PalArch's Journal of Archaeology of Egypt / Egyptology

MODELLING INFORMAL SETTLEMENTS EXPANSION FOR SUSTAINABLE URBAN DEVELOPMENT: A SCIENTOMETRIC REVIEW

Amadu Monday. Ambugadu[1], *Nafisa Binti. Hosni*[2]

[2]Faculty of Building Environment and Surveying, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia

[1]Faculty of Environmental Sciences, Nigerian Army University, Biu, Borno State,

Corresponding Email: [1]ambugadu@graduate.utm.my , [1]mondayambugadu@gmail.com

Amadu Monday. Ambugadu, Nafisa Binti. Hosni. Modelling Informal Settlements Expansion for Sustainable Urban Development: A Scientometric Review -- Palarch's Journal of Archaeology of Egypt/Egyptology 19(1), 1567-1592. ISSN 1567-214x

Keywords Informal Settlements, Modelling, Urban Growth Models, Scientometric

ABSTRACT:

The number of formal and informal settlements in emerging economies has continued to rise due to urbanisation and other related factors. Hence, research studies on the rapid expansion, spatial analysis, and prediction of the evolution of informal settlements that utilise urban growth prediction models are critical to researchers and urban policymakers. The proliferation of informal settlements in metropolitan areas has increased urban complexity and uncontrolled spatial development, which hampers long-term and sustainable planning. Therefore, this paper employs the scientometric analysis and the scientific mapping approach to identify, screen, and review the literature on the modelling of informal settlements. The paper also seeks to enhance the understanding the urban growth modelling of the fundamentals and evolution of informal settlements for sustainable urban planning. Consequently, a scientometric review was conducted using the VOSViewer software and Scopus database to determine the state-of-art studies on informal settlement modelling. The data was retrieved from the Scopus database (from 1985 and 2020) using keywords from publications on urban growth models and informal settlement modelling. The study revealed that PLOS One and Habitat had the highest citation with South Africa as the most influential on informal settlement publication. Moreover, cellular automata urban growth model was revealed as the most commonly employed traditional urban growth model in both hybrid and single model applications. It further indicated a low interest in modelling of IFS using urban growth models and driving factors. The weaker association between the keyword (informal settlement and urban growth models) indicates low interest in publication regarding IFS modelling using urban growth models.

INTRODUCTION

Rapid urbanisation and population growth are common social phenomena transforming the global urban landscape. These phenomena have dramatically proliferated formal and informal settlements (IFSs) in urban areas, especially in the global south. Hence, urbanisation has become synonymous with the formation of IFSs in developing countries [1]. Currently, the development of urban IFSs settlements has surpassed the expansion of formal settlements in the global south. Therefore, the global number of IFSs dwellers has increased from approximately 1 billion [2] to 1.5 billion in 2020 [3] but could increase to 3 billion in 2050 [4]. According to Hofmann, Taubenböck [5], the term 'IFSs' refers to urbanisation that has occurred beyond the scope of existing urban planning legislation. Kamalipour and Dovey [6] and Sietchiping [7] claim that IFSs are overcrowded urban districts that have developed outside the state's urban planning regulations with inadequate basic facilities, unsanitary conditions, and endangered health issues. In this context, IFSs can be defined as non-directional developed settlements that have violated the urban planning laws with a view to reducing housing needs.

The violations of urban planning legislation caused by the proliferation of IFSs, along with inadequate prior information about their growth, have resulted in numerous urban issues. For instance, the urban systems' rising greenhouse gases, the expansive layout of urban spaces, and the unhealthy use of soil [8]. Similarly, agricultural land depletion, fragmented ecosystems, habitat degradation, and reduction in ecological services are other urban issues generated by the expansion of IFSs [9-11], which underscore the importance of modelling the expansion of IFSs for sustainable urban planning. Consequently, research on monitoring, managing, and modelling the development of IFSs has become a global priority for researchers and policymakers in urban planning. Therefore, it is essential to conduct a comprehensive literature review on the state-of-the-art publications on urban growth models and modelling concepts for monitoring the expansion of IFSs. This typically requires separating the essential and irrelevant literature and independent studies using techniques for the various variants of the h-file [12].

Previous studies have examined urban growth modelling using varieties of literature review techniques. For instance, Triantakonstantis and Mountrakis [13] explored urban growth models using the PRISMA framework. According to Triantakonstantis and Mountrakis, the most often used urban growth model for modelling urban growth is cellular automata (CA). Similarly, Musa, Hashim [14] conducted a systematic literature review of geospatial-based urban growth models. The authors identified CA, artificial neural network (ANN), fractals, logistic regression (LR), agent-based model (ABM), and decision tree models (DTM) as the leading models for modelling urban growth with CA taking precedence [15-18]. However, Veizaj, Islami [19], suggested that spatial characteristics of urban morphologies can be accurately described when tools like fractal theory and network concepts are combined.

Although multiple studies have utilised various literature review methodologies to evaluate urban growth models for both urban and IFS expansion, only a handful have used the scientometric approach to evaluate IFS modelling. This scenario has prompted this study to ask the following questions: (1) What is the current state-of-art of publications of IFS modelling? (2) What are the strengths and weaknesses of urban growth models in modelling IFS? (3) What are the dominant urban growth models used for modelling urban and IFS expansion? In order to answer these questions, the study extensively attempted to: (1) identify the state-of-art of publications on IFS modelling, (2) identify the strengths and weaknesses of urban growth models in modelling IFS, and (3) identify the dominant urban growth models used for modelling urban and IFS expansion. In addition, the concepts of IFS, UGMs, and scientometric review techniques were discussed.

Urban settlements are broadly classified into formal (FS) and informal settlements (IFS) [20]. FS are established and developed according to officially authorised plans by government bodies or housing associations. In contrast, IFS are settlements that have been developed illegally on either government or private land in a haphazard manner that violates a country's government planning norms [20-24]. In this context, the emphasis will be exclusively on IFS. Previous studies have viewed IFS in various ways. For example, Agheyisi [25] opined that 'IFSs are illegal and chaotic settlements in sub-Saharan countries [25, 26], while Abunyewah, Gajendran [27] confirmed IFS as areas where illegal buildings are built outside the land-use scheme and without planning permission. Similarly, Adam [28] and Amime [29] view IFS as any settlement that has violated customary law regarding land occupation, land use, subdivision norms, modes of transfer, and infringement of official building permit requirements. Typologically, IFS is classified into several groups based on the region concerned. In Delhi (India), IFSs are classified into five types namely; illegal and unauthorised colonies, historical settlements (Katras), resettled colonies, urban villages, and rural villages [20]. Curci [30] also grouped IFS into the following classes; public or privately held squatter settlements, migrants and insecure settlements, improved squatter settlements, unauthorised, private-law residential subdivisions and unauthorised reform in land-use laws, mainly on the metropolitan fringes; and overcrowded and degraded housing without sufficient amenities [30]. Another school of thought classified IFSs into water-front, power-line, and motorway or roadside settlements using a linear factor [31]. In Jos, the Plateau State capital, IFSs are classified into hilltops and valleys settlements [32-34]

In the literature, IFS is termed squatter settlements, shantytowns, favelas, slums, unplanned towns, shacks, or spontaneous settlements [27, 35-37]. It is viewed as a form of speculation in real estate for all income levels of urban and peri-urban residents, including affluent and poor often sit on the periphery of urban areas [38, 39]. This is most likely due to several interconnected driving forces including demographic increase, rural-urban movement, lack of appropriate housing, and ineffective administration [24, 37]. The expansion of IFS has drawn the attention of urban planners and policymakers over the future impacts of IFS growth on the ecosystem [40]. Therefore, the simulation, prediction, and establishment of particular policies to manage current conditions surrounding the spread of IFS by urban growth prediction models are required for ecosystem management and sustainable urban planning [41, 42].

MATERIALS AND METHODS

The primary analytical approach utilized in this study is the scientometric technique. The VOSviewer (Version 1,6.16) a freely available Java software, and Scopus database were utilised to mine data, visualize maps, and analyse the descriptive statistics. The analyses were based on network data, using data generated from keywords on urban growth prediction models of IFS settlements [43]. VOSviewer was adopted because of its availability as an open source software and its capability to accommodate and visualize large volumes of bibliometric data in a simple to-interpret way [43, 44]. The scientometric approach was adopted due to its objective ability to visualize systematic trends in vast bodies of literature. It can also display the visual connectedness of research based on the volume of bibliographic data used to assess the growth of the research field using quantitative index and less subjective method of study [45-48].

