Bibliometric Analysis of Forest Gross Primary Productivity Research Trends Over the Past 20 Years

Yueming Chen[1], ZhengHong Xie[1*], Luo Xu[1], Biao Zheng[2], and Caiying Huang[3]

[1]Guangdong Eco-Engineering Polytechnic, Guangzhou, 510642, China;
[2]Hunan University of Finance and Economics, Changsha, 410205, China;
[3]College of Civil Engineering, Jiaying University, Meizhou, , 514015, China

*Corresponding author:zhenghong9527@foxmail.com

Abstract. With the intensification of human activities and the impact of climate change, among others, gross primary productivity (GPP) is one of the most basic life activities of forest ecosystems and one of the important factors to maintain ecosystem stability. Therefore, the study of changes in forest primary productivity and the factors influencing is essential for understanding the health and sustainability of ecosystems. This paper analyses the worldwide research dynamics on forest primary productivity in the period from 1990 to 2022. A bibliometric analysis of 1534 articles was conducted. The aim of this study is to conduct a comprehensive analysis of global forest primary productivity research through a bibliometric approach to identify research hotspots, trends and future research directions in this area. Throughout the research history, there were three main research hotspots, which were forest GPP estimation model, optimization of the GPP model, and GPP model based on remote sensing and FLUXNET dataset.

Keywords: Forest; Gross primary productivity; Bibliometrics; Citespace

1 INTRODUCTION

Forest ecosystem carbon cycle models are effective tools for studying and predicting forest carbon fluxes and the mechanisms of their cycling processes [1]. Forests cover 31% of the earth's land area and play a key role in addressing climate change and achieving strategic carbon neutrality targets, conserving terrestrial biodiversity, enhancing ecosystem services, and building resilient and sustainable economies [2].

Increases in forest gross primary productivity (GPP) not only improve the health and stability of forest ecosystems, but also contribute too many important ecosystem services, such as soil conservation, water resources, and climate regulation. At the same time, it provides the energy and nutrients needed by other organisms within the ecosystem. This process not only supports biodiversity within the forest ecosystem, but also provides us with many important resources and services.

As research on forest GPP, it is necessary to conduct a systematic bibliometric analysis of this research area. Bibliometrics is a discipline that combines mathematics, science and statistics [3].

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In this study, we conducted a bibliometric analysis to provide an overview of scientific publications in forest GPP during last 20 years. This will help scholars who wish to work on ways to achieve carbon neutrality goals with forest GPP management to better understand the overview and cutting-edge progress in the field.

2 Materials and Methods

2.1 Data source

The study was based on the core collection of Web of Science database, and the search topics included both "gross primary production" and "forest". The search formula was TS="gross primary production" and forest*. We added the time condition of publication, and the time period included in the core collection of Web of science was 1900-2022. 1593 articles were retrieved, and 1534 articles remained after excluding the invalid and de-duplicated articles.

2.2 Method

Citespace software can clearly and accurately interpret information on trends, research frontiers, and research hotspots in a particular field of knowledge [3]. CiteSpace was used for the study of 1534 articles on forest GPP, because of its good visualization. The full records of articles and references cited were exported, and the number of articles was counted based on the statistics in web of science and Excel.

3 Results and Discussion

3.1 Analysis of the pattern of change in the volume of literature

The change in the number of articles was plotted according to the year of publication of the 1534 retrieved articles on GPP and forest (Figure 1). Based on the analysis of the number of publications in Figure 1, it is possible to roughly divide the research into 3 phases. The first phase: 1992-2003 was the initial phase, with low annual publication volume, slow growth and fluctuating growth rate. In the 20th century, due to the underdevelopment of the Internet and other technologies and the world environment, it was not until the end of the century that there was a decrease in the number of articles published. The second phase: 2004-2011 was a period of rapid growth, during which the number of publications increased significantly except for some minor fluctuations. The growth rate is relatively stable thanks to the rapid spread of the Internet and the development of remote sensing, as well as the explosion of technology to pay more attention to the environment. The third phase: 2012-present is the explosive growth phase, excluding 2016 and 2018 growth rate is negative other than positive growth. Among them, the United Nations Strategic Plan for Forests (2017-2030) was considered and adopted by the 71st session of the United Nations General Assembly in April 2017, which is the first global forest development strategy formulated on behalf of the United Nations.

