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THE ECONOMIC VALUE OF FOREST FRUITS. A BIBLIOMETRIC ANALYSIS RESEARCHED DURING THE PERIOD OF 1978 TO 2023

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Abstract

Forest fruits, an important component of non-wood forest products, have significant ecological and economic importance, bringing numerous material benefits to small landowners as well as companies specialised in their commercialization. This bibliometric study analysed their economic value using data extracted from the Web of Science and processed with Excel and Vosviewer programs. The results show that, since 1978, a significant number of articles on this topic have been published annually in the fields of Forestry, Environmental Sciences, Plant Sciences, and Ecology. This is done by authors from numerous countries, most notably from China, Brazil, the USA, and India, in various journals across different domains, particularly in Forestry, Ecology, and Economics. The most represented journals are Forest Ecology and Management, Economic Botany, and Agroforestry Systems. The most frequently used keywords were conservation, forest and biodiversity. Initially, more general keywords were used, but in recent years they have focused more on food security for the population. Although there are numerous types of forest tree fruits harvested around the globe, their harvesting can have a negative impact on the environment, while the monetary advantage of harvesting them is very low, and their commercialisation is scarce. In addition to certain forest fruits used in various regions around the world (marula, almonds, uppage, Brazil nut, baobab fruits), two other categories of fruits (berries and wild cherries) are frequently harvested, processed into high-value products (jams, preserves, yogurts, juices, liqueurs), and marketed.

Key words**:** *forest fruits, bibliometric research, economic value, biodiversity*

INTRODUCTION

Forest fruits are part of non-wood forest products (NWFPs) [62, 60, 12, 20]. NWFPs encompass all biological materials found in forests, except timber. This includes wild food plants, honey, resin, spices, wildlife products, fuel wood, charcoal, and materials for handicrafts like rattan, vines, bamboo, and grasses [33, 67].

Globally, especially for low-income households, NWFPs can constitute 10–60% of household income [1, 4, 18], serving as a crucial subsistence source [6, 40, 15]. They also enhance food security by compensating for seasonal food shortages and play a significant cultural and spiritual role [32, 26].

In Europe, gathering NWFPs is a key part of cultural heritage [53, 26], closely connected to forest recreational activities [26, 61], and can be used for improving degraded lands [16].

Recently, global climate change, overgrazing, tourism development, insect pests, plant diseases, and other factors have endangered the ecological environment of wild fruit forests [59]. Land managers need to understand how fruit availability varies across forest types, seasons, and years [29].

Forest fruits are vital for the profitability of numerous small and medium forest-based enterprises [29].

Wild fruit varieties are consumed raw by rural communities and are rich sources of protein, starch, fat, and other nutrients. Compared to cultivated fruits, they haven't been extensively considered as alternative food sources. Many countries' rural populations use these wild fruits as income sources, particularly for poor

rural inhabitants and unemployed youth, by making various edible products like jam, juice, and sauce [3].

Forest fruit trees are crucial for biodiversity conservation and enrichment, as well as in the food chain [21, 27, 48, 27].

Economic fruit forests are vital in agriculture, playing an irreplaceable role in increasing farmers' income, promoting green agriculture, and fostering rural revitalization [32].

The integration among knowledge domains, various theoretical perspectives, and axes contributes to the development of bibliometric indexes that help refine and understand scientific output with a focus on its practical applications.

In this context, bibliometry serves as a method to evaluate scientific activities on particular subjects, enabling the anticipation of trends identified through the analysis and study of literature that best represents the current state of the field.

Advancements in constructing scientific knowledge, derived from academic literature, are influenced by the growth rate and interest in bibliometric studies. These methods assess national and international academic production, highlighting the most relevant articles, authors, and themes. They also examine trends in thematic and methodological approaches in leading journals, fostering better alignment between researched themes and available academic output.

Bibliometric studies are crucial for synthesising findings from a diverse range of authors, contexts, and reflections, collectively forming comprehensive research conclusions through the amalgamation of results from multiple sources.

Many articles of this type are published in the fields of economics [29, 17, 51] or environment [70, 23, 11]. Regarding the topic chosen for this article, we have identified only one bibliometric review article that studied non-timber forest products in Brazil [56].