Concept of Scientometric Technique

As the philosophy of sustainable development extends into land science, the concept of scientometric analysis has also evolved to visualise, evaluate, and measure urban development. Recent studies by Glänzel and Zhang [49] and Mansuri, Udeaja [47] demonstrated that scientometric analysis (SMA) is an effective tool for evaluating and measuring scientific research. This idea was initially described by Nalimov and Mulʹchenko [50] as “the quantitative approaches of the research on the evolution of science as an informational process”. Studies have further shown that scientometric analysis has focused on communication in the sciences, social sciences, and humanities [51]. Hood and Wilson [52] opined that SMA plays a significant role in social and environmental science research. However, the term “scientometric analysis” is an interdisciplinary research activity that was established by Vassily Nalimov in 1960 [52]. In addition, Van Raan [53] explained that SMA is a concept that is devoted to the development of and the maintenance of information systems. Recently, Zakka, Abdul Shukor Lim [12] asserted that scientometric analysis examines the quantitative aspects of science, science policy, and science communication. The focus is to quantify the impact of authors, papers, journals, and institutions along with their associated citations. Lastly, it aims to visualise, map, and evaluate research disciplines and their indicators for future management and policy.

In addition, Hood and Wilson [52] described SMA as the “quantitative study of scientific practices, including, but not limited to, publication, and hence overlaps somewhat with bibliometrics”. To conduct an SMA, Börner [54] proposed the following sequential steps: tools selection, data collection, pre-processing and data interpretation, modelling, visualization, and design and communication of results (Figure 1). Similarly, Cobo, López-Herrera [48] outlined data retrieval, pre-processing, network extraction, normalization, mapping, analysis and visualization as the steps for science mapping analysis. One of the advantages of scientometric research is its ability to strike a balance between applications and basic research as well as its unbiased and less subjective results in analysing vast bodies of literature [12].

Figure 1. Flowchart for conducting scientometric analysis

The first step in Figure 1 is to identify and select the science mapping tools such as VOSViewer, BibExcel, CiteSpace, CoPalRed, Sci2, VantagePoint, based on availability, strength, and capabilities [44, 48, 55]. The data acquisition phase relies on databases like Scopus, Web of Science, and Google Scholar in conjunction with the relevant keywords concerned for the study. At the pre-processing stage, the duplication and misspelt elements operations are conducted to extract duplicated and valuable records from the data collected [48]. The modelling or mapping phase is one of the most critical stages of the process. It is concerned with building the network maps using the algorithm in the selected software. Once the models have been developed for visualisation, the analysis of the results is performed using various methods like network analysis, temporal analysis, or geospatial analysis [56-58].

To conduct a scientometric analysis, the source data must be noted. The ISI Web of Science (WoS), Elsevier Scopus, Google Scholar, NLM's MEDLINE, arXiv, CiteSeerX, Digital Bibliography and Library Project, SAO/NASA Astrophysics Data System, and Science Direct are database sources [48]. Several studies have argued that WoS, Scopus, and Web of Science cover a distinct aspect of science, while Google Scholar covers study fields like social sciences [59-61]. However, the WoS and Scopus index and monitor citations for 20,000 and 23,000 journals, respectively, which is a more conventional method for indexing and tracking citations [60].

DATA COLLECTION

In order to extract bibliographic data for review, it is essential to identify a reliable database. In this paper, the logical choice was the Elsevier Scopus database based on its conventional methods of indexing and tracking citation as well as its more comprehensive coverage of academic researches and reliability [60, 62]. The search terms for data collection were derived from the keywords (urban models, urban modelling, slum, and informal settlements) carefully selected from five sample articles on models for predicting urban expansion and informal settlements [63-66]. To complete this task, the search query TITLE-ABS-KEY (informal AND settlement AND modelling OR modelling) AND (LIMIT-TO (LANGUAGE, "English")) was used to generate and collate data. The retrieved data was from articles, conference papers, books, and chapters in the Elsevier Scopus database. In addition, the search was limited to published English Language literature between 1985 and 2020. The flow chart in Figure 2 further illustrates the data collection process from the Scopus database. The resulting data was subsequently saved and exported in RSA, CSV, and Plain Text formats for science mapping and record analysis. The information saved from the Scopus database were citations, records bibliography, abstract, keywords, and results from the Scopus database. The search generated a total of 174 documents between 1985 and 2021 on October 18, 2021, with only169 communicated in the English language.

Figure 2. Flowchart of data collection, document exportation, scientometric analysis, and results of data collected

RESULTS AND DISCUSSION

The results and discussion of this study are presented under the following sub-headings: state-of-the-art publications on urban and IFS modelling, strength and weakness of urban growth models, and the dominant urban growth models for urban and IFS expansion modelling.

State-of-the-Art Publication on IFS Modelling

This section presents and discusses the document types, citation patterns, and contributing countries on the subject matter.

Document Types

In this study, the document types retrieved for analysis were articles, journals, conference papers, book reviews, and book chapters. As observed in Figure 3, 79.9% of the documents collected were articles from top Scopus journals, while the remaining were from conference papers (12.4%), book chapters (1.8%), and reviews (1.2%). The findings indicate that the majority of the publications were taken from top-Scopus journal articles.

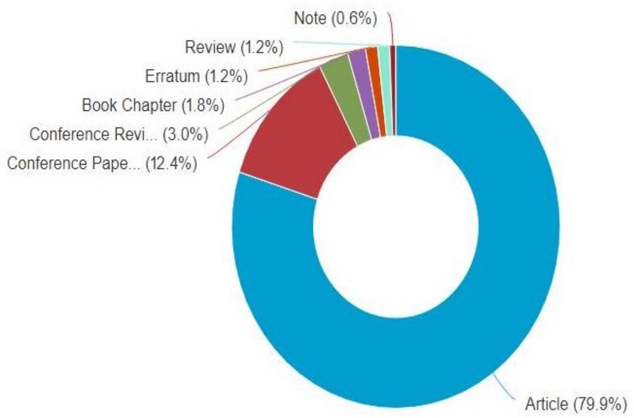

Figure 3. Types of documents collected (Elsevier Scopus August 2021)
Published documents by subject area

Figure 4 shows the various subject areas in which research on urban growth models on informal settlements and urban expansion are indexed in the Elsevier Scopus database between 1985 and 2021. According to the findings, environmental and social sciences have the highest publications with 20.8% each, while engineering, computer science, earth and planetary science, agricultural analysis, and others account for 10.6%, 7.6%, 9.1%, 3.8%, and 20.1% respectively. This further suggests a marked interest in modelling informal settlement in environmental sciences when compared to other subject areas.

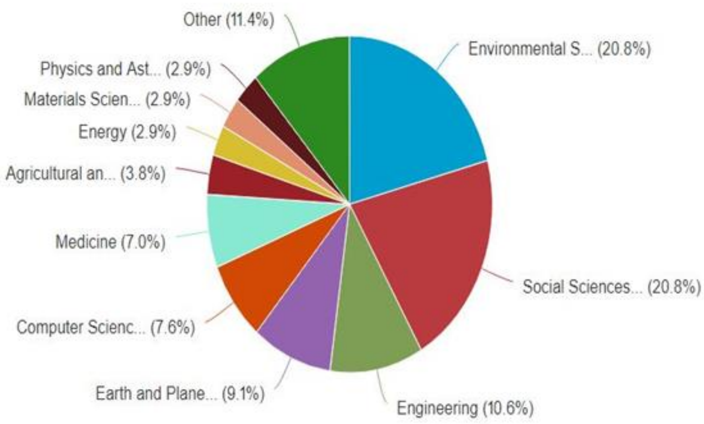

Figure 4. Sampled documents based on the subject matter (Elsevier Scopus August 2021

Document and Citation Pattern

In Figure 5 shows the published documents on the topic and their accrued citations retrieved from Elsevier Scopus database. The findings show that there was limited interest in IFS modelling based on the observed publications between 1985 and 2009. However, the number of articles published on IFS modelling subsequently increased between 2010 and 2020. Likewise, the citation pattern revealed a substantial degree of interest in IFS modelling between 1997 and 2018. The highest number of publications was observed in 2020 with about 219 citations. Nevertheless, the highest citation (626) was recorded in 2018, with only 18 publications. Surprisingly, about 556 and 582 citations were also recorded in 2011 and 2015, respectively. In summary, the trendline indicated a gradual increase in research interest, number of publications, and documents cited in IFS modelling for sustainable urban planning.

