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Mapping of a field: A systematic review of reviews on forestry and the forest-based sector in Europe

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ABSTRACT

This study applies PRISMA guidelines to map and analyze trends and patterns in evidence synthesis within the field of Forestry and Forest-based Sector (F&FS). Given the role of evidence synthesis in shaping research priorities and informing policy, the study investigates potential biases in evidence synthesized by examining different forms of synthesis (i.e. systematic and non-systematic), topics covered and geographical distribution of underpinning studies. Following a thorough expert-led classification of F&FS topics, we identified 35,015 reviews from Europe, of which 642 were systematic. Although rapidly growing, systematic literature reviews (SLRs) still account for under 1% of all scientific production in F&FS (~5% of all evidence synthesis). Reviewed topics are dominated by management, biodiversity and climate change, even though the field is sprawling away from core silviculture themes and into more transdisciplinary issues. However, SLRs are more abundant in health-related and social science topics compared to non-systematic reviews, while syntheses of forest technologies and forest products are underrepresented. We also find an uneven geographical distribution of systematized evidence, South-eastern Europe the least and Mediterranean-Northern-Western Europe the most represented. Factors best explaining observed patterns are investment in Research & Development and economic contribution of value in million US dollars added in the forest sector. Our results show evidence synthesis within the F&FS field comes with structural biases in selected research themes, geographical distribution, and methodological approaches. The resulting partial understanding of the knowledge base may influence not only scientific agendas but also policy priorities, assuming such evidence is taken up by policymakers.

1. Introduction

The EU Forest Strategy for 2030 highlights the need for innovative, science-based solutions to support healthy, biodiverse, and resilient forests across Europe, recognizing forests' multifunctional role in providing forest-based products and services (European Commission, 2021). To achieve these goals, evidence-based policymaking and practice, which rely on a clear understanding of existing research and knowledge in forestry and the forest-based sector (F&FS), are essential. Therefore, mapping the current knowledge base helps inform better decisions for managing Europe's forests.

In recent years, the volume of scientific research has grown

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significantly, making periodic reviews of the existing literature crucial for organizing and applying knowledge effectively. This appraisal of previous research, often termed "evidence synthesis", gathers, evaluates, and summarizes research findings to comprehensively understand current knowledge and trends in a field, identify gaps and biases, evaluate theories, set a research agenda, and answer questions beyond the scope of individual studies Grant and Booth (2009) provide a useful typology of review methods, highlighting different approaches that serve distinct purposes: systematic literature reviews (SLRs) rigorously collect and assess research to answer specific policy or practice questions; meta-analyses combine quantitative findings from multiple studies to determine overall trends or effects; and scoping reviews broadly map available research to highlight areas lacking sufficient investigation. A step further, 'umbrella reviews' offer a high-level systematic way of synthesizing review articles rather than primary studies (Fernandez et al., 2025). As a reflection of the growing importance of evidence synthesis, by 2020, quantitative (e.g. meta-analysis) and qualitative (e.g. scoping) systematic literature reviews (SLRs) accounted for 1.79% of all published studies (Gusenbauer, 2021).

F&FS is a relative latecomer in the use of systematic reviews compared to pioneering fields in the health and life sciences (Gusenbauer, 2021). Some F&FS sub-fields developed their own outlets for evidence synthesis, such as the Tamm and Acorn reviews. Tamm reviews are invitation-only, solicited by the editors of the Journal of *Forest Ecology and Management* for particularly high-profile topics. Acorn Reviews are brief assessments for non-specialists. Although some follow a systematic approach, this is not required. As reviewed topics have transcended traditional subject-expert boundaries and expanded coverage of an expanding field, methods for evidence synthesis have expanded to also include bibliometrics and network analyses (Fernandez et al., 2025; Zhao et al., 2024).

Over the years, several studies have attempted to systematically map parts of the European F&FS research and development landscape, most of them focusing on specific sub-fields of the forest-based sector, such as forest ecosystems (e.g. Aznar-Sánchez et al., 2018), forest bioeconomy (e.g. Hetemäki et al., 2024) or forest restoration (e.g. Nunez-Mir et al., 2015). Lovrić et al. (2020) mapped the research in the field of forest-based bioeconomy by looking at projects from the EU framework programs and the European Research Area. The analysis revealed that the field of forest-based bioeconomy is not well-integrated on its own, and that actors involved in primary and secondary processing are not present in topics closely related to forestry (Lovrić et al., 2020). Weiss et al. (2020) implemented a systematic literature review on innovation from a social science perspective of the entire forestry and forest-based industries. This review showed that new approaches are emerging and extending the research field, for example, toward user-centered, open, inclusive, or social innovations in forestry. Most recent reviews have targeted the role of AI for revolutionizing industrial processes in F&FS (e.g. Holzinger et al., 2024). A few studies have conducted umbrella reviews of meta-analyses within a narrow topic of F&FS, such as forest-bathing therapies or forest soils (Antonelli et al., 2022; Martin and Izquierdo, 2022). Although most of these reviews rely on similar sources for data collection (e.g., Web of Science, Scopus, or Google Scholar), their scopes are narrow, and the approaches used to conduct these reviews differ considerably, making an overall assessment of evidence synthesis in the field challenging.

Structured approaches to evidence synthesis enhance evidence-based policy and practice by reducing the risk of overlooking important studies or introducing selection biases. Moreover, systematic and transparent methods help policymakers and practitioners easily compare results over time and across different contexts (Linnenluecke et al., 2020). Regularly reviewing and synthesizing research thus enables stakeholders to stay informed of emerging issues, clarify knowledge gaps, and make informed, evidence-based decisions (Page et al., 2021).

To date, only partial attempts like the ones mentioned above have been made to map the state of evidence synthesis in the field of F&FS. The size, composition, and boundaries of the scientific production on F&FS remain in uncharted territory. This may have implications beyond the scientific community in important ways. Studies that synthesize the state of the art, identify gaps and trends, qualify confidence in findings, and provide recommendations for the direction of future research are useful tools for knowledge brokers who require an overview of the field. Evidence synthesis in its many forms is already commonly used as a core input for high-level decision-making, which affects the prioritization of future lines of research, funding, and on-the-ground development (e.g., IPCC, IPBES, and IUFRO periodic reports). We refer to this as "agenda-setting" input. In the EU, the Strategic Research and Innovation Agendas (SRIAs) are a good example of this. While individual studies may have limited influence on agenda-setting within the science-policy interface, the cumulative body of evidence within a field plays a critical role in shaping policy priorities and guiding decision-making over time. Therefore, a critical analysis of the content, patterns and trends of the knowledge that gets synthesized is essential to identify potential biases in the synthesis process and ensure a transparent and fair agenda-setting at the science-policy interface.

Although evidence synthesis is increasingly used in F&FS, a comprehensive overview of its application across the field is still lacking. Existing reviews tend to focus on narrow sub-fields or specific technologies, leaving the broader landscape of synthesized knowledge uncharted. This review addresses this gap by systematically mapping the use of evidence synthesis methods in F&FS, thereby offering a meta-perspective on how knowledge is structured, prioritized, and potentially biased. A key innovation of this review is the application of network analyses (Borgatti et al., 2022) using bibliometric data as an approach to evidence synthesis. By analyzing the connections between review articles, topics, and methodologies, this perspective reveals structural patterns in the knowledge base—such as clustering, fragmentation, and centrality—that traditional reviews may overlook. Integrating this approach from the outset allows for a more nuanced understanding of how evidence is organized and mobilized within F&FS, and how it influences both research and policy agendas.

