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RESEARCH ARTICLE

Research trends in the environmental assessment of poplar plantations in Hungary: A bibliometric analysis

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Abstract – Climate change mitigation and adaptation are essential issues at many summit meetings. Environmental assessment is a possible tool to describe the potential sequestration of carbon and greenhouse gas emissions. The forest carbon stock and life cycle assessment approach was used here to analyze poplar plantations in Hungary. This study aims to describe the research trends of environmental assessment of poplar plantations in Hungary using VOSviewer software. A total of 1,528 documents from the Scopus database were used in this research. VOSviewer analysis was conducted to detail the bibliometric maps from generic ("forest" OR "forestry" AND "Hungary"), medium ("poplar" AND "Hungary"), and specific ("poplar" AND "carbon" AND "Hungary" / ("poplar" AND "life cycle assessment") OR ("LCA" AND "Hungary"). The findings show that the number of documents on forest research in Hungary has increased significantly since the 2000s. However, items on environmental assessment, either forest carbon or life cycle assessment, produced only a tiny number with weak links. In conclusion, i). the large number of collected documents produced more clusters; ii). The item of Hungary is the most frequently used keyword in the research article; and iii). The research theme of environmental assessment (carbon sequestration and life cycle assessment) of poplar plantations in Hungary is the continuing lack of knowledge. Furthermore, the research on biodiversity and climate change mitigation (carbon stock and sequestration) were prominent topics that many researchers do. In the future, research on climate change mitigation through the life cycle assessment to analyze global warming potential (GWP) from forestry activities is a prospective research topic to enrich the study on poplar bioenergy plantations.

Keywords – research map, bioenergy plantation, forest carbon, life cycle assessment

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1. Introduction

Climate change and the transition to renewable energy are essential topics at many summit meetings because rising temperatures contribute to global warming. In 2020, the temperature was 1.2 ± 0.1 °C above the temperature baseline of 1850–1900 (World Meteorological Organization, 2021). The IPCC (2014) reported that the temperature increase will affect communities worldwide due to extreme weather. The impacts of extreme weather, such as droughts, heavy rain, and floods, are forest fires, decreasing agricultural yields, and hydrometeorological disasters.

Agriculture, forestry, and other land use contribute around 25% of total greenhouse gas emissions to the atmosphere (FAO, 2019). Globally, human activities in agriculture have released around 25% CO_2, 50% CH_4, and 70% N_2O (Hutchinson et al., 2007). Furthermore, the FAO (2019) indicated that rehabilitating degraded soil, reducing deforestation, and rehabilitating degraded forests can cut emissions of around 51 and 5 Giga tonnes of CO_2 equivalent from the atmosphere.

However, the forest also plays an essential role in absorbing CO_2 from the atmosphere through photosynthesis. For instance, the mangrove forest can absorb more CO_2 from the atmosphere than other terrestrial ecosystems (Murdiyarso et al., 2015). Moreover, the energy transition from fossil fuels to bioenergy can be supported by bioenergy forest plantation (poplar, willow, black locust, and other fast-growing species) through a carbon neutrality scheme. Therefore, it is important

to analyze forests through environmental assessment regarding their ability to release and absorb emissions.

In Hungary, developing short rotation coppice (SRC) bioenergy plantations, such as black locust, willow, and poplar, is essential to support renewable energy sources and climate change mitigation. The total area of poplar forest, either native or hybrid poplars, was around 10% of the total forest area (National Food Chain Safety Office, 2016). Furthermore, poplar hybrids are tolerant to low-quality land and some critical limiting factors (temperature and water supply) and provide economic benefits (Schiberna et al., 2021).

Conducting environmental assessment in bioenergy forest plantations, it is necessary to understand the research trends in the past, present, and prospective research in the future. The prominent method to get information on research trends is bibliometric analysis. Bibliometric analysis is an approach to evaluate and examine a literature database (Broadus, 1987), and the output is a visualization of research trends and prospective research themes. Bibliometric analysis has been used in various aspects of science to analyze quantitative and qualitative research performance (Ellegaard and Wallin, 2015). Generally, the literature data for bibliometric analysis are collected from Google Scholar, Scopus, and the Web of Science.

Bibliometric analysis in the forestry sectors has been applied to describe specific research trends, such as ecosystem services (Di Franco et al., 2021; Zhang et al., 2019), forest degradation (Aleixandre-Benavent et al., 2018), agroforestry practices (Leal et al., 2019), climate change (Araujo et al., 2023; Nam et al., 2022; Zhang et al., 2022), forestry big data (Gao et al., 2022), and forest bioeconomy (Jankovský et al. 2021; Verma and Ghosh, 2023). Analyzing and mapping the bibliography can also use software such as the Bibliometrix R package (Gao et al., 2022; Zhang et al., 2022), Citespace (Li et al., 2022; Xie et al., 2023), and VOSviewer (Cheng et al., 2021; Hamidah et al., 2020; Singh, 2022; Soegoto et al., 2022). Each software package has advantages and disadvantages; therefore, the researcher's preference is essential in choosing the suitable bibliography analysis software. The research objective was to describe the research trends in the forests and environmental assessment of poplar plantations in Hungary.

2. Materials and Method

2.1. Literature selection

We downloaded the articles from the Scopus database on March 21, 2023. The articles in the Scopus database have all been published in reputable scientific journals. The Scopus database is well-known in the scientific works conducting comprehensive peer-viewed content (Hamidah et al., 2020; Klapka and Slabý, 2020). Furthermore, Klapka and Slabý (2020) explained that the Scopus database also provides metadata on publications.

To retrieve the selected literature, we used a keyword string from general to specific (Figure 1.). First, we used the keywords "forest" OR "forestry" AND "Hungary" applied to the criteria "titles, keywords, and abstract." We did not use the period limitation because we wanted to analyze the pattern of publications from the first publication until now. The search profile used in the Scopus database was TITLE-ABS-KEY((forest*) AND (Hungary)) and found 1,528 documents.

Second, we used the keywords "poplar" AND "Hungary." The poplar species in Hungary is of interest as a potential bioenergy source. Screening related articles, more specifically, will be helpful in data analysis (Cosofret and Bouriaud, 2019). The query string used in the Scopus database was TITLE-ABS-KEY((poplar) AND (Hungary)) and found 109 documents.