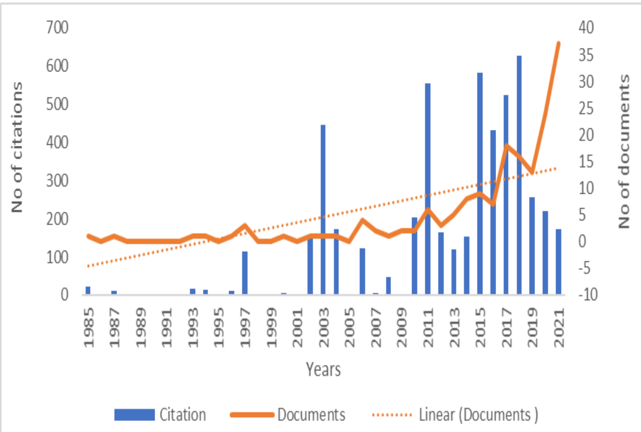

Figure 5. Published Documents and citations based on year (Elsevier Scopus August 2021)

Contributions and the most cited Country's Contributions

VOSViewer was used to generate an optical network for the data generated from the Scopus database, as shown in Figure 6 and Table 1 (Appendix A).

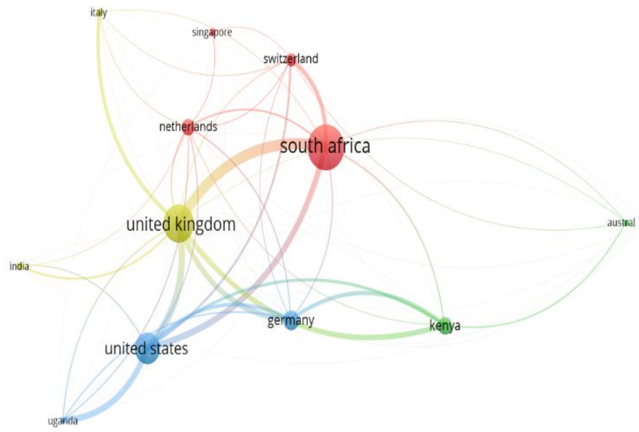

Figure 6. Network visualization of country-contributions

The results indicate that South Africa is the most influential with 490 citations for the publications on informal settlement modelling. Surprisingly, the full link strengths of the United Kingdom (2487) and the United States (1998) are higher than South Africa (1718). This implies a need for more publications on informal settlement modelling in other emerging economies like Nigeria, Ghana, and Liberia based on strong link strength and citations from other countries.

Keywords

Keywords are a list of terms that represent the core idea of an article [67]. To establish the relationships and patterns of related keywords in an article, a network of related keywords is necessary [55]. Hence, co-occurrence analysis was performed using VOSViewer software to generate the visual network relationship between keywords related to informal settlements modelling. The analysis of association in Table 2 indicates that informal settlement has a strong total network link and occurrences to other keywords, while the term structural equation model has the lowest total links and occurrences. The total strength and occurrences of the keywords as illustrated and presented in Table 1 and Figure 7 revealed interesting gaps and problems of modelling IFS using urban growth models. In Figure 6 and Table 2 (Appendix B), IFS has the highest occurrences (71) with a total link strength of 67, urban growth models like logistic regression, cellular automata, and machine learning had the lowest occurrences (5), and total link strength (5). These findings indicate low interest in the application of urban growth models in modelling IFS in urban areas.

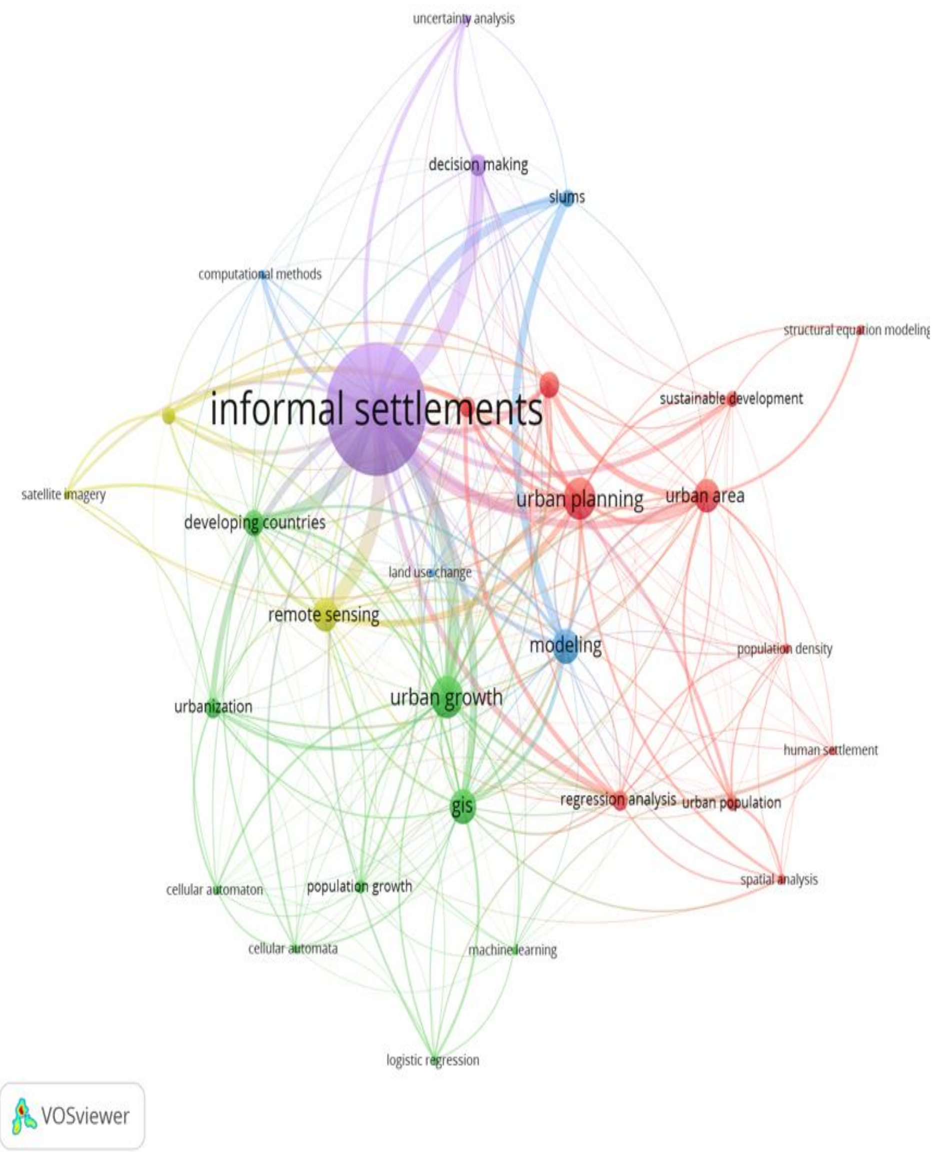

Figure 7. Selected keyword network visualization

Visualization of sources with the highest citation

The visualization of sources with the highest citation was analysed by co-citation and cited sources analyses. The threshold minimum number of citations of a source was minimized with number two in the VOSviewer software (out of 4237 sources, 754 met the threshold). Figure 8 shows the network visualization of sourced journals examined in this study.