The European focus of this review reflects both the institutional context of the authors and their involvement in a Horizon Europe funded interdisciplinary research project endeavoring to greatly strategically improve the forestry and forest-based sector's research and innovation funding and governance structure. The European Union offers a unique policy and research environment where structured funding mechanisms (e.g., Horizon Europe) and strategic agendas (e.g., SRIAs) play a central role in shaping forestry research. Understanding evidence synthesis within this context is crucial for informing policy and ensuring that research priorities align with societal and environmental needs.

Building on these premises, this research article aims to analyze the use of evidence synthesis methods in F&FS (such as reviews and systematic reviews) to systematically map and analyze the patterns and trends within the field. Consequently, the study is mainly descriptive, employing network analysis and natural language processing techniques to visualize F&FS. The second, European-level goal is to offer an empirical overview of the forestry and forest-based sectors as depicted through systematic reviews, operating under the assumption that the topics covered by these reviews reflect the main research areas. Additionally, the study examines the prominence of F&FS research at the country level and investigates factors that may influence research productivity.

2. Methods

Our analysis was based on the collection of a large dataset which was analyzed quantitatively and a subset that was analyzed qualitatively. The first dataset included all review papers that meet our criteria, irrespective of the review method employed (n=35,015). For the analysis of this dataset, we used an inductive approach based on analyzing patterns

from the documents' metadata. The second dataset represents the subset of studies that used a systematic literature review (SLR) approach (n=642). Documents in this dataset were qualitatively coded following a classifying framework drawn by experts (deductive approach). From these, we collected information on the countries where empirical studies included in the SLR were conducted and correlated it with different measures of geographical incidence in F&FS. Trends and patterns from the subset of SLRs were compared with the overall picture emerging from the full dataset.

2.1. Methodological approach to defining the conceptual boundaries of F&FS

Before detailing the methodological approach, it is important to clarify what is meant by forestry and the forest-based sector. One of the main challenges faced by this type of analysis is the sprawling and blurred boundaries of the F&FS field, increasingly cutting across traditional scientific disciplines, industries, policy spheres, and institutional mandates. We followed an encompassing definition of forestry as consisting of those biological, quantitative, managerial, and social sciences that are applied to forest management and conservation; it includes specialized fields such as agroforestry, urban forestry, forest ecology, physiology and genetics, industrial forestry, non-industrial forestry, and wilderness and recreation forestry. It also includes fire prevention, assessment, harvesting, non-wood forest products, etc. For the definition of the forest-based sector, we use the approach of EUROSTAT (2024), which is rooted in the NACE classification of industrial activity (EUROSTAT, 2008).

We have compiled subfields, definitions, and key-words relevant to forestry and forest-based industry based on scientific literature (e.g., Lovrić et al., 2020; Chazdon et al., 2016; Helms, 2002; Schuck et al., 2002), the dictionary of forestry (Helms, 1998), IUFRO's (2024) classification of IUFRO divisions (Helms, 2002), Global Forest Decimal Classification (Holder et al., 2006), and reports from the previous mappings of research activity and capacities in the field. For certain complex topics, we used specialized literature, e.g., for ecosystem services (Haines-Young and Potschin, 2018; Maes et al., 2011) or for secondary processing. All of this was compiled into a single working document, listing topics that fall within the scope of the study as well as their definitions.

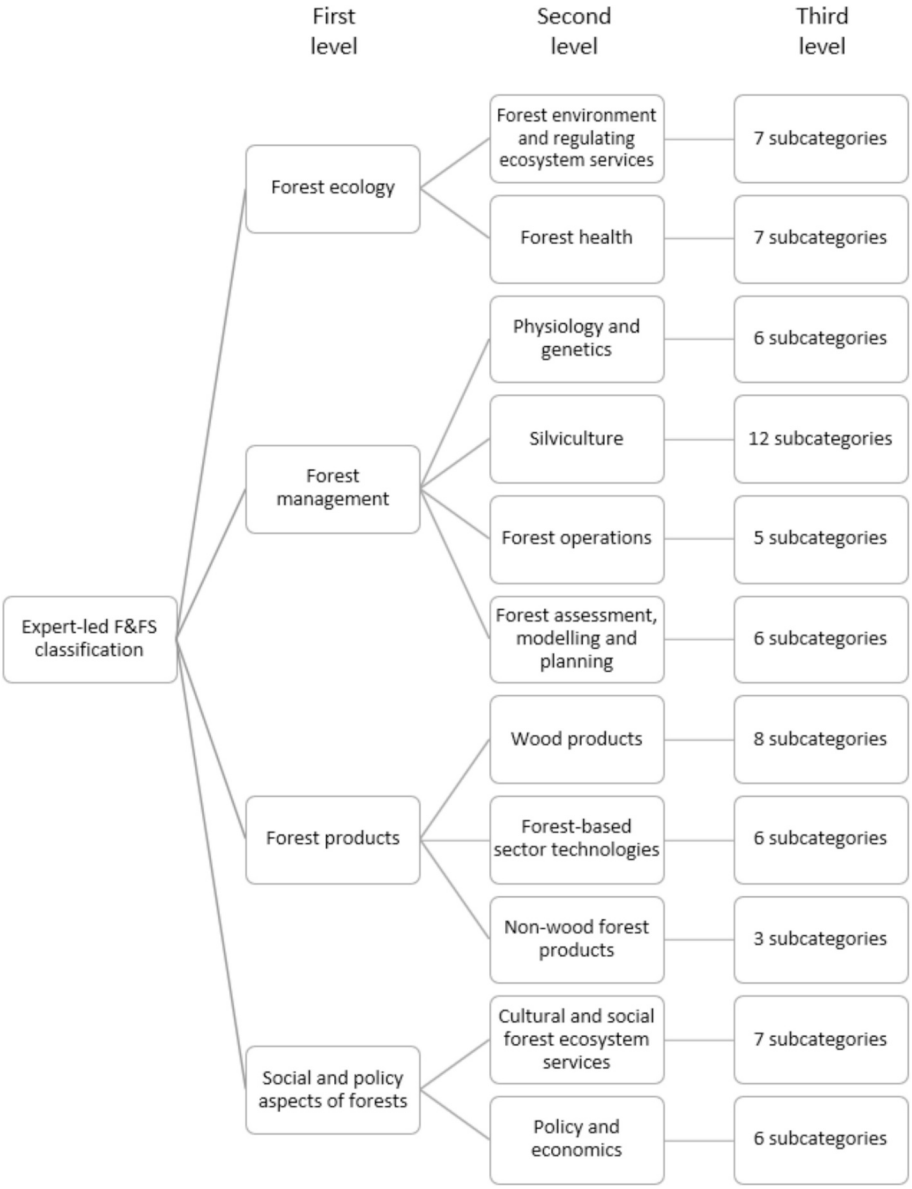

Fig. 1. Overview of the expert-led classification of F&FS used for thematic classification of SLRs (see Supplementary Information, SI-1).

This document was then iteratively reviewed by more than 20 European experts within the Horizon Europe funded interdisciplinary research project representing academia, industry and the science-policy interface, and covering with their expertise the wide palette of topics that fall within the scope of the study. Revisions followed a series of guided discussions as well as written feedback.

