Review

Assessment and Valorization of Non-Wood Forest Products in Europe: A Quantitative Literature Review

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Abstract: This article presents a quantitative review of non-wood forest products (NWFPs) at the regional scale in Europe. A text mining approach was applied to titles, abstracts, and keywords extracted from articles in the Scopus database. Different investigations, such as concept mapping and specificity analyses of textual corpus, were performed. Our search yielded a massive number of NWFP-related papers. Specifically, research was distributed in different countries, being more prevalent in the Mediterranean and Scandinavian contexts. Several NWFPs were analyzed, with mushrooms, resin, cork, and other forest fruit being the most common ones. Local socioeconomic improvement was one of the major aspects investigated in scientific literature. The proposed methodology applies specific scripts that can be updated, and the output of the present research can be compared with that of the future works. For instance, interest trends of products and methods can be investigated, and gap analyses performed. Finally, the potential implications of this review for researchers and stakeholders are discussed.

Keywords: forest ecosystem services; literature review; big data; text mining; Europe

1. Introduction

According to the Food and Agriculture Organization of the United Nations (FAO), non-wood (or non-timber) forest products (NWFPs) are defined "goods of biological origin other than wood derived from forests and other wooded land and trees outside forests" [1] or as "goods derived from forests that are tangible and physical objects of biological origin other than wood" [2]. According to Weiss et al. [3], NWFPs contribute to different classes of ecosystem services, such as providing social (human nutrients and renewable materials) and cultural (maintenance of traditions and experiences) services, as well as creating jobs and income opportunities in agroforestry areas. Therefore, these products play pivotal roles in forestry and rural development.

However, few countries systematically monitor and collect data on these resources; therefore, their use and value may be underestimated [4]. Moreover, Sorrenti [4] has reported on the definitions and terminologies of NWFPs, emphasizing how various individuals, institutions, and countries opt for diverse terms depending on their needs and objectives. The Harmonized Commodity Description and Coding System (HS), Central Product Classification (CPC), and International Standard Industrial Classification of All Economic Activities (ISIC) are the major statistical classification systems for NWFPs. However, NWFPs are widespread from the local to international level, and additional typologies of categorization are available.

Under this framework, the analysis of such products is problematic from both quantitative and qualitative viewpoints, and indicators of sustainable forest management must be modelled, including the quantification and analysis of NWFPs [5]. Modelling of NWFPs

is limited by factors related to data requirements and methodologies such as asymmetrical distribution, spatial and temporal variability, short harvesting period compared to timber, and number of species classified as NWFPs [6].

Previous studies have analyzed the status of NWFPs by focusing on the socioeconomic and environmental impacts of a single product or a group of products at different scales. Girão Rodrigues de Mello et al. [7] examined the sustainability of NWFP use and/or commercialization from a socioecological perspective; the authors evaluated 72 articles, highlighting how the sociocultural dimension is often not encompassed in the NWFP chain as well as how ecological unsustainability is prevalent among the analyzed articles. Furthermore, Shackleton and Pandey [8] underscored the lack of NWFP inclusion in the political agenda to improve the conditions of local communities and alleviate poverty. Guariguata et al. [9] assessed the conflicts, trade-offs, and potential solutions to improve the compatibility between timber and NWFPs in the tropical areas, stressing the importance of the integrated management of the entire spectrum of forest ecosystem services. Lovrić et al. [10] analyzed the economic value of NWFP picking through a household survey of 17,346 respondents from 28 European countries and estimated the total annual economic value of €23.3 billion, which is comparable to 70.7% of the annual economic value of roundwood removals in Europe.

Given the importance of NWFPs highlighted in the literature, the difficulties related to their categorization, such as the massive amount of scientific data, local peculiarities, and drastic increase in the number of publications in recent past, should be addressed, and the full potential of NWFPs must be examined from a scientific viewpoint.

A common strategy to overcome these problems would be the application of big data analysis and text mining. As such, published articles can be selected through electronic databases (e.g., ISI Web of Science, Scopus, and Google Scholar) and quantitatively evaluated using text analysis. Text mining reduces the information of large texts, enabling a more straightforward understanding of complex data and automated information retrieval from textual data sources. Text mining has been used in the context of sustainable forest management [11] and forest bioeconomy [12,13]; however, few studies have focused on NWFPs.

To this end, the present article provides a quantitative literature review of NWFPs and their relevance to the pillars of sustainability (social, economic, and environmental). Differentiation at the geographic level and logical steps that drive the user (e.g., researchers) through this quantitative review are also appointed. The proposed method can facilitate knowledge transfer to policy and decision-makers involved in the NWFP sector and forest chains. This review is focused on the European context.

2. Materials and Methods

2.1. Extraction from Scientific Literature and Attribution to the Geographic Context

Titles, abstracts, and keywords of articles extracted from the Scopus database [11] were analyzed. The Scopus database was used for research because of its wider publication coverage than that of other Web-based databases (e.g., Web of Science). Only a single electronic database was selected, and grey literature was excluded from the analysis to avoid potential multiple accounting of a single study. The corpus used for the analysis was extracted using a query algorithm (script) in the Scopus advanced search platform. The script analyzed the titles, abstracts, and keywords of the examined articles. The query included the NWFP domain, in extended or acronym form ("non wood forest product*" OR "non timber forest product*" OR NWFP OR NTFP), as well as the term "forest*". To extend the search query, specific names of NWFPs (e.g., mushroom, cork, and so on) were also introduced, based on a systematic review by Sorrenti [4].

Localization of the studies, that is, the attribution of an article to a geographic context, was achieved by applying the concepts of "geographical regions" and "major areas" of United Nations (UN) [14]. The UN classifies countries into six major areas: Africa, Asia, Europe, Latin America and the Caribbean, Northern America, and Oceania. These major

areas are further divided into 21 geographic regions. This review is focused on Europe and its four regions, namely eastern, northern, southern, and western Europe (Figure 1). European countries were assigned to regions according to the UN categorization, as reported in Appendix A.
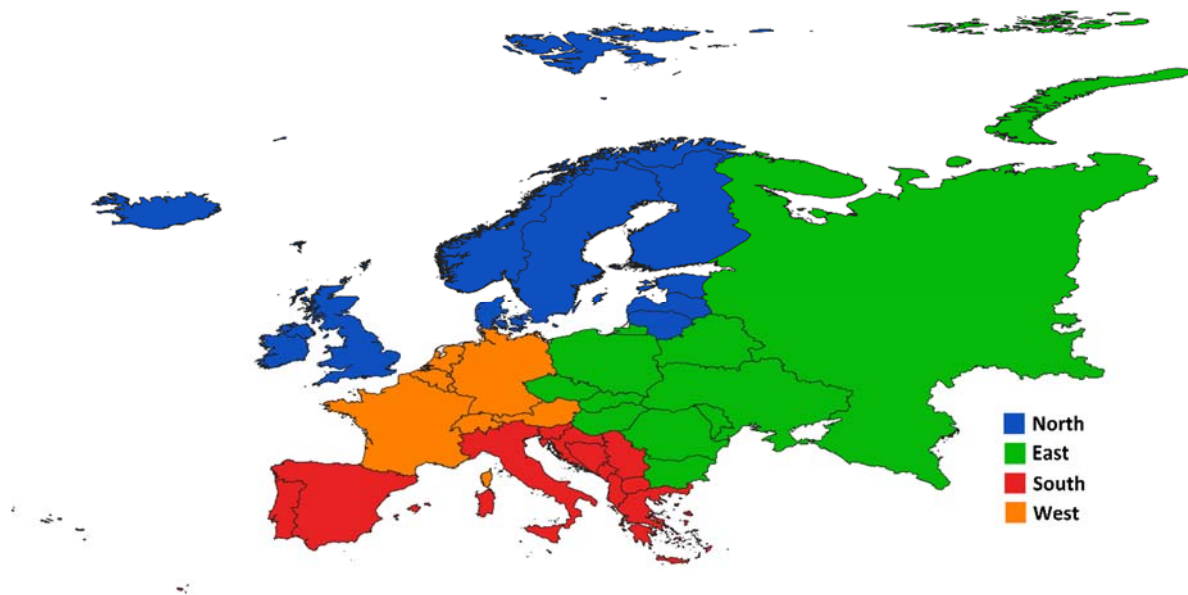
Figure 1. Identification of European regions according to the United Nations classification.