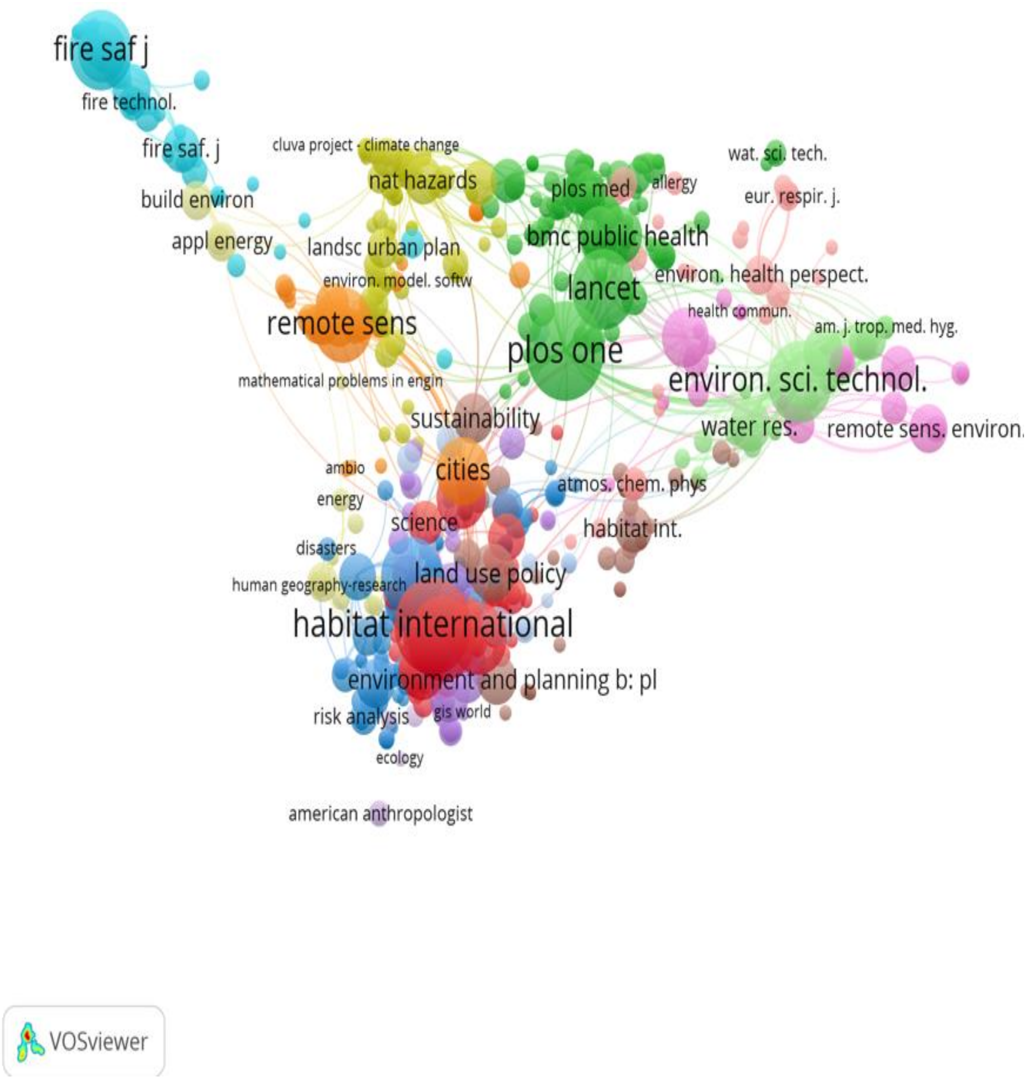

Figure 8. Network Visualization of sourced journals

The results show that PLOS One has the highest citations (48) and total link strengths (1577), while Habitat International, Computers Environmental and Urban Systems, Environmental Science Technology, Lancet, Environmental and Urbanization, Remote Sensing, and Cities have 47, 37, 35, 33, 32, 30 and 25 citations, respectively. Table 3 in Appendix C presents the first ten selected journal sources that contributed to the publication of IFS modelling.

Documents with the highest citations

The citation document analysis feature of VOSviewer was used to generate a network visualization map that was used to identify the documents and authors with the highest citations. Figure 9 shows that the article published by Dubovyk et al. (2011) on IFS modelling received the highest citations (100). This is followed by the articles by Mahabir R (2016), Rüther H (2002), and Parikh P (2015), which gained 80, 68, and 45 citations respectively, as shown in Table 4 (Appendix D). Overall, the findings indicate that the citations for the top 10 most cited documents on the topic ranged from 23 to 100, whereas the total link strengths were from 2 to 58. On average, the top 10 most cited documents each received an average of 46 citations, whereas the total link strength was 20.3.

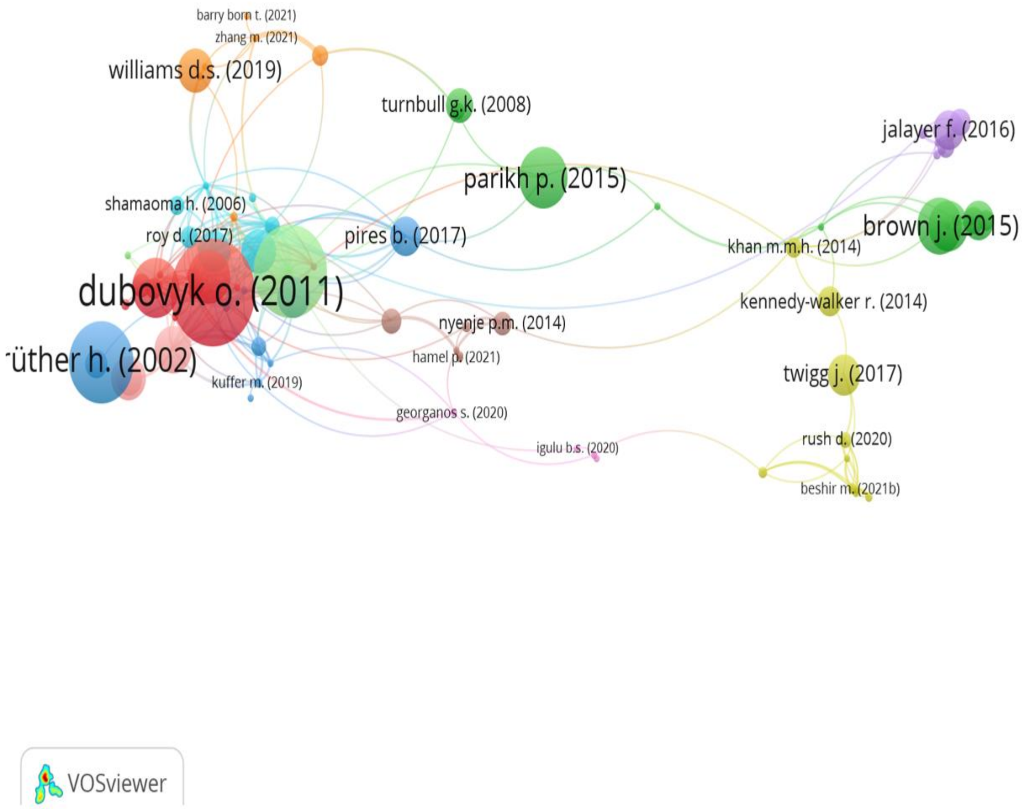

Figure 9. Network Visualization of documents and authors with the highest citations

Urban growth models and limitations

The idea of an urban growth model (UGM) has become a critical factor in determining the viability of urban planning. This section discusses urban growth models for modelling IFS. It is a subtype numeric model that incorporates economics, geography, sociology, and statistics to investigate the processes of urban evolution and response in the urban system [68]. However, several scholars have examined its evolution from various perspectives. For instance, QuanLi, Kun [69] and Wray and Cheruiyot [70] defined UGM as a simulation tool used to test hypotheses of spatial locations and the fundamental relationships between urban land use and related activities. Similarly, Triantakonstantis and Mountrakis [13] viewed UGM as models charged with the responsibility of capturing inherent and dynamic spatial and temporal relationships. In this context, UGM for IFSs can be defined as a modelling technique for testing theories of spatial locations and fundamental relationships between urban land uses and related activities to provide an estimate of future IFSs expansion for sustainable urban planning.

Given the key importance of monitoring the spatial impacts of urbanization, research on urban spatial change has continued resulting in the development of many complex modelling and projection models for urban growth and land use over time [14]. UGM is now a widely used concept in urban planning. Many studies have focused on conventional and quantitative models such as cellular automata, Markov chain, and logistic regression for modelling IFS expansion [65, 71], while others have coupled remote sensing and GIS techniques to model urban growth. In this literature review, the focus is on six collective urban growth models (CA, MC, LR, ANN, ABM, and ML) typically used for modelling urban and IFS expansion. However, previous studies have shown that various urban growth models have their strengths and limitations [72, 73]. Table 5 presents a summary of the strengths and limitations of urban growth models used for modelling urban and IFS expansion.