Finally, we focussed on the environmental assessment of poplars in Hungary using the keywords "poplar" AND "carbon" AND "Hungary" to retrieve information on the potential of poplars to absorb carbon dioxide from the atmosphere. However, poplar plantations also negatively impact the environment through global warming potential, acidification, eutrophication, and ozone depletion (Polgár et al., 2018). We then used the keywords "LCA" OR "life cycle assessment" AND "poplar" AND "Hungary" to obtain appropriate literature related to the potential negative impacts of poplar plantations on the environment.

2.2. Visualization using VOSviewer software

The selected literature from the Scopus database was downloaded and saved in *.ris and *.csv format. The *.ris format is used for visualization in VOSviewer software, while the *.csv format is used for publication growth analysis through Microsoft Excel 365. Analysis of the publication growth in a certain period aims to determine whether the research is increasing or decreasing. The publication growth can also be seen as the trend of researchers' preference for specific topics. Furthermore, the *.csv format can also be utilized to get information on the most influenced articles. The most influenced articles show a high number of citations by other articles.

This research is the latest VOSviewer version 1.6.19, released on January 23, 2023 (van Eck and Waltman, 2023). For example, Zhang et al. (2019) revealed the research trends on ecosystem services, Hamidah et al. (2020) analyzed the COVID-19 research trends, Soegoto et al. (2022) described the bioenergy management in Indonesia, and Araujo et al. (2023) reviewed the biomass and carbon stock in the Amazon rainforest. In the VOSviewer, we conducted a co-occurrence analysis for keywords to determine the prominence items. Prominence items have shown a high value on total strength links, occurrences, and links. In the visualization, the prominence items were indicated by larger circles and thicker links.

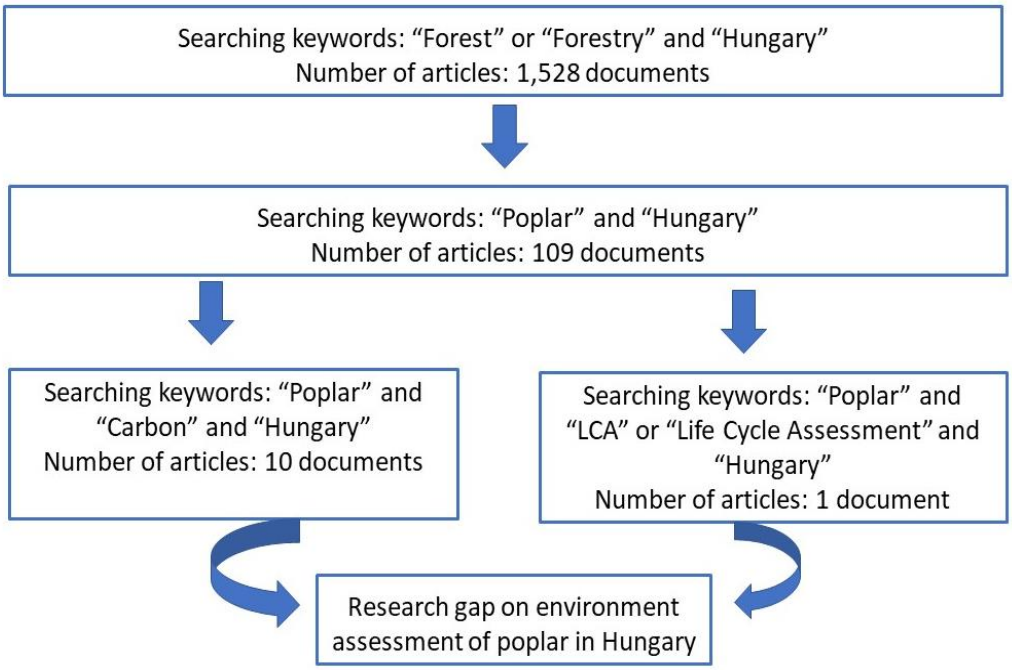

Figure 1. Literature selection from the Scopus database

3. Result and Discussion

3.1. Research trends of forests in Hungary

In the period 1936–2023 (March), we found 1,528 articles related to "forest" OR "forestry" AND "Hungary." Generally, for the period 1936–1980, the number of publications was flat at around 1–2 articles/year and then increased gradually until 1990 and increased significantly after 1990 (Figure 2). Referring to Xie et al. (2023), the research trends can be divided into the initial, rapid, and deep development stages based on annual publication numbers. In this research, the initial stage was the period 1936–1980, the development stage was 1980-1990, and the rapid publication stage was 1990–2023.

Based on Figure 2, the first article on forests and Hungary indexed in the Scopus database was in 1936. For almost 25 years, there were no articles on forests and Hungary. Since 1961, the number of articles indexed by Scopus increased smoothly. The significant increase happened in the 2000s and peaked in 2013 with 100 articles. Similar trends can also be seen in life cycle sustainability analysis, where articles increased significantly from 2010 to 2022 (Biró and Szalmáné Csete, 2023).

Research topics on forest in Hungary were varied from 2010 to 2023 (March). In this bibliometric analysis we did not make a systematic content analysis. However, based on the retrieved database, has shown the climate change mitigation and adaptation issues were the dominant topic. Research on climate change mitigation is multidisciplinary and interdisciplinary field that covers wide range of subjects (environmental sciences, ecology, forestry, environmental science, soil science, biodiversity and conservation, and economic) (Huang et al., 2020).

The increasing number of articles in the forestry research field also showed a similar pattern, where publications increased significantly from 2015 to 2021 (Gao et al., 2022). The European countries that contributed significantly to forestry research were the United Kingdom, France, Germany, Spain, and Italy (Gao et al., 2022; Yuan and Sun, 2021). Forestry and specific topics such as biomass and carbon have grown exponentially in publications since the 2010s (Araujo et al., 2023). Specifically, in the journal *Forest* from MDPI, the number of articles has also shown exponential growth from 2010 (fewer than 100 articles) until 2018 (around 600 articles) (Uribe-Toril et al. 2019). Therefore, research on forestry topics has received much attention from researchers and publishers.

Because the forest or forestry research theme covers broad and diverse fields, no specific topics dominated the top 10 most-cited articles (Table 1). The highest citation was 418 for an article explaining the glacial forests in the European region. Not only the research topic but also the journal varied for each article. However, based on the publication period, the top 10 most-cited articles published ranged from 2000 to 2010, except for one paper published in 2014.