In the scripts, countries and regions were identified with both specific names and their adjectival and demonymic forms [15,16] (Appendix B). The corpus was extracted at the end of August 2020. Publications were limited to English. The query excluded articles not strictly related to the forest sector (e.g., when keywords, title, or abstract included the term "random forest") or when NWFPs were not analyzed from the perspective of forest ecosystem services [17]. The scripts used for extraction based on these conditions are presented in Appendix B.

2.2. Preparation of Corpus and Pre-Processing

The corpus was imported to T-LAB (https://www.tlab.it/) (accessed on 10 February 2021), a text mining tool for large datasets. Automatic pre-processing of the corpus was performed through disambiguation, lemmatization, and lexicalization. Disambiguation allows for the simplification of similar words with different meanings. Lemmatization facilitates the encoding of words with the same root or similar meaning in a new (and unique) form that sums occurrences (e.g., "manager"→"management"). Lexicalization permits the tracing of repeated segments back to a single form (e.g., from "non wood forest products" to "non_wood_forest_products"). The results of disambiguation, lemmatization, and lexicalization were presented as lexical units (LUs). The text was automatically cleaned from stop-words (e.g., "and" or "or"), and paragraphs were selected as the elementary context (EC) to be analyzed. Out-of-topic (OOT) abstracts, titles, or keywords were also manually removed. In such cases, OOT studies may be included in the preliminary version of the corpus due to presence of species names (e.g., "European" beech or "Scots" pine), extra-European areas (e.g., "British" Columbia), or publisher names (e.g., "Polish" Academy), which replicate the adjectival and demonymic forms of terms.

2.3. Quantitative Analysis

The first quantitative analysis of the corpus was embodied by concept mapping (CM)—graphical representation of the relationships among the words (i.e., LUs) within a space of reduced dimensions.

In the first step, the relationships among LU co-occurrences were evaluated. The analysis was developed between a single LU and the (maximum) 100 most represented LUs in each EC selected automatically. Relationships were quantified using one of the association indices available in T-LAB. In this review, cosine was applied because of its suitability to large datasets [18]. Figure 2 shows how the base data for the cosine calculation are identified (https://www.tlab.it/) (accessed on 10 February 2021).

	EC_1	EC_2	EC_3	EC_4
LU_1	1	0	0	1
LU_2	1	1	0	1

(a)

		LU_2		
LU_1		*Present*	*Absent*	*Total*
Present		2	0	2
Absent		1	1	2
Total		3	1	4

(b)

		LU_2		
LU_1		*Present*	*Absent*	*Total*
Present		a	b	a + b
Absent		c	d	c + d
Total		a + c	b + d	n

(c)

Figure 2. Example of preliminary steps for cosine calculation: (**a**) identification of the presence/absence (1/0) of a lexical unit (LU) in the elementary context (EC); (**b**) quantification of co-occurrences; and (**c**) representation of co-occurrences.

For instance, for two LUs and four ECs, the presence of LU in each EC is stressed by Figure 2a; the same data can be reported as co-occurrences between LUs, as shown in Figure 2b. Figure 2c translates the numerical data in letters to be applied in the formula for cosine calculation (Equation (1)).

$$\text{Cosine} = \frac{a}{\sqrt{a+b}\sqrt{a+c}} \tag{1}$$

Matrices of the $N \times N$ dimensions (where N corresponds to the number of rows and columns, that is, the number of LUs) reporting cosine can thus be produced and used to interpret both the relationships among LUs (proximity) and dimensions of LUs (proportional to the size of circles in CM) that organise the space in which they are represented. Visual representation is based on multidimensional scaling (MDS) using Sammon's method (a non-metric MDS used in T-LAB) [19]. In Sammon's method, the correspondence between the input matrix and distances among LUs defined by the MDS map is evaluated using a stress (S) function (Equation (2)). A small stress value indicates a good fit, whereas a high stress value (>0.20) indicates a poor fit [20].

$$S = \sum_{i \neq j} \frac{\left(d^*_{ij} - d_{ij}\right)^2}{d^*_{ij}} \tag{2}$$

where d^*_{ij} is the distance between the LUs i and j in the proximity matrix, and d_{ij} is the distance between the same LUs in the MDS map.

In the second step, quantitative analysis was performed to evaluate the specificities for each European region. Specificities can be defined as typical (overused) LUs in a corpus subset. Specifically, each subset (e.g., southern Europe) was compared with the whole corpus. Overused LUs were identified using the chi-square (χ^2) test, which is used to check whether the frequency values detected in cross-tables produced by the software (observed frequencies O) are different from the threshold values (expected frequencies, E) (in general, the value of E is 3.84, when the degree of freedom is 1 and *p*-value is 0.05, or 6.64, when the degree of freedom is 1 and *p*-value is 0.01) (https://www.tlab.it/) (accessed on 10 February 2021). The formula for calculating the χ^2 value is as follows (Equation (3)):

$$\chi^2 = \sum \frac{(O-E)^2}{E} \tag{3}$$

3. Results

The corpus was derived from 1040 articles, including 434, 111, 434, and 61 papers from northern, eastern, southern, and western Europe, respectively. The corpus constituted a 270-page-long description of NWFPs.

