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# Are Urbanisation and Biodiversity Antithetical? A Bibliometric Analysis

## *Kentleşme ve Biyoçeşitlilik Birbirine Karşıt mı? Bibliyometrik Bir Analiz*

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**ABSTRACT**
Urbanisation is a process that negatively affects biodiversity. Many scholars report that natural habitats suffer from urban development. The habitats of plant and animal species shrink because of the fragmentation of ecosystems caused by urbanisation. This leads to the extinction of endemic species and a decline in the number of resident species. The main interest of the present study was to examine how urban expansion relates to biodiversity. To this end, a basic search on Scopus using the keywords "biodiversity" and "urban" was made, later which was filtered with the keyword "loss". The obtained final total of 1827 documents were recorded and then subjected to the bibliometric network analysis by using the tool named Bibliometrix. These studies conclude in sum that half of the world's forests and a significant proportion of wetlands have been destroyed over the past few centuries. Moreover, millions of people die each year from air pollution, and one billion of the world's population suffers from chronic hunger. The 1827 documents retrieved date back to the 1990s, suggesting that more in-depth research is required to determine the potential impacts of urbanisation on the wetlands and forestry and consequently on the habitat of animal and plant species.
**Keywords:** Environmental problems, Species decline, Loss of natural habitats

**ÖZ**
Kentleşme, biyoçeşitliliği olumsuz yönde etkileyen bir süreçtir. Birçok araştırmacı doğal yaşam alanlarının kentsel gelişmeden zarar gördüğünü rapor etmektedir. Kentleşmenin neden olduğu ekosistem parçalanmasının sonucunda bitki ve hayvan türlerinin yaşam alanları daralmaktadır. Sonuç olarak endemik türler yok olmakta ve yerli türler sayıca azalmaktadır. Bu çalışma ile temelde kentsel yayılımın biyolojik çeşitlilik ile ilişkisi incelenmiştir. Bu amaç kapsamında Scopus veri tabanında "biodiversity", "urban" anahtar kelimeleri kullanılarak bir arama yapılmış, bu arama daha sonra "loss" kelimesi ile filtrelenmiştir. Söz konusu işlemlerin sonucunda elde edilen toplam nihai 1827 doküman kayıt edilmiş ve devamında Bibliometrix adıyla bilinen araç kullanılarak bibliyometrik ağ analizine tabi tutulmuştur. İncelenen çalışmalar sonuç olarak özetle, geçtiğimiz birkaç yüzyılda dünyadaki ormanların yarısının ve sulak alanların önemli bir kısmının tahrip edildiğini göstermektedir. Buna ek olarak her yıl milyonlarca insan hava kirliliğinden ölmekte ve dünya nüfusunun bir milyarı kronik açlık çekmektedir. Geçmişi 1990'lı yıllara kadar dayanan çalışmaya konu 1827 doküman kentleşmenin, sulak alanlar ve ormanlar ve dolayısıyla da hayvan ve bitki türlerinin yaşam alanları üzerindeki potansiyel etkilerinin belirlenmesi için daha fazla sayıda derinlikli araştırmanın gerekliliğini ortaya koymaktadır.
**Anahtar kelimeler:** Çevre sorunları, Türlerin azalması, Doğal yaşam alanlarının kaybı

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## 1. INTRODUCTION

The Industrial Revolution is one of the most significant events in world history (Crafts 2011; Albritton Jonsson 2012; M. Xu et al. 2018). Beginning in the mid-18th century in England, the Industrial Revolution brought issues of productivity, economic prosperity, population growth and urbanization to the fore (Jedwab and Vollrath 2015; Davenport 2020). The global population growth rate increased consistently from the Industrial Revolution until the 1980s. Although the rate slowed slightly after the 1980s, the world population has now reached approximately 8 billion (Figure 1a). The process of urbanisation, which accelerated with the Industrial Revolution in the mid-1800s, resulted in the urban population surpassing the rural population for the first time in 2007 (Figure 1b). This shows that the world's urban population is growing. As the urban population grows, cities also grow in size. As a result, cities are expanding into and destroying natural areas.

As the urban population continues to outnumber the rural population, the environmental problems caused by urbanization are becoming more pronounced. From China to the Amazon forests, deforestation and environmental pollution continue to worsen in many parts of the world due to urbanisation and human impacts (Birpınar et al. 2009; Richards and VanWey 2015; Lin et al. 2019; Yang et al. 2021). Many studies have reported that as cities grow, natural habitats are destroyed and environmental problems increase (Gönençgil, 2011; Özüpekçe, 2021). Urbanisation also destroys agricultural and grazing land (Biró et al. 2013; Uchida et al. 2018). In addition, urbanisation damages both animal and plant diversity (McKinney 2008; Elmqvist et al. 2015; Olivier et al. 2020) and can be seen as the main cause of the major environmental problems we are experiencing today. Therefore, it is important to study the impact of urbanisation on different ecosystems and biodiversity.

This study examined the relationship between the expansion of urban areas and biodiversity. To this end, a systematic search of the Scopus database was conducted using the keywords "biodiversity", "urban" and "loss". Details of the screening process are described in section 2.3. The documents retrieved from Scopus because of this search were analysed using bibliometric network analysis.

Bibliometric network analysis was used to answer the following questions:

- When did research on the relationship between biodiversity loss and urbanisation start, and since when has it become prominent? What are the annual growth rates of studies on this topic?
- Who are the researchers studying biodiversity loss and urbanization, which countries do they come from and what are their disciplines?
- In which journals is research on biodiversity loss and urbanisation most frequently published? What is the citation performance of these publications by year? What are the most cited studies on this topic?
- Is research into the relationship between biodiversity loss and urbanisation interdisciplinary?
- What are the main concepts in research on the relationship between biodiversity loss and urbanisation?
- What issues are highlighted by research on the relationship between biodiversity loss and urbanization?

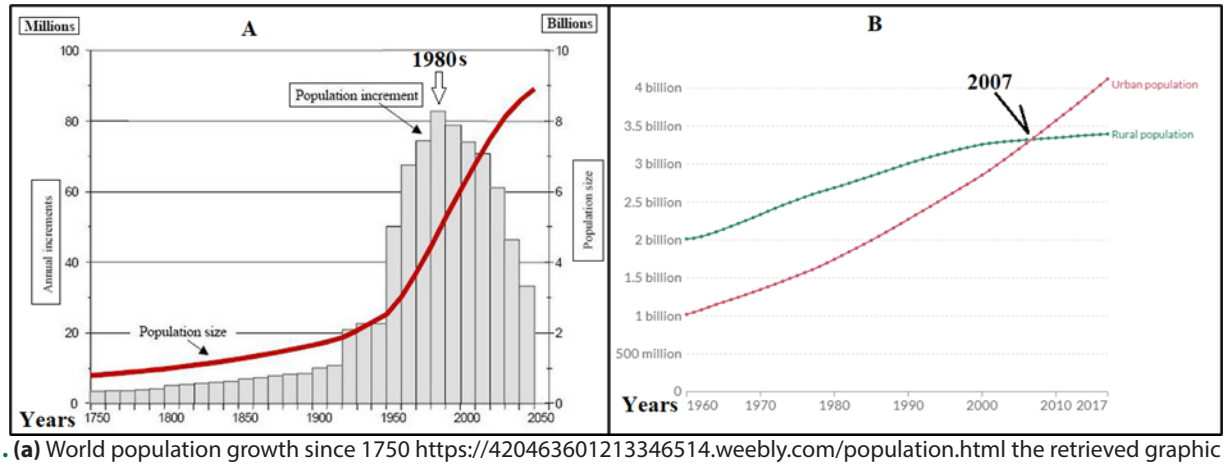


**Figure 1. (a)** World population growth since 1750 https://420463601213346514.weebly.com/population.html the retrieved graphic has been edited (Date of access: 12.06.2023) and (b) rural and urban population rates https://ourworldindata.org/urbanization the retrieved graphic has been edited (Date of access: 12.06.2023)

## 2. DATA AND METHODS

### 2.1. Data Source

Data were taken from the online version of the Scopus database. Scopus indexes 44,737 major and current journals as of June 12, 2023. It is a bibliographic database that indexes articles, books, conference proceedings, patents, and websites in scientific literature. This database is one of the most important and extensive sources of scientific documents covering a wide range of fields (Burnham 2006; Boyle and Sherman 2006). In addition to providing researchers with access to a large pool of resources, Scopus also supports functions such as performing bibliometric analyses (de Moya-Anegón et al. 2007), tracking indexed publications, and measuring their scholarly impact (Boyle and Sherman 2006). Because of these features, Scopus has become an important tool for researchers to conduct literature reviews and citation analysis and to identify new areas of research.

### 2.2. Dimension reduction

As environmental conditions continue to change, the number of reports on these changes is expected to increase (Çelik and Sarıboğa 2023). Review articles are often used to propose new research approaches or to identify gaps in the literature in particular research areas. However, the number of review articles with bibliometric analysis is lower than that of descriptive or narrative review articles. Therefore, this section discusses a theoretical framework that focuses on bibliometric analysis. It includes approaches to analysis, document collection and dimension reduction. Bibliometrix (https://www.bibliometrix.org/home/), free online software based on R-Studio, and VOSviewer version 1.6.17 were used to conduct the research. BibTeX and CSV file formats of Scopus documents were obtained for content analysis.