Table 5. Summary of urban growth model's strengths and limitations

UGMs	Strengths	Limitations	Model Citation
CA	- Has the potential to predict changes in urban land use. - It is simple and easy to integrate with other models.	- Inability to integrate social, human, and economic factors to model urban growth. - Depends on spatial data	Tripathy and Kumar [15]; Hyandye and Martz [18]; Arsanjani, Javidan [74]
MC	- Capable of modelling urban land-use change. - Provide a level ground for complex computations.	- Firmly depend on spatial data. - Application in a compacted build-up area is a change.	Yang, Zheng [17]; Yang, Liu [75]
LR	- Suitable for measuring relationships between urban expansion and driving factors. - Has the predictive power to model urban expansion.	- Limited to time-based analysis and quantification of change. - Limitation of incorporating socioeconomic factors in modelling urban growth.	Allen and Lu [76]; Khajeh Borj Sefidi and Ghalehnoee [77]; Hu and Lo [78]; Arsanjani, Helbich [79]
ANN	- Can capture spatial heterogeneity. - Can incorporate other urban growth models.	- Modelling 3D urban growth is a challenge. - Cannot explicitly specify the impact of each variable	Triantakonstantis and Mountrakis [13]
ABM	- Can capture developing phenomena, as well as describe the natural picture of the real urban environment.	- The outcome of the model is difficult to assess in terms of validation. - It has a challenge of model comparison and replication of results.	Hyandye and Martz [18]; Chen [80]

	- Flexible for integration with other urban growth models.		
ML	- Simple to build and apply. - Development is cost-effective. - Capable of handling large data.	- Limitation of discarding irrelevant features (misclassification). - Results depend firmly on selected attributes used.	Malhotra [81]; Koumetio Tekouabou, Diop [82]

Note: **CA**- Cellular Automata; **LR**- Logistic Regression; **MC**- Markov Chain; **HBM**- Hybrid model; **ABM**- Agent-Based Model, **ANN**- Artificial Neural Network; **ML-** Machine learning (Bayesian, Rule-Based, Neural Network, Decision Tree, Support Vector Machine, and Random Forest).

Despite the advantages of the urban growth models in modelling urban expansion, previous research (shown in Table 5) has revealed that the models have shortcomings. Therefore, it is essential to integrate urban growth models on a level playing ground to address their specific weaknesses in modelling urban and IFS expansion for sustainable urban planning. It further revealed that more socio-economic driving factors should be incorporated in modelling urban and IFS modelling.

Dominant urban growth model

There are several urban growth techniques used for modelling IFS expansion. In this section, the urban growth models used in previous studies to model the scenario of both urban and IFS expansion are summarised. Table 6 presents a tabular summary of the studies and the models used.

Table 6. Summary of urban growth model's strengths and targeted problems

References	Urban Growth Models								Study Area	Targeted Problems
	CA	LR	MC	ANN	ABM	ML	HBM + CA	HBM - CA		
[66]							**X**		Cairo (Egypt)	IFS growth
[71]							**X**		South Africa	IFS growth
[83]				**X**					Lusaka (Zambia)	Urban land use change
[15]	**X**								Dahil (India)	Urban growth
[84]						**X**			Shenzhen (S/China).	Exposure of IFS
[85]	**X**								Ghana	Urban growth

[86]							X		Lagos (Nigeria)	Slum growth
[87]						X			Burkina Faso	Urban development
[88]	X								Bangkok (Thailand)	Urban growth
[89]	X								Arma city (India)	Urban growth
[90]			X						Mashhad (Iran)	Urban growth
[91]	X								Cairo (Egypt)	Urban change
[92]	X								Cairo (Egypt)	IFS expansion
[93]							X		Dhaka (Bangladesh)	Urban growth
[94]							X		Dhaka (Bangladesh)	IFS growth
[95]									Wuhan (China)	Urban expansion
[96]					X				Developing countries	Slum growth
[97]					X				Dar es Salaam, (Tanzania):	IFS growth
[65]		X							Sancaktepe District (Istanbul, Turkey)	IFS development
[98]	X								Penang (Malaysia)	Land use change
[99]		X							Western Missouri	Urban growth
[76]								X	South Africa	Urban growth
[100]							X		Australia	Urban growth
[101]	X								Brazil	Urban growth
[102]							X		California	Urban growth/land use change
[103]							X		City of Irbid (Jordan)	Land use change
[104]			X						Spanish urban areas	Urban population
[105]							X		Uttar Pradesh (India)	Urban growth
[106]		X							Kigali City (Rwanda)	Urban growth
[107]									Nairobi	IFS
Total	**8**	**3**	**2**	**1**	**2**	**3**	**9**	**1**		

Ranking	**2**	**3**	**5**	**5**	**4**	**3**	**1**	**5**		

Note: CA- Cellular Automata; LR- Logistic Regression; MC- Markov Chain; HBM- Hybrid model; ABM- Agent-Based Model, ANN- A Neural Network; ML- Machine learning (Bayesian, Rule-Based, Neural Network, Decision Tree, Support Vector Machine, and Random Forest).

Table 6 reveals that earlier studies on modeling IFS, urban growth, and land use change uterlised the integrated urban growth models with CA inclusive (ranked 1), while 8 studies (ranked 2 for CA column) focused solely on the CA model. Other single urban development models, such as MC, ANN, ABM, ML, and LR, received less attention due to their inability to explicitly simulate urban or IFS growth. In addition, the Table 6 revealed that majority of the studies conducted on IFS and urban growth focused on urban growth than IFS scenarios.

FINDINGS, DISCUSSIONS, AND CONCLUSION

In this study, the scientometric analysis and visualization of the bibliographic data provided by Scopus was used to review the literature on IFS expansion modelling. In addition, the technique was used to examine the state-of-art as well as identify the strengths, weaknesses, and the most popular urban growth model used in modelling IFS expansion. The findings indicate that majority of the documents reviewed were articles published in environmental science subject areas. The study also revealed low interest in IFS modelling publications between 1985 and 2009, although the trend was reversed between 2010 and 2020. Specifically, the highest citation (626) and publications of documents were recorded in the year 2018 and 2020, respectively. Moreover, the bibliographic analysis revealed that South Africa contributed the most in publications related to modelling IFS expansion, which necessitates further research on IFS modelling in other emerging economies. The weaker association between the keyword (informal settlement) and urban growth models indicates low interest in modelling IFS using urban growth models. The study also showed that the article with the highest citation was published by Dubovyk [65]. The authors revealed that individual urban growth models have limits when it comes to modelling urban and IFS growth. To improve the capability of these models, urban growth models should be coupled and integrated with socio-economic and other human driving factors to model urban or IFS expansion. The present study observed that the CA urban model is the most commonly employed traditional urban growth model in both hybrid and single model applications, which is corroborate by Musa, Hashim [14].

Based on the findings of this study, the following areas have been identified for future studies:

1) Further research on modelling IFS expansion in developing economic systems for urban regions is required.

2) The incorporation of socio-economic and human elements (such as insecurity) into hybrid urban growth models is essential to effectively model

urban or IFS expansion.

3) Urban growth models like ML needs improvement to improve their capacity to discard irrelevant or extraneous features when modelling IFS expansion scenarios.

4) Further studies are needed to model the interrelationships between driving factors such as the location of urban areas during urban or IFS expansion.

5) Spatial analysis and modelling studies for sustainable urban planning should also focus on modelling IFS expansion along with general urban growth by integrating driving factors.

This study reviewed IFS expansion, models, and modelling in urban areas through a comprehensive scientometric analysis. The technique employed bibliometric data obtained between 1985 and 2021 to identify and visualize the state-of-art of publications on IFS expansion modelling using the Scopus database and VOSviewer for network visualization. Hence, the most cited document on IFS expansion per year, the country that contributed the most, the weaker association between the keyword (informal settlement) and urban growth models, and the article and author with the highest citation were identified and examined critically. The study also identified and analysed six urban growth models along with their respective strengths and weaknesses. The results revealed that CA model is the most commonly used traditional urban growth model for modelling the scenarios of IFS expansion and other urban growth. In addition, the study revealed areas that require further study.

This study's findings can be applied to a wide range of spatial urban growth modeling and planning, including land use changes, population, and transportation planning. Furthermore, the research's findings and areas for further research can be used to look at the evolution of urban areas in developing economies and as well as predicting their (IFS and other urban growth phenomena) spatial urban scenarios for long-term urban planning for sustainable urban development. In particular, in the incorporation of unique driving factors of IFS scenario in an urban growth prediction model.