The result was a listing of 73 specific domains of F&FS, belonging to 11 meso-level topics and four overarching themes (henceforth "expert-led classification"), which were also used to classify SLRs according to the topic (Fig. 1). Full classification is found in the Supplementary Information (SI-1), and more details are provided in the Methods section.

2.2. Data collection

2.2.1. Information sources for keyword identification

Our search, identification, and analysis strategy followed the PRISMA guidelines of best practices for systematic literature reviews (Page et al., 2021). The keyword identification followed an iterative approach using several information sources, i.e., from experts, from documents, and complemented with semi-automated curation techniques. Expert input was drawn mostly from the exercise and the classification document described in section 2.1. The keywords of this document were used as a starting point. We continued expanding the scope of the query to capture terms specific to all value chains in the forest-based sector and disciplines within forestry (e.g., genetics) by requesting field-specific keywords from project partners.

In Web of Science (WoS), we then initiated a basic search using general keywords (*forest*, tree*, *wood*, *timber*) to find other relevant keywords. We searched titles, abstracts, author keywords, and WoS tags (Keywords Plus). Keywords Plus are WoS composite document keywords that draw from an article's references, but do not appear in the title of the article itself (Clarivate, 2022). We used WoS 'all databases' (ca. 200 million records) rather than the 'core collection' (ca. 87 million records) (Clarivate, 2024). All databases selected also claim to have the "strongest coverage of natural sciences & engineering, computer science, materials sciences, patents, data sets". We did not impose a time limit, so the search was done across all available years by our cut-off date (available online before January 1st 2023). As a validation of our search string, project partners provided key review papers in their respective fields that should be captured in our search.

A limitation with traditional scientific databases (like WoS or Scopus) is that they almost exclusively index articles from academic outlets. Therefore, they may overlook "grey literature," which is "articles that are not formally published by commercial academic publishers" (Haddaway et al., 2015). As the selection method excludes scientific publications outside internationally published, peer-reviewed English-language journals, it also omits other forms of knowledge relevant to the analysis of knowledge production in the forests and forest-based sector. As a result, the study is limited to scientific knowledge and does not incorporate local, indigenous, or practitioner-based knowledge. Nevertheless, given the majority of evidence-based research in F&FS is published in English-language journals, this approach remains justified for the purposes of this analysis. This also implies that we may inadvertently weigh our analysis toward scholarly impact (Martín-Martín et al., 2018). However, given that our primary interest lies in mapping trends and impact within academic literature, the focus on peer-reviewed sources is arguably appropriate. Moreover, while platforms such as Google Scholar index a broader range of content, there is, to our knowledge, no tractable solution to reliably extract structured metadata from them. Therefore, we must suffice with WoS (or Scopus), which, incidentally, are the most established sources of bibliographic data (Visser et al., 2021), and which largely have similar coverage on most core scientific topics (Martín-Martín et al., 2018; Visser et al., 2021).

2.2.2. Search and identification strategy

The next step was to refine the keywords to capture as many relevant papers as possible while reducing the number of irrelevant results (Table 1). We did this in three ways: 1) Automated search for more specific two-word or sentence search terms to limit irrelevant documents, using the R package Litsearchr. 2) Identification of confounding terms by looking into irrelevant WoS categories. 3) Trying anchoring words related to trees, forests, and conceptual synonyms as a condition to appear in conjunction with the other identified terms (including broad terms such as "resilience", "ecosystem services" or "natural resources").

We iteratively identified confounding words that drove spurious hits (articles not connected to F&FS) by checking the titles of scientific categories in WoS and determining whether they were less relevant for F&FS (marine biology, dentistry, ophthalmology, etc.). There is a trade-off between optimizing our results to get only forestry-relevant papers through exclusionary terms and the potential loss of some marginally relevant papers. For example, by excluding "forest plot*" we lost nine forestry papers but also filtered 1800 potentially irrelevant papers that

Table 1
Main query components (i.e. category) and examples of search terms included.

Category	Description	Examples
Review	Derivations of the word 'review'	**Query 1:** Review*
	Systematic literature review terms	**Query 2:** "Systematic literature review*", "Systematic review*", "systematically review*"
Core forest and tree terms	Include main words associated with forestry	*forest*, *tree*, *wood*, *timber*
	Scientific and common names of tree species in Europe	"quercus palustris", "pin oak*", "cupressus sempervirens", "mediterranean cypress*"
Additional forestry sector terms	Forest products	"fiber*", "extractives", "texture", "bark", "medicinal"
	Forest environment and regulating services	"ecosystem service*", "regulating", "resilien*", "carbon captur*", "groundwater", "mitigation"
	Cultural ecosystem services and social aspects	"nature-based tourism", "recreation", "urban green", "human wellbeing"
	Physiology and genetics	"Xylem", "hydraulic architecture*", "shoot growth", "rhizosphere*", "DNA marker*"
	Forest health	"plant pathology", "parasitic", "disease cycle*", "insect resistan*"
	Silviculture	"conifer*", "plantation", "biomass", "intercropping", "thinning", "phytoremediation"
	Forest operations engineering and management	"*harvest*", "stand treatment*", "logging operation", "transportation engineering"
	Forest assessment, modelling and planning	"inventory", "monitoring", "leaf-area index", "landscape planning", "liDAR"
	Forest policy and economics	"innova*", "policy", "trade-off*", "option value", "replacement cost", "certification*"
	Primary processing of wood-based materials	"manufactur*", "biorefin*", "sawmill*", "pyrolysis", "lignin"
	Secondary processing of wood-based materials	"pallet*", "varnish*", "coating", "sealer", "enzyme*", "catalyst*"
	Downstream processes	"veneer", "centrifuge*", "*filtration", "chromatography", "distillation"
(potential) exclusions	Confounding terms, e.g.	
	Non-forestry uses of common forest terms	"bronchial tree", "tree-in-bud", "glass fiber", "nerve branch*", "fish tending"
	Proper names (surnames, towns, universities)	"Dixon-Woods", "cawood", "Bournewood case", "Wake Forest"
	Very broad methods used commonly in non-relevant disciplines (but some also in Forestry)	"Quad tree", "Semliki forest vector*", "inference tree*", "Wood units"

employ the forest plot method in other contexts. In this case, the gain in accuracy was deemed large enough to merit the loss in breadth. Examples of other hard-to-avoid terms that work for both forestry and other unrelated disciplines are "phylogenetic tree", "cellulose", "branch", or "rainforest", as well as author surnames such as Lockwood, Englewood, or Norwood. We also found some of the irrelevant hits were the result of misspellings in the titles or abstracts of papers (e.g. "tree" instead of "three").

Below, we present the two query structures we used. The choice of query has implications for the number and relevance of records we capture. On the one hand, we were only interested in relevant papers, but at the same time, we also wanted to capture most papers in F&FS. Thus, the queries represent our attempt to balance the implied trade-off between accuracy and breadth. The full list of keywords and the final query is in the Appendix.

Query 1 (more inclusive):

TS= **((**review**) AND ((**Core forest + tree species terms**) AND (**Additional forestry sector terms**)) NOT (**confounding terms**)))** + **category and geographical refinements**

This query conditions the search to include "review*" and one of the core forestry terms in conjunction with some of the broader terms in the forestry sector and core terms. Core terms also include all the scientific and common names of tree species in Europe, as per the European Tree Atlas[1]. The NOT function in the query excluded papers with terms not relevant to our search (e.g., "deciduous teeth", "pulmonary tree*", "optical fiber*", etc.).