### 2.3. Source strategies

Many databases are now available to access information and perform bibliographic or bibliometric searches (Kulak et al., 2019; Celik et al. 2021). The Web of Science (WoS), Scopus, Google Scholar, PubMed, and MEDLINE are among the most important databases (Gavel and Iselid 2008; Chen 2017). The main purpose of this study was to access more documents; therefore, it was important to make comparisons between databases. A search for publications (article, book, book chapter, conference paper, conference review, editorial, letter, note, review, short survey) using the same keywords showed that Scopus contained more documents on the subject under study than the other databases. Scopus has a more heterogeneous structure than the other databases and allows researchers to access publications from different sources (Ramalho et al. 2020). Due to its comprehensive and rich content, Scopus is very convenient for researchers to collect data and was therefore the database chosen for this study.

The study searched for documents in three steps using the TITLE-ABS-KEY philtre

- In the first step, the keywords "biodiversity" AND "urbanization" were searched and 11,380 studies were found (search date: 12/06/2023).
- In the second step, the keyword "loss" was included to make the search more specific and 1936 documents were found (search date: 12/06/2023).
- In the third step, studies published in 2023 were excluded, and 1827 documents were obtained (search date: 12/06/2023) (Table 1).

**Table 1.** Types and numbers of the retrieved documents

| Document Types | Number |
|---|---|
| Article | 1428 |
| Article in press | 1 |
| Book | 20 |
| Book chapter | 148 |
| Conference paper | 104 |
| Conference review | 2 |
| Editorial | 6 |
| Letter | 2 |
| Note | 6 |
| Retracted | 1 |
| Review | 102 |
| Short survey | 7 |

Source: Obtained from descriptive analysis of documents retrieved from Scopus using the R-based software Bibliometrix.

## 3. RESULTS AND DISCUSSION

Scopus identified 1,827 documents discussing biodiversity loss in relation to urbanisation (Figure 2). The first studies reporting that urbanisation causes biodiversity loss were published in the early 1990s. One of these studies focussed on birds in Argentina. This study did not directly address the relationship between urbanisation and biodiversity. However, it highlighted the negative impact of urbanisation on birds (Canevari et al. 1991).


**Figure 2.** Summary information on the retrieved documents (Source: Obtained from the descriptive analysis of the documents retrieved from Scopus using the R-based software Bibliometrix)

Research on biodiversity loss and urbanisation has grown rapidly in recent years (Figure 3). This indicates that the impact of urbanization on biodiversity is ongoing. If the negative impact of urbanisation on biodiversity had ceased, the annual growth rate of studies on this topic would have been low. The fact that the annual growth rate of studies on urbanisation and biodiversity is 19.51% shows that this topic continues to be intensively studied. In other words, urbanisation continues to have a negative impact on biodiversity, as reported in many studies (McDonald et al. 2013; Zahoor et al. 2022).

The number of studies on biodiversity loss caused by urbanisation has increased steadily over the years (2001-2021) while the number of citations of these studies has not. It was also observed that although the number of citations to studies discussing the concepts of biodiversity loss and urbanization was significant in some years (1997-1998; 2004-2006), it has been low in recent years (Figure 4). The increase in the number of biodiversity loss and urbanisation studies and the decline in the number of citations might be attributed to an array of reasons, including the open access status of the article-type documents that comprise the majority of those studies (Table 1). As well-known and reported by Koo (2017), the review papers are frequently cited in the introduction section of research papers. Therefore, such review papers have the potential to receive more citations. However, the review papers are addressed to the compilation of the original research papers. Considering the article types retrieved for this study (Table 1), 102 documents are "review" papers, which is equivalent to 5,58%. Such a low rate of these papers may further explain the decline in the number of citations.

Figure 5 shows that there is a close and significant relationship between biodiversity loss and urbanisation. The findings of the analysis showed that the terms, *viz*. "biodiversity", "ecosystem", "animals", "forestry", and "species" are linked to "urbanisation",

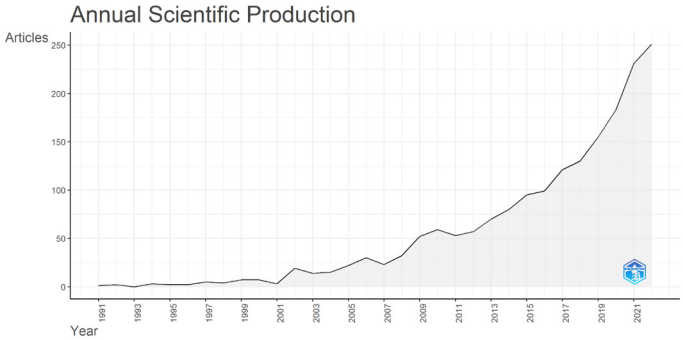


**Figure 3.** Annual scientific production on the topic between 1991 and 2021 (Source: Obtained from the annual document production analysis of the documents retrieved from Scopus using the R-based software Bibliometrix)

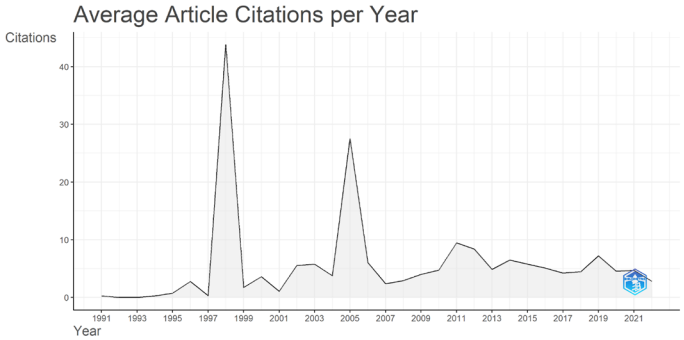


**Figure 4.** Average annual documents' citations between 1991 and 2021 (Source: Obtained from the annual documents' citations analysis of the documents retrieved from Scopus using the R-based software Bibliometrix)

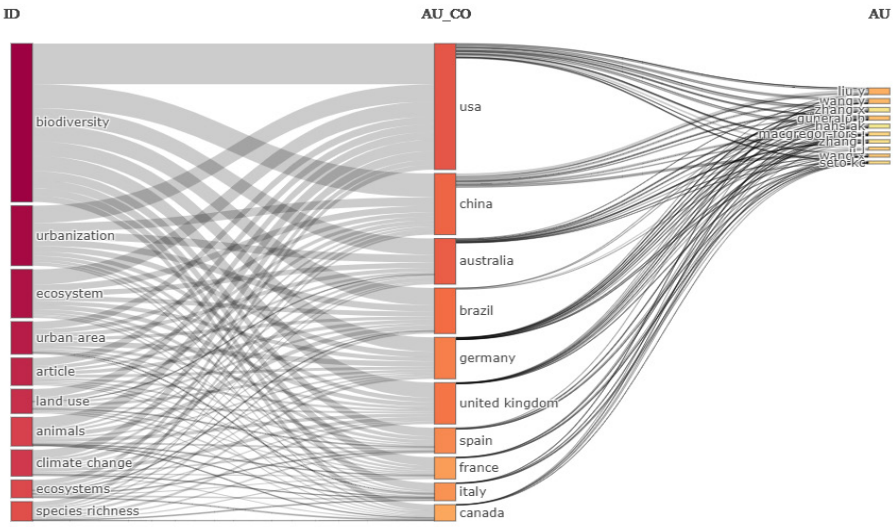


**Figure 5.** The relationships between the concepts frequently mentioned in research into biodiversity loss and urbanization and the countries that they were conducted (Source: Obtained from the three-field plot analysis of the documents retrieved from Scopus using the R-based software Bibliometrix)

"urban area" and "land use", and were reported and reviewed by an array of studies (McKinney 2008; Elmqvist et al. 2015; X. Xu et al., 2018; Olivier et al. 2020). Such reports have been more conducted by countries including USA, China, Australia, Brazil, Germany and the UK (Figure 6).

In the analysis of "country scientific production", out of 1827 documents, the United States contributed 946, Australia 443, China 437, Brazil 364, the United Kingdom 320 and Germany 317 documents. However, the total number exceeds 1827 because of international co-authorship. The very dark blue colour in the visual representation indicates significant contributions from these countries. This discrepancy is due to overlapping research efforts involving several countries (Fig 6).

It was also observed that a large amount of research on the "biodiversity loss and urbanisation" nexus has been conducted in the US, which has the most populated metropolitan area in the world (Figure 6). In the US, the number of studies on these issues is increasing every year (Figure 7).

In this field of research, two researchers from China (Liu Y and Wang Y) were found to be the most productive researchers with 12 and 9 studies, respectively (Figure 8). Considering the topics considered in the studies of both authors, "sustainability" is of the most focussed topics.