APPENDICES

Appendix A

Table 1. Summary of most cited countries and total link strength

Top Countries	Documents	Citations	Total link strength
United Kingdom	35	337	2487
United State	29	352	1998
South Africa	42	490	1718
Germany	18	178	1175
Kenya	16	180	992

Switzerland	12	127	738
Netherland	15	381	719
Uganda	5	16	673
Italy	7	137	416
Australia	5	40	319
India	7	78	275
Japan	5	54	138
Singapore	7	24	120

Appendix B

Table 2. Summary of most cited countries and total link strength

Selected keywords	Occurrences	Total link strength
Informal settlements	71	67
Urban planning	23	23
Urban growth	23	23
GIS	19	19
Urban area	18	18
Remote sensing	18	18
Modelling	19	17
Developing countries	14	14
Land use	14	14
Decision making	12	12
Numerical model	11	11
Urbanization	11	11
Regression analysis	11	11
Slums	10	10
Computer simulation	10	19
Urban population	9	9
Population growth	7	7
Sustainable development	0	7
Population density	6	6
Spatial analysis	6	6
Structural equation modelling	6	6
Satellite images	5	5
Uncertainty analysis	5	5
Land-use change	5	5
Logistic regression	5	5
Cellular automation	5	5
Human settlements	5	5
Machine learning	5	5
Cellular automata	5	5

Appendix C

Table 3. Summary of most cited countries and total link strength

Sources	Citations	Total link strength
PloS ONE	48	1577
Habitat international	47	1518
Computer, environment, and urban systems	37	800
Environment science and technology	35	2157
Lancet	33	1017
Environment and urbanization	32	955
Remote sensing	30	812
World development	28	668
Nature	22	704
Cities	25	782
Urban studies	19	661

Appendix D

Table 4. Authors/documents citations

Top Ten documents/Authors	Citations	Total link strength
Dubovyk O (2011)	100	23
Mahabir R. (2016)	80	58
Rüther H (2002)	68	7
Parikh P. (2015)	45	4
Augustijn-Beckers E. (2011)	36	11
Kuffer M. (2017)	30	36
Patel A. (2012)	28	21
Hofmann P. (2015)	25	35
Erickson B. (1997)	25	5
Saucy A (2018)	23	3

REFERENCES

UN-Habitat, State of the World's Cities 2006/7. New York: United Nations, 2006292.

UN-Habitat, State of the world's cities 2010/2011–cities for all: bridging the urban divide. UN Habitat, Nairobi, 2010.

Arimah, B.C., The face of urban poverty: Explaining the prevalence of slums in developing countries. 2010: WIDER working paper.https://www.econstor.eu/handle/10419/54181

Montgomery, M.R., The urban transformation of the developing world. Science, 2008319: p. 761-4.https://www.ncbi.nlm.nih.gov/pubmed/18258903.

Hofmann, P., H. Taubenböck, and C. Werthmann. Monitoring and modelling of informal settlements-A review on recent developments and challenges. in 2015 joint urban remote sensing event (JURSE). 2015. IEEEhttps://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7120513.

Kamalipour, H. and K. Dovey, Mapping the visibility of informal settlements. Habitat International, 201985: p. 63-75.https://doi.org/10.1016/j.habitatint.2019.01.002.

Sietchiping, R. Understanding informal urban patterns by integrating Geographical Information Systems and Cellular Automata. in Proceedings of the International Conference on Systems Thinking in Management. 2000. Citeseer.

Jiang, Y., et al., A review of urban planning research for climate change. Sustainability, 20179: p. 2224.https://doi.org/10.3390/su9122224.

Lombard, M., Constructing ordinary places: Place-making in urban informal settlements in Mexico. Progress in Planning, 201494: p. 1-53.https://doi.org/10.1016/j.progress.2013.05.003.

Maheshwari, B., V.P. Singh, and B. Thoradeniya, Balanced Urban Development: Options and Strategies for Liveable Cities. Vol. 72. 2016: Springer Berlin, Germany.DOI 10.1007/978-3-319-28112-4

Sutton, P.C., et al., The ecological economics of land degradation: Impacts on ecosystem service values. Ecological Economics, 2016129: p. 182-192.https://doi.org/10.1016/j.ecolecon.2016.06.016.

Zakka, W.P., N.H. Abdul Shukor Lim, and M. Chau Khun, A scientometric review of geopolymer concrete. 2021.https://doi.org/10.1016/j.jclepro.2020.124353.

Triantakonstantis, D. and G. Mountrakis, Urban growth prediction: a review of computational models and human perceptions. 2012.DOI:10.4236/jgis.2012.46060.

Musa, S.I., M. Hashim, and M.N.M. Reba, A review of geospatial-based urban growth models and modelling initiatives. Geocarto International, 201732: p. 813-833.https://doi.org/10.1080/10106049.2016.1213891.

Tripathy, P. and A. Kumar, Monitoring and modelling spatio-temporal urban growth of Delhi using Cellular Automata and geoinformatics. Cities, 201990: p. 52-63.

Triantakonstantis, D., G. Mountrakis, and J. Wang, A spatially heterogeneous expert based (SHEB) urban growth model using model regionalization. Journal of Geographic Information System, 20113: p. 195.

Yang, X., X.-Q. Zheng, and L.-N. Lv, A spatiotemporal model of land use change based on ant colony optimization, Markov chain and cellular automata. Ecological Modelling, 2012233: p. 11-19.https://doi.org/10.1016/j.ecolmodel.2012.03.011.

Hyandye, C. and L.W. Martz, A Markovian and cellular automata land-use change predictive model of the Usangu Catchment. International journal of remote sensing, 201738: p. 64-81.

Veizaj, D., G. Islami, and A. Maliqari, Lacunarity and the Size of Road Network as Contributors to Spatial Identity: Informal Patterns VS. Vernacular Urban Settlements. Civil Engineering and Architecture, 20219: p. 1283-1288.

Ishtiyaq, M. and S. Kumar, Typology of informal settlements and distribution of slums in the NCT, Delhi. Journal of Contemporary India Studies: Space and Society, 20111: p. 37-46.https://hindas.hiroshima-u.ac.jp/PDF/2010/Ishtiyaq_and_Kumar(2011).pdf.

UN-Habitat, The Challenge of Slums: Global Report on Human Settlements, 2003. Vol. Vol. 15 No. 3, . 2003: Routledge.https://doi.org/10.1108/meq.2004.15.3.337.3.

Acioly Jr, C. and C. Horwood, A Practical Guide for Conducting: Housing Profiles-Supporting evidence-based housing policy and reform. United Nations Human Settlements Programme (UN-HABITAT), 2011.https://unhabitat.org/sites/default/files/documents/201907/a_practical_guide_for_conducting_housing_profiles_-_revised_version.pdf.

Abebe, M.S., K.T. Derebew, and D.O. Gemeda, Exploiting temporal-spatial patterns of informal settlements using GIS and remote sensing technique: a case study of Jimma city, Southwestern Ethiopia. Environmental Systems Research, 20198: p. 6.https://doi.org/10.1186/s40068-019-0133-5.

Wahab, B., Transforming Nigerian Informal Settlements into Liveable Communities: Strategies and Challenges. 2017, NITP Mandatory Continuing Professional Development Programme (MCPDP) at Awka …

Agheyisi, J.E., Land subdivision in peri-urban areas of sub-Saharan African cities: conceptual definitions and policy guidelines. Ghana Journal of Geography, 201810: p.98128.https://www.ajol.info/index.php/gjg/article/view/170408.

Rakodi, C. and R.C. Leduka, Informal land delivery processes and access to land for the poor in six African cities: Towards a conceptual framework. 2003: UniversityofBirmingham.https://www.ajol.info/index.php/gjg/article/view/170408.

Abunyewah, M., T. Gajendran, and K. Maund, Profiling informal settlements for disaster risks. Procedia engineering, 2018212: p. 238-245.https://doi.org/10.1016/j.proeng.2018.01.031.

Adam, A.G., Informal settlements in the peri-urban areas of Bahir Dar, Ethiopia: An institutional analysis. Habitat International, 201443: p. 90-97.https://doi.org/10.1016/j.habitatint.2014.01.014.

Amime, M.B., The impact of squatter settlements on socioeconomic development of town: The case of Shewa town, North Shewa zone, Amahara National Regional State. 2019http://hdl.handle.net/123456789/2613

Curci, F., The informal component of mediterranean littoralization: unlawful ricreational homes by the sea at the turn of the third millennium. 2012, Italyhttps://www.politesi.polimi.it/handle/10589/68281

Kamalipour, H., Form of informality and adaptations in informal settlements. ArchNet-IJAR, 201610.https://orca.cardiff.ac.uk/116314/1/ARCHNET%20IJAR%20DTP103177.pdf.

Dung-Gwom, J.Y. and A.S. Jugu, Characteristics and planning challenges of hilltop settlements in Jos Metropolis, Nigeria. UPLanD-Journal of Urban Planning, Landscape & environmental Design, 20172: p. 129-149.https://doi.org/10.6092/2531-9906/5262.

Miner, K.J., et al., Survey on Household Awareness and Willingness to Participate in E-Waste Management in Jos, Plateau State, Nigeria. Sustainability, 202012: p. 1047.https://doi:10.3390/su12031047.

Lohor, A., et al., Territoriality, Territorial Claims and Planning Challenges in a fragile Urban Setting: Jos, Nigeria. Emerging Issues in Urban Planning and Development, 2013: p. 149-170.https://scholar.google.com/scholar?q=Lohor,+A.,+et+al.,+Territoriality,+Territorial+Claims+and+Planning+Challenges+in+a+fragile+Urban+Setting:+Jos,+Nigeria.+Emerging+Issues+in+Urban+Planning+and+Development,+2013:+p.+149-170.&hl=en&as_sdt=0,5.