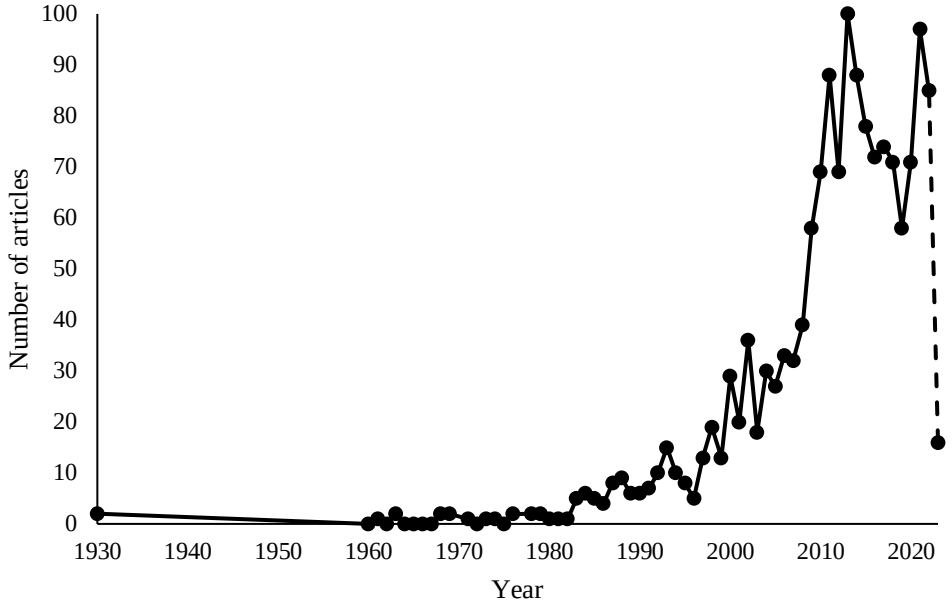

Figure 2. Number of articles on the topic of forests and Hungary

Table 1. Top 10 most-cited articles on the topics of forests and Hungary

Title	Journal	Cited by	Reference
The full-glacial forests of central and south-eastern Europe	Quaternary Research	418	Willis et al. (2000)
Formation of secondary organic aerosols from isoprene and its gas-phase oxidation products through reaction with hydrogen peroxide	Atmospheric Environment	280	Claeys et al. (2004)
Response of plant species richness and primary productivity in shrublands along a north-south gradient in Europe to seven years of experimental warming and drought: Reductions in primary productivity in the heat and drought year of 2003	Global Change Biology	208	Peñuelas et al. (2007)
Diversity of dead wood inhabiting fungi and bryophytes in semi-natural beech forests in Europe	Biological Conservation	200	Ódor et al. (2006)
The economic and environmental performance of miscanthus and switchgrass production and supply chains in a European setting	Renewable and Sustainable Energy Reviews	189	Smeets et al. (2009)
Hydroxydicarboxylic acids: Markers for secondary organic aerosol from the photooxidation of α-pinene	Environmental Science and Technology	181	Claeys et al. (2007)
Root controls on soil microbial community structure in forest soils	Oecologia	180	Brant et al. (2006)
Soil enzyme activity in response to long-term organic matter manipulation	Soil Biology and Biochemistry	179	Kotroczó et al. (2014)
Factors controlling regional differences in forest soil emission of nitrogen oxides (NO and N_2O)	Biogeosciences	177	Pilegaard et al. (2006)
Carabids and forest edge: Spatial pattern and edge effect	Forest Ecology and Management	172	Magura (2002)

From 1936 to March 2023, there were 1,528 documents with the keywords “forest” OR “forestry” AND “Hungary” in the title, abstract, or keywords. Based on the document types, the corpus can be divided into original research articles (1,324 documents), books (1 document), book chapters (35 documents), conference papers (106 documents), review articles (54 documents), and other types (8 documents). For almost nine decades, the contribution of original research articles dominated publications on forests in Hungary at around 86.75%.

Using VOSviewer, we mapped the bibliography and found 821 items in 9 clusters (Figure 3). A different color indicates each cluster. Meanwhile, the variation in the frame size indicates the links' different strengths. For example, the term “Hungary,” with the most enormous frame, has a total link strength of 7,656, with 814 links and 733 occurrences.