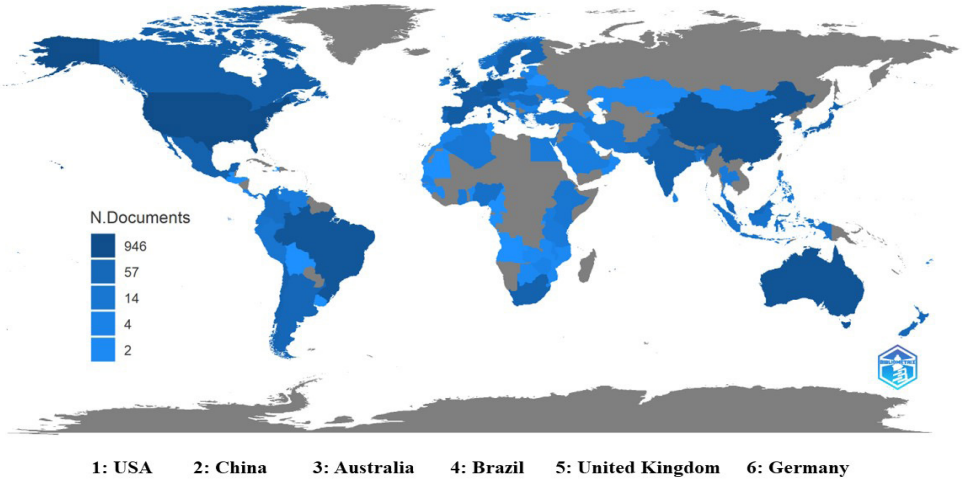


**Figure 6.** Scientific production with respect to countries (Source: Obtained from country scientific production analysis of the documents retrieved from Scopus using the R-based software Bibliometrix)

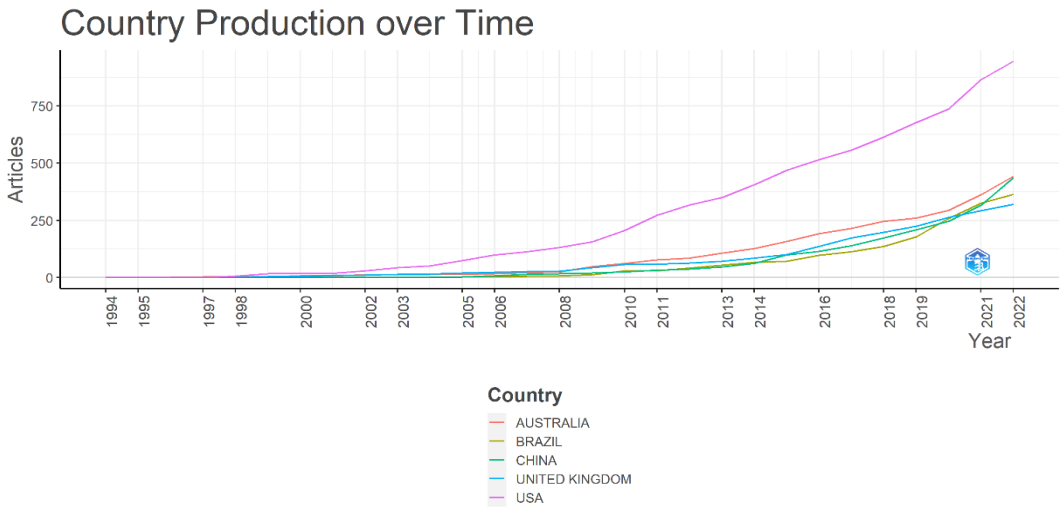


**Figure 7.** Scientific production by countries over time (1994-2022) (Source: Obtained from country scientific production according to the time-trend using analysis of the documents retrieved from Scopus using the R-based software Bibliometrix)

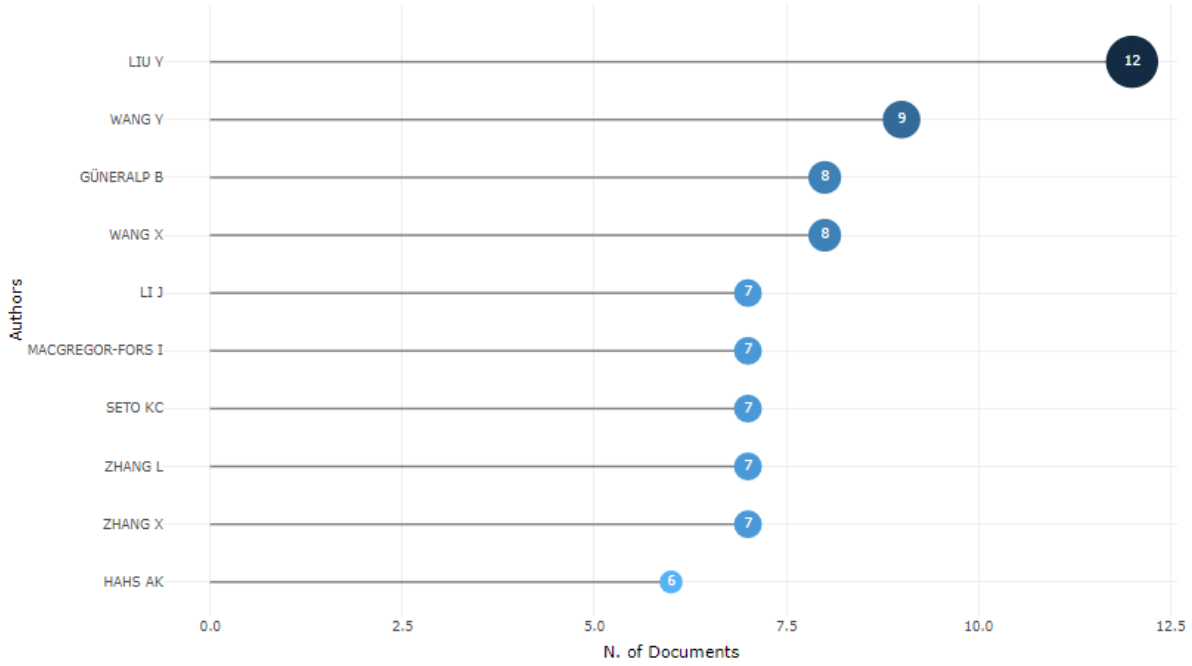


**Figure 8.** Most productive authors on the topic (Source: Obtained from the most productive authors analysis of the documents retrieved from Scopus using the R-based software Bibliometrix)

Considering 65 documents (61 articles, 2 short surveys, 1 conference paper, and 1 review). "Landscape and Urban Planning" is the journal with the highest number of documents on biodiversity loss and urbanisation is published. This is followed by the journal "Urban Ecosystems" with 46 documents "Urban Forestry and Urban Greening" and "Biological Conservation" have the third and fourth highest number of documents on the same topic (Figure 9).

Although "Landscape and Urban Planning" has published the highest number of documents on "biodiversity loss and urbanisation", they were not cited at the same level and the citations remained only at 1113. However, the number of citations to documents on this topic in "Science" journal was found to be 1760, and to only 37 documents published in "Biological Conservation" the citations was found to be as many as 1218 (Figure 10).

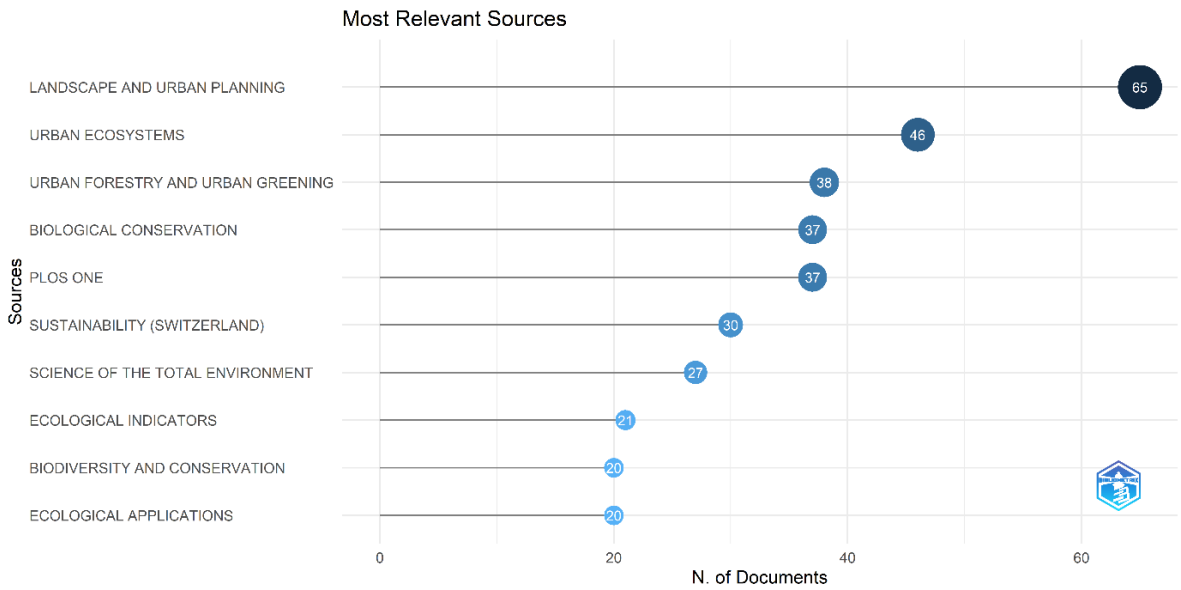


**Figure 9.** Journals that published the highest number of documents on the topic (Source: Obtained from the journal analysis of the documents retrieved from Scopus using the R-based software Bibliometrix)