We added WoS topical category (see Appendix) and geographical refinements. A large share of the identified documents was largely irrelevant to the core topics we were mapping. Therefore, tangent to the initial search and identification strategy, we iteratively evaluated whether subsets of WoS's categorization were relevant based on expert input. To refine the document selection, six forest science experts individually identified the most relevant WoS categories for F&FS. After several rounds of consensus-building, a final set of 14 categories was agreed upon. Furthermore, because determining the geographical scope of each document manually (as done for the SLRs) was infeasible, we decided to refine our results further based on whether the affiliated authors are from a country within the EU, third countries associated with Horizon Europe by transitional agreements, and regional partner countries not in Europe (see in Supplementary Information SI-1, worksheet "geographical scope") using WoS's country/region classification.

To compare the scientific production of empirical papers, rather than reviews exclusively, we also ran Query 1, dropping the first condition (review*) but otherwise filtered and cleaned in the same way (n= 236,561). This was used in the results as a reference of scientific production sections compared to evidence synthesis (Fig. 2) but not otherwise analyzed.

The second query was limited to systematic literature review approaches (including meta-analyses).

Query 2 (more restrictive):

TS = **((**systematic review terms**) AND (((**Core forest + tree species terms**) AND (**Additional forestry sector terms**)) NOT (**confounding terms**)))**

2.2.3. Selection process and eligibility criteria

The Review of Reviews (RoR) resulted in two datasets: one of all review types (Dataset 1), which we analyzed quantitatively using bibliometrics tools, and a subset of exclusively systematic literature reviews (Dataset 2), which we analyzed qualitatively using content analysis. In Fig. 2 we provide an overview of the PRISMA workflow.

Dataset 1, which followed the more inclusive query outlined in Dataset 1, resulted in 45,878 review papers. We excluded 11,148 documents which were outside WoS topical categories (see Appendix) or geographical scope. After deduplication (i.e. eligibility), where we removed documents if their titles were exact matches, we were left with 34,616 unique documents.

For Dataset 2, systematic review papers, which were manually curated, we followed the criteria and decision rule below (Fig. 3) to include or exclude the papers during title and abstract screening or full-paper check. As opposed to Dataset 1, here we did not classify geographical scope based on author affiliation but based on the explicit reporting of inclusion of empirical studies into the SLR from a given European country, a more robust measure of the geographical provenance of the underlying data. To ensure comprehensive coverage of review literature, we accounted for limitations in the WoS document categorization, which can be misleading. Specifically, WoS systematically omits several actual review articles, partly due to inconsistent metadata practices where some journals fail to label reviews explicitly as such. To address this, we included multiple article types that contained the term "review*" in the Abstract, Author Keywords, or Title (see query in Appendix). Each article was manually screened to confirm its relevance and type, and only those meeting the criteria for systematic literature reviews (SLRs) were included in the final subset (Fig. 3).

From the final selection, 587 SLR articles made their search terms partially or fully available. However, beyond this indicator, the quality of the SLRs was not assessed nor used as an eligibility criteria because of very different conventions used across the scientific disciplines intersecting the F&FS field.

2.3. Data analysis

2.3.1. Network analysis of Dataset 1: all reviews

To identify central topics and themes in the F&FS literature (at present and over time), we conducted a bibliometric network analysis using the metadata contained in Dataset 1. Specifically, we used the keywords (keywords provided by the authors and Keywords Plus) of the included documents in Dataset 1 to construct a co-occurrence network, in which each keyword represents a node and links between nodes indicate that two keywords appear together in the same document. Based on this information, i.e., the nodes and the edges between them, it is possible to analyze how research topics are related across the field.

We used a variety of descriptive properties to summarize the structure of the network:

- Connectivity (components). We assessed whether all keywords belong to a single connected set. In other words, whether any topic could be reached from any other through a chain of co-occurring terms. This provided a basic check of the network's overall connectivity.
- Distances (steps). We evaluated how many steps, i.e., the number of links separating any two topics, and the maximum number of steps between the two most distant keywords.
- Frequency or degree centrality. For each keyword, we determined how many other keywords it co-occurs with. Because the co-occurrence network is undirected, the degree of a node reflects the number of other keywords with which it co-occurs. Degree centrality is a common first step in measuring the connectivity of nodes (Prell and Schaefer, 2024). In our application, this allowed us to rank keywords based on their frequency of use.
- Eigenvector centrality. It measures the extent to which a keyword is connected to other highly connected keywords. In this sense, it can be thought of as a measure of popularity (see, e.g., Borgatti et al., 2022). Therefore, it is often used to measure the relative "importance" of a node to a network (see, e.g., Guler et al. (2016) or Kong et al. (2019)) or its influence (see, e.g., Borgatti (2005)). However,