3.1. CM

CM of NWFPs in northern Europe (Figure 3) highlighted how the term "forest" was strictly related to the management perspective.
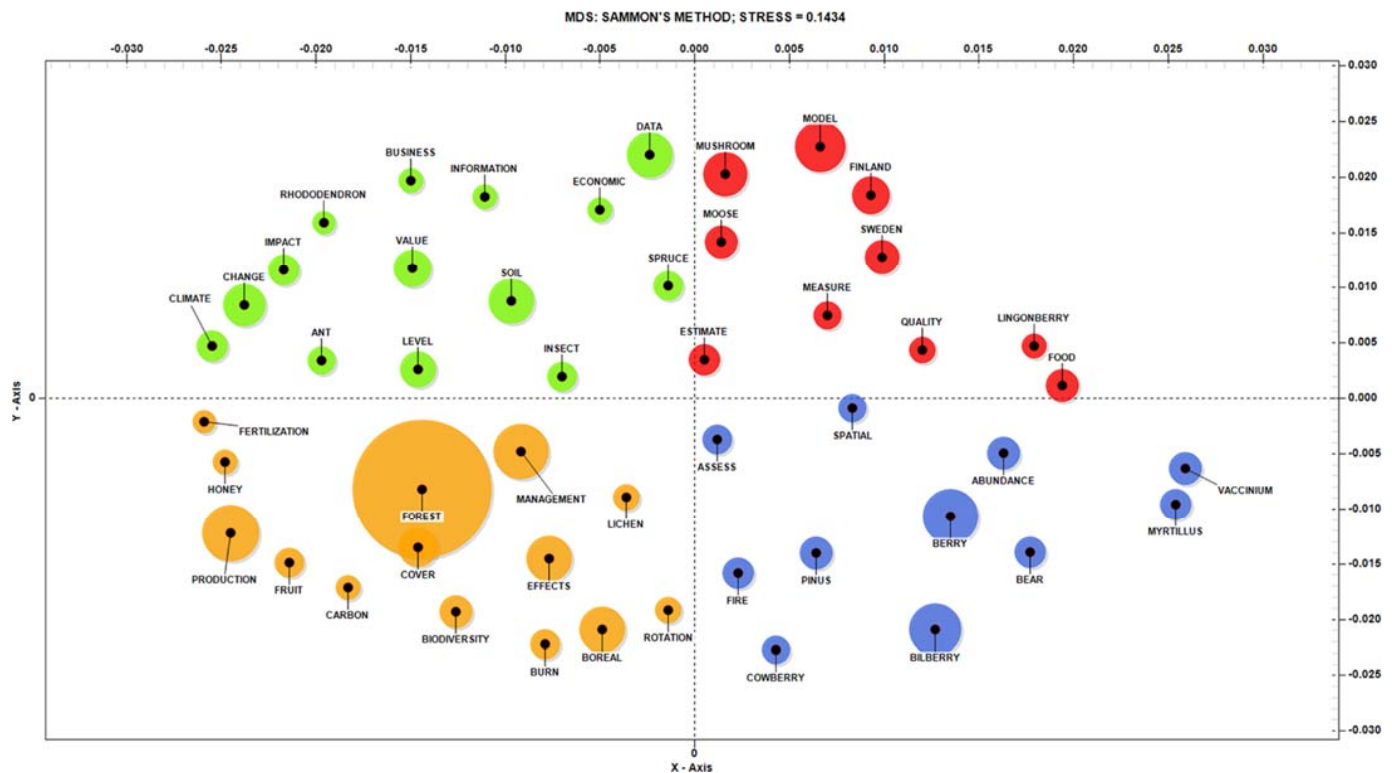

Figure 3. Concept map for northern Europe.

In fact, the terms cover, management, effect, production, (controlled) burns, and rotation co-occurred significantly more frequently with the term forest in the third quadrant. The first and fourth quadrants indicated the importance of forest fruit as a source of food in Scandinavian countries. Sweden and Finland were the most evaluated zones for NWFP research. Products such as bilberry (*Vaccinium myrtillus*), cowberry, and lingoberry were the focus of many scientific articles, and they were analyzed in terms of both abundance and quality. Studies on forest products, including mushrooms, were performed using modelling and estimation techniques, such as spatial analysis (see LUs: model, estimation, spatial, assess, and measure). Wildlife (bear and moose) was also studied, but with a lower quantitative importance than NWFPs. The second quadrant indicated the relevance of NWFPs in northern Europe from the economic, business, and value viewpoints, indicating how forest chains other than the timber-related ones are important in this region. Entomofauna was an emergent set of LUs (e.g., ant and insect), which highlighted the significance of habitats or risks associated with trees damage (e.g., when associated with spruce). Some studies also focused on the potential impact of climate change on NWFPs in northern Europe.

Studies in western Europe (Figure 4) highlighted the importance of resin and phenolic compound extraction from conifers (e.g., pine and spruce).
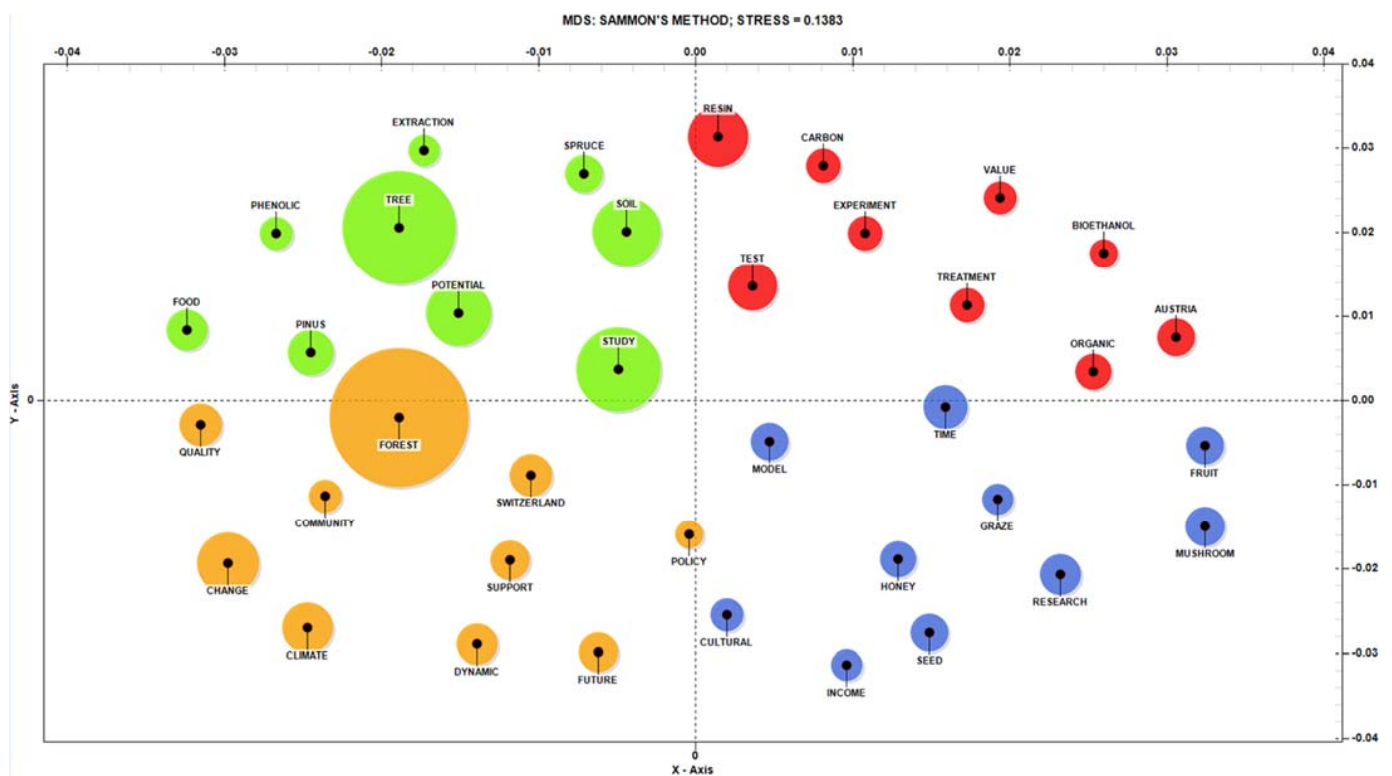
Figure 4. Concept map for western Europe.