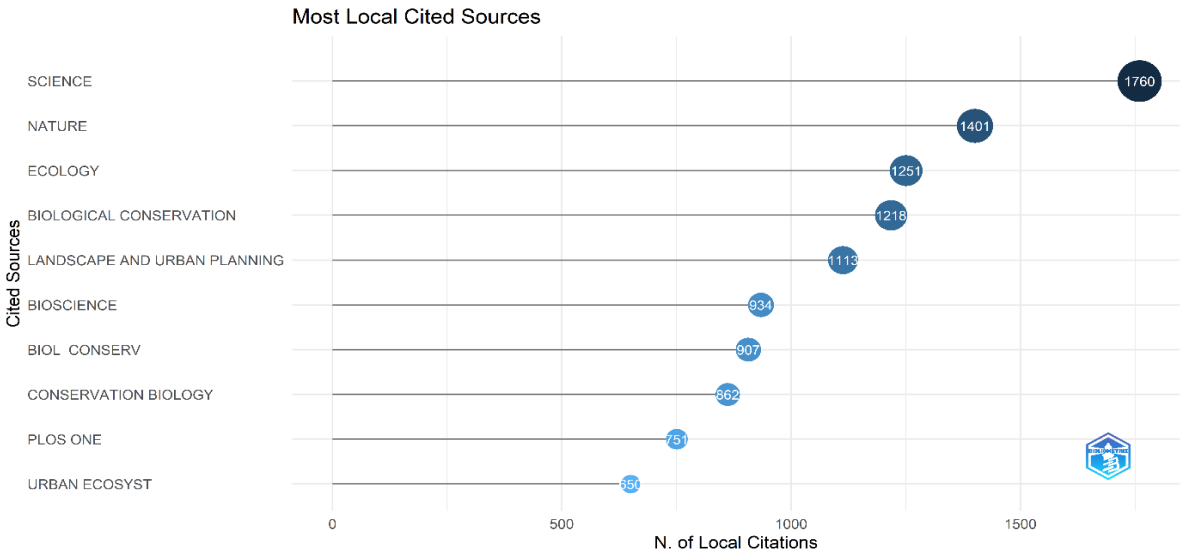


**Figure 10.** Most Local Cited Sources (from Reference Lists) (Source: Obtained from the journal citation analysis of the documents retrieved from Scopus using the R-based software Bibliometrix)

The analysis of "Most Local Cited Sources (from Reference Lists)" aims to identify the most frequently cited references in the reference list of a single article or a group of articles. In this context, the term 'Local' signifies the references within the examined article or article group. Thus, the analysis is geared towards determining the sources that receive the highest frequency of citations within a specific research field. This analysis is particularly utilised for identifying key references in a specific subject or discipline and understanding significant works in the literature, serving the purpose of recognising and characterising the most cited and influential sources within a given research context (Aria and Cuccurullo, 2017). It was also found that the journals that published the highest number of documents on "biodiversity loss and urbanization" were those on urban planning, biology, environment, and sustainability concepts. This finding might indicate that the studies have been disseminated from different disciplines.

The "Keywords Plus" analysis is a feature of the Bibliometrix analysis programme that helps researchers identify trends and patterns in scientific publications. This analysis is based on the indexed keywords generated from the titles of cited documents,


**Figure 11.** WordCloud of 50 Keywords Plus in the documents (Source: Obtained from the keywords plus analysis of the documents retrieved from Scopus using the R-based software Bibliometrix)

which appear at least twice in the bibliography (Tomaszewski, 2023). Keywords Plus is used to visualise the structure of scientific knowledge and can be used to explore the evolution of research fields, identify emerging trends, and understand the relationships between different research topics (Zhang et al. 2016). Accordingly, "biodiversity", with 1371 mentions, was found to have the highest frequency among the concepts highlighted in the 1827 documents (Table 1) (Figures 11 and 12).

"Urbanization" was the second most frequently mentioned concept with 494 occurrences, followed by a related concept, "urban area", mentioned 278 times. The concept of "ecosystem", which is related to "biodiversity", was mentioned 329 times. In total, the terms "biodiversity" and "ecosystem" were mentioned 1700 times (Figure 12). That is, almost all documents retrieved from Scopus contained the term "biodiversity" or "ecosystem" while the terms "urbanisation" and "urban area" were used 772 times in total. In other words, approximately 42% of the studies on the "biodiversity loss and urbanisation" nexus emphasised the concepts of "urbanisation" or "urban area".

Another notable concept mentioned in these studies is climate change (CC). The concept of CC is often used in research on the "biodiversity loss and urbanisation" nexus because the excessive growth of cities in recent years has had an impact not only on this loss but also on CC. Urbanisation causes CC, which in turn causes further biodiversity loss. As expected, there are numerous studies in the literature on the relationship between urbanisation and CC (Grimmond 2007; Nelson et al. 2009; Satterthwaite 2009; Chapman et al. 2017; Tiba 2019; Sarvari 2019).

The presence of concepts such as animals and species richness in research examining the relationship between "biodiversity loss and urbanisation" indicates a focus on understanding the effects of urbanisation on species diversity. McKinney (2008) conducted a comprehensive review that provided insights into the effects of urbanisation on species richness. It is evident that urbanisation has variable effects on this richness, with some cases showing a decrease, others an increase, and some cases only a change. These effects are influenced by factors such as the taxonomic group studied (birds, reptiles, mammals, etc.), the scale of analysis, and the intensity of urbanisation. Expanding on this topic, Olivier et al. (2020) conducted a study that further explored the effects of

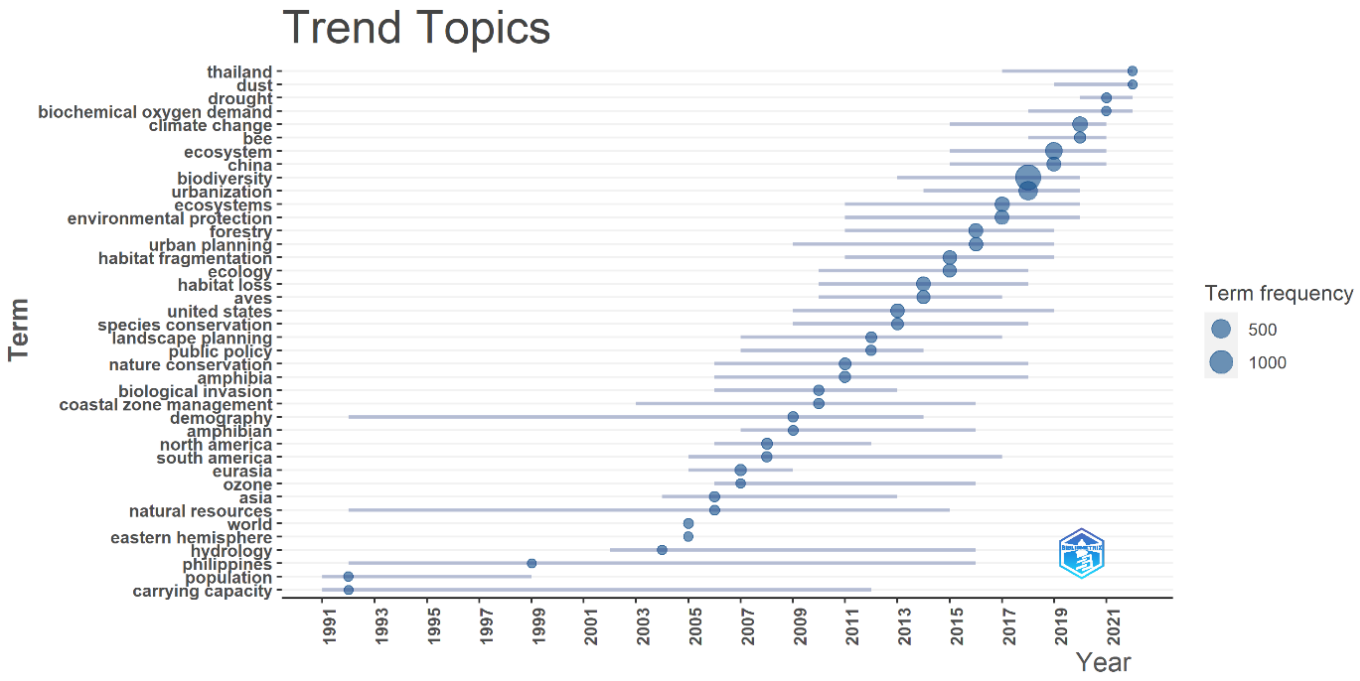


**Figure 13.** Historical trending topics in the retrieved documents (1991-2021) (Source: Obtained from historical trending topics analysis of the documents retrieved from Scopus using the R-based software Bibliometrix)

urbanisation, agricultural intensification, and diversity loss on animal communities. Their results showed that these factors affect animal communities in different ways. This research highlights the complexity of anthropogenic impacts on biodiversity and underlines the importance of considering multiple drivers when assessing the stability of animal communities. In their study focussing on the impact of urbanisation on bird species and overall biodiversity, X. Xu et al. (2018) point out how urbanisation leads to habitat loss, particularly in wetlands and shrubland, resulting in a gradual decline in bird species diversity over time. This study lays the groundwork for further exploration of the impacts of urbanisation on biodiversity. Building on this significance, Cai et al. (2019) reported that the identification of threatened vertebrate habitats and the main factors affecting natural resources are of fundamental importance. Their analysis establishes links among vertebrates, threatened vertebrates, the rainfall-runoff chain, the food chain, and the human impacts of urbanisation. By linking these factors, their study provides valuable insights into understanding biodiversity changes in urban environments.