[1] https://forest.jrc.ec.europa.eu/en/european-atlas/atlas-download-page/

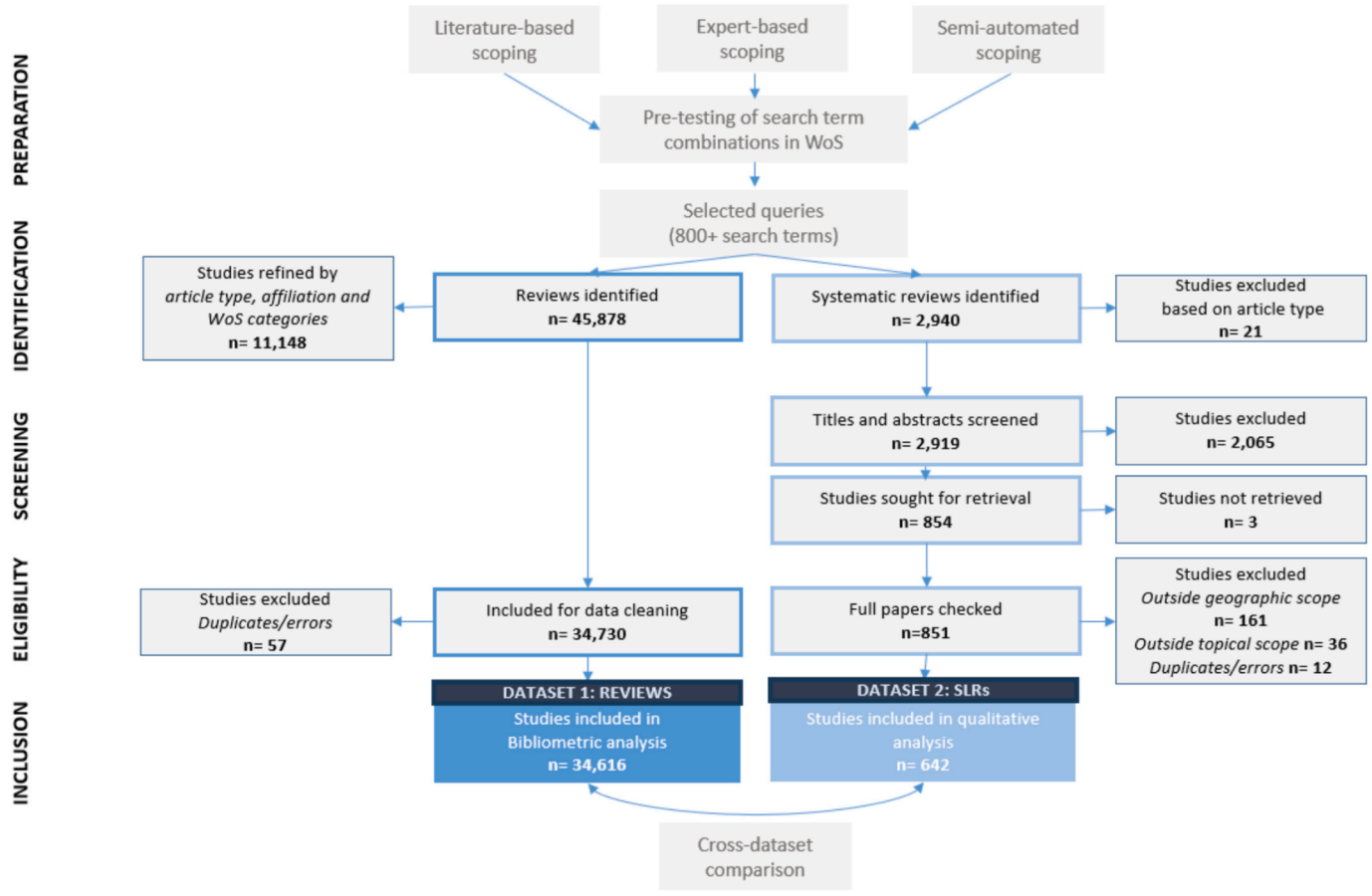

Fig. 2. Diagram of document identification and selection strategy for both datasets included in the analysis.

without knowing the nature of the keywords being connected, and because a node's score depends on the centrality of its neighbors, a more cautious interpretation is that eigenvector centrality is best interpreted as a measure of structural prominence (Bonacich, 2007). Or how structurally embedded a keyword is within the overall network.

Our network analyses were carried out in UCINET (Borgatti et al., 2002), Python (packages: NetworkX (Hagberg et al., 2008)), and R (packages: Bibliometrix (Aria and Cuccurullo, 2017), Tidyverse (Wickham et al., 2019), and igraph (Csárdi et al., 2024).

To classify and compare the documents in Dataset 1 with those from Dataset 2, we also performed a correspondence analysis, a type of dimension reduction analysis like principal component analysis but used with categorical data (Greenacre, 2010). We then compared the results of the analysis that categorizes Keywords Plus into four dimensions with the four overarching topics from the expert-led classification.

2.3.2. *Thematic analysis of Dataset 2: systematic reviews*

The 642 systematic literature reviews (Supplementary Information, SI-2) included in the qualitative analysis were drawn from Dataset 2 and subsequently examined and coded according to their thematic focus and geographical scope using the MAXQDA 2020 software (VERBI Software, 2021). The coding of the thematic scope adhered to the expert-led F&FS classification framework described in section 2.1.

To identify potential geographical biases in evidence synthesis, we collected information during the thematic coding of SLRs of the country's provenance of the empirical studies included in the systematic literature review. While reporting of the country of study is encouraged in SLRs, not all of them did. Thus, the analysis of geographical patterns constituted a sub-sample of dataset 2 (n=469), which explicitly reported the European country where the empirical study took place (see criteria in section 'Selection process and eligibility criteria'). In the case of several countries, within the geographical scope, were reported, they were all coded. With this, we obtained for each country the frequency with which an SLR reports at least one article from that country.

The relative distribution across our dataset was then correlated with different indicators meant to capture the relevance of F&FS for the country. We selected indicators within four distinct categories, i) forest resources, ii) economic importance of the forest sector, iii) investment in research and innovation, and iv) forest resource exposure to environmental risk. Two indicators of forest resources were selected, the *forest cover in percentage of land area,* and the *absolute forest cover measured in 1000 ha* (FAO, 2021; World Bank, 2024a). Kosovo data was based on Wikipedia as no World Bank or FAO data was available. We selected two indicators for economic importance of the forest sector in a country, the *forest rents in % of GDP* (World Bank, 2024b) and the *economic contribution of value added in the forest* (Li et al., 2022). The *R&D expenditure as a percentage of GDP* (World Bank, 2024c) is assumed to indicate a country's investment in innovation and technological advancement. Higher spending typically reflects strong support for research infrastructure, fostering scientific discoveries and economic growth (Jiménez-Sáez et al., 2013). Further, we included the *European Innovation Scorecard* as an indicator of investment into innovation (European Commission Directorate-General for Research and Innovation, 2024). It may highlight national priorities towards a knowledge-based economy and is expected to correlate with increased research productivity. Lastly, it is expected that countries, which have been exposed to significant risk from storms and insects are more inclined to focus on research into mitigation and adaptation strategies, thereby enhancing research

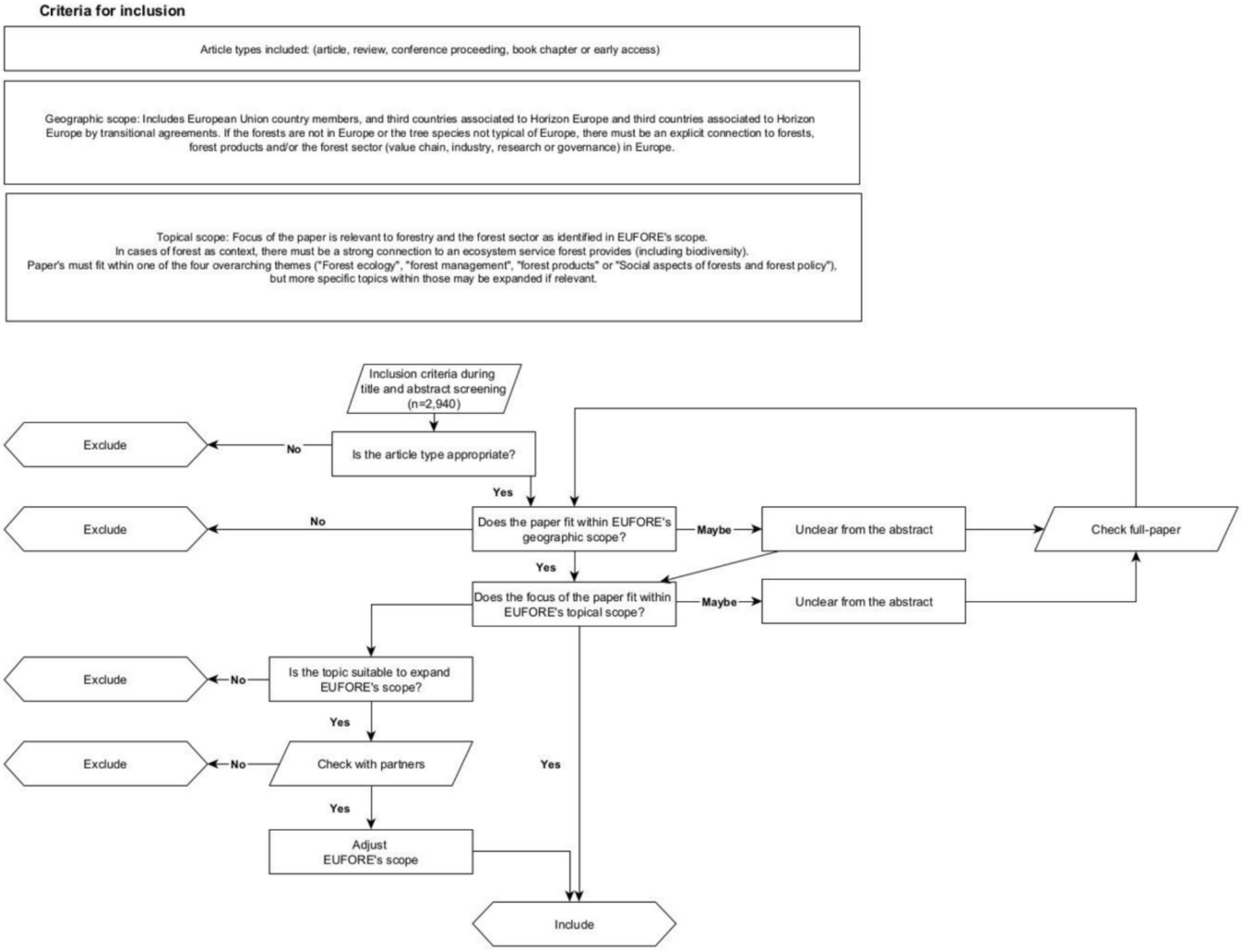

Fig. 3. Decision flowchart with criteria to include document in Dataset 2.