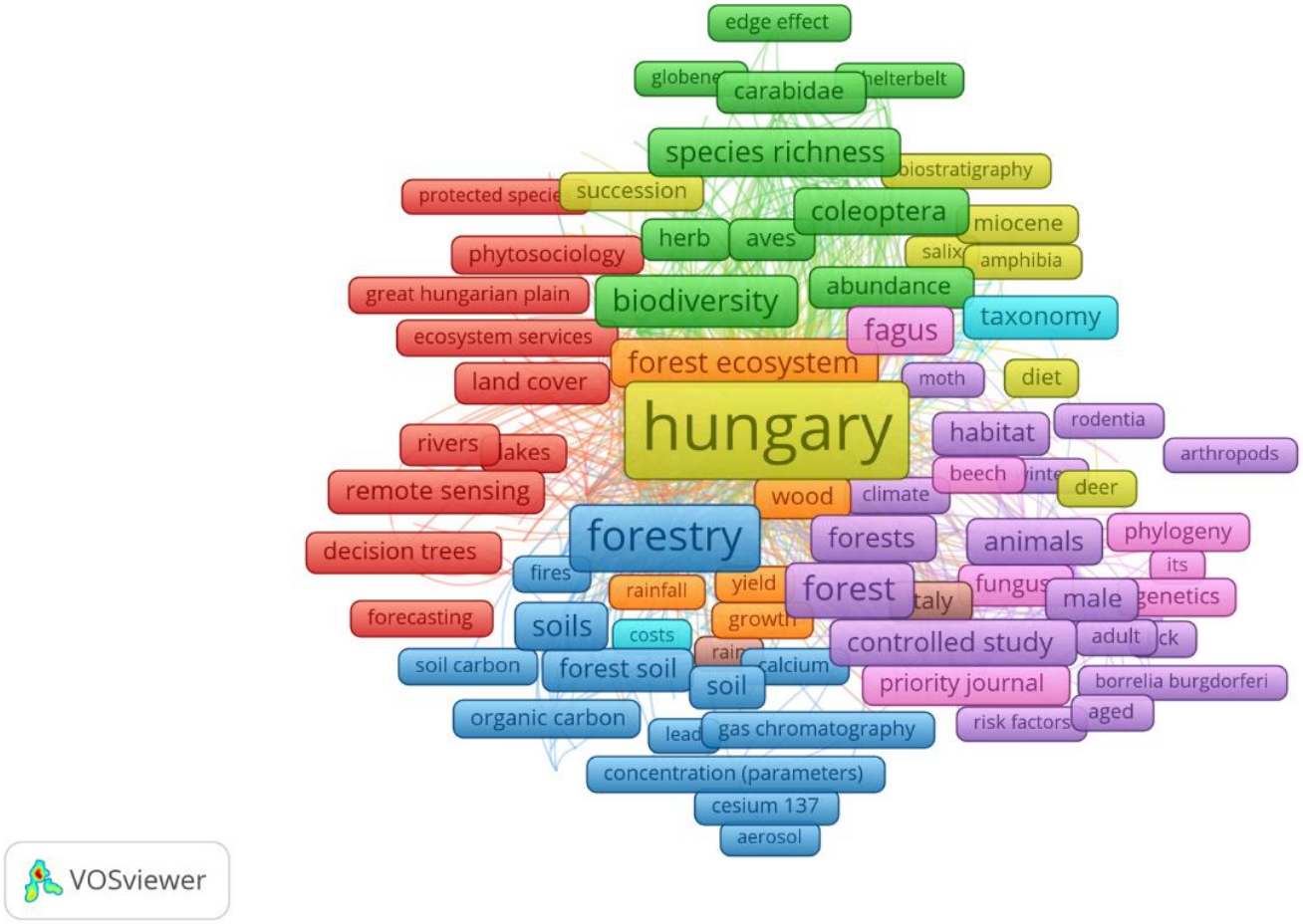

Figure 3. Visualization of VOSviewer on the topics of "forest" OR "forestry" AND "Hungary."

Referring to Figure 3, 1,528 articles on the topics of "forest" OR "forestry" AND "Hungary" have been divided into 9 clusters. The clusters are:

Cluster 1 (158 items/red); the top 3 items were vegetation, land use, and ecosystem (Supplement Figure S1). The items of vegetation were connected to 429 links in 6 clusters, and 75 occurrences were detected. Moreover, the items of land use had 58 occurrences and were linked to 5 clusters (the total link strength was 761), and items of the ecosystem were linked to 4 clusters and had 43 occurrences.

Regarding environmental assessment, items of carbon balance can be found in cluster 1 and were detected in 5 occurrences but do not have links to other items. The item of soil organic carbon is also listed in cluster 1 with five occurrences but does not have a link to other items. This means that either carbon balance or soil organic carbon are potential research areas in the future since only a few researchers have investigated this topic.

Furthermore, the item in cluster 1 related to environmental assessment is environmental protection. This item was observed in 29 occurrences and linked to 5 clusters. In cluster 1, environmental protection is linked to the item land use and conservation of natural resources. Meanwhile, the link to other clusters is biodiversity (cluster 2), forestry (cluster 3), Hungary (cluster 4), ecosystem and forest (cluster 5), and agriculture (cluster 8).

Cluster 2 (130 items/green): The dominant items in cluster 2 were biodiversity, forest management, and species richness (Supplement Figure S2). The occurrence of biodiversity, forest management, and species richness in the articles was 75, 64, and 62, respectively.

From the perspective of environmental assessment, cluster 2 contains the items of environmental assessment (6 occurrences), environmental disturbance (5 occurrences), lowland environment (5 occurrences), and environmental factors (22 occurrences). The first three items had no links to cluster 2 or other clusters. However, the items of environmental factors are linked to Hungary (cluster 4) and climate change (cluster 7).

Cluster 3 (125 items/dark blue); the dominant items in cluster 3 were forestry, soils, and forest soils. Forestry items are found in 235 documents and placed second after the items of Hungary (733 occurrences) (Supplementa Figure S3). Furthermore, the items related to environmental assessment were environmental impact (8 occurrences) and environmental monitoring (22 occurrences). The item of

environmental impact does not have a link to other items. However, environmental impact is linked to Hungary (cluster 4).

The items related to environmental assessment in cluster 3 are carbon (19 occurrences), carbon dioxide (18 occurrences), carbon emissions (6 occurrences), carbon sequestration (14 occurrences), organic carbon (19 occurrences), and soil carbon (10 occurrences). Almost all items, except carbon emissions, have links to items of forestry and Hungary. However, they are not linked despite being similar in the keyword carbon.

Cluster 4 (106 items/yellow), the most significant item in all clusters is Hungary (Supplement Figure S4). It had 733 occurrences and connected to all clusters. Europe (137 occurrences) and Eurasia (93 occurrences) were the following items. Cluster 4 contains environmental changes (7 occurrences), paleoenvironment (18 occurrences), and temperate environment (9 occurrences). All the items were linked to items of Hungary, and only the item paleoenvironment was also linked to paleoecology (cluster 4).

Cluster 5 (76 items/purple); the most prominent items in cluster 5 were forest (115 occurrences), followed by non-human (74 occurrences) and animals (52 occurrences). The item of forest is linked to Hungary (cluster 4), forestry (cluster 3), climate change (cluster 7), biodiversity (cluster 2), and vegetation (cluster 1) (Supplement Figure S5). Regarding environmental assessment topics, this cluster is relatively low and only found 1 item (environmental temperature). The items of environmental temperature are distributed in 5 occurrences and do not have links to other items.

Cluster 6 (63 items/light blue); from 63 items in cluster 6, the dominant item is biomass (34 occurrences). The item of biomass linked to Hungary (cluster 4), vegetation (cluster 1), bioenergy, and biomass production (cluster 6) (Supplement Figure S6). In this cluster, the items are mostly scattered with weak links (fewer than five links to other items).

Cluster 7 (61 items/orange); in cluster 7, the dominant item is climate change (104 occurrences), followed by ecosystem (55 occurrences), and *Fagus sylvatica* (37 occurrences) (Supplement Figure S7). In this cluster, the items related to environmental assessment are also rare. Items of environmental conditions (11 occurrences) linked to the item Hungary (cluster 4).