The most historically recurrent concepts in research on the biodiversity loss and urbanisation relationship, which began in the early 1990s and continues to date, have been elucidated. For example, concepts such as "carrying capacity (term frequency N=6)" and "population (term frequency N=8)" were frequently used in this research in the early 1990s (Figure 13). The research in that period suggests that population growth during that period exceeded the limits of nature. Considering the historically recurrent concepts in research on the biodiversity loss and urbanisation relationship, it becomes evident that human efforts towards progress can have far-reaching consequences on the environment and society. According to Garg and Singh (1990), human efforts to progress can lead to negative consequences in the future, despite long-term improvements in well-being. Global environmental degradation is considered to be a common consequence of human activities, as reported and reviewed in an array document (Bogan et al. 2015; Choudhary et al. 2015; Bisht et al. 2020;). Degradation can, in turn, cause dysfunction in ecosystem services and a loss of biodiversity (Spangenberg and Settele 2010; Ayanlade and Proske 2015; Upreti 2023). These problems can also lead to social inequalities and resource scarcity. The profound effects of human progress on the environment and society, as observed from the retrieved documents, indicate that the impact of urbanisation on biodiversity is still an active area of research. While historically recurring concepts have provided valuable insights into the complex biodiversity loss and urbanisation relationship, recent studies, such as those conducted by Shochat et al. (2010), highlight the need for a deeper understanding of community-level diversity loss in urban environments. These studies shed light on the competitive exclusion of resident species by invasive species and their influence on foraging efficiency, prompting us to consider the far-reaching consequences of urban development on our natural ecosystems. A deeper insight into the documents on the impacts of urbanisation on biodiversity made it clear that addressing biodiversity concerns in urban planning and architectural design is crucial. Zari (2018) highlights the urgency of incorporating an ecosystem services model to understand the interrelationship between cities and biodiversity, as well as the impact of urban biodiversity on human populations. Furthermore, the frequency of the term "Philippines (term frequency N=6)" in these studies (Figure 13) underline the prominence of the country as a focal point for research exploring the complex relationship between biodiversity loss and urbanization.

It was also observed that the term "ozone" was frequently (term frequency N=7) used in the research conducted during the period 2003-2013 (Figure 13). This concept is not often used in research published after 2013. This is because the problem of ozone depletion has been partially solved (Jensen et al. 2015; Solomon et al. 2016). Over the past few decades, significant progress has been made in addressing the ozone layer problem. The phase-out of ozone-depleting substances, such as chlorofluorocarbons (CFCs), has been successful in reducing the depletion of the ozone layer (UNEP 2000; Woodcock 2023). As recognised by World Meteorological Organisation (WMO) and the United Nations Environment Programme (UNEP), global policies and the implementation of the Montreal Protocol have played a crucial role in these recovery efforts (Albrecht and Parker 2019; Fang et al. 2019), which are also supported by recent literature (Velders et al. 2007; Solomon et al. 2016; Neale et al. 2021). By using full and sustained implementation of this Protocol, it is projected that the ozone layer will recover by the middle of the current century (UNEP 2000).

Recent literature not only supports the notion that the Montreal Protocol has been successful in addressing the ozone layer problem but also emphasises the potential for the Protocol to be used to address climate change by phasing out other harmful substances such as hydrofluorocarbons (HFCs) (Jensen et al. 2015; Albrecht and Parker 2019). The recovery of the ozone layer is a positive environmental success story, demonstrating the effectiveness of international cooperation and environmental agreements in protecting the Earth's atmosphere (UNEP 2000; Woodcock 2023; Egorova et al. 2023).

The frequent use of terms such as "climate change" (term frequency N=188) and "drought" (term frequency N=14) in recent years (Figure 13), as pronounced in the literature (Chen et al. 2023; Lane et al. 2023; Ferchichi et al. 2024; Pei et al. 2024), indicates that biodiversity loss is indeed influenced by these phenomena (Opoku et al., 2021). The impact of climate change on biodiversity is profound, leading to changes in the duration, magnitude and frequency of extreme events such as droughts, wildfires and heatwaves (Poumadere et al. 2005; Jentsch and Beierkuhnlein 2008; Jiguet et al. 2011; IPCC 2012; Bell et al. 2018; Breshears et al. 2021; Opoku et al. 2021; Harvey et al. 2023).

Studies examining the impacts of climate change on biodiversity in different regions of the world show that it is a complex issue that affects all levels of biodiversity, from genes to species to entire biomes (Rinawati et al. 2013; Sintayehu 2018; Opoku et al. 2021; Aurelle et al. 2022). In addition, directional selection induced by climate change has been shown to reduce the genetic diversity of populations, affecting the fundamental components of biodiversity (Bellard et al. 2012). However, it is important to recognise that biodiversity loss cannot be solely attributed to climate change. Human-induced environmental changes, such as habitat loss, overexploitation of bioresources, and introduction of alien species, interact with climate change to exacerbate the impacts on biodiversity and ecosystems (Shivanna 2022). As a result of climate change and other environmental pressures, there are several impacts on biodiversity, including loss of local species, increased disease, and the onset of the sixth mass extinction crisis (Rinawati et al. 2013; Guisan et al. 2019; Marselle et al. 2019; Shivanna 2022). The interplay of these factors underlines the urgency of comprehensive efforts to address climate change and its interactions with other human-induced environmental changes to effectively conserve global biodiversity.

It was observed that studies on the relationship between biodiversity loss and urbanisation fall into four categories. The keywords included in the studies in the 'Niche Themes' category were concepts such as "functional traits", "pollinators" and "global change" (Figure 14). The keywords included in the research in the 'Motor Themes' category was related to topics that have been popular for a long time. The research included in this category is ongoing. The concepts mentioned in the research in this category were "urbanization", "urban ecology" and "fragmentation" (Figure 14). The keywords included in the research in the 'Emerging or Declining Themes' category were