The innovative perspective of NWFP research in western Europe was highlighted by the terms study, test, experiment, and treatment co-occurring with the terms organic and bioethanol products (first and fourth quadrants). Austria and Switzerland were mainly represented in scientific articles. In this region, NWFPs were evaluated in terms of the potential income related to mushrooms, fruit, seeds, honey, and grazing, but cultural value also emerged (fourth quadrant). Interestingly, some studies focused on the impact of climate change and the need for policies to cope with future dynamicity of the forest sector and support the local communities (third quadrant).

The Iberian Peninsula was the most represented area in southern Europe (Spain and Portugal) (Figure 5).

Cork was the main NWFP in southern Europe. Additional products such as mushroom, graze, livestock, and fruit in the fourth quadrant; resin and truffle in the first quadrant; chestnut, nut, and honey for Italy in the second quadrant; and eucalyptus gum in the third quadrant, also appeared, albeit with little relevance. Studies in southern Europe stressed the role of NWFPs in biodiversity conservation. A typical trend in the region was, however, the study of risks associated with forested areas and NWFP production. Some studies in this region also discussed climate change; however, the relevance of this term was low, and it often co-occurred with different terms such as water scarcity and risk of drought in the first quadrant; cone reduction (probably due to alien insects damaging umbrella pine cones), reduction of precipitation, increase in ozone, and abandonment of mountainous or marginal areas in the second quadrant; and fire hazard in the third quadrant. The cultural value of NWFPs and the need of identifying indicators (second quadrant) for their assessment and management were reported for southern Europe.

Figure 5. Concept map for southern Europe.

Studies across countries in eastern Europe focused on diverse themes (Figure 6).
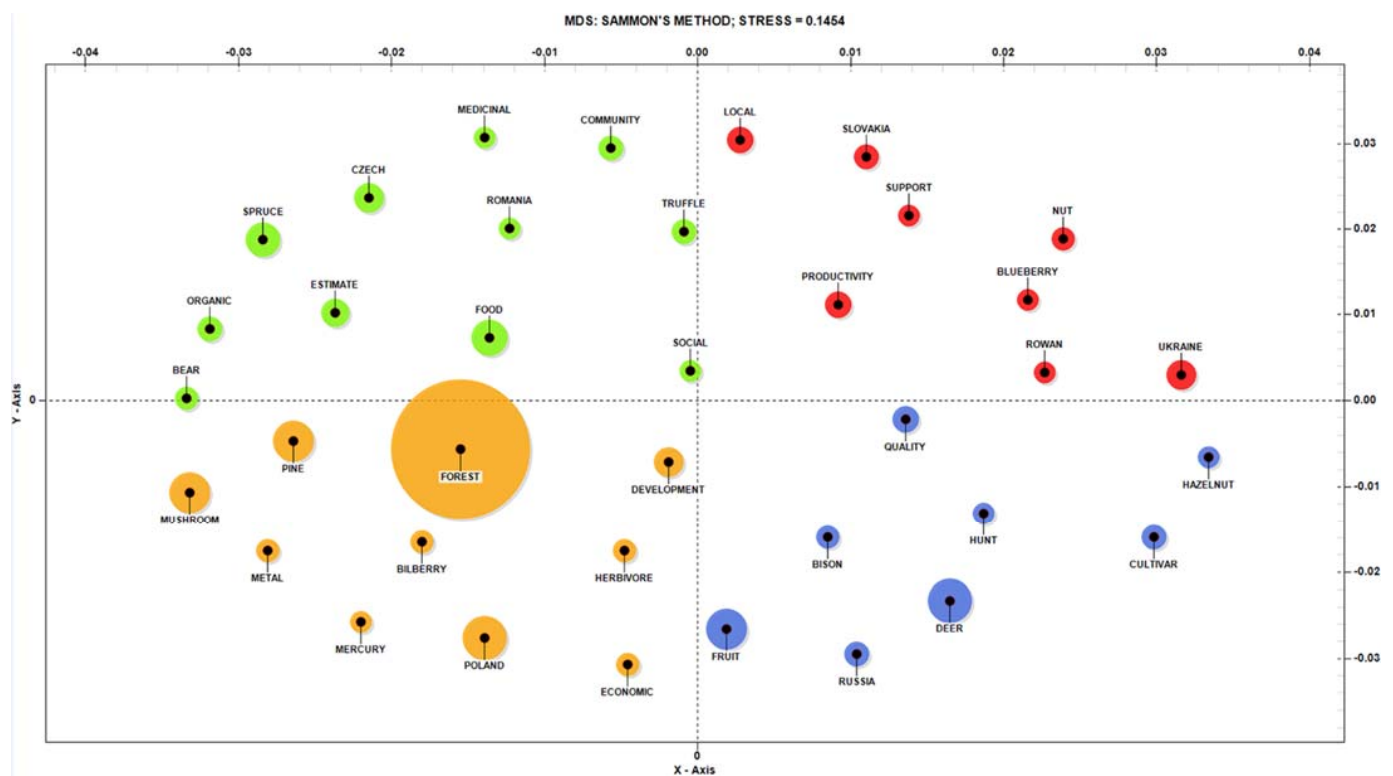

Figure 6. Concept map for eastern Europe.

In eastern Europe, in addition to their consumption as food, mushrooms were considered indicators of pollution and heavy metal accumulation (e.g., mercury) in soil (third

quadrant). This aspect was particularly prominent in Poland. Among fruit, bilberry, hazel-nut, blueberry, and rowan were important in Poland and Ukraine; truffle was important in Romania and Slovakia. Russia was mainly associated with a specific set of NWFPs, including hunt for bison, deer, and herbivores, in general. The socioeconomic aspects of NWFPs were evident in Slovakia, Romania, and the Czech Republic (first and second quadrants). In this region, the productivity and medicinal uses of NWFPs were relevant to supporting local communities, uses as food, and social value.

All CM outputs showed significant stress values (Figures 3–6).

3.2. Specificity Analysis

Specificity analysis partially reflected LUs presented in the CM. However, additional and more specific terms within the subsets were identified (Table 1). In Table 1, 25 LUs for each sub-corpus are listed.

Table 1. Specificity analysis for European subsets.