Cluster 8 (57 items/black, is similar to clusters 6 and 9, and this cluster also shows weak links. In cluster 8, the items Slovakia (45 occurrences), Germany (31 occurrences), Czech Republic (29 occurrences), Romania (28 occurrences), and Austria (26 occurrences) were linked to each other or made a spider web pattern (Supplement Figure S8). However, the item of environmental management (8 occurrences) does not have links to other items.

Cluster 9 (45 items/pink); in cluster 9, the dominant items were tree (35 occurrences), fungi (37 occurrences), and classification (29 occurrences) (Supplement Figure S9). They showed weak links to other items in other clusters. No items related to environmental assessment topics could be found in this cluster.

3.2. Research trends of Poplars in Hungary

In this section, we will elaborate more deeply on poplar species as promising bioenergy sources from forests in Hungary. Referring to Figure 1, we used the search keywords "poplar" AND "Hungary," which showed 109 documents. In contrast, if we used the keywords "poplar" AND "forest" OR "forestry" AND "Hungary," the documents retrieved were 69 articles. Therefore, in this section, we used the keywords "poplar" and "Hungary" to obtain more documents.

Compared to the visualization of "forest" OR "forestry" AND "Hungary," the bibliometric map of the keywords "poplar" AND "Hungary" is more straightforward. There were 3 clusters from 109 documents. However, both bibliometric maps have shown a similarity; that is, the item of Hungary is the biggest and linked to other clusters (Figure S7).

According to Supplement Figure S10, the cluster (which one?) is displayed clearly in 3 groups. There are 33 items divided into 3 clusters, namely, i). Cluster 1 (3 items/red): biomass, deciduous tree, Europe, forestry, Hungary, plantation forestry, plants (botany), populus, populus alba, populus pseudoacacia, tree, and wood. ii). Cluster 2 (10 items/green): article, biodiversity, conservation, floodplain, forest, forests, nonhuman, plantation, robinia, and vegetation. iii). Cluster 3 (10 items/blue): Araneae, deciduous forest, forest-steppe, grassland, invertebrate, poplar, species richness, spider, and vegetation structure.

Using query string TITLE-ABS-KEY((research) AND (poplar)), in the Scopus database can be found 109 documents as review papers worldwide. In the VOSviewer analysis for the co-occurrence of keywords, the review papers have been grouped into four clusters: climate change and biodiversity, biotechnology and pollution, forest management and genetic engineering, and physiology. According to Figure 3, the researchers in Hungary who researched Poplar focused on the topics of climate change (biomass, carbon stock, and sequestration), biodiversity (species composition, vegetation structure, species richness), and forest management (forest, plantation). Furthermore, future researchers could elaborate on the genetic engineering, physiology, and biotechnology of poplar plantations (Figure 4).

Based on bibliographic coupling analysis for the country network in the VOSviewer, the researchers conducting review papers on poplar come from the United States, China, Germany, United Kingdom, Spain, France, and Canada. They have connected to research poplar. Collaborative research with many researchers from various countries is vital to strengthening the network and sharing information related to best practices of poplar plantation management.