The agreement, reached at the climate change conference in Glasgow in November 2021, demonstrates the international community's commitment to forestry. It is therefore speculated that the increasing international attention to ecology has led to a surge in the number of publications in recent years. Due to the statistical time of 2022, the statistics of that year are not representative.

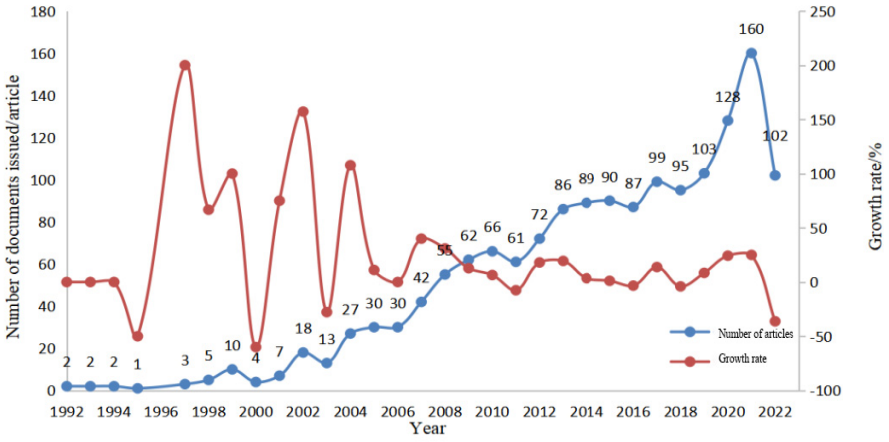

Fig. 1. about gross primary production and forest Change in the number of issued articles.

3.2 Research power

The countries with more than 70 publications were labeled to show 15 countries in total, resulting in the international cooperation relationship map (Figure 2) and the information table of research strength of 15 countries (Table 1).

Combining the table figure 1 and table 2, it can be seen that (1) The literature analysis of About gross primary production and forest shows that the U.S. is the world leader in research capacity, with 681 publications or co-publications by U.S. scholars, the earliest of which was published in 1992, surpassing the second place of China with 192 publications, but Japan is the highest in the centrality comparison, indicating the close cooperation between Japan and other countries in the world. (2) The top two in terms of centrality are Japan and the Netherlands, and it is well known that Japan is an island nation with scarce forest resources and almost all timber has to be imported (3) China research started late, and the first international literature appeared in 2004, and China ranked second in the world according to the number of literatures. However, the number of cited papers and h-index of our country are lower than the first and third place, which further indicates that there is still room for improvement in this field, and the quality of research should be improved along with the quantity. Among these 15 countries, there are only two Asian countries, namely Japan and China. Only one developing country is China, and the top 4 countries are all rich in forest resources and have strong research strengths, thus indicating that research on forest primary productivity is strongly related to geography and research strengths.

Fig. 2. International partnership netview.

Table 1. Information sheet of scientific research strength

Number	Frequency	Country	Year of first publication	Centrality	Cited frequency	h-index
1	675	USA	1992	0.12	49893	115
2	485	CHIAN	2004	0.06	12958	55
3	196	GERMANY	2000	0.09	20754	64
4	170	CANADA	2000	0.06	10565	53
5	159	JAPAN	2002	0.24	7644	47
6	154	FRANCE	2000	0.14	16473	55
7	127	ITALY	2000	0.16	15248	45
8	115	AUSTRALIA	1998	0.05	8346	44
9	97	FINLAND	2000	0.02	9677	35
10	91	SPAIN	2004	0.06	7139	37
11	84	SWEDEN	1998	0.08	8670	34
12	81	NETHERLANDS	2000	0.19	9341	42
13	75	BELGIUM	1999	0.11	10824	38
14	72	ENGLAND	1998	0.11	7777	35
15	70	SWITZERLAND	2004	0.12	7621	34

Centrality*, or intermediary centrality, refers to the number of times a node acts as the shortest bridge between two other nodes; the more times a node acts as an intermediary, the greater its intermediary centrality.