Northern Europe		Western Europe		Southern Europe		Eastern Europe	
LU	χ^2	LU	χ^2	LU	χ^2	LU	χ^2
bilberry	333.01	Switzerland	134.04	cork	334.24	Poland	278.19
boreal	244.31	Austria	86.46	oak	213.86	deer	174.61
berry	232.49	NSC	82.96	Spain	153.64	Czech	110.17
moose	197.08	elevational	65.26	Portugal	127.08	Russia	78.31
Finland	167.48	particle	56.37	Mediterranean	85.02	ungulates	66.46
bear	111.27	structural	54.14	Quercus	51.6	Hg	59.44
Vaccinium	109.82	canal	53.22	cone	50.85	rowan	50.98
Sweden	108.26	mow	47.58	pinaster	47.97	browse	44.72
cowberry	105.31	Alps	42.32	suber	46.67	nursery	42.36
myrtillus	68.41	nitrate	41.47	water	35.22	medicinal	38.76
reindeer	63.95	roe	40.31	private	30.46	bite	38.59
vitis-idaea	58.06	resin	39.44	eucalyptus	28.16	Romania	38.59
rotation	56.32	cell	37.57	fuel	26.58	Cr	38.26
burn	53.26	epoxy	36.5	drought	25.3	food	36.98
prescribe	52.18	solution	32.37	growth	23.37	Zn	33.83
herbivory	49.86	L-type	29.64	climate	21.4	Elaphus	32.66
thin(ning)	47.29	Capreolus	29.64	ilex	21	cultivar	29.35
business	44.03	treeline	28.86	plantation	20.6	pollution	28.99
optimal	43.1	germination	25.93	gum	20.25	bee	26.67
circular	31.67	buzzard	25.23	pinea	20.25	truffle	26.45
mammal	30.32	ethanol	22.23	Catalonia	20.22	propolis	25.66
bioeconomy	30	C-type	22.23	holm	18.94	socio-economic	23.6
ground	29.53	tissue	21.81	vine	17.68	CAP	23.6
Lactarius	29.01	nest	21.63	precipitation	16.42	consume	23.11
Suillus	28.23	extractives	20.94	abandonment	16.42	collect	22.68

Countries and local descriptions in each region were listed. Typical terms included boreal, Finland, and Sweden in northern Europe; Switzerland, Austria, and Alps in western Europe; Spain, Portugal, Mediterranean, and Catalonia in southern Europe; and Poland, Czech, Russia, and Romania in eastern Europe, highlighting minor differences from CM results. Typical NWFPs included forest fruit and mushrooms in northern Europe (bilberry, cowberry, *Vaccinium* spp., *Lactarius*, and *Suillus*); innovative products in western Europe (resin, epoxy, solution, ethanol, and extractive); cork, pine cone, and eucalyptus gum in southern Europe; and products associated with medicinal use and food in eastern Europe, with a particular focus on bees (e.g., propolis) and truffles.

Wildlife was important in most subsets. Specific mentions in the northern context included moose, bear, reindeer, herbivory, and mammal. Roe, *Capreolus*, buzzard, and nest were the overused animal-related terms in western Europe. Deer, ungulates, browse, and (*Cervus*) *elaphus* were typical terms in eastern Europe.

Specificity analysis revealed optimal forest planning and management from the perspective of NWFP valorization in the boreal region, based on LUs such as rotation, controlled "fire", thin(ning), and business. In northern countries, a characteristic economic framework for NWFPs linked to the circular bioeconomy was revealed. In the western subset, terms related to the structural function and characteristics of timber tissue and their influence on non-timber production were highlighted. Specifically, cell-related (L-type and C-type lectin) or environmental (elevational and treeline) LUs co-occurred with functional characteristics of trees. The acronym NSC (non-structural carbohydrates), particle, structural, canal, nitrate, cell, solution, and germination were typical elements of the Alpine region. In the southern region, terms related to the Mediterranean forests (e.g., *Quercus suber* and *Quercus ilex*) or conifer formations (*Pinus pinaster* and *Pinus pinea*) and problems related to both climatic (water, fuel, drought, growth, climate, and precipitation) and socioeconomic problems (private property, and abandonment) were highlighted. In this area, additional specific terms indicated the significance of plantations for NWFPs (e.g., cork oak and *Eucalyptus* forests), in addition to other terms related to rural or agricultural chains (e.g., the term "wine" linked to "cork" stopper). In the eastern region, specificity analysis revealed the functions of NWFPs as indicators of pollution, specifically mercury, chromium, and zinc contamination of soil. The identified socioeconomic functions included NWFP collection and consumption. Valorization of these products was also pursued through the use of international funding (e.g., the term CAP, Common Agricultural Policy). Finally, cultivars grown in nurseries, potential impacts of wildlife (bite), and specific NWFPs (rowan) were also reported.

4. Discussion

The present review applied quantitative analysis and text mining of a corpus of abstract, titles, and keywords derived from the Scopus database. Majority of the research was concentrated in northern and southern Europe, followed by the eastern and western regions, in line with scientific production for the topic "ecosystem services" [16]. Moreover, the differences among investigated countries can result from history, culture, climate, habit, and environmental characteristics.

NWFPs were identified as important forest outcomes from the financial and economic viewpoints, particularly in northern and eastern Europe. In boreal regions, forest management and planning perspectives for both timber production and NWFPs were highlighted, indicating their relevance to the forest chains. In Scandinavian countries, a circular bioeconomy emerged from NWFP research, confirming the innovative application of traditional forest (by)products. In Sweden is concentrated 1% of the world's commercial forest areas and circular bioeconomy is considered as a leading process to promote. Whilst much of the effort has been on bioenergy, a considerable interest on other by-products arises [21]. Our results are also confirmed by Holmgren et al. [22] and Lovrić et al. [23] that highlighted how social science forest-based bioeconomy research is mainly focused on northern Europe, in correlation with the distribution of funding for bioeconomy investigation.

In eastern Europe, financial value was accompanied by the social relevance of these products, mainly related to collection, as well as to use as medicine and food. Moreover, valorization of NWFPs was also achieved through national and international funding. Instead of new applications and pioneering chains or technologies, specific studies in eastern countries were, in fact, related to the implementation of CAP and sustenance of local communities. This framework seems to confirm the central role of environment and forests to foster all dimensions of sustainability in post-communist area and in particular in eastern Europe [24]. In fact, Staddon and Turnock [24] stressed the significance of environmental dimensions in post-communist transformations, e.g., for pollution abatement, restructuring over rights to natural resources such as forests or the implementation of local redevelopment strategy.

Innovative products were relevant in the western context, where the quality of NWFPs was investigated in relation to environmental characteristics and forest typologies. An

emblematic case is—the Germany—despite the absence of significance in CM—where innovative wood-based products such as ligno-cellulose-based textile fibers and, in particular, chemical derivatives were thoroughly investigated [25,26]. In western Europe, particular attention was also paid to the future dynamics of the forest sector, their potential impacts on NWFPs, and policies to cope with these problems.

Meanwhile, the cultural value of NWFPs was significant in southern Europe thanks to the high variability of socio-economic, geomorphological, climatic and vegetation characteristics; these aspects lead to a combination of forest ecosystem services' furniture with a particular emphasis for touristic and recreational functions [27].

Climate change was projected to play a key role in future changes in western Europe, in addition to northern and southern Europe. As example, simulation by Takolander et al. [28] reported a shift of forests that could impact Alps, Scandinavian countries, and Mediterranean area. Specifically, adverse effects of climate change were reported to be substantial in southern countries, and these impacts were evaluated in terms of both direct (e.g., drought and fire hazards) and indirect (e.g., high biotic damage caused by insects or pathogens) effects. Such threats were often investigated perhaps because this region has been and is still subject to sever problems, such as abandonment of rural areas (particularly in mountainous and inner regions) and poor forest management due to uneconomic production processes and fragmentation of properties caused by private ownership.