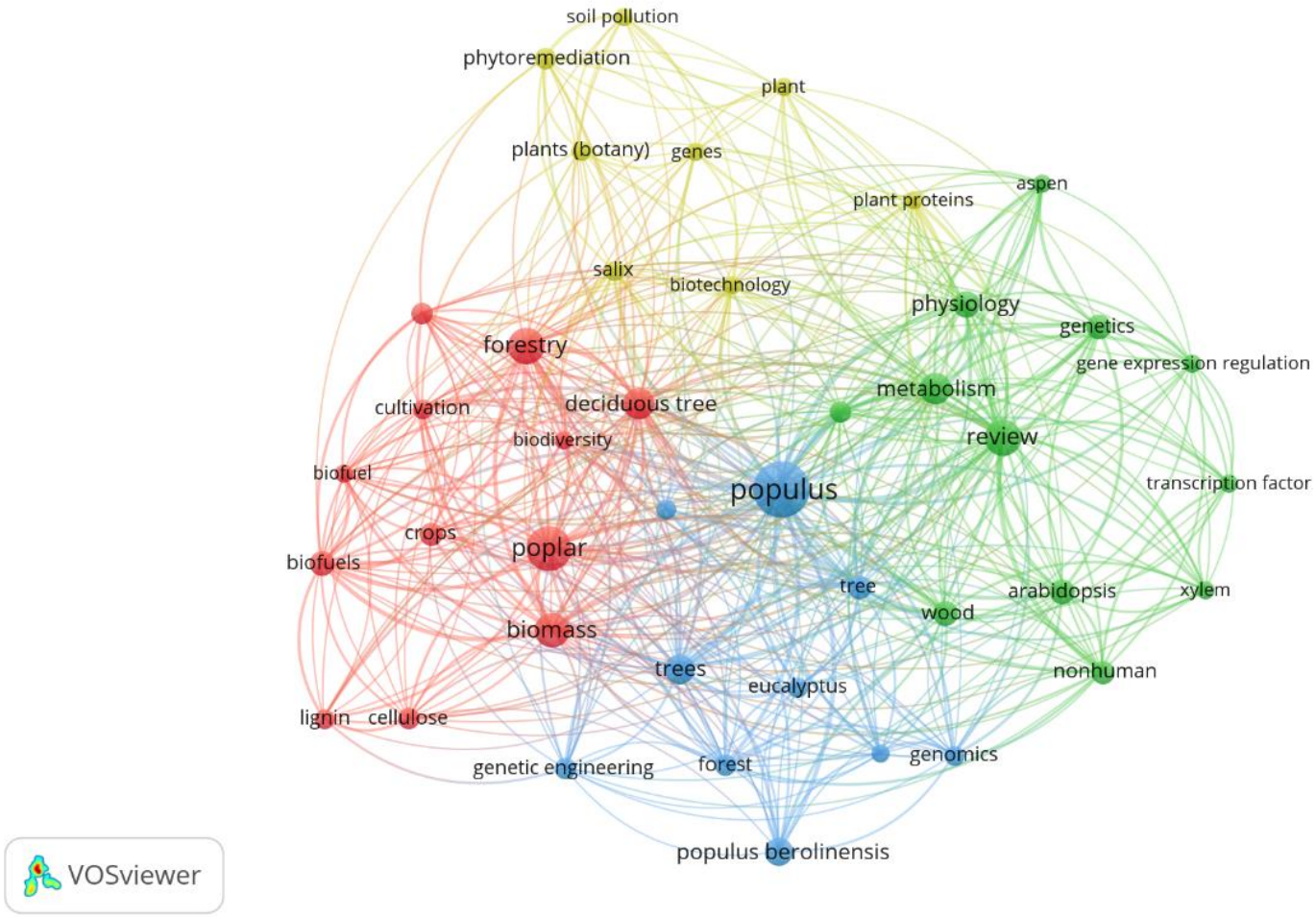

Figure 4. Visualization of worldwide research on poplar

3.3. Research trends of environmental assessment of poplars in Hungary

Surprisingly, based on VOSviewer analysis for the keywords "poplar" AND "Hungary," there is no item-related environmental assessment, either as carbon or a life cycle assessment. Referring to Figure 1, the number of documents retrieved for the keywords "poplar" AND "carbon" AND "Hungary" were ten articles. However, searching using the keywords "poplar" AND "life cycle assessment" OR "LCA" AND "Hungary" retrieved 1 article. Therefore, the research topic on the environmental assessment of poplar plantations in Hungary still has potential for future research.

The keywords "poplar" AND "carbon" AND "Hungary" can be visualized using VOSviewer, while the keywords "poplar" AND "life cycle assessment" OR "LCA" AND "Hungary" cannot be analyzed. Based on the VOSviewer analysis, there are 2 clusters and ten items. Items in cluster 1 were biodiversity, environmental monitoring, forest, Hungary, populus, and vegetation. Items in cluster 2 were climate change, drought, forest steppe, and temperature.

Similar to the analysis by the VOSviewer in the previous section, whether searching for poplar in Hungary or the environmental assessment of poplar in Hungary, the most prominent item is Hungary. Although this section has the smallest number of items (10 items), these items are linked to each other and displayed as a spider web pattern (Figure S8).

According to Supplement Figure S11, the issue of forest carbon in Hungary appears to have been receiving attention since 2010. Based on the articles downloaded from the Scopus database, the first article listed in Scopus related to forest carbon was published in 1997. The article "Forest health status in Hungary" was published in the Journal of Environmental Pollution. Although the article emphasized monitoring forest health, the author suggested further intensive research on climatic factors, air pollution effects, and carbon and nutrient cycles (Szepesi 1997).

In 1997, the United Nations announced the Kyoto Protocol, and several countries, including Hungary, committed to reducing greenhouse gas emissions (United Nations, 1998). Referring to Figure 12, in the early 2010s, the research focused on environmental monitoring, forest, populus, and drought. In 2016–2018, the research emphasized the items of Hungary and temperature. Furthermore, since 2019, the research items were forest-steppe, vegetation, biodiversity, and climate change.

In the global context, using query string TITLE-ABS-KEY((lca OR life cycle assessment) AND (poplar)), there was one review paper. This review paper elaborated 26 studies on bioenergy production from poplar and willow from 1990-2009 (Djomo et al., 2011). It indicates that the research theme on the life cycle assessment of poplar plantations and its utilization is still promising in the future to support climate change mitigation actions.

3.4. Limitation of study

The findings of this research deserve severe consideration and provide direction for future research on the environmental assessment of poplar plantations in Hungary. However, we also recognize that there are some limitations to this study. First, the bibliometric data used were derived only from the Scopus database; therefore, some related documents that Scopus does not index may have been omitted from the analysis. For example, the article with the keywords "life cycle assessment" OR "LCA" AND "poplar" AND "Hungary" for title, abstract, and keywords on the Scopus database produced only one article, but it did not mean that research on life cycle assessment for poplars in Hungary was rare. We tried to elaborate the search in the Google Scholar database with the keywords "life cycle assessment" OR "LCA" AND "poplar" AND "Hungary" from 1960–2022 and found 198 articles. The keywords in the Google Scholar database are not limited to title, abstract, and keywords. However, articles in the Google Scholar database are mixed between peer-reviewed and non-peer-reviewed documents.

Second, we used a feature search within article titles, abstracts, and keywords to search for documents in the Scopus database. The article related to LCA in Hungary's forestry sector but not listed in the article title, abstract, or keywords cannot be analyzed in this paper. For instance, the article titled "Environmental life cycle assessment of arable crop production technologies compared to different harvesting work systems in short rotation energy plantations" published in the journal Acta Silvatica et Lignaria Hungarica (indexed in Scopus database) volume 15 number 2 (2019) was not listed in our bibliometric analysis. This article did not match the keywords "life cycle assessment" OR "LCA" AND "poplar" AND "Hungary." However, the article discussed comparing the life cycle assessment of crop production and poplar plantations in Hungary (Polgár et al., 2019).

4. CONCLUSION

Bibliometric analysis in this research has shown some critical findings. First, the more documents we collected, the more items and clusters we identified. From 1,528 documents, 9 clusters with 821 items have been produced. Moreover, in other searches, 109 documents and ten documents have produced 3 clusters (33 items) and 2 clusters (10 items), respectively. Second, Hungary was the most prominent item and linked to other clusters from generic to specific topics/keywords. It demonstrated that the authors searched the title, abstract, and keywords using Hungary. It is essential to emphasize the research areas in Hungary.

The last conclusion is that the research theme on environmental assessment in a poplar plantation in Hungary still needs serious attention. The research on environmental assessment, either carbon sequestration to absorb emissions from the atmosphere or a life cycle assessment to describe the potential emissions released to the environment, is vital to support climate change action. So far, there appears to be no research in Hungary. This lack of knowledge should be addressed by researching the environmental assessment of the poplar in Hungary and publishing it in a journal indexed by Scopus or Web of Science.