Heriberto, R.T.H., Political economy of packaged food: A study of exchange and consumtion in Metro Manila's slums.2019.https://repository.kulib.kyoto.ac.jp/dspace/bitstream/2433/242452/3/dkeik00588.pdf.

Nthoki, L., Influence of Community Based Organizations' Activities on Sustainable Livelihoods in "Selected" Urban Poor Settlements in Nairobi County, Kenya. 2016, University of Nairobihttp://hdl.handle.net/11295/100094

UN-Habitat. Habitat III issue papers 22—Informal settlements. in United Nations Conference on Housing and Sustainable Urban Development. 2015. 2015.https://unhabitat.org/habitat-iii-issue-papers-22-informal-settlements.

Funmilayo, L.A. and B. Ogunlade, Effect of urban informal settlements and outdoor advertisement on the quality of built environment and urban upgrading in Nigeria. Journal of Emerging Trends in Economics and Management Sciences, 20156: p. 332-339.https://journals.co.za/doi/pdf/10.10520/EJC174491.

Potsiou, C. and I. Boulaka, Informal Development in Greece: New Legislation for Formalization, the Chances for Legalization and the Dead. Int. Federation of Surveyors, March, 2012: p. 1-19.https://www.fig.net/resources/monthly_articles/2012/march_2012/march_2012_potsiou_boulaka.pdf.

Aburas, M.M., et al., The simulation and prediction of spatio-temporal urban growth trends using cellular automata models: A review. International Journal of Applied Earth Observation and Geoinformation, 201652: p. 380-389.https://doi.org/10.1016/j.jag.2016.07.007.

Ghasempour, A., Informal settlement: Concept, challenges, and intervention approaches. Spec. J. Arch. Constr, 20151: p. 10-16.https://sciarena.com/storage/models/article/7gJgekjY2MTomUVdYp8CXdRa4sKbO7U6tuwMTL3Lf60oHbAj8mPeg8XmkyVV/informal-settlement-concept-challenges-and-intervention-approaches.pdf.

Yao, F., C. Hao, and J. Zhang, Simulating urban growth processes by integrating cellular automata model and artificial optimization in Binhai New Area of Tianjin, China. Geocarto International, 201631: p. 612-627.https://doi.org/10.1080/10106049.2015.1073365.

Van Eck, N.J. and L. Waltman, VOSviewer manual. Leiden: Univeristeit Leiden, 20131: p. 1-53.

van Eck, N.J. and L. Waltman, Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics, 201084: p. 523-538.https://www.ncbi.nlm.nih.gov/pubmed/20585380.

Sheikhnejad, Y. and T. Yigitcanlar, Scientific landscape of sustainable urban and rural areas research: A systematic scientometric analysis. Sustainability, 202012: p. 1293.https://doi.org/10.3390/su12041293.

Xiao, X., et al., Mapping knowledge in the economic areas of green building using scientometric analysis. Energies, 201912: p. 3011.https://doi.org/10.3390/en12153011.

Mansuri, L., et al., Scientometric analysis and mapping of digital technologies used in cultural heritage field. Management, 2019255: p. 264.https://it-india-project.com/wp-content/uploads/2020/02/ARCOM-2019-IT-India-Heritage-Platform.pdf.

Cobo, M.J., et al., Science mapping software tools: Review, analysis, and cooperative study among tools. Journal of the American Society for information Science and Technology, 201162: p. 1382-1402.https://doi.org/10.1002/asi.21525.

Glänzel, W. and L. Zhang, Scientometric research assessment in the developing world: A tribute to Michael J. Moravcsik from the perspective of the twenty-first century. Scientometrics, 2018115: p. 1517-1532.https://link.springer.com/content/pdf/10.1007/s11192-018-2647-4.pdf.

Nalimov, V.V.e. and Z.M. Mulʹchenko, Measurement of Science. Study of the Development of Science as an Information Process. 1971.

Mingers, J. and L. Leydesdorff, A review of theory and practice in scientometrics. European journal of operational research, 2015246: p. 1-19.https://doi.org/10.1016/j.ejor.2015.04.002.

[Hood, W.W. and C.S. Wilson, The literature of bibliometrics, scientometrics, and informetrics. Scientometrics, 200152: p. 291-314.https://link.springer.com/content/pdf/10.1023/A:1017919924342.pdf.

Van Raan, A., Scientometrics: State-of-the-art. Scientometrics, 199738: p. 205-218.https://doi.org/10.1007/bf02461131.

Börner, K., Atlas of science: Visualizing what we know. 2010: Mit Press.DOI 10.1007/s11192-011-0409-7.

Van Eck, N.J. and L. Waltman, Visualizing bibliometric networks, in Measuring scholarly impact. 2014, Springer. p. 285-320.

Batty, M., Spatial and Locational modelling in human geography. 2003, Blackwell Publishing.

Garfield, E., Scientography: Mapping the tracks of science. Current contents: social & behavioural sciences, 19947: p. 5-10.https://clarivate.com/webofsciencegroup/essays/scientography-mapping-the-tracks-of-science/.

Carrington, P.J., J. Scott, and S. Wasserman, Models and methods in social network analysis. Vol. 28. 2005: Cambridge university press.https://pdfs.semanticscholar.org/782a/9fb4d537e32a0bacca872a02bb27b61907a9.pdf.

Mongeon, P. and A. Paul-Hus, The journal coverage of Web of Science and Scopus: a comparative analysis. Scientometrics, 2016106: p. 213-228.DOI 10.1007/s11192-015-1765-5.

Chapman, K. and A.E. Ellinger, An evaluation of Web of Science, Scopus and Google Scholar citations in operations management. The International Journal of Logistics Management, 2019.https://doi.org/10.1108/IJLM-04-2019-0110.

Martín-Martín, A., et al., Google Scholar, Web of Science, and Scopus: A systematic comparison of citations in 252 subject categories. Journal of informetrics, 201812: p. 1160-1177.https://doi.org/10.1016/j.joi.2018.09.002.

Aghaei Chadegani, A., et al., A comparison between two main academic literature collections: Web of Science and Scopus databases. Asian social science, 20139: p. 18-26.https://arxiv.org/ftp/arxiv/papers/1305/1305.0377.pdf.

Park, H., et al., Spatiotemporal changes of informal settlements: Ger districts in Ulaanbaatar, Mongolia. Landscape and Urban Planning, 2019191: p. 103630.https://doi.org/10.1016/j.landurbplan.2019.103630.

Roy, D., et al., The emergence of slums: A contemporary view on simulation models. Environmental modelling & software, 201459: p. 76-90.https://doi.org/10.1016/j.envsoft.2014.05.004.

Dubovyk, O., R. Sliuzas, and J. Flacke, Spatio-temporal modelling of informal settlement development in Sancaktepe district, Istanbul, Turkey. ISPRS Journal of Photogrammetry and Remote Sensing, 201166: p. 235-246.https://doi.org/10.1016/j.isprsjprs.2010.10.002.

Badwi, I.M., M.M. El_Barmelgy, and A.S. El_Din Ouf, Modeling and prediction of expected informal growth in the Greater Cairo Region, Egypt. Environment and Planning B: Urban Analytics and City Science, 2021: p. 23998083211002207.

Li, L.-L., et al., Global stem cell research trend: Bibliometric analysis as a tool for mapping of trends from 1991 to 2006. Scientometrics, 200980: p. 39-58.https://DOI: 10.1007/s11192-008-1939-5.

Li, X. and P. Gong, Urban growth models: progress and perspective. Science bulletin, 201661: p. 1637-1650.https://doi.org/10.1007/s11434-016-1111-1.

QuanLi, X., et al., Agent-based modeling and simulations of land-use and land-cover change according to ant colony optimization: a case study of the Erhai Lake Basin, China. Natural Hazards, 201575: p. 95-118.https://link.springer.com/content/pdf/10.1007/s11069-014-1303-4.pdf.

Wray, C. and K. Cheruiyot, Key challenges and potential urban modelling opportunities in South Africa, with specific reference to the Gauteng City-region. South African Journal of Geomatics, 20154: p. 14-35.http://dx.doi.org/10.4314/sajg.v4i1.2.

Daniels, R.H., Spatio-temporal modelling of informal settlement growth using a hybrid GIS and CA-Markov model. 2021.https://open.uct.ac.za/bitstream/handle/11427/33691/thesis_ebe_2021_daniels%20roger%20hubert.pdf?sequence=1&isAllowed=y.