Relatively few NWFPs have been studies in the whole European context—mushroom being one of these. The LU "mushrooms" co-occurred with terms related to forest management, data collection and modelling, and research in the field of forest fruit. A specific role of mushrooms, as an indicator of the heavy metal contamination of soil (e.g., mercury, chromium, and zinc), was represented in eastern Europe. The specificity of this use to the eastern areas may be attributed to the Chernobyl disaster and the need for practical and widespread indicators of pollution [29].

Studies on other NWFPs were reported in different regions. Majority of the studies in northern and eastern Europe focused on forest fruit (berries), while truffle was highly relevant to eastern and southern Europe. In addition, bee products (such as propolis or honey) were prominent in western and eastern Europe, while resin was prominent in western and southern Europe. Many studies in the southern and eastern context focused on nuts. Some NWFPs were specific to particular regions. For instance, berries, moose, and some mushroom species (*Lactarius* and *Suillus*) were specific to the northern regions; resin and buzzard to the western regions; cork and eucalyptus gum to the southern regions; and ungulates, bees, and truffle to the eastern regions. This picture confirms results from Wolfslehner et al. [30] that investigated presence, use and consumption of NWFP at European level (apart from wildlife). Of note, however, such specificities must not be considered as "typical" products of a specific area, even though this is true in some cases (e.g., for cork and gum in southern Europe and moose in northern Europe). As explained in Materials and Methods, specificities must be simply considered over-investigated topics in that region relative to others. This aspect represents a limitation of quantitative analysis that a general framework of an argument can only be provided when it is thoroughly investigated scientifically. Therefore, a classic qualitative literature review is warranted for comprehensive evaluation of a specific LU or geographic context.

A quantitative review provides evidence of the most examined countries. The comparison of CM and specificities across regions listed in Appendix A indicates that only a few states are covered in the analysis. In general, the amount of scientific data generated (depending on funds dedicated to research, area of the country, and percentage of forested land) may influence the attention paid to NWFP analysis. For instance, the United Kingdom in northern Europe (low percentage of forest land, 13%), Montenegro in southern Europe (the lowest gross development production in Europe), Republic of Moldova in eastern Europe, and Liechtenstein in western Europe (reduced area) are not sufficiently represented in the corpus for quantification. Thus, additional data and tools must be integrated to represent arguments and contexts with little quantitative relevance.

Another weakness of text mining is the inability to distinguish the terms posed in the corpus with positive or negative meanings. For instance, the impact of ungulates, and wildlife in general, can be perceived as positive to promote tourism (hunting—as in eastern Europe—or photo-hunting) or to maintain biodiversity [31]; however, the potential negative impacts of the damage to forest restoration caused by deer (typical in some areas of southern in eastern Europe), damage to the rural infrastructure caused by bears, and risk of road accidents due to moose and reindeer [32] are difficult to depict in text mining.

Furthermore, this review may have underestimated scientific literature; as such, adjectival and demonymic forms of a country's name do not consider sub-regions (e.g., NUTS-2 or NUTS-3 levels of Eurostat classification) or cities. However, these circumstances are rare in international scientific articles, because abstracts or keywords usually report the national context even though the case study is limited to local areas. Exclusion of grey literature implies a reduction in European scientific production. Nevertheless, such selection facilitates the replication of analysis in other contexts, extra-European regions, and/or future periods. Temporal trends can also be investigated based on the Scopus platform to evaluate how research interest into NWFPs varies over time. The application of big data (in the form of text mining) simplifies NWFP research in a modular way (from a spatiotemporal viewpoint).

5. Conclusions

Conventional literature reviews on NWFPs have generally concentrated on specific topics. The lack of policies or financial support for non-timber products is, in fact, a commonly evaluated topic. However, a comprehensive investigation on NWFPs cannot be analyzed with classic qualitative reviews, that is, by reading extensive text and extrapolating relevant information. This is mainly because of the massive number of manuscripts published, as evidenced by over 1000 articles just in the context of Europe analyzed in the present review.

The outputs of the present work are relevant to different actors of the forestry sector, taking into account the limitations mentioned in discussion.

Integration of quantitative and qualitative literature reviews would allow decision-makers to form a basis for policies and management plans to optimize the evaluation and valorization of NWFPs, strictly relevant to the local and national socioeconomic and environmental improvement. For instance, preliminary guidelines can be established at the regional level: (i) in northern Europe, the effects of a particular form of forest management on NWFP production should be assessed; ii) in western Europe, attention should be paid to the potential impacts of the future forest dynamics (e.g., in terms the negative effects of climate change on NWFPs); (iii) in southern Europe, the potential economic impacts of climatic change, both direct and indirect, as well as the socioeconomic threats (rural abandonment or lack of management) should be assessed based on a cost–benefit analysis to establish mitigation strategies; and (iv) in eastern Europe, the economic value of NWFPs should be estimated to justify and optimize the NWFP chain.

Thanks to the quantitative and graphical representation of the output, the present review can be useful for knowledge transfer from the scientific sector to stakeholders of the forest and NWFP chains.

Finally, researchers can apply text mining in future investigations for (i) gap analysis to represent under-investigated arguments; and (ii) additional text mining through sequence and network analysis, emerging theme modelling, or cluster analysis to emphasize scientifically sound and innovative application of big data in the forest sector.

Author Contributions: Conceptualization: S.S., R.F., and I.B.; methodology and software use: S.S. and C.B.; data acquisition: C.B.; writing—original draft preparation: S.S.; writing—review and editing: S.S., C.B., R.F. and I.B.; supervision and funding acquisition: S.S; project administration: S.S., I.B. All authors have read and agreed to the published version of the manuscript.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Appendix A. Classification of States in European Regions

State	European region
Åland Islands	Northern Europe
Albania	Southern Europe
Andorra	Southern Europe
Austria	Western Europe
Belarus	Eastern Europe
Belgium	Western Europe
Bosnia and Herzegovina	Southern Europe
Bulgaria	Eastern Europe
Croatia	Southern Europe
Czech Republic	Eastern Europe
Denmark	Northern Europe
Estonia	Northern Europe
Faroe Islands	Northern Europe
Finland	Northern Europe
France	Western Europe
Germany	Western Europe
Gibraltar	Southern Europe
Greece	Southern Europe
Guernsey	Northern Europe
Holy See	Southern Europe
Hungary	Eastern Europe
Iceland	Northern Europe
Ireland	Northern Europe
Isle of Man	Northern Europe
Italy	Southern Europe
Jersey	Northern Europe
Latvia	Northern Europe
Liechtenstein	Western Europe
Lithuania	Northern Europe
Luxembourg	Western Europe
Malta	Southern Europe
Monaco	Western Europe
Montenegro	Southern Europe
Netherlands	Western Europe
Norway	Northern Europe
Poland	Eastern Europe
Portugal	Southern Europe
Republic of Moldova	Eastern Europe
Romania	Eastern Europe