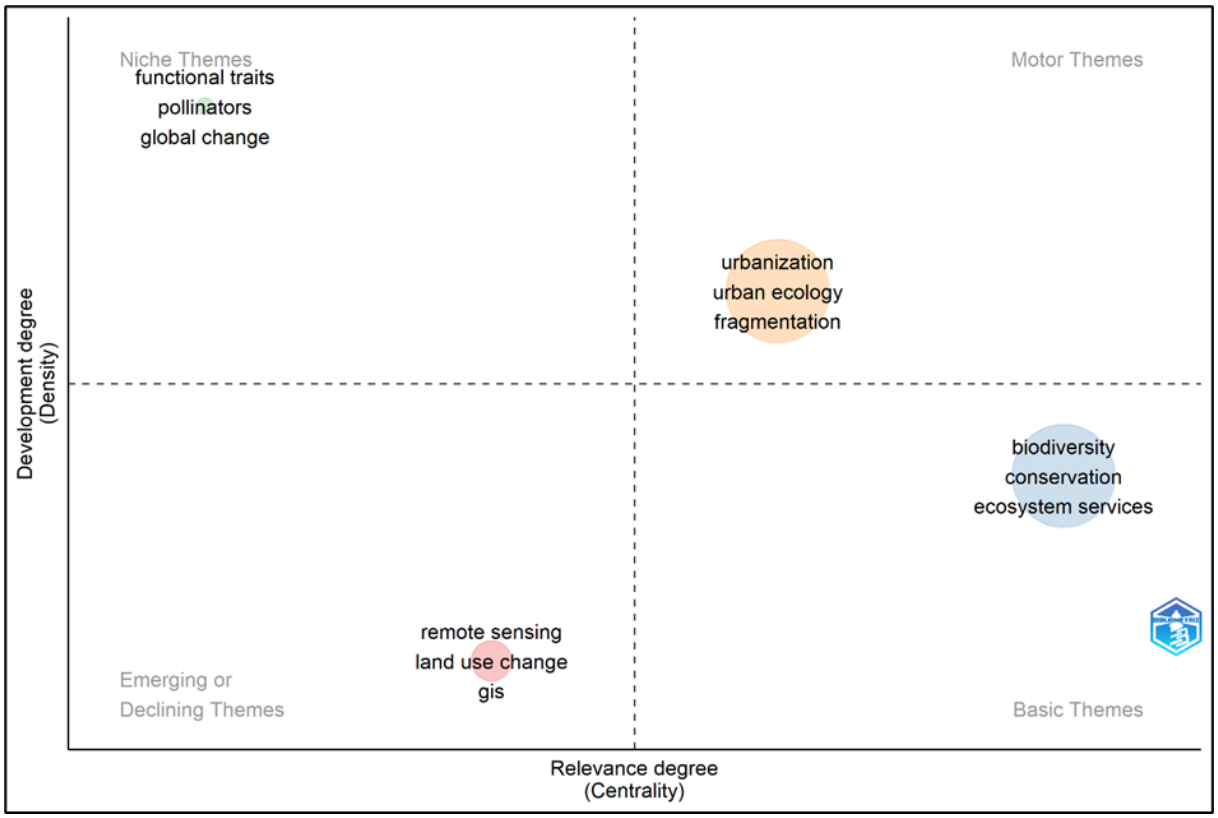


**Figure 14.** The distribution of concepts used in Biodiversity loss and urbanization the retrieved documents among four categories (Source: Obtained from thematic map analysis of the documents retrieved from Scopus using the R-based software Bibliometrix)

concepts related to new methods or technologies that have great potential for future use. The terms used in these studies were "remote sensing", "land use" and "GIS" (Figure 14). As explained by Di Cosmo et al. (2021), the keywords included in the 'Basic Themes' studies were not used as intensively as the concepts used in the 'Motor Themes' studies, although they remained popular at certain times. The results of this analysis can be used to identify research trends in a given period and potential topics for future research. These data can be useful for conducting literature reviews or identifying new research topics.

In a "Conceptual Structure Map" analysis performed in the Bibliometrix programme, the proximity or distance of words appearing on the map is typically indicative of their semantic similarity or relatedness (BP et al. 2021) (Figure 15). The closer two words are to each other on the map, the more closely related they are conceptually (Faraji et al. 2022; Rodríguez-Sabiote et al. 2023). When plotted on the plane axis, words that frequently co-occur in documents or have similar contexts tend to cluster together. This clustering reflects the underlying conceptual relationships between these words (Rodríguez-Sabiote et al. 2023). Conversely, words that are distant from each other on the map are less related in meaning or context.

As a result of the content analysis of articles containing the keywords "biodiversity", "urban" and "loss", carried out using the programme Bibliometrix R, two separate clusters were formed, offering different perspectives and concepts (Figure 15).

The first cluster offering a more specific perspective, includes terms such as "biodiversity", "urbanization", "urban area", "land use", "climate change", "ecosystems", "species richness", "China", "forestry", "habitat loss", "land use change", "urban planning", "habitat fragmentation", "United States", "conservation", "ecosystem service", "urban growth", "ecology", "anthropogenic impact", "biodiversity", "sustainable development", "agriculture", "urban ecosystem", "aves", "Australia", "bird", "urban development", "conservation management", "green space", "land cover" and "abundance" (Figure 15). The concepts grouped in this cluster focus on the impact of environmental change and human activities on biodiversity and refer to how biodiversity loss is linked to factors such as urbanisation, land use, and climate change. For example, concepts such as "habitat loss" and "habitat fragmentation" illustrate how humans affect natural habitats and the negative consequences of these impacts on biodiversity. "Land-use change" and "urbanization" refer to the replacement of natural

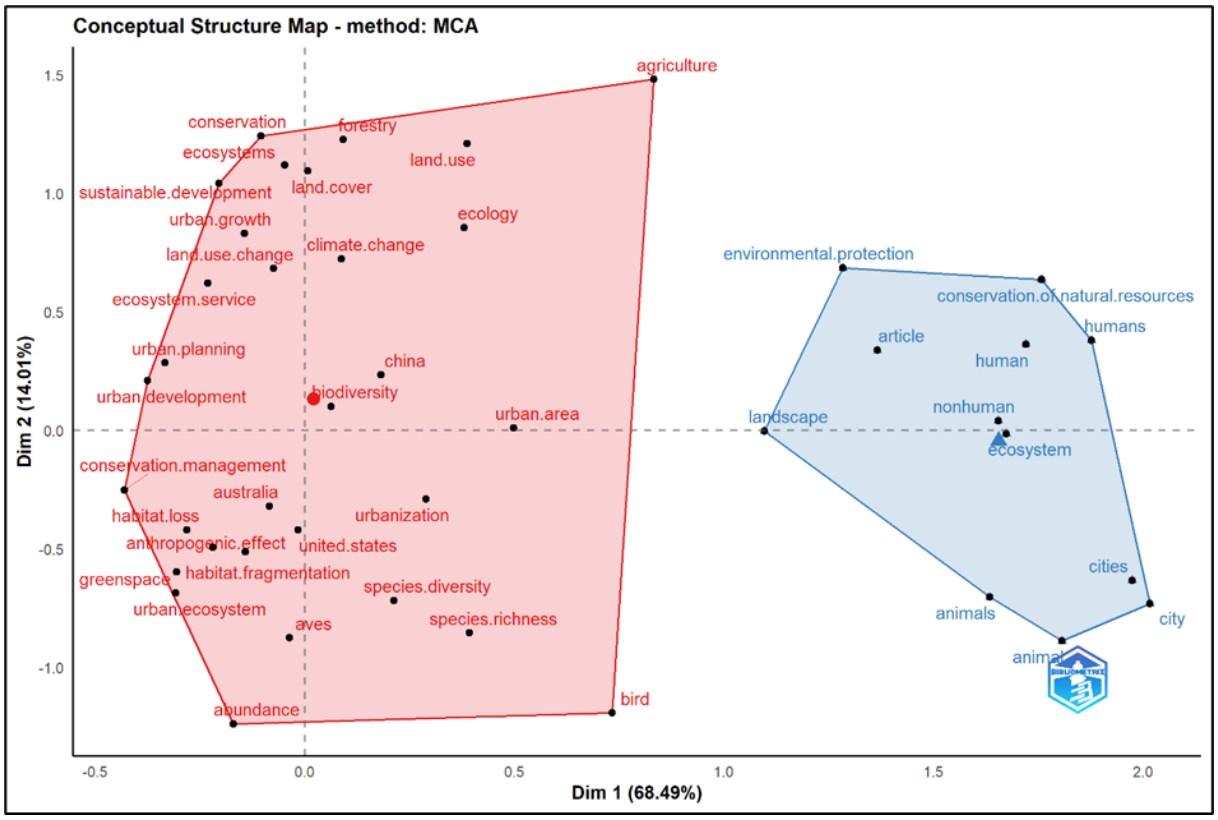


**Figure 15.** Conceptual structure map of the retrieved documents (Source: Obtained from conceptual structure map analysis of the documents retrieved from Scopus using the R-based software Bibliometrix)

areas by human settlements and urban areas, and highlight the impact of development on the environment.

As can be seen in Figure 15, the terms 'biodiversity', 'urban area', "urban planning", and 'urban development' are close together, while terms such as 'agriculture', "land use" and 'ecology' are further apart. This suggests a strong link between biodiversity loss in urban areas and urban development, with agriculture and ecology being considered in different contexts. Biodiversity loss in urban areas is often directly linked to the growth and use of urban space, while the impact of agriculture and ecology can be considered from a broader perspective. This analysis highlights the importance of biodiversity loss and urban development as interrelated issues, although agriculture and ecology are also recognised as important factors, albeit in different contexts.

The second cluster contains terms such as "ecosystem", "animals", "environmental protection", "conservation of natural resources", "human", "non-human", "city", and "landscape" (Figure 15). These terms focus on protecting ecosystems, promoting the sustainable use of resources and emphasing the value of the natural environment, in line with the principles of sustainability. As can be seen in Figure 15, the terms "non-human" and "ecosystem" appear to be closely related, while other terms such as "animals," "environmental protection," "conservation of natural resources," "human," "city," and "landscape" are further apart. This a particular focus on the relationship between non-human entities and ecosystems in the context of urbanisation and biodiversity loss. The proximity of "non-human" and "ecosystem" may indicate an emphasis on understanding how urbanisation affects ecosystems and the non-human elements within them, potentially highlighting the importance of considering non-human entities in environmental conservation efforts in the midst of urban development. Conversely, the distancing of terms such as "animals," "environmental protection," and "human" from these central concepts may imply a broader scope of discussion encompassing different aspects of urbanisation and biodiversity loss, including their impacts on human societies and the wider environment beyond ecosystems.