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REFERENCES

Aleixandre-Benavent, R., Aleixandre-Tudó, J.L., Castelló-Cogollos, L., Aleixandre, J.L., 2018. Trends in global research in deforestation. A bibliometric analysis. *Land use policy 72,* pp.293–302.
DOI: 10.1016/j.landusepol.2017.12.060

Araujo, E.C.G., Sanquetta, C.R., Dalla Corte, A.P., Pelissari, A.L., Orso, G.A., Silva, T.C., 2023. Global review and state-of-the-art of biomass and carbon stock in the Amazon. *Journal of Environmental Management 331,* p.117251.
DOI: 10.1016/j.jenvman.2023.117251

Biró, K., Szalmáné Csete, M., 2023. Revealing the concept of sustainability in life cycle assessment. *Ecocycles 9,* pp.49–58.
DOI: 10.19040/ecocycles.v9i2.277

Brant, J.B., Myrold, D.D., Sulzman, E.W., 2006. Root controls on soil microbial community structure in forest soils. *Oecologia 148,* pp.650–659.
DOI: 10.1007/s00442-006-0402-7

Broadus, R.N., 1987. Toward a Definition of "Bibliometric." *Scientometrics 12,* pp.373–379.
DOI: 10.1007/BF02016680

Cheng, P., Tang, H., Dong, Y., Liu, K., Jiang, P., Liu, Y., 2021. Knowledge mapping of research on land use change and food security: A visual analysis using citespace and vosviewer. *International Journal of Environmental Research and Public Health 18,* p.13065.
DOI: 10.3390/ijerph182413065

Claeys, M., Szmigielski, R., Kourtchev, I., Van Der Veken, P., Vermeylen, R., Maenhaut, W., Jaoui, M., Kleindienst, T.E., Lewandowski, M., Offenberg, J.H., Edney, E.O., 2007. Hydroxydicarboxylic acids: Markers for secondary organic aerosol from the photooxidation of α-pinene. *Environmental Science & Technology 41(5),* pp.1628–1634.

DOI: 10.1021/es0620181

Claeys, M., Wang, W., Ion, A.C., Kourtchev, I., Gelencsér, A., Maenhaut, W., 2004. Formation of secondary organic aerosols from isoprene and its gas-phase oxidation products through reaction with hydrogen peroxide. *Atmospheric Environment 38(25),* pp.4093–4098.
DOI: 10.1016/j.atmosenv.2004.06.001

Cosofret, C., Bouriaud, L., 2019. Which silvicultural measures are recommended to adapt forests to climate change? A literature review. *Bulletin of the Transilvania University of Brasov, Series II: Forestry, Wood Industry, Agricultural Food Engineering 12,* pp.13–34.
DOI: 10.31926/but.fwiafe.2019.12.61.1.2

Di Franco, C.P., Lima, G., Schimmenti, E., Asciuto, A., 2021. Methodological approaches to the valuation of forest ecosystem services: An overview of recent international research trends. *Journal of Forest Science (Prague) 67,* pp.307–317.
DOI: 10.17221/13/2021-JFS

Djomo, S.N., Kasmioui, O.E., Ceulemans, R., 2011. Energy and greenhouse gas balance of bioenergy production from poplar and willow: a review. *GCB Bioenergy 3,* pp.181-197.
DOI: 10.1111/j.1757.2010.01073.x

Ellegaard, O., Wallin, J.A., 2015. The bibliometric analysis of scholarly production: How great is the impact?. *Scientometrics 105,* pp.1809-1831.
DOI: 10.1007/s11192-015-1645-z

FAO, 2019. FAO'S Work on Climate change. United Nations Climate Change Conference 2019. Rome.

Gao, W., Qiu, Q., Yuan, C., Shen, X., Cao, F., Wang, Guibin, Wang, Guangyu, 2022. Forestry Big Data: A Review and Bibliometric Analysis. *Forests 13,* p.1549.
DOI: 10.3390/f13101549

Hamidah, I., Sriyono, Hudha, M.N., 2020. A Bibliometric Analysis of Covid-19 Research Using VOSviewer. *Indonesian Journal of Science & Technology 5,* pp.209–216.
DOI: 10.17509/ijost.v5i2.24522

Huang, L., Zhou, M., Jie, L., Chen, K., 2020. Trends in global research in forest carbon sequestration: A bibliometric analysis. *Journal of Cleaner Production 252,* p.119908.
DOI: 10.1016/j.jclepro.2019.119908

Hutchinson, J.J., Campbell, C.A., Desjardins, R.L., 2007. Some perspectives on carbon sequestration in agriculture. *Agricultural and Forest Meteorology 142*, pp.288–302.
DOI: 10.1016/j.agrformet.2006.03.030

IPCC, 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

Jankovský, M., García-Jácome, S.P., Dvořák, J., Nyarko, I., Hájek, M., 2021. Innovations in forest bioeconomy: A bibliometric analysis. *Forests 12,* p.1392.
DOI: 10.3390/f12101392

Klapka, O., Slabý, A., 2020. Visual analysis of search results in Scopus database focused on sustainable tourism. *Czech Journal of Tourism 9,* pp.41–53.
DOI: 10.2478/cjot-2020-0003

Kotroczó, Z., Veres, Z., Fekete, I., Krakomperger, Z., Tóth, J.A., Lajtha, K., Tóthmérész, B., 2014. Soil enzyme activity in response to long-term organic matter manipulation. *Soil Biology and Biochemistry 70,* pp.237–243.
DOI: 10.1016/j.soilbio.2013.12.028

Leal, A.I., Correia, R.A., Palmeirim, J.M., Bugalho, M.N., 2019. Is research supporting sustainable management in a changing world? Insights from a Mediterranean silvopastoral system. *Agroforestry Systems 93,* pp.355–368.
DOI: 10.1007/s10457-018-0231-9

Li, J., Mao, Y., Ouyang, J., Zheng, S., 2022. A Review of Urban Microclimate Research Based on CiteSpace and VOSviewer Analysis. *International Journal of Environmental Research and Public Health 19,* p.4741.
DOI: 10.3390/ijerph19084741

Magura, T., 2002. Carabids and forest edge: spatial pattern and edge effect. *Forest Ecology and Management 157,* pp.23–37.
DOI: 10.1016/S0378-1127(00)00654-X

Murdiyarso, D., Purbopuspito, J., Kauffman, J.B., Warren, M.W., Sasmito, S.D., Donato, D.C., Manuri, S., Krisnawati, H., Taberima, S., Kurnianto, S., 2015. The potential of Indonesian mangrove forests for global climate change mitigation. *Nature Climate Change 5,* pp.1089–1092.
DOI: 10.1038/nclimate2734

Nam, J., Bae, H.M., Lee, C.H., Lee, G.S., 2022. An Analysis on the Long-term Management of Urban Tree Carbon Reduction "Forestry Inventory Analysis" towards Climate Change Adaptation. *Journal of People, Plants, and Environment 25,* pp.759–772.
DOI: 10.11628/ksppe.2022.25.6.759

National Food Chain Safety Office, 2016. Forest Resources and Forest Management in Hungary 2015. National Food Chain Safety Office, Budapest, Hungary.