The purpose of the presented work was to deliver a systematic review and evaluation of the economic value of forest fruits over the 1978–2023 period, using a bibliometric method. The analysis included publication types, scientific fields, the distribution of articles by year, the authors and their countries of origin, the institutions they are affiliated with, the journals and their editors, and the main keywords used.

MATERIALS AND METHODS

The bibliometric analysis followed several steps, from keyword selection to analysis criteria (author, citations, country). Data for the analysis were extracted from the academic databases within the Science Citation Index, Science Citation Index Expanded, and Web of Science citation index databases, which offer extensive citation information across various disciplines. This database is user-friendly and has the advantage of English language accessibility compared to national databases and other sources. The topic/keyword "the economic value of forest fruits" was selected to access publications related to this topic from the Web of Science Core Collection.

Data were processed using resources from the Web of Science Core Collection [13], Excel [44] and the Vosviewer program, version 1.6.20 [65].

RESULTS AND DISCUSSIONS

The bibliometric study has revealed a total of 372 publications related to the economic value of forest fruits.

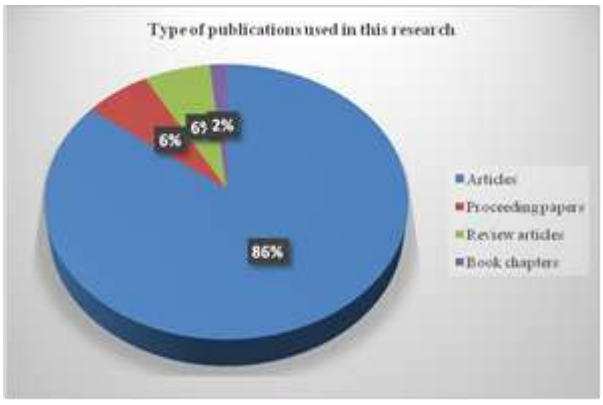

Fig. 1. Distribution of the main types of publications used in the bibliometric analysis.
Source: our own graph.

Their classification is as follows: 318 are articles (86%), 24 are proceeding papers (6%),

24 are review articles (6%), and 6 are book chapters (2%) (Figure 1).

Concerning the scientific fields to which the articles about the economic value of forest fruits belong, the most representative are: Forestry (88 articles-24%), Environmental Sciences (66 articles-18%), Plant Sciences (62 articles-17%) and Ecology (59 articles-16%), and Economics (Fig. 2).

Fig. 2. Distribution of the main 10 scientific fields of publications used in the bibliometric analysis.
Source: Web of Science [6, 13].

The first article on this topic was published in a renowned scientific journal in 1978. The number of published articles has grown relatively steadily over the years, with the peak (44 articles) recorded in 2022 (Figure 3). As with other topics [18, 45], an exponential increase in the number of articles published on the economic value of forest fruits has been observed over the last 20 years. This is due to the growing interest in this topic, as well as the increasing number of authors and high-impact journals available for publication.