## 4. CONCLUSION

This study presents key findings based on an analysis of 1,827 documents discussing the impact of urbanisation on biodiversity loss. The results show a close and significant relationship between biodiversity loss and urbanisation with a continuous and intense focus on this issue over the years. In the early 1990s, the first studies reported the negative impact of urbanisation on biodiversity, particularly in Argentina, focussing on birds (Canevari et al. 1991). Since then, research on the subject has grown rapidly and has shown that urbanisation continues to pose a serious threat to biodiversity. The annual growth rate of 19.51% for studies on urbanisation and biodiversity underlines the continuing importance of this topic.

The frequency analysis of terms in the documents analyzed showed that terms such as "biodiversity", "ecosystem", "animals", "forests" and "species" often overlap with "urbanization", "urban area" and "land use". This highlights the consistent association of urbanisation-related terms with biodiversity, ecosystems, animals, forests, and species. Researchers from countries such as the United States, China, Australia, Brazil, Germany, and the United Kingdom are at the forefront of studying the relationship between biodiversity loss and urbanisation. The US, with its densely populated metropolitan areas, has become a major contributor to research on this topic, and the number of studies in the country continues to grow. The analyses of individual researchers, Liu Y and Wang Y, emphasise the continuing interest in the topic, with their publications showing a focus on "sustainability". The increasing citation rates for their studies confirm the continuing relevance of the impact of urbanisation on biodiversity. Notably, although the journal "Landscape and Urban Planning" published the highest number of documents on biodiversity loss and urbanisation, the journal "Science" had the highest number of citations. The disparity in citations suggests that while research in this area is growing, studies may need to target higher impact journals to gain wider recognition and influence.

The study also highlights that several fields, including environmental science, biology, and urban planning, are interested in the link between biodiversity loss and urbanisation. It also draws attention to the impact of climate change on biodiversity, with terms such as "climate change" and "drought" appearing frequently in recent studies. Climate change is interacting with urbanisation and other human-induced environmental changes to intensify biodiversity loss, underlining the need for comprehensive efforts to conserve global biodiversity.

In conclusion, this study confirms that urbanisation continues to have a negative impact on biodiversity and that this issue remains a prominent and intensively researched topic worldwide. The continuing significance of the impact of urbanisation on

biodiversity highlights the importance of integrating biodiversity concerns into urban planning and design to address the complex challenges posed by human progress. In addition, the success of the Montreal Protocol in addressing the ozone layer problem serves as a positive example of international cooperation and environmental agreements, highlighting the potential for similar approaches in addressing other pressing environmental issues, such as climate change.

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## REFERENCES / KAYNAKÇA

Aria M, Cuccurullo C (2017). A brief introduction to bibliometrix. Journal of Informetrics, 11(4): 959-975.

Albrecht F, Parker CF (2019). Healing the ozone layer. Great policy successes, 304-322.

Albritton Jonsson F (2012). The industrial revolution in the Anthropocene. J Mod Hist 84(3): 679-696.

Aurelle D, Thomas S, Albert C, Bally M, Bondeau A, Boudouresque CF, Fady B (2022). Biodiversity, climate change, and adaptation in the Mediterranean. Ecosphere 13(4): e3915.

Ayanlade A, Proske, U. (2015). Assessing wetland degradation and loss of ecosystem services in the Niger Delta, Nigeria. Marine and Freshwater Research, 67(6), 828-836.

Bell JE, Brown CL, Conlon K, Herring S, Kunkel KE, Lawrimore J, Uejio C (2018). Changes in extreme events and the potential impacts on human health. J Air Waste Manag Assoc 68(4), 265-287.

Bellard C, Bertelsmeier C, Leadley P, Thuiller W, Courchamp F (2012). Impacts of climate change on the future of biodiversity. Ecol Lett 15(4): 365-377.

Bisht A, Kamboj N, Kamboj V, Bisht A (2020). A review on the role of emerging anthropogenic activities in environmental degradation and emphasis on their mitigation. Archives of Agriculture and Environmental Science, 5(3), 419-425.

Birpınar ME., Talu, G. F., & Gönençgil, B. (2009). Environmental effects of maritime traffic on the Istanbul Strait. Environmental monitoring and assessment, 152, 13-23.

Biró M, Czúcz B, Horváth F, Révész A, Csatári B, Molnár Z (2013). Drivers of grassland loss in Hungary during the post-socialist transformation (1987–1999). Landsc Ecol 28: 789-803.

Bogan E, Doina S, Vărvăruc D (2015). The impact of anthropogenic activities on components of the natural environment of the Titu Plain. GEOREVIEW: Scientific Annals of Stefan cel Mare University of Suceava. Geography Series, 24(1), 54-64.

Boyle F, Sherman D (2006). Scopus™: The product and its development. The Serials Librarian, 49(3): 147-153.

BP, M., Mamdapur, G. M. N., & Sahoo, S. (2021). Twenty-Five Years Study (1995-2019) of Food and Bioproducts Processing: An Overview of Research Trends. Library Philosophy and Practice (e-journal), 5196, 01-15.

Breshears DD, Fontaine JB, Ruthrof KX, Field JP, Feng X, Burger JR, Hardy GESJ (2021). Underappreciated plant vulnerabilities to heat waves. New Phytol 231(1): 32-39.

Burnham JF (2006). Scopus database: a review. Biomedical digital libraries, 3(1): 1-8.

Cai D, Fraedrich K, Guan Y, Guo S, Zhang C, Carvalho LM, Zhu X (2019). Causality of Biodiversity Loss: Climate, Vegetation, and Urbanization in China and America. Sensors, 19(20), 4499.

Canevari MP, Canevari GR, Carrizo G, Harris JR, Straneck RJ (1991) Aves Argentinas, Tomo l. Fundacion Acindar, Buenos Aires. 411.

Celik E, Durmus A, Adizel O, Nergiz Uyar H. (2021). A bibliometric analysis: what do we know about metals (loids) accumulation in wild birds? Environ Sci Pollut Res 28: 10302-10334.

Çelik E, Sarıboğa L (2023). Assessment of The Role of Birds in Seed Distribution: A Bibliometric Analysis of Studies on This Subject (Book Chapter). Recent Advances in Natural and Engineering Sciences, 38-60.

Chapman S, Watson JE, Salazar A, Thatcher M, McAlpine CA. (2017). The impact of urbanization and climate change on urban temperatures: a systematic review. Landsc Ecol 32: 1921-1935.

Chen C (2017). Science mapping: a systematic review of the literature. J Data Inf Sci 2(2):1-40.

Chen J, Fan Y, Zhang Y, Peng J, Zhang J, Cao C (2023). Comprehensive propagation characteristics between paired meteorological and hydrological drought events: Insights from various underlying surfaces. Atmospheric Research, 107193.

Choudhary MP, Chauhan GS, Kushwah YK (2015, February). Environmental degradation: causes, impacts and mitigation. In National seminar on recent advancements in protection of environment and its management issues (NSRAPEM-2015)

Crafts N (2011). Explaining the first Industrial Revolution: two views. Eur Rev Econ Hist 15(1): 153-168.

Davenport, R. J. (2020). Urbanization and mortality in Britain, c. 1800–50. The Economic History Review, 73(2): 455-485.

De Moya-Anegón F, Chinchilla-Rodríguez Z, Vargas-Quesada B, Corera-Álvarez E, Muñoz-Fernández FJ, González-Molina A, Herrero-Solana V (2007). Coverage analysis of Scopus: A journal metric approach. Scientometrics, 73: 53-78.

Di Cosmo A, Pinelli C, Scandurra A, Aria M, D'Aniello, B (2021). Research trends in octopus biological studies. Animals, 11(6), 1808.

Egorova T, Sedlacek J, Sukhodolov T, Karagodin-Doyennel A, Zilker F, Rozanov E (2023). Montreal Protocol's impact on the ozone layer and climate. Atmos Chem Phys 23(9): 5135-5147.

Elmqvist T, Zipperer WC, Güneralp B (2015). Urbanization, habitat loss and biodiversity decline: Solution pathways to break the cycle. In The Routledge handbook of urbanization and global environmental change (pp. 163-175). Routledge.

Fang X, Pyle JA, Chipperfield MP, Daniel JS, Park S, Prinn RG (2019). Challenges for the recovery of the ozone layer. Nat Geosci 12(8): 592-596.

Ferchichi Ahlem, Chihaoui M, Ferchichi, Aya (2024). Spatio-temporal modeling of climate change impacts on drought forecast using Generative Adversarial Network: A case study in Africa. Expert Systems with Applications, 238, 122211.

Garg M, Singh M (1990). Environmental Degradation. Environment Planning and Management in India, 2, 119.

Gavel Y, Iselid L (2008). Web of Science and Scopus: a journal title overlap study. Online information review, 32(1): 8-21.

Grimmond S (2007). Urbanization and global environmental change: local effects of urban warming. Geogr J 173(1): 83-88.

Gönençgil, B. (2011) Şehirleşmenin Sıcaklık Trendleri Üzerine Etkileri ve Şehirsel Isı Adası Kavramı, Fiziki Coğrafya Araştırmaları, Sistematik ve Bölgesel. Prof. Dr. M. Yıldız Hoşgören Anısına Armağan, Türk Coğrafya Kurumu Yayını

Guisan A, Broennimann O, Buri A, Cianfrani C, D'Amen M, Di Cola V, Vittoz P (2019). Climate change impacts on mountain biodiversity. In Biodiversity and climate change: Transforming the biosphere (pp. 221-233). Yale University Press.