3.3 Research process

As shown in Figure 3, the analysis yields a broad development of research related to forest primary productivity.

(1) The key words of the keywords of the 1990s are Climate, productivity, CO_2, exchange, carbon dioxide, deciduous, climate change, eddy covariance and photosynthesis in 1996-1997. Eddy covariance is a currently popular micrometric method for directly observing the exchange of gases, energy and momentum between ecosystems and the atmosphere. The theoretical basis of the vorticity correlation technique was established by Reynolds in 1895[4]. The vorticity correlation method is currently the most direct and the most rapidly developing theoretical and technical micrometeorological method for determining the net CO_2 exchange (NEE) between the atmosphere and vegetation communities, and is widely accepted and recognized by the micrometeorological and ecological communities. It is noteworthy that net primary production (NPP) appears for the first time in the 1998-1999 time slices. This illustrates that the study moved from macro to micro level and the forest GPP prototype appeared [5].

(2) The key words at the beginning of the 21st century were respiration, carbon. By 2000-2001, gross primary production (GPP) emerged as a buzzword due to the international community's interest in ecological civilization. Flux, forest, carbon dioxide exchange, leaf area index, net ecosystem exchange, soil respiration, ecosystem respiration, People deepen their research on GPP.

(3) In the 2008-2009 slices, satellites made their debut, which in combination with satellites allowed us to raise the level of research to that of outer space, independent of natural conditions and geopolitical influences. The scientific results are more objective and accurate.

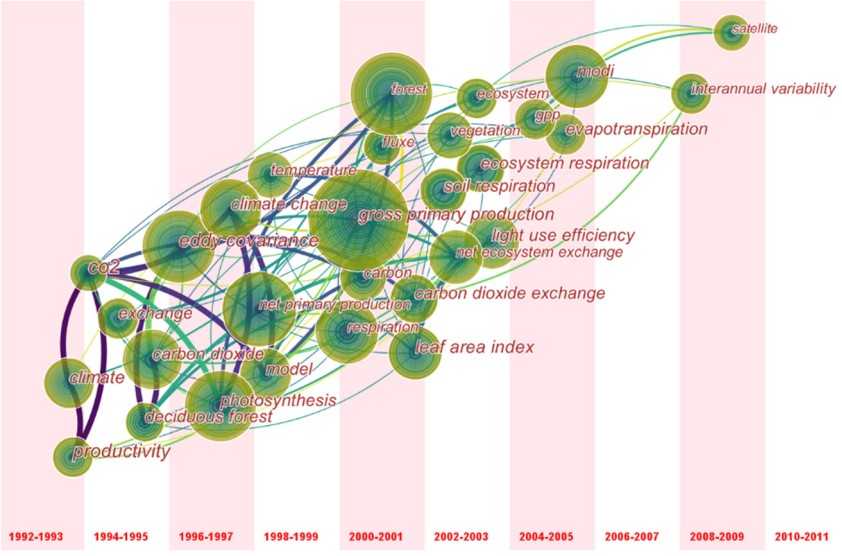

Fig. 3. Gross primary production and forest Keyword network diagram (Timezone).

3.4 Research Frontier Analysis.

Suddenness refers to the steep increase in the number of citations for a particular article in a certain period of time. The higher the number of citations, the greater the number of relevant studies appearing in the period, so the recent suddenness can represent the research frontier to a certain extent. In this paper, we screened the 25 most emergent papers and selected 10 of them with the most recent emergent phase, as shown in Table 2 (each bar represents a year, and the thicker bars represent the emergent period), as the current research frontier.

Table 2. Recent emergence of literature on gross primary production and forest research.