Punia, M. and L. Singh, Entropy approach for assessment of urban growth: a case study of Jaipur, India. Journal of the Indian Society of Remote Sensing, 201240: p. 231-244.https://link.springer.com/content/pdf/10.1007/s12524-011-0141-z.pdf.

Aburas, M.M., et al., Spatio-temporal simulation of future urban growth trends using an integrated CA-Markov model. Arabian Journal of Geosciences, 202114: p. 1-12.https://doi.org/10.1007/s12517-021-06487-8.

Arsanjani, T.J., et al., Spatiotemporal monitoring of Bakhtegan Lake's areal fluctuations and an exploration of its future status by applying a cellular automata model. Computers & Geosciences, 201578: p. 37-43.https://doi.org/10.1016/j.cageo.2015.02.004.

Yang, Y., et al., Quantifying spatio-temporal patterns of urban expansion in Beijing during 1985–2013 with rural-urban development transformation. Land Use Policy, 201874: p. 220-230.

Allen, J. and K. Lu, Modeling and prediction of future urban growth in the Charleston region of South Carolina: a GIS-based integrated approach. Conservation Ecology, 20038.

Khajeh Borj Sefidi, A. and M. Ghalehnoee, Analysis of urban growth pattern using logistic regression modeling, spatial autocorrelation and fractal analysis Case study: Ahvaz city. Iran University of Science & Technology, 201626: p. 183-194.https://DOI:10.22068/ijaup.26.2.183.

Hu, Z. and C. Lo, Modeling urban growth in Atlanta using logistic regression. Computers, Environment and Urban Systems, 200731: p. 667-688.https://doi.org/10.1016/j.compenvurbsys.2006.11.001.

Arsanjani, J.J., et al., Integration of logistic regression, Markov chain and cellular automata models to simulate urban expansion. International Journal of Applied Earth Observation and Geoinformation, 201321: p. 265-275.

Chen, L., Agent-based modeling in urban and architectural research: A brief literature review. Frontiers of Architectural Research, 20121: p. 166-177.https://doi.org/10.1016/j.foar.2012.03.003.

Malhotra, R., A systematic review of machine learning techniques for software fault prediction. Applied Soft Computing, 201527: p. 504-518.https://doi.org/10.1016/j.asoc.2014.11.023.

Koumetio Tekouabou, S.C., et al., Reviewing the application of machine learning methods to model urban form indicators in planning decision support systems: potential, issues and challenges. Journal of King Saud University-Computer and Information Sciences, 2021.https://doi.org/10.1016/j.jksuci.2021.08.007.

Simwanda, M., et al., Simulating Scenarios of Future Intra-Urban Land-Use Expansion Based on the Neural Network–Markov Model: A Case Study of Lusaka, Zambia. Remote Sensing, 202113: p. 942.https://doi.org/10.3390/rs13050942.

Zhu, Y., C. Geiß, and E. So. Using deep neural networks for predictive modelling of informal settlements in the context of flood risk. in Journal of Physics: Conference Series. 2019. IOP Publishing1343.doi:10.1088/1742-6596/1343/1/012032.

Agyemang, F.S. and E. Silva, Simulating the urban growth of a predominantly informal Ghanaian city-region with a cellular automata model: Implications for urban planning and policy. Applied Geography, 2019105: p. 15-24.https://doi.org/10.1016/j.apgeog.2019.02.011.

Badmos, O.S., et al., Simulating slum growth in Lagos: An integration of rule based and empirical based model. Computers, Environment and Urban Systems, 201977: p. 101369.https://doi.org/10.1016/j.compenvurbsys.2019.101369.

Schug, F., et al., Mapping patterns of urban development in Ouagadougou, Burkina Faso, using machine learning regression modeling with bi-seasonal Landsat time series. Remote Sensing of Environment, 2018210: p. 217-228.https://doi.org/10.1016/j.rse.2018.03.022.

Kamarajugedda, S.A. and E.Y. Lo, Modelling urban growth for Bangkok and assessing linkages with road density and socio-economic indicators. The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, 201942: p. 255-262.https://doi.org/10.5194/isprs-archives-XLII-4-W19-255-2019

Jat, M.K., M. Choudhary, and A. Saxena, Urban growth assessment and prediction using RS, GIS and SLEUTH model for a heterogeneous urban fringe. The Egyptian Journal of Remote Sensing and Space Science, 201710: p. 1-19.

Kazemzadeh-Zow, A., et al., A spatial zoning approach to calibrate and validate urban growth models. International Journal of Geographical Information Science, 201731: p. 763-782.https://doi.org/10.1080/13658816.2016.1236927.

Abutaleb, K. and F. Ahmed, Modeling of urban change using remote sensing data and cellular automata technique. Arabian Journal of Geosciences, 20169: p. 1-10.DOI 10.1007/s12517-016-2696-z.

Badwi, I.M., M.M. El-Barmelgy, and A.S.E.-D. Ouf, Modeling and simulation of greater Cairo region urban dynamics using SLEUTH. Journal of Urban Planning and Development, 2015141: p. 04014032.https://doi.org/10.1061/(ASCE)UP.1943-5444.0000193.

Ahmed, S. and G. Bramley, How will Dhaka grow spatially in future?-Modelling its urban growth with a near-future planning scenario perspective. International Journal of Sustainable Built Environment, 20154: p. 359-377.https://doi.org/10.1016/j.ijsbe.2015.07.003.

Shuvo, F.K. and P. Janssen, Modelling informal settlements using a hybrid automata approach. 2013.http://papers.cumincad.org/data/works/att/caadria2013_205.content.pdf.

Wang, H., et al., Simulating urban expansion using a cloud-based cellular automata model: A case study of Jiangxia, Wuhan, China. Landscape and urban planning, 2013110: p. 99-112.https://doi.org/10.1016/j.landurbplan.2012.10.016.

Patel, A., A. Crooks, and N. Koizumi, Slumulation: An agent-based modeling approach to slum formations. Journal of Artificial Societies and Social Simulation, 201215: p. 2.DOI: 10.18564/jasss.2045.

Augustijn-Beckers, E.-W., J. Flacke, and B. Retsios, Simulating informal settlement growth in Dar es Salaam, Tanzania: An agent-based housing model. Computers, Environment and Urban Systems, 201135: p. 93-103.https://doi.org/10.1016/j.compenvurbsys.2011.01.001.

Samat, N., R. Hasni, and Y.A.E. Elhadary, Modelling land use changes at the peri-urban areas using geographic information systems and cellular automata model. Journal of Sustainable Development, 20114: p. 72.http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.980.9775&rep=rep1&type=pdf.

Luo, J., D. Yu, and M. Xin, Modeling urban growth using GIS and remote sensing. GIScience & Remote Sensing, 200845: p. 426-442.Download citation https://doi.org/10.2747/1548-1603.45.4.426.

Liu, Y. and Y. Feng, A logistic based cellular automata model for continuous urban growth simulation: A case study of the Gold Coast City, Australia, in Agent-based models of geographical systems. 2012, Springer. p. 643-662.https://link.springer.com/chapter/10.1007/978-90-481-8927-4_32.

Leao, S., I. Bishop, and D. Evans, Simulating urban growth in a developing nation's region using a cellular automata-based model. Journal of urban planning and development, 2004130: p. 145-158.https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.906.455&rep=rep1&type=pdf.

Clarke, K.C., Mapping and modelling land use change: an application of the SLEUTH model, in Landscape analysis and visualisation. 2008, Springer. p. 353-366.https://link.springer.com/chapter/10.1007/978-3-540-69168-6_17.

Gharaibeh, A., et al., Improving land-use change modeling by integrating ANN with Cellular Automata-Markov Chain model. Heliyon, 20206: p. e05092.https://www.ncbi.nlm.nih.gov/pubmed/33024869.

Le Gallo, J. and C. Chasco, Spatial analysis of urban growth in Spain, 1900–2001. Empirical economics, 200834: p. 59-80.

Siddiqui, A., et al., Urban growth dynamics of an Indian metropolitan using CA Markov and Logistic Regression. The Egyptian Journal of Remote Sensing and Space Science, 201821: p. 229-236.

Jiwaji, N.T., Recognition of astronomy as an essential discipline at all levels of education in Tanzania. Rwanda Journal, 20161.

Githira, D.N., Growth and eviction of Informal Settlements in Nairobi. 2016, University of Twentehttp://essay.utwente.nl/83895/1/githira.pdf