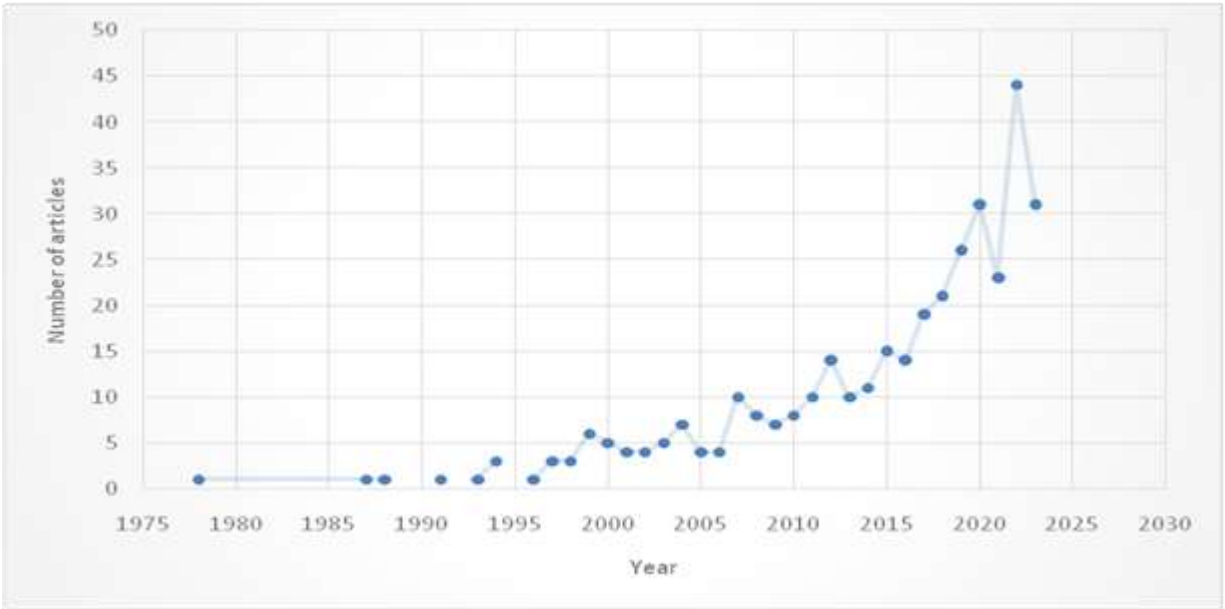

Fig. 3. Distribution of published articles by year.
Source: own graphic based on the data from Web of Science [6, 13].

A total of 196 authors have published articles on this topic, with the most articles (5 each) written by Alexandra Klein and Teja Tscharntke.

From a total of 84 countries where the authors of these articles come from, the most representative countries are: China (51 articles), Brazil (49), the USA (46), and India (30). Besides the four countries mentioned above, Spain, France, Kenya, Mexico, Australia, and Canada are also represented.

The topic has been studied by researchers from all over the world, with authors from all continents publishing articles in this field.

The top four countries are large territories with significant forest areas: China (208.3 million hectares of forest land), Brazil (493.5 million hectares), the USA (100.9 million hectares), and India (80.9 million hectares). Additionally, these countries have a great diversity of forest fruits [41, 6, 55, 68, 69, 57, 22].

Regarding the connection between these articles/countries, the strongest total link strength is recorded for England, the USA, and Brazil (Table 1 and Figure 4).

Table 1. The most representative countries of authors who published articles on the economic value of forest fruits

	Review	Documents	Citations	Total link strength
1	England	24	998	43
2	USA	46	5,745	43
3	Brasil	49	989	41
4	Germany	21	4,616	38
5	Indonesia	17	273	21
6	Spain	18	329	19
7	France	13	4,263	18
8	Kenya	10	215	17
9	Mexico	15	479	17
10	Netherlands	9	422	16
11	Australia	9	4,175	15
12	Canada	10	366	14
13	India	30	486	13
14	Switzerland	7	135	
15	China	51	604	15

Source: own data obtained with VOSviewer [33, 65].

The countries can be grouped into four clusters: the first includes Brazil, England, Spain, Colombia, and Mexico; the second includes China, Canada, Italy, and the Czech Republic; the third includes India, Germany, Pakistan, and Saudi Arabia; and the fourth includes South Africa, Kenya, Argentina, Sweden, Finland, and Poland.

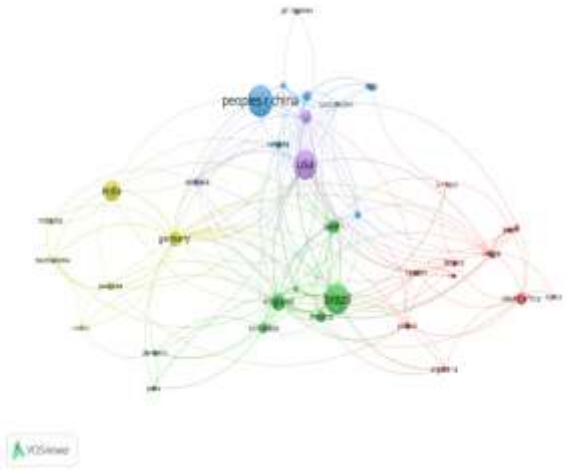

Fig. 4. Countries with authors of articles on the economic value of forest fruits. The node size and thickness of the connecting lines are proportional to the number of documents assigned to each country. The connections represent the collaboration network among research institutions.
Source: own graphic obtained with VOSviewer [33, 65].