productivity and fostering innovation in this area (Pasgaard et al., 2015; Pasgaard and Strange, 2013). The *volume of damaged timber from environmental risk by 1000 ha forest cover* is applied as an indicator for exposure to environmental risk from storms and insects (Patacca et al., 2023). In summary, for all indicators it is assumed the number of SLRs correlates positively with the indicators.

The first author conducted the full-paper criteria check and content analysis for Dataset 2. A random subset of about 15% of the dataset was independently coded by co-authors and the results compared. To ensure robustness in the thematic coding, intercoder reliability was calculated using the MAXQDA formula, which divides total cases in agreement by the total number of cases with unselected codes, those left "blank" by all coders also counting as matches. The scores were 95.9 for the most specific level (47 categories) and 86.5 for the second level of classification (11 categories), significantly above the conventional threshold for acceptable inter-rater reliability in content analysis of 60% (good) (Bostrom et al., 1994; White et al., 2015). These results suggest conceptually coherent codes and a good understanding of concepts across reviewers.

To understand how the macro trends of dataset 1 (all reviews) relate to the deductive approach used in classifying dataset 2 (systematic literature reviews), we conducted a Multiple Correspondence Analysis (MCA) on dataset 1. The analysis was configured to extract four dimensions, allowing comparison with the four overarching categories defined in the expert-led classification. To assess the similarity between abstracts in each dataset and the expert-defined sub-topics, we employed two text similarity approaches. Firstly, a cosine similarity method, which evaluates similarity based on the frequency of root words (e.g., "manag" instead of "management", "managers", etc.) after removing stop words such as "and", "for", and "the". Secondly, we used a pre-trained transformer-based language model (BERT) (Devlin, 2018) implemented in PyTorch (Paszke et al., 2019) to compare sentence-level semantic similarity. Similarity scores from both methods were normalized to percentages to facilitate interpretation. Although 73 individual topics were identified in the classification, we aggregated them into broader categories for visualization purposes.

2.4. Limitations

There are several limitations specific to the data and techniques we have used; many, common to systematic reviews. For example, the choice of authors' keywords follows different considerations depending on the discipline and keywords tend to be generic. Our analysis of trends in scientific production only reflected the year of publication of the reviews and not the papers included in them. Thus, a recent review might not necessarily reflect the most recent empirical studies. Likewise, our identification of relevant documents, as explained above, strived to strike a balance between breadth and relevance. It is possible that we have captured a number of both false positives and negatives, especially with the dataset that was not manually screened. In some cases, the

choice for breadth was deliberate: for example, our search terms may capture papers dealing with so-called “trees outside forests” (e.g. street trees, orchards, etc.). The inclusion of these in the study of F&FS depends on the discipline, so we preferred to be inclusive. Importantly, the quality of the included reviews and SLRs was not assessed.

A standard way to increase robustness in systematic literature reviews that use content analysis is to have multiple coders (people who classify documents). Given scarce resources and an extensive dataset (n=642), it was not practical to apply the four-eye principle for the whole dataset, so 10 co-authors classified a random sample of about 15% of the dataset, which was then compared against the main coder. This exercise yielded a high intercoder agreement rate, as reported in the methods. We also urge caution against drawing causal conclusions from our analyses in both datasets, as our unit of analysis is at the document level (e.g. co-occurrence of keywords, presence of themes/geographical areas) and are not based on the results exposed in such documents.

However, a strength of our study is the triangulation of data sources, methods, and expert knowledge used to answer each research question, thus circumventing approach-specific limitations.

3. Results: size, composition and trends of evidence synthesis in F&FS

The results section is structured from the broad overview of trends and patterns across all reviews (dataset 1, which comprises dataset 2) to the zoom-in of systematic literature reviews (dataset 2).

3.1. Scientific production trends and thematic patterns

3.1.1. Size and patterns

The keyword co-occurrence network (based on the Keywords Plus of each document) has $n = 71,696$ nodes (keywords) and $e = 935,537$ edges. The network density is 0.000364 (the number of realized edges relative to possible edges if every keyword were connected to every other keyword), which means that only a fraction of one percent of all possible edges exist. We visualize the scope and size of this network in the supplementary materials (SI-4). The network is one component; i.e., it is possible to reach any single node (topic) from any other node (topic). The maximum distance (diameter) from one topic to another is 22 steps, while the average distance is short - only 4.69 steps. This means that any single keyword can be reached through < 5 other keywords on average, and that there can be 22 keywords between two topics at most. We did not find any "singleton" nodes or sub-graphs that are completely disconnected from the rest of the network. This would have been the case if a document included keywords not included in any other document.

The structure of the network is highly non-random. Some areas of the network were much denser than others (see Supplementary Information SI-4). In terms of a network, the density refers to the number of connections observed compared to the number of all possible connections. A network is considered complete if all keywords are connected to every other possible keyword. When we refer to an area of the network as “dense”, this means that the number of connected keywords is relatively high. This suggests that some keywords are used substantially more than others, both individually and in conjunction. In other words, the network is centered around a few highly connected nodes that can be thought of as core subjects (e.g., ‘forest’, ‘conservation’) in the field of F&FS, both in terms of being key concepts and methods. The structure of the network, with few nodes having many ties and the vast majority having few ties, is common to most bibliographic networks and highlights that the reviews in Dataset 1 share several common topics that typically overlap with other core topics and more rarely with peripheral topics at the boundaries of the F&FS literature.

In Fig. 4, we illustrated these characteristics of the network. In the leftmost panel of Fig. 4, we plotted the densest subgraph of the network, which contains the most connected nodes in the entire co-occurrence network. Here, we find keywords that are central tenets of the F&FS, like ‘management’ and ‘ecosystem services’. These examples of central keywords are associated with established, influential research areas that serve as conceptual anchors within the field and are foundational to the ongoing scholarly discourse.