State	European region
Russia	Eastern Europe
San Marino	Southern Europe
Serbia	Southern Europe
Slovakia	Eastern Europe
Slovenia	Southern Europe
Spain	Southern Europe
Svalbard and Jan Mayen Islands	Northern Europe
Sweden	Northern Europe
Switzerland	Western Europe
The former Yugoslav Republic of Macedonia	Southern Europe
Ukraine	Eastern Europe
United Kingdom	Northern Europe

Appendix B. Queries Applied to Create the Corpus [a,b]

TITLE-ABS-KEY (("non wood forest product*" OR "non timber forest product* OR NWFP OR NTFP") OR (forest* AND (nuts OR resin* OR gum* OR forage OR dyeing OR tanning OR perfumery OR pharmaceutical* OR insecticidal OR fungicidal OR cork OR syrup OR sugar OR butter OR molasses OR mushroom* OR truffle* OR berry OR berries OR hides OR skins OR "trophies" OR "wild game" OR "game meat" OR "bushmeat" OR "natural medicines" OR honey OR cosmetic* OR silk OR candle* OR "edible insect*" OR beer OR latex))) AND TITLE-ABS-KEY (*portugal OR portuguese OR "Isle of Man" OR manx OR luxembourg OR luxembourgish OR luxembourgers OR spain OR spanish OR spaniards OR sweden OR swedish OR swedes OR switzerland OR swiss OR finland OR finnish OR finns OR romania OR romanian OR romanians OR belgium OR belgian OR belgians OR slovenia OR slovenian OR slovene OR slovenes OR slovenians OR norway OR norwegian OR norwegians OR austria OR austrian OR austrians OR "United Kingdom" OR british OR welsh OR "Northern Irish" OR scots OR scottish OR english OR englishmen OR englishwomen OR britons OR "Northern Irishmen" OR "Northern Irishwomen" OR scotsmen OR scotswomen OR welshmen OR welshwomen AND NOT ("British Virgin Islands" OR "British Virgin Islanders") OR netherlands OR dutch OR netherlandic OR dutchmen OR dutchwomen OR netherlanders AND NOT ("Netherlands Antilles") OR hungary OR hungarian OR magyar OR hungarians OR magyars OR bulgaria OR bulgarian OR bulgarians OR belarus OR belarusian OR belarusians OR "Czech Republic" OR czech OR czechs OR italy OR italian OR italians OR estonia OR estonian OR estonians OR slovakia OR slovak OR slovaks OR germany OR german OR germans OR france OR french OR frenchmen OR frenchwomen AND NOT ("French Guiana" OR "French Guianese") AND NOT ("French Polynesia" OR "French Polynesian" OR "French Polynesians") OR gibraltar OR gibraltarians OR greece OR greek OR hellenic OR greeks OR hellenes OR denmark OR danish OR danes OR iceland OR icelandic OR icelanders OR ukraine OR ukrainian OR ukrainians OR lithuania OR lithuanian OR lithuanians OR poland OR polish OR poles OR malta OR maltese OR "east europe" OR "eastern europe" OR "east of europe" OR "east european" OR "eastern european" OR "north europe" OR "northern europe" OR "north of europe" OR "north european" OR "northern european" OR "southern europe" OR "south europe" OR "south of europe" OR "southern european" OR "south european" OR "western europe" OR "west europe" OR "west of europe" OR "western european" OR "west european" OR russia OR russian OR russians OR serbia OR serbian OR serbs OR serbians OR latvia OR latvian OR latvians OR letts OR "The former Yugoslav Republic of Macedonia" OR macedonia OR macedonian OR macedonians OR albania OR albanian OR albanians OR ireland OR irish OR irishmen OR irishwomen OR "Svalbard and Jan Mayen Islands" OR svalbard OR "Åland Islands" OR "Åland Island" OR "Åland Islanders" OR andorra OR andorran OR andorrans OR "Bosnia and Herzegovina" OR bosnian OR herzegovinian OR bosnians OR herzegovinians OR croatia OR croatian OR croatians OR croats OR "Faroe Islands" OR faroese OR faroese OR guernsey OR "Holy See" OR vatican OR "Vatican citizens" OR "Jersey Island" OR "Channel Island" OR "Channel Islanders" OR liechtenstein OR liechtensteiners OR monaco OR monégasque OR monacan OR monégasques OR monacans OR montenegro OR montenegrin*

