthrough and serves as an economic tool for marginalized and remote regions in the European Union. In contrast to China, which reconstructs smart villages with a top-down smart village model as a reflection of the centralization of power and dominance of the public economy [85], smart village planning provides several perspectives that need to be considered, including community willingness, history, culture, economy, ecosystem, technological readiness, and its impacts, as well as technical and political processes [19]. New insights from the concept of smart villages for sustainable development are relevant to a multidisciplinary field because the implementation of smart villages is highly dependent on the potential and problems of each region. This description opens up information on great opportunities for researchers to conduct research related to intelligent models and fields, per the geographical conditions of the region.

4. CONCLUSION AND IMPLICATION

The bibliometric approach comprehensively analyzes the relationship between rural transformation and smart villages

toward sustainable development. Proper rural transformation will accelerate sustainable development; conversely, rural transformation that does not pay attention to the environment hurts sustainable development. A new systematic review of rural transformation to accelerate the achievement of sustainable development requires a framework for evaluating village-scale resilience based on several dimensions: resources, morphology, human, environment, and function. The use of technology in the rural transformation process is an option in the digitalization era. Meanwhile, smart villages, as a derivative concept of smart cities, have brought new debates among academics. New insights from smart villages that emphasize more aspects of digital technology play a role as a driver in the process of achieving sustainable development. The implementation of smart villages is highly dependent on the needs and problems of each region, so that the geographical aspect of the location is the key to the success of the "smart" implementation. At least measurable "smart" potential can be seen in six areas: management, quality of life, economy, natural environment, and multidisciplinary mobility. The good practices of rural transformation and smart villages that have been carried out in several regions have been proven to encourage sustainable development in rural areas and even in disadvantaged areas.

Theoretically, the research contributes to knowledge insights on the interconnection between rural transformation and smart villages towards sustainable development. Agricultural themes are still the principal themes often discussed in both studies, thus providing considerable opportunities for academics to develop research in other themes, considering that these two study concepts are multidisciplinary and can reach various fields. Meanwhile, this study provides an overview for planners and policymakers in the development of rural areas through innovation with the use of technology and a combination of the two study concepts, so that the target of achieving sustainable development at the regional micro level can be achieved. The limited number of documents is a weakness of this study, and further research could expand the analysis to include more documents.

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