The institutions represented by the authors of these articles with the most publications are: Consortium of International Agricultural Research Centres – CGIAR (14 articles), Chinese Academy of Sciences (11 articles), Center for International Forestry Research - CIFOR (8 articles), Universidad National de Colombia (8 articles), and Universidade de São Paulo (8 articles).

Articles published on this topic are found in 215 journals, with most articles appearing in Forest Ecology and Management (16 articles), Economic Botany (13 articles), and Agroforestry Systems (11 articles). Based on total link strength, the most important journals are Forest Ecology and Management, Biodiversity and Conservation, and Economic Botany (Figure 5).

The journals can be grouped into two major categories: Forestry journals – the most numerous - (Forest Ecology and Management, International Forestry Review, Tree Forestry and People, Forests, Austrian Journal of Forest Science) and general Ecology journals

(Ecological Applications, Ecological Economics, Human Ecology, Biodiversity and Conservation).

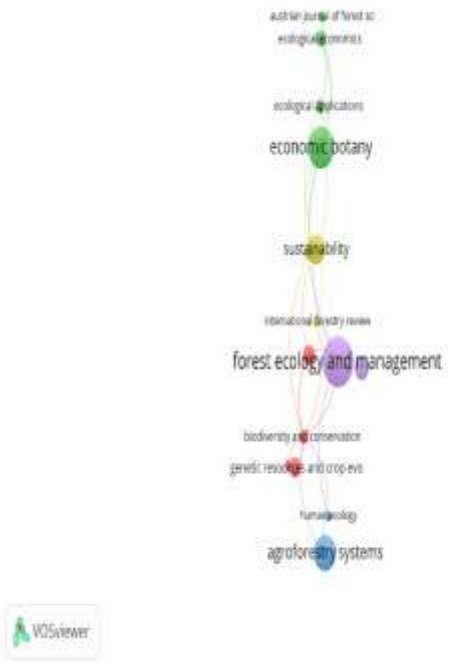

Fig. 5. The main journals where articles on the economic value of forest fruits were published.
Source: own graphic obtained with VOSviewer [33, 65].

Table 2. The most representative journals where articles on the economic value of forest fruits were published

	Review	Documents	Citations	Total link strength
1	Forest Ecology and Management	16	466	12
2	Biodiversity and Conservation	4	241	10
3	Economic Botany	13	383	9
4	Sustainability	9	69	6
5	Ecological applications	4	247	4
6	Ecological economics	5	190	4
7	Human Ecology	3	15	4
8	Ethnobiology and Ethnomedicine	6	236	4
9	International forestry	3	56	3
10	Tree forestry and people	5	36	3
11	Agroforestry systems	11	199	2
12	Forests	7	71	2
13	Sustainable forestry	3	4	2
14	Austrian J. of forest science	3	4	2

Source: own data obtained with VOSviewer [33, 65].

The most representative publishers who have published articles on the economic value of forest fruits are Elsevier (81 articles), Springer Nature (74 articles), and MDPI (33 articles).
The most frequently used keywords are conservation, forest, and biodiversity (Figure 6 and Table 3).

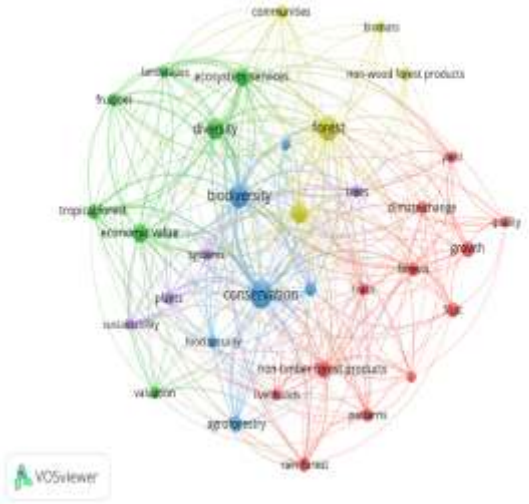

Fig. 6. Authors' keywords concerning the economic value of forest fruits. The node size and thickness of the connecting lines are proportional to the number of documents in which the keyword appears. The colours indicate the cluster the item belongs to, and the connection line between nodes represents co-occurrence; the shorter the distance between the different nodes, the stronger the relationship between the keywords.
Source: Own graph, obtained with VOSviewer [33, 65].