OR montenegrins OR "republic of moldova" OR moldova OR moldovan OR moldovans OR "San Marino" OR sammarinese) AND NOT "random forest" AND (LIMIT-TO (EXACTSRCTITLE, "Forest Ecology And Management") OR LIMIT-TO (EXACTSRCTITLE, "Canadian Journal Of Forest Research") OR LIMIT-TO (EXACTSRCTITLE, "Forests") OR LIMIT-TO (EXACTSRCTITLE, "Scandinavian Journal Of Forest Research") OR LIMIT-TO (EXACTSRCTITLE, "Silva Fennica") OR LIMIT-TO (EXACTSRCTITLE, "Journal Of Applied Ecology") OR LIMIT-TO (EXACTSRCTITLE, "Forestry") OR LIMIT-TO (EXACTSRCTITLE, "Journal Of Ecology") OR LIMIT-TO (EXACTSRCTITLE, "Forest Systems") OR LIMIT-TO (EXACTSRCTITLE, "Advanced Materials Research") OR LIMIT-TO (EXACTSRCTITLE, "Agroforestry Systems") OR LIMIT-TO (EXACTSRCTITLE, "European Journal Of Forest Research") OR LIMIT-TO (EXACTSRCTITLE, "Environmental Monitoring And Assessment") OR LIMIT-TO (EXACTSRCTITLE, "Journal Of Animal Ecology") OR LIMIT-TO (EXACTSRCTITLE, "Plos One") OR LIMIT-TO (EXACTSRCTITLE, "Journal Of Agricultural And Food Chemistry") OR LIMIT-TO (EXACTSRCTITLE, "Industrial Crops And Products") OR LIMIT-TO (EXACTSRCTITLE, "Agricultural And Forest Meteorology") OR LIMIT-TO (EXACTSRCTITLE, "Biological Conservation") OR LIMIT-TO (EXACTSRCTITLE, "Food Chemistry") OR LIMIT-TO (EXACTSRCTITLE, "Forest Policy And Economics") OR LIMIT-TO (EXACTSRCTITLE, "Oecologia") OR LIMIT-TO (EXACTSRCTITLE, "Remote Sensing Of Environment") OR LIMIT-TO (EXACTSRCTITLE, "Atmospheric Environment") OR LIMIT-TO (EXACTSRCTITLE, "Biological Invasions") OR LIMIT-TO (EXACTSRCTITLE, "Canadian Journal Of Zoology") OR LIMIT-TO (EXACTSRCTITLE, "Environmental Pollution") OR LIMIT-TO (EXACTSRCTITLE, "Forestry Chronicle") OR LIMIT-TO (EXACTSRCTITLE, "Geobotany Studies") OR LIMIT-TO (EXACTSRCTITLE, "Geoderma") OR LIMIT-TO (EXACTSRCTITLE, "Global Change Biology") OR LIMIT-TO (EXACTSRCTITLE, "Wood Research") OR LIMIT-TO (EXACTSRCTITLE, "Acta Horticulturae") OR LIMIT-TO (EXACTSRCTITLE, "Annals Of Forest Science") OR LIMIT-TO (EXACTSRCTITLE, "Applied Mechanics And Materials") OR LIMIT-TO (EXACTSRCTITLE, "Journal Of Forest Economics") OR LIMIT-TO (EXACTSRCTITLE, "Journal Of Insect Conservation") OR LIMIT-TO (EXACTSRCTITLE, "Journal Of Wildlife Management") OR LIMIT-TO (EXACTSRCTITLE, "Wood Science And Technology") OR LIMIT-TO (EXACTSRCTITLE, "Agricultural Water Management") OR LIMIT-TO (EXACTSRCTITLE, "Ambio") OR LIMIT-TO (EXACTSRCTITLE, "Bioresources") OR LIMIT-TO (EXACTSRCTITLE, "Ecological Indicators") OR LIMIT-TO (EXACTSRCTITLE, "European Journal Of Soil Science") OR LIMIT-TO (EXACTSRCTITLE, "European Journal Of Wood And Wood Products") OR LIMIT-TO (EXACTSRCTITLE, "Folia Forestalia Polonica Series A") OR LIMIT-TO (EXACTSRCTITLE, "Journal Of Range Management") OR LIMIT-TO (EXACTSRCTITLE, "Remote Sensing") OR LIMIT-TO (EXACTSRCTITLE, "Sustainability Switzerland") OR LIMIT-TO (EXACTSRCTITLE, "Acta Oecologica") OR LIMIT-TO (EXACTSRCTITLE, "Biomass And Bioenergy") OR LIMIT-TO (EXACTSRCTITLE, "Bioresource Technology") OR LIMIT-TO (EXACTSRCTITLE, "Cancer Research") OR LIMIT-TO (EXACTSRCTITLE, "Catena") OR LIMIT-TO (EXACTSRCTITLE, "Ecological Economics") OR LIMIT-TO (EXACTSRCTITLE, "Ecology") OR LIMIT-TO (EXACTSRCTITLE, "Ecology And Society") OR LIMIT-TO (EXACTSRCTITLE, "Economic Botany") OR LIMIT-TO (EXACTSRCTITLE, "Forest Science") OR LIMIT-TO (EXACTSRCTITLE, "Functional Ecology") OR LIMIT-TO (EXACTSRCTITLE, "Iforest") OR LIMIT-TO (EXACTSRCTITLE, "International Journal Of Environmental Research And Public Health") OR LIMIT-TO (EXACTSRCTITLE, "Japanese Journal Of Ecology") OR LIMIT-TO (EXACTSRCTITLE, "Journal Of Ethnobiology And Ethnomedicine") OR LIMIT-TO (EXACTSRCTITLE, "Land Use Policy") OR LIMIT-TO (EXACTSRCTITLE, "Plant Ecology") OR LIMIT-TO (EXACTSRCTITLE, "Scientific Reports") OR LIMIT-TO (EXACTSRCTITLE, "Soil Use And Management") OR LIMIT-TO (EXACTSRCTITLE, "Urban Forestry And Urban Greening") OR LIMIT-TO (EXACTSRCTITLE, "Basic And Applied Ecology") OR LIMIT-TO (EXACTSRCTITLE, "Biodiversity And Conservation") OR LIMIT-TO (EXACTSRCTITLE, "Bird Study") OR LIMIT-TO (EXACTSRCTITLE, "Canadian Field Naturalist") OR LIMIT-TO (EXACTSRCTITLE, "Canadian Journal Of Botany") OR LIMIT-TO (EXACTSRCTITLE,

"Climate Change Management") OR LIMIT-TO (EXACTSRCTITLE, "Ecosphere") OR LIMIT-TO (EXACTSRCTITLE, "Ecosystem Services") OR LIMIT-TO (EXACTSRCTITLE, "Energies") OR LIMIT-TO (EXACTSRCTITLE, "Environmental Management") OR LIMIT-TO (EXACTSRCTITLE, "Forest Chemicals Review") OR LIMIT-TO (EXACTSRCTITLE, "Forest Products Journal") OR LIMIT-TO (EXACTSRCTITLE, "Ibis") OR LIMIT-TO (EXACTSRCTITLE, "Journal Of Cleaner Production") OR LIMIT-TO (EXACTSRCTITLE, "Journal Of Environmental Management") OR LIMIT-TO (EXACTSRCTITLE, "Key Engineering Materials") OR LIMIT-TO (EXACTSRCTITLE, "Land Degradation And Development") OR LIMIT-TO (EXACTSRCTITLE, "Landscape And Urban Planning") OR LIMIT-TO (EXACTSRCTITLE, "Molecules") OR LIMIT-TO (EXACTSRCTITLE, "New Forests") OR LIMIT-TO (EXACTSRCTITLE, "New Phytologist") OR LIMIT-TO (EXACTSRCTITLE, "Rangelands") OR LIMIT-TO (EXACTSRCTITLE, "Sensors Switzerland") OR LIMIT-TO (EXACTSRCTITLE, "Wildlife Biology") OR LIMIT-TO (EXACTSRCTITLE, "Wildlife Research") OR LIMIT-TO (EXACTSRCTITLE, "Aip Conference Proceedings") OR LIMIT-TO (EXACTSRCTITLE, "Annales Botanici Fennici") OR LIMIT-TO (EXACTSRCTITLE, "Behavioral Ecology And Sociobiology") OR LIMIT-TO (EXACTSRCTITLE, "Biotropica") OR LIMIT-TO (EXACTSRCTITLE, "Boreal Environment Research") OR LIMIT-TO (EXACTSRCTITLE, "Botany") OR LIMIT-TO (EXACTSRCTITLE, "Canadian Journal Of Plant Science") OR LIMIT-TO (EXACTSRCTITLE, "Dendrochronologia") OR LIMIT-TO (EXACTSRCTITLE, "Diversity And Distributions") OR LIMIT-TO (EXACTSRCTITLE, "Dryland Forests") OR LIMIT-TO (EXACTSRCTITLE, "Ecoscience") OR LIMIT-TO (EXACTSRCTITLE, "Environmental Entomology") OR LIMIT-TO (EXACTSRCTITLE, "European Journal Of Forest Pathology") OR LIMIT-TO (EXACTSRCTITLE, "European Journal Of Wildlife Research") OR LIMIT-TO (EXACTSRCTITLE, "Herpetological Journal") OR LIMIT-TO (EXACTSRCTITLE, "International Wood Products Journal") OR LIMIT-TO (EXACTSRCTITLE, "Journal Of Chemical Ecology") OR LIMIT-TO (EXACTSRCTITLE, "Journal Of Forest Research") OR LIMIT-TO (EXACTSRCTITLE, "Journal Of Forest Science") OR LIMIT-TO (EXACTSRCTITLE, "Journal Of Mammalogy") OR LIMIT-TO (EXACTSRCTITLE, "Undefined")) AND (LIMIT-TO (LANGUAGE, "English"))

[a] In italic, to be selected according to the investigated region.

[b] Articles related to Russia were manually investigated to exclude those specifically related to Asia.

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