Harvey JA, Tougeron K, Gols R, Heinen R, Abarca M, Abram PK, Chown SL (2023). Scientists' warning on climate change and insects. Ecol Monogr 93(1): e1553.

Faraji, O., Asiaei, K., Rezaee, Z., Bontis, N., & Dolatzarei, E. (2022). Mapping the conceptual structure of intellectual capital research: A co-word analysis. Journal of Innovation & Knowledge, 7(3), 100202.

IPCC (2012) Managing the risks of extreme events and disasters to advance climate change adaptation. In: A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (eds CB Field, V Barros, TF Stocker et al.), Cambridge University Press, Cambridge, NY, USA

Jedwab R, Vollrath D (2015). Urbanization without growth in historical perspective. Explor Econ Hist 58: 1-21.

Jensen, N. R., Putaud, J. P., & Borowiak, A. (2015). Literature review on ODS (Ozone Depleting Substances) measurement methods and data. Publications Office of the European Union: Ispra, Italy.

Jentsch A, Beierkuhnlein C (2008). Research frontiers in climate change: effects of extreme meteorological events on ecosystems. C. R. - Geosci 340(9-10): 621-628.

Jiguet F, Brotons L, Devictor V (2011). Community responses to extreme climatic conditions. Curr Zool 57(3): 406-413.

Koo M (2017). A bibliometric analysis of two decades of aromatherapy research. BMC Res. Notes 10, 46. https://doi.org/10.1186/s13104-016-2371-1.

Kulak M, Ozkan A, Bindak R (2019). A bibliometric analysis of the essential oil-bearing plants exposed to the water stress: How long way we have come and how much further?. Sci Hortic 246, 418-436.

Lane TP, King AD, Perkins-Kirkpatrick SE, Pitman AJ, Alexander LV, Arblaster J M, ... Ukkola AM (2023). Attribution of extreme events to climate change in the Australian region–A review. Weather and Climate Extremes, 100622.

Lin Y, Qiu R, Yao J, Hu X, Lin J (2019). The effects of urbanization on China's forest loss from 2000 to 2012: Evidence from a panel analysis. J Clean Prod 214: 270-278.

Marselle MR, Stadler J, Korn H, Irvine KN, Bonn A (2019). Biodiversity and health in the face of climate change (p. 481). Springer Nature.

McDonald RI, Marcotullio PJ, Güneralp B (2013). Urbanization and global trends in biodiversity and ecosystem services (Book chapter). Urbanization, biodiversity and ecosystem services: challenges and opportunities: a global assessment, 31-52.

McKinney ML (2008). Effects of urbanization on species richness: a review of plants and animals. Urban Ecosyst 11: 161-176.

Neale RE, Barnes PW, Robson TM, Neale PJ, Williamson CE, Zepp RG, Zhu M (2021). Environmental effects of stratospheric ozone depletion, UV radiation, and interactions with climate change: UNEP Environmental Effects Assessment Panel, Update 2020. Photochem Photobiol Sci 20(1): 1-67.

Nelson KC, Palmer MA, Pizzuto JE, Moglen GE, Angermeier PL, Hilderbrand RH, Hayhoe K (2009). Forecasting the combined effects of urbanization and climate change on stream ecosystems: from impacts to management options. J Appl Ecol 46(1): 154-163.

Olivier T, Thébault E, Elias M, Fontaine B, Fontaine C (2020). Urbanization and agricultural intensification destabilize animal communities differently than diversity loss. Nat Commun 11(1): 2686.

Opoku SK, Filho WL, Hubert F, Adejumo O (2021). Climate change and health preparedness in Africa: analysing trends in six African countries. Int J Environ Res Public Health 18(9): 4672.

Özüpekçe, S. (2021). Built-up İndeks Kullanılarak Türkiye'nin Yavaş Şehirlerinin (Cittaslow) Zamansal Değişimi. Coğrafya Dergisi , (43) , 19-36 . DOI: 10.26650/JGEOG2021-880191

Poumadere M, Mays C, Le Mer S, Blong R (2005). The 2003 heat wave in France: dangerous climate change here and now. Risk Analysis 25(6), 1483-1494.

Pei W, Hao L, Fu Q, Liu H, Ren Y, Li T (2024). Analysis of spring drought in Northeast China from the perspective of atmosphere, snow cover, and soil. Catena, 236, 107715.

Ramalho A, Souza J, Freitas A (2020) The use of artificial intelligence for clinical coding automation: a bibliometric analysis. In International Symposium on Distributed Computing and Artificial Intelligence. Springer, Cham, pp 274–283

Richards P, VanWey L (2015). Where deforestation leads to urbanization: how resource extraction is leading to urban growth in the Brazilian Amazon. Ann Am Assoc Geogr 105(4): 806-823.

Rinawati F, Stein K, Lindner A (2013). Climate change impacts on biodiversity the setting of a lingering global crisis. Diversity 5(1): 114-123.

Rodríguez-Sabiote, C., Úbeda-Sánchez, Á. M., Lorenzo-Quiles, O., & Álvarez-Rodríguez, J. (2023). Knowledge structures of scientific production on COVID-19 in the sphere of education: the case of publications indexed in the Web of Science during 2020. Quality & Quantity, 57(5), 4285-4305.

Sarvari H (2019). A survey of relationship between urbanization and climate change for major cities in Iran. Arab J Geosci 12(4): 131.

Satterthwaite D (2009). The implications of population growth and urbanization for climate change. Environ Urban 21(2): 545-567.

Shivanna KR (2022). Climate change and its impact on biodiversity and human welfare. Proceedings of the Indian National Science Academy, 88(2), 160-171.

Shochat E, Lerman SB, Anderies JM, Warren PS, Faeth SH., Nilon CH (2010). Invasion, competition, and biodiversity loss in urban ecosystems. BioScience, 60(3): 199-208.

Sintayehu DW (2018). Impact of climate change on biodiversity and associated key ecosystem services in Africa: a systematic review. Ecosyst Health Sust 4(9): 225-239.

Solomon S, Ivy DJ, Kinnison D, Mills MJ, Neely III RR, Schmidt A (2016). Emergence of healing in the Antarctic ozone layer. Science, 353(6296): 269-274.

Spangenberg JH, Settele J (2010). Precisely incorrect? Monetising the value of ecosystem services. Ecological Complexity, 7(3), 327-337.

Tiba S (2019). A non-linear assessment of the urbanization and climate change nexus: the African context. Environ Sci Pollut Res 26: 32311-32321.

Tomaszewski R (2023). Visibility, impact, and applications of bibliometric software tools through citation analysis. Scientometrics, 1-22.

Uchida K, Fujimoto H, Ushimaru A (2018). Urbanization promotes the loss of seasonal dynamics in the semi-natural grasslands of an East Asian megacity. Basic Appl Ecol 29: 1-11.

Upreti G (2023). Valuation of Biodiversity, Ecosystem Services, and Natural Capital. In Ecosociocentrism: The Earth First Paradigm for Sustainable Living (pp. 163-188). Cham: Springer Nature Switzerland.

UNEP (2000). The Montreal protocol on substances that deplete the ozone layer. United Nations Environment Programme, Nairobi, Kenya.

Velders GJ, Andersen SO, Daniel JS, Fahey DW, McFarland M (2007). The importance of the Montreal Protocol in protecting climate. Proc Natl Acad Sci 104(12), 4814-4819.

Woodcock A (2023). Hydrofluorocarbons, Climate, and Health—Moving the Montreal Protocol beyond Ozone-Layer Recovery. N Engl J Med 388: 2404-2406.

Xu M, David JM, Kim SH (2018). The fourth industrial revolution: Opportunities and challenges. International Journal of Financial Research, 9(2): 90-95.

Xu, X., Xie, Y., Qi, K., Luo, Z., Wang, X. (2018). Detecting the response of bird communities and biodiversity to habitat loss and fragmentation due to urbanization. Science of the total environment, 624, 1561-1576.

Yang C, Liu H, Li Q, Cui A, Xia R, Shi T, Wu G (2021). Rapid urbanization induced extensive forest loss to urban land in the Guangdong-Hong Kong-Macao Greater Bay Area, China. Chin Geogr Sci 31: 93-108.

Zahoor Z, Latif MI, Khan I, Hou F. (2022). Abundance of natural resources and environmental sustainability: the roles of manufacturing value-added, urbanization, and permanent cropland. Environ Sci Pollut Res 29(54): 82365-82378.

Zari MP (2018). The importance of urban biodiversity–an ecosystem services approach. Biodivers Int J 2(4): 357-360.

Zhang J, Yu Q, Zheng F, Long C, Lu Z, Duan Z (2016). Comparing keywords plus of WOS and author keywords: A case study of patient adherence research. J Assoc Inf Sci Technol 67(4), 967-972.