Reference information	Published	Burst	Start time	End time	1992-2022 From 1992-2022
Wu CY, 2010, REMOTE SENS	2010	15.84	2012	2015	
Guanter L, 2014, P NATL ACAD SCI USA, V111, P0, DOI	2014	23.05	2014	2019	
Yang X, 2015, GEOPHYS RES LETT, V42, P2977, DOI	2015	16.52	2016	2021	
Porcar-Castell A, 2014, J EXP BOT, V65, P4065, DOI	2014	16.24	2016	2019	
Anav A, 2015, REV GEOPHYS, V53, P785, DOI	2015	15.73	2016	2021	
Sun Y, 2017, SCIENCE, V358, P0, DOI	2017	18.94	2018	2022	
Badgley G, 2017, SCI ADV, V3, P0, DOI	2017	17.2	2018	2022	
Tramontana G, 2016, BIOGEOSCIENCES, V13, P4291, DOI	2016	16.61	2018	2022	
Li X, 2018, GLOBAL CHANGE BIOL, V24, P3990, DOI	2018	15.49	2018	2022	
Pastorello G, 2020, SCI DATA, V7, P0, DOI	2020	17.58	2020	2022	

The current research frontiers are summarized in Table 2 and related literature in the following 3 areas.

(1) Exploration of forest GPP estimation models. GPP is defined as the total rate of carbon fixation during plant photosynthesis and is important for carbon cycle and climate change studies. To provide a new direction for international exploration of the ecological environment, remote sensing and eddy covariance data were used to propose a more accurate estimation model for prediction by comparing a large amount of analytical data [6-7].

(2) The model is further optimized for expansion. After the continuous development of current models for GPP estimation is not satisfactory, so a new round of research fever began, the research expanded to forest GPP more researchers further proposed new supporting evidence such as by Sellers proved that NIRV and GPP are closely related, and solar-induced chlorophyll fluorescence (SIF) remote sensing satellite has new breakthroughs, people have a deeper understanding of the carbon cycle and climate [8].

(3) model based on FLUXNET dataset and remote sensing satellites. In recent years, there has been an emerging trend of using FLUXNET data and combining it with meteorological remote sensing for GPP modeling [9-11]. With the increase of global eddy covariance data sets and remote sensing data, it provides an opportunity for scholars to study forest GPP in long time series and multi-scale.

3.5 Cluster Analysis

The frequent co-citations indicate that they share a common and relevant research theme, so the co-citation analysis can be used to cluster related references according to the similarity of content, and thus to analyze the research hotspots in this field [12]. In this paper, 1534 articles were clustered in three years as a slice, resulting in 15 clusters, and the cluster names were calculated by LLR (Log-likelihood Ratio) algorithm, and displayed in Timeline view, with each node representing a literature, and the lines between nodes representing their common cited relationships, resulting in a network diagram of citation clustering (Figure 4).

In this clustering, the Q value (Modularity clustering module value) of 0.8291 represents a significant clustering structure and the S value (Silhouette) of 0.9213 indicates a high confidence level of clustering. The top 5 clusters are selected for specific analysis of the articles.

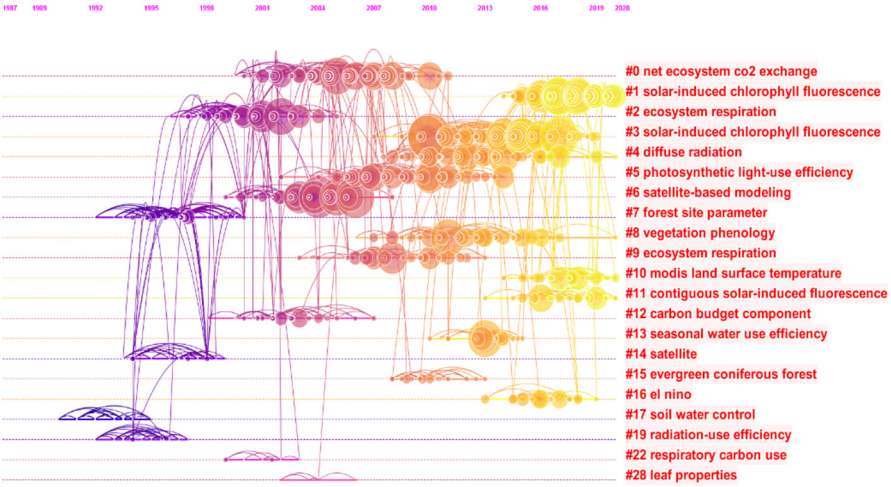

Fig. 4. Network diagram of citation clustering (Timeline).