Table 3. The most used keywords in articles published about the economic value of forest fruits

	Key word	**Occurrences**	**Total link strength**
1	conservation	60	141
2	biodiversity	44	124
3	forest	48	107
4	diversity	34	88
5	economic value	27	82
6	management	32	80
7	ecosystem services	27	78
8	tropical forest	18	57
9	fruit-set	14	55
10	ethnobotany	16	50
11	non-timber forest products	23	46
12	landscape	11	43
13	rain-forest	16	38
14	trees	13	37
15	agroforestry	19	34
16	patterns	14	31

Source: own data obtained with VOSviewer [33, 65].

Three main clusters of keywords can be observed: the first includes non-timber forest products, fruits, forests, climate change, and rain-forest; the second includes diversity, ecosystem services, economic value, and landscape; the third includes conservation, biodiversity, agroforestry, and food security.
Regarding the distribution of keywords over the years, it is noted that in the early years, the most used keywords were general and related to forest types where the fruits appear (non-timber forest products, economic value, tropical forest, rain-forest), while in the last three years, keywords are more focused on population and food security (communities, food security) (Figure 7).

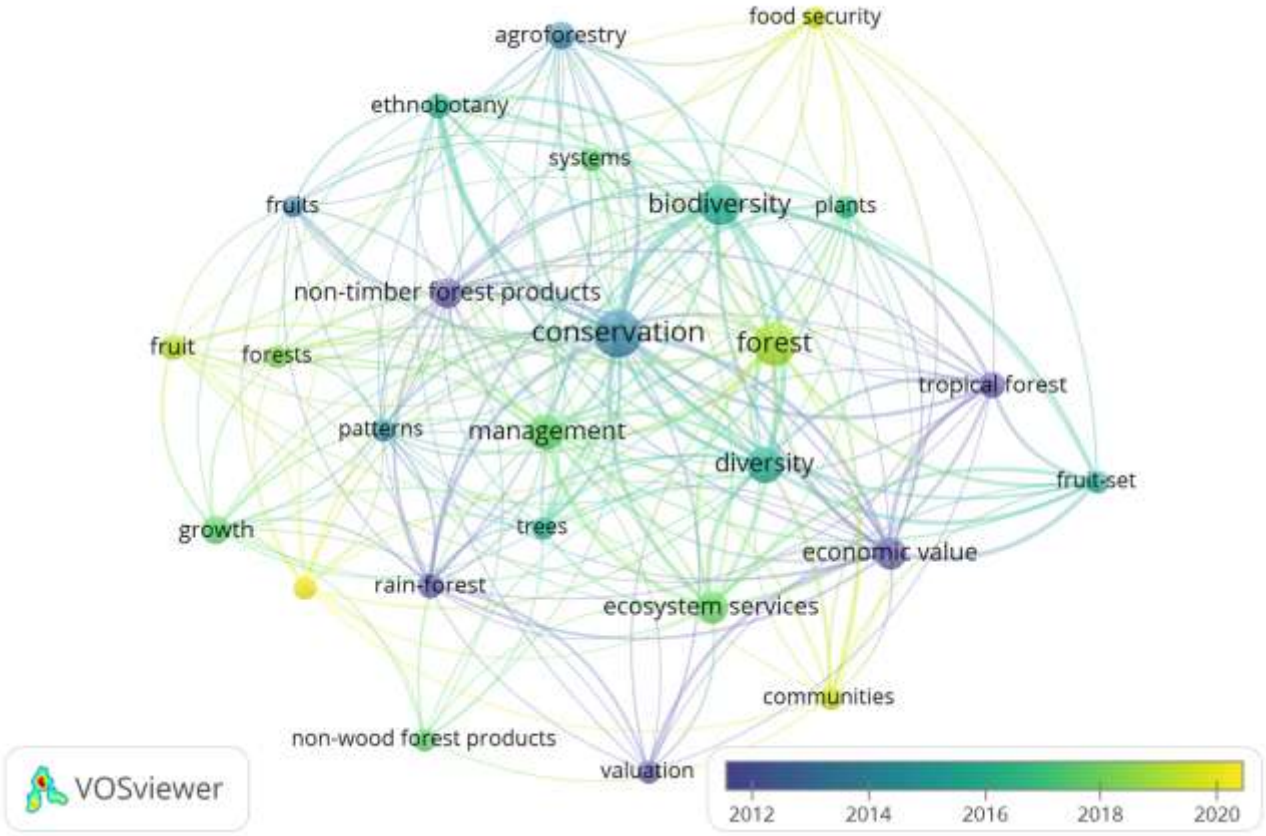

Fig. 7. Distribution of keywords over the years regarding the economic value of forest fruits. The node size and thickness of the connecting lines are proportional to the number of documents in which the keyword appears. The colours indicate the cluster the item belongs to, and the connection line between nodes represents co-occurrence; the shorter the distance between the different nodes, the stronger the relationship between the keywords.
Source: our own graph, obtained with VOSviewer [33, 65].

The economic value of forest fruits

Investigating the effects of fruit harvesting is crucial, as fruits serve as reproductive organs for plant species. However, excessive harvesting can negatively influence species sustainability, particularly over the long term, as noted by Peres et al. [49].
Some authors have concluded that there is no direct environmental risk posed by some fruit species collection (especially those that are widespread and have a high production); this is the case for marula [39], tagua (*Phylephus seemannii* O.F. Cook), [7], *Garcinia lucida* Vesque [24]. Unlike them, Boot and Gullison [10] and Peters [50] argued that other species with abundant fruiting have shown marked reduction in recruitment and changes in size structure profile as a result of fruit harvesting.
Research indicates that although forest fruits hold significant economic value, small-scale collectors, producers, and processors receive a