Ódor, P., Heilmann-Clausen, J., Christensen, M., Aude, E., van Dort, K.W., Piltaver, A., Siller, I., Veerkamp, M.T., Walleyn, R., Standovár, T., van Hees, A.F.M., Kosec, J., Matočec, N., Kraigher, H., Grebenc, T., 2006. Diversity of dead wood inhabiting fungi and bryophytes in semi-natural beech forests in Europe. *Biological Conservation 131,* pp.58–71.
DOI: 10.1016/j.biocon.2006.02.004

Peñuelas, J., Prieto, P., Beier, C., Cesaraccio, C., de Angelis, P., de Dato, G., Emmett, B.A., Estiarte, M., Garadnai, J., Gorissen, A., Láng, E.K., Kröel-dulay, G., Llorens, L.,

Pellizzaro, G., Riis-nielsen, T., Schmidt, I.K., Sirca, C., Sowerby, A., Spano, D., Tietema, A., 2007. Response of plant species richness and primary productivity in shrublands along a north-south gradient in Europe to seven years of experimental warming and drought: Reductions in primary productivity in the heat and drought year of 2003. *Global Change Biology 13,* pp.2563–2581.
DOI: 10.1111/j.1365-2486.2007.01464.x

Pilegaard, K., Skiba, U., Ambus, P., Beier, C., Brüggemann, N., Brüggemann, B., Butterbach-Bahl, K., Dick, J., Dorsey, J., Duyzer, J., Gallagher, M., Gasche, R., Horvath, L., Kitzler, B., Leip, A., Pihlatie, M.K., Rosenkranz, P., Seufert, G., Vesala, T., Westrate, H., Zechmeister-Boltenstern, S., 2006. Factors controlling regional differences in forest soil emission of nitrogen oxides (NO and N_2O). *Biogeosciences 3,* pp.651–661.
DOI: 10.5194/bg-3-651-2006

Polgár, A., Horváth, A., Mátyás, K.S., Horváth, A.L., Rumpf, J., Vágvölgyi, A., 2018. Carbon footprint of different harvesting work systems in short rotation energy plantations. *Acta Silvatica et Lignaria Hungarica 14,* pp.113–126.
DOI: 10.2478/aslh-2018-0008

Polgár, A., Kovács, Z., Fodor, V.E., Bidló, A., 2019. Environmental Life-Cycle Assessment of Arable Crop Production Technologies Compared to Different Harvesting Work Systems in Short Rotation Energy Plantations. *Acta Silvatica et Lignaria Hungarica 15,* pp.55–68.
DOI: 10.2478/aslh-2019-0005

Schiberna, E., Borovics, A., Benke, A., 2021. Economic modelling of poplar short rotation coppice plantations in Hungary. *Forests 12(5),* p.623.
DOI: 10.3390/f12050623

Singh, S., 2022. "Forest fire emissions: A contribution to global climate change." *Frontiers in Forests and Global Change 5,* p.925480.
DOI: 10.3389/ffgc.2022.925480

Smeets, E.M.W., Lewandowski, I.M., Faaij, A.P.C., 2009. The economical and environmental performance of miscanthus and switchgrass production and supply chains in a European setting. *Renewable and Sustainable Energy Reviews 13,* pp.1230-1245.
DOI: 10.1016/j.rser.2008.09.006

Soegoto, H., Soegoto, E.S., Luckyardi, S., Rafdhi, A.A., 2022. A Bibliometric Analysis of Management Bioenergy Research Using Vosviewer Application. *Indonesian Journal of Science and Technology 7,* pp.89–104.
DOI: 10.17509/ijost.v7i1.43328

Szepesi, A., 1997. Forest Health Status in Hungary. *Environmental Pollution 98,* pp.393–398.
DOI: 10.1016/S0269-7491(97)00147-4

United Nations, 1998. Kyoto Protocol to the United Nations Framework Convention on Climate Change.

Uribe-Toril, J., Ruiz-Real, J.L., Haba-Osca, J., Valenciano, J. de P., 2019. Forests' first decade: A bibliometric analysis overview. *Forests 10,* p.72.
DOI: 10.3390/f10010072

van Eck, N.J., Waltman, L., 2023. VOSviewer. Retrieved from: https://www.vosviewer.com/download (accessed on 21 March 2023).

van Eck, N.J., Waltman, L., 2010. Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics 84,* pp. 523–538.
DOI: 10.1007/s11192-009-0146-3

Verma, P., Ghosh, P.K., 2023. The economics of forest carbon sequestration: a bibliometric analysis. *Environment, Development and Sustainability*.
DOI: 10.1007/s10668-023-02922-w

Willis, K.J., Rudner, E., Sümegi, P., 2000. The full-glacial forests of central and southeastern Europe. *Quaternary Research 53,* pp.203–213.
DOI: 10.1006/qres.1999.2119

World Meteorological Organization, 2021. State of the Global Climate 2020. World Meteorological Organization, Geneva.

Xie, J., Zhang, G., Li, Y., Yan, X., Zang, L., Liu, Q., Chen, D., Sui, M., He, Y., 2023. A Bibliometric Analysis of Forest Gap Research during 1980–2021. *Sustainability 15,* p.1994.
DOI: 10.3390/su15031994

Yuan, B.Z., Sun, J., 2021. Research trend and status of forestry based on essential science indicators during 2010–2020: A bibliometric analysis. *Applied Ecology & Environmental Research 19,* pp.4941–4957.
DOI: 10.15666/aeer/1906_49414957

Zhang, X., Estoque, R.C., Xie, H., Murayama, Y., Ranagalage, M., 2019. Bibliometric analysis of highly cited articles on ecosystem services. *PLoS One 14,* p.e0210707.
DOI: 10.1371/journal.pone.0210707

Zhang, Y., Fei, X., Liu, F., Chen, J., You, X., Huang, S., Wang, M., Dong, J., 2022. Advances in Forest Management Research in the Context of Carbon Neutrality: A Bibliometric Analysis. *Forests 13,* p.1810.
DOI: 10.3390/f13111810