Tag #0 The labels of this cluster mainly indicate that the eddy covariance technique measures the balance between net ecosystem exchange (NEE) of CO_2, carbon released and taken up by ecosystem respiration (Reco) and GPP [13]. Ankur et al. used 23 gap-filling methods to estimate GPP and RE from flux tower data, and the results showed good agreement between the methods on annual and seasonal scales [14]. While Lasslop et al. introduced an algorithm that makes the model more accurate and provides performance [13]. The articles in this label were published mainly between 2000-2010 and focuses on measuring the net ecosystem exchange of CO_2 and supplementing and comparing models to achieve

Tag #1 is related to solar-induced chlorophyll fluorescence, which was published relatively recently. Badgley et al. report a new approach for quantifying the near-infrared reflectance of terrestrial vegetation, which provides a foundation for a new approach to estimate GPP accurately [8]. The Orbiting Carbon Observatory-2 (OCO-2) SIF showed strong correlations with tower GPP at both mid-day and daily timescales [15].

Tag #2 This tag indicates that research has focused primarily on the respiratory level of ecosystems and that long-term studies of gas exchange between the biosphere and the atmosphere can help fill knowledge gaps and build stronger predictive capabilities. It is in this context that the EUROFLUX project was established citing [16]. In 2001, eddy covariance data were typically reported every half hour with the aim of collecting data 24 hours per day and 365 days per year. However, due to system failure or missing data, the average data availability in a year is only 65%, requiring poor data [17].

Tag #3 This tag shares the same focus on solar-induced chlorophyll fluorescence as #1, and these papers were published relatively close to each other, so the general direction of research is similar, as in Sun [18] and Zhang [19]. Yang et al. found that ground-based evidence that SIF is directly related to both photosynthetically active radiation and light use efficiency (LUE) and thus GPP [20]. Anav et al. reported that there is no GPP model dataset that perfectly matches the global, and this study suggests that more

time is needed to observe the new breakthroughs in infrastructure that are still needed [21].

Tag #4 In addition, changes in scattered radiation are in turn closely related to the photosynthesis of plants, thus affecting the carbon source status of the ecosystem. Especially since the industrial revolution, the increasingly serious atmospheric pollution, the change of atmospheric composition content, aerosol particles increase and other environmental problems have brought a great impact on scattered radiation, has attracted the great attention of scholars at home and abroad. Scattered radiation studies have been reported more frequently abroad, while most of the studies on scattered radiation in China are short-term or discontinuous observations [22]. The papers on this label used MODIS to assist in studying GPP. It has been shown that improving the leaf-to-canopy scaling and the values of those model parameters that control the LUE has a large effect on estimating GPP [23].

4 Conclusion

This paper analyzes the current research on forest primary productivity in the world by conducting an econometric analysis of the literature search related to forest GPP.

Recent research on gross primary production and forest has been done mainly by ecologists in North America, China, and Germany, and there is an increasing trend. The research direction is mainly trying to estimate by building a mathematical model, combined with the development of satellite remote sensing in the 21st century, and the continuous supplementation of the estimation model. On the research frontier, there are mainly 3 aspects of forest GPP estimation model exploration, model further optimization extension, model based on FLUXNET dataset and remote sensing satellites. A better understanding of the relationship between SIF and vegetation production is important, as well as improving the LUE model. Furthermore, improving the quantity and quality of forcing data on environmental variables and canopy structure is important for estimating vegetation production. High temporal resolution remote sensing data sources and non-optical band data (e.g., microwave remote sensing) can effectively reduce data missing and improve model performance.

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