very small share of the final sale price, resulting in low profitability. One major reason for the limited profitability of NTFP enterprises is the absence of a structured information system to assist producers in organizing production, setting prices, selecting markets, understanding supply and demand, or promoting products. Even when market data exists, it is often not shared with small-scale producers.

Forest fruit commercialization frequently faces challenges. Marketing and sales are generally identified as the most significant barriers to success [43]. The price received by the collector depends on the length of the marketing chain and the political context of the market [8].

Examples of forest fruits: harvesting, usage and economic value.

Pentadesma butyracea Sabine is a tree that appears in riparian forests, and which produces fruit almonds that can be transformed into butter for cooking and cosmetics. An analysis of this species from Benin [2] has shown that, although the net present value of fruit harvesting and almond processing activities showed both activities were financially profitable, fruit harvesting was significantly more profitable than almond processing. In addition, the people involved in this activity can recuperate between 49% and 80% of the price paid by the consumer, depending on the quality of the product and the length of commercial channel used.

Sclerocarya birrea (A. Rich.) Hochst is a tree species from South Africa with a variety of uses including the consumption of the fresh fruit (marula), the usage of the fresh fruit to make juice, jam and beer. The high fruit yield, planting practices and density of marula trees make it likely that in the near-term future commercialization of marula fruit will be limited not by fruit availability but more probably from market forces [19]. Today, the most known product of the marula fruits is Amarula cream, an alcoholic beverage produced from the fruit pulp [25]. The total value of the commercial marula trade to rural communities in South Africa was estimated to be worth $160,000 a year in 2001/2002 season [42]. The trade resulted in an average annual income of $85 per trader per year.

In India, the harvest of fruits from the rain forest tree uppage (*Garcinia gummigutta*) has increased in the mid 1990's. The fruit of this tree is harvested by villagers, who, after removing the seeds and pulp, sell the dried rind to traders. Starting with 1990, the fruits' price has increased because of the interest of drug manufacturers from the United States of America. However, the price started to decrease after 2000 [52].

Brazil nut (*B. excelsa* Humb. and Bonpl.) has fruits that have been collected for decades, and in 2002 in Brazil alone, was worth over US$ 10 million [28]. Harvesting and processing this fruit generates income for thousands of families in Bolivia, Brazil, and Peru [14]. Studies have been realized on how to manage natural populations for increasing Brazil nut production [31, 66, 47].