Meanwhile, the right-hand side of Fig. 4 contains an example of a peripheral area of the network. These peripheral areas include niche themes (e.g., ringwoodite), niche methods (e.g., sequence stratigraphy),

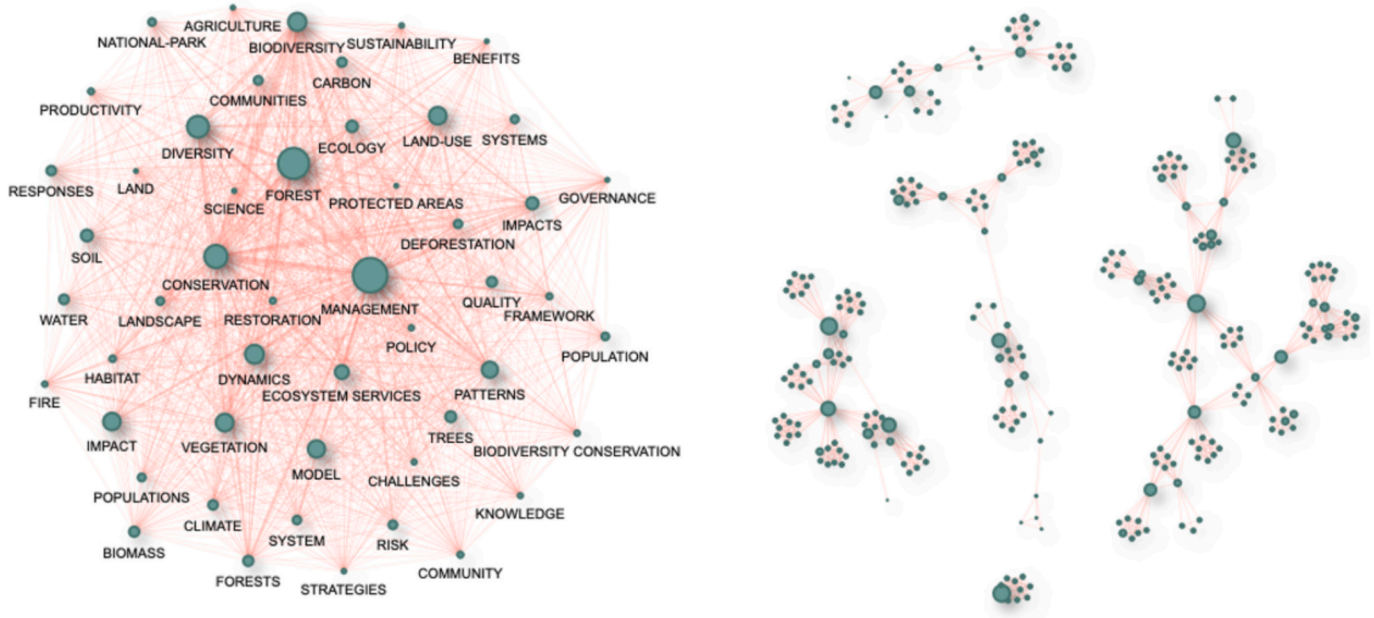

Fig. 4. Subgraphs of the co-occurrence network. The left figure depicts the densest area toward the middle of the graph, while the right figure is a less connected area. For comparison, the left subgraph has n = 50 nodes and e = 1,168 edges. Meanwhile, the right one has n = 284 nodes and e = 1,123 edges. Therefore, the leftmost subgraph is substantially denser than the right-hand counterpart, as indicated by the many edges between the fewer nodes. In both panels, the nodes are scaled according to the number of ties they have. Both networks were produced using visNetwork and igraph in R. The nodes are laid out according to a Fruchterman-Reingold force-directed layout.

niche products (e.g., resin in dentistry), and hyper-specific locations (e.g., Karoo region, South Africa). These keywords were less connected and may appear in more specialized or emerging contexts, reflecting niche topics or recent research topics that have not yet achieved widespread integration into the core of the field. Even being peripheral, such keywords can be important indicators of innovation or indicate shifting trends if they begin to move toward the core over time. This further substantiates that the content in reviews in the F&FS predominantly relates to a few core keywords and, every so often, a few more specific and/or detailed topics.

In Table 2, we present the normalized degree centrality and normalized eigenvector centrality. The topic climate-change had the highest values for both normalized degree centrality (0.085) and normalized eigenvector centrality (0.134), indicating that it is not only widely connected to other topics but also closely associated with other influential themes in the network. Management and forest were also high, suggesting they are also central and influential within the thematic structure, likely serving as bridges between multiple research areas. Oppositely, topics like dynamics and growth have lower centrality scores, implying they are more peripheral and less interconnected, though still relevant within specific subfields.

Notably, the close alignment of degree and eigenvector rankings suggests that the most frequently used topics were also the most structurally embedded within the field's conceptual network. Following Bonacich (2007), this pattern is reflective of a characteristic core-periphery structure, where a small set of densely interconnected topics anchors the field and peripheral topics connect mainly through these core themes. In this sense, eigenvector centrality helps reveal how the field's thematic focus is shaped around a few dominant topics or keywords, such as those in Table 2 (see also Supplementary Information, SI-4).

In addition to the main co-occurrence analysis presented here, we conducted a series of supplementary analyses to further examine the structure of the 'review of reviews' network. These included measures of connectivity, distance, core-periphery structures, faction routines, and the "key player" routine (see Supplementary Information, SI-4).

3.1.2. Trends

As scientific production in the field of F&FS has increased dramatically over time, so has evidence synthesis (Fig. 5). Since the turn of the century, systematic literature reviews have grown at a higher rate than other review formats that have a much older history in the field (Fig. 5b), although these still represented only 4.21% of all reviews and 0.91% of all publications in F&FS by 2022. This is in line with findings of Bornmann et al. (2021) showing an overall growth rate of science output at 4.1 % with a doubling time of 17.3 years. The smoothed LOESS curves of the derivative of annual publication growth are generally positive but show a declining trend over time across all three categories, indicating a slowdown in growth.

Based on the network analysis, we provided an overview of the eigenvector centrality of used keywords within F&FS from 2000 to 2022 in Fig. 6. The heatmap on the left-hand side represents keyword centrality over time, showing how central each keyword is across different years, with darker shades indicating higher centrality. The bar on the right-hand side shows the average eigenvector centrality of keywords over the entire period, illustrating which keywords have maintained significant prominence across the years.

Keywords such as "management", "forest", "conservation", and "climate change" had consistently been structurally prominent topics over time as reflected by the darker cells stretching across multiple years. In particular "management" had the highest average eigenvector centrality underscoring its continuous relevance as the field adapts to new challenges policies and ecological practices. Besides "management" and "forest," keywords such as "conservation," "climate change," and "biodiversity" stood out indicating a research trend focusing on ecological resilience sustainable practices and climate adaptation within forest ecosystems. In recent years we also saw emerging attention on "dynamics", "land-use," and "ecosystem services," suggesting a growing interest in understanding complex interactions within ecosystems and the implications of land-use changes on forests. Taken together we see an increased use of keywords related to complex global challenges in the international policy agenda and a decrease in narrower disciplinary terms (e.g. "vegetation", "growth").

Table 2
Top-10 nodes by normalized degree centrality and eigenvector centrality. Full list and analysis are available in the Supplementary Information (SI-3).

Topic	Normalized degree centrality	Normalized eigenvector centrality
CLIMATE-CHANGE	0.085	0.134
MANAGEMENT	0.076	0.132
FOREST	0.069	0.128
CONSERVATION	0.052	0.113
DIVERSITY	0.049	0.103
GROWTH	0.049	0.096
DYNAMICS	0.043	0.102
BIODIVERSITY	0.041	0.103
VEGETATION	0.040	0.094
LAND-USE	0.040	0.096

3.1.3. Comparison of themes across datasets

The results of the MCA are depicted in Fig. 7 and illustrate the similarity between abstracts in datasets 1 and 2 and the expert-led sub-topic descriptions organized into 11 meso-level topics (see section 2.1 and SI-1). The normalized similarity scores indicate which forestry topics the reviews and systematic literature reviews are most likely associated with, based on both cosine similarity and BERT-based semantic analysis.