Uapaca kirkiana (Muell. Arg.) is a valued indigenous fruit species from Malawi. Harvesting this fruit is in progress in the southern Africa region, and form part of a global initiative to promote indigenous fruit trees in agroforestry for community livelihood benefits [36]. On average, fruits were saleable for only 3–4 days, this being attributed to inherent fruit characteristics combined with immaturity at harvest, and damage during harvesting and storage in hot dry conditions [30].

Baobabs (*Adansonia digitata*) produce fruits that are requested for subsistence purposes and traded to generate cash. The fruit comprises two distinct parts: the seed and the surrounding pulp. The seed can be pressed to extract oil for cosmetics or consumed roasted and pounded, while the tart pulp, a dry powder encasing the seed, is also used as a food ingredient [54]. Non-timber forest products (NTFPs) contribute 14% and 33% to annual income, with baobab fruit accounting for 38% and 4% of these figures, respectively. Expanding the commercialization of baobab fruit can have significant benefits, with secured tree access and investment in local processing further enhancing its value for marginalized communities in southern Africa [64].

Berry fruits, including raspberries, blueberries, strawberries, blackberries, and cranberries, are harvested from forests worldwide. These fruits are sold fresh or, more commonly, transformed into high-value products such as juices, jams, yogurts, liqueurs, and more. Recently, berries have attracted growing attention as functional food ingredients as they have numerous health benefits and various industrial and nutraceutical usages. Traditionally, raspberry crops were predominantly sold to processors for freezing, jam-making, canning, and flavorings in ice cream and yogurt. However, fresh market production has significantly grown, becoming a key industry sector [5]. Wild strawberries are harvested for home use and utilized in the pharmaceutical and cosmetic industries. Their unique aroma and taste make them ideal for confectionery, jams, and liqueurs [34]. Blueberries are enjoyed fresh but are also widely processed into juices and wine [37]. Blueberry fruits are highly valued for their health benefits, with over a billion tons harvested globally each year [35]. Bilberries are consumed fresh or processed into juices, jams, preserves, purees, and nutraceuticals [9]. Blackberries, too, are versatile, enjoyed fresh or used in making jams, syrups, teas, desserts, and baked goods [71].

In Iran the mean annual income derived from the harvest and sale of reddish blackberry in the sample rural household incomes was USD 142 [22].

Cherry (or wild cherries in plural form) is another category of forest fruits with a high economic value. The importance of cherry fruits is mentioned in Belgium [46], Great Britain [63], Romania [58], Iran (Ghanbari et al., 2022), and Chile [38].

CONCLUSIONS

So far, 372 materials related to the economic value of forest fruits have been published, most of them (86%) being articles. The main scientific fields in which the published articles are categorised are Forestry, Environmental Sciences, Plant Sciences, and Ecology. The first article was published in a recognized journal in 1978, while most articles were published in 2022. The authors who have published such articles come from numerous countries (which can be grouped into four clusters) from all continents, with the most representative being China, Brazil, the USA, and India. The institutions represented by the authors with the most published articles are the Consortium of International Agricultural Research Centres (CGIAR) and the Chinese Academy of Sciences. The journals with the most publications on this topic are Forest Ecology and Management, Economic Botany, and Agroforestry Systems; these belong mainly to the fields of Forestry or Ecology and are associated with the main publishers Elsevier, Springer Nature, and MDPI. The most frequently used keywords are conservation, forest, and biodiversity, which can be grouped into three major clusters. The evolution of keyword usage over time shows that, after an initial use of general keywords or those referring to the types of forests where the fruits appear, in the last three years, the keywords have focused more on the population and food security. There are numerous fruit species of forest trees that are harvested around the globe (some examples include: the Brasil nut; marula in South Africa; the baobab fruits; fruits almond of *Pentadesma butyracea* in Benin; *Uapaca kirkiana* in Malawi; uppage (*Garcinia gummigutta* in India). However, their excessive harvesting may have a negative impact on species sustainability as well as on the environment. The proportion of the final sale price for the collector is small, while commercialisation is scarce due to lacks in product marketing and sales, especially as these fruits are mainly harvested in subdeveloped countries.

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