The cosine method should work well when abstracts include specific keywords or technical terms. BERT is better at capturing semantic relationships. We would expect higher text similarities for cosine than BERT when abstracts share many keywords with the expert led classifications, and oppositely when abstracts and the classifications use different words but convey similar meanings. Overall, there is little difference between the two text similarity measures. Furthermore, there does not appear to be a large disparity between the topics covered by reviews and SLRs. Rather, they seem to be closely aligned. By far, the most common topic covered by the reviews and SLRs was silviculture, which had almost double the score (according to either method) of the second most common topic. Conversely, the least common topic wasnon-wood forest products. Generally, the results using BERT were slightly less uniform across topics, while the cosine similarity measures were almost identical between the two datasets.

3.1.4. Content analysis of systematic literature reviews (SLRs)

The manually coded thematic analysis of the systematic literature reviews showed a more nuanced picture than the text analysis between datasets 1 and 2. Here, the distribution of SLRs across topics was more uneven (Fig. 8). Within forest ecology, studies on climate change and biodiversity dominate, probably reflective of a research and policy agenda geared towards tackling these macro-crises (Table 3). SLRs within this topic tended to address the regulating (e.g., soil erosion, carbon sequestration, water regulation) and habitat services of forests (e.g., issues of community ecology and protected areas).

Within the larger forest management category (57%), silviculture was the most common sub-category (31%). Systematic reviews in this theme aimed to take stock of different management modalities with an emphasis on the co-benefits of forests (e.g., nature-based solutions to reduce risks, multifunctional forestry, and agroforestry). A second prevalent theme explored practices and challenges of forest restoration, afforestation, and reforestation, often in the face of increased risks (e.g., wildfires, pests, windthrow).

The overarching category with the fewest SLRs was forest products

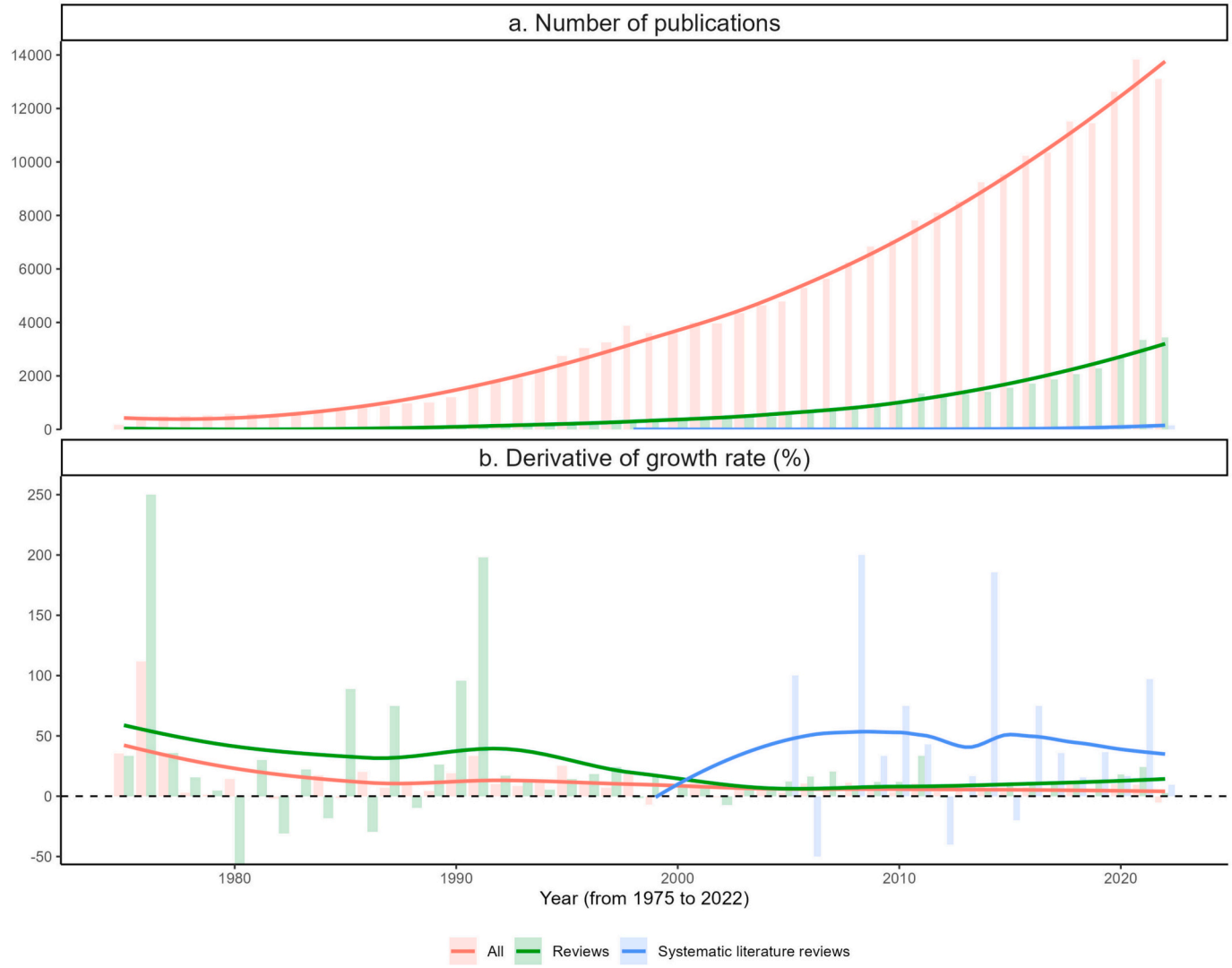

Fig. 5. a. The scientific production over time for all papers in F&FS (red line); dataset 1 of review papers (green line), and systematic literature reviews (blue line). b. Derivative of the annual growth rate (in per cent) shown by bars and smoothed Loess-curves to show trends in growth. Both figures use data from 1975 to 2022.

(30%). The documents included were heavily influenced by sustainability concerns, for example, decarbonizing the pulp and paper industry (Furszyfer Del Rio et al., 2022), waste management practices (Derhab and Elkhwesky, 2023), and recyclability potential (Cesprini et al., 2020), often using life-cycle assessments (Mendes et al., 2019), as well as the perception of stakeholders vis-à-vis specific applications (Harju, 2022; Lipovac and Burnard, 2021; Wallius et al., 2023). New applications of the industry by-products (e.g. biosolids, biochar, cardboard in construction) were also framed within a broader bioeconomy agenda (Ploughe et al., 2021; Venkatesan et al., 2023), with few highly technical exceptions (Bazli et al., 2022; Boccacci et al., 2022; Drahota et al., 2022). Niche wood-based product applications included the use of wood barrels for beer production (Kocijan et al., 2021), biomass-based fuels in the iron and steelmaking industry (Suopajärvi et al., 2017), biochar biofilters for stormwater pollutant removal (Boehm et al., 2020) and soil remediation (Lima et al., 2022), and woody plants for animal feed (Torres-Fajardo et al., 2021).

SLRs on human health and wellbeing—the most numerous of all subthemes, 23%—mainly explored the physical and mental health benefits from exposure to forests in research about forest baths and other immersive nature experiences (Rowley et al., 2022; Stier-Jarmer et al., 2021; Wen et al., 2019), and other health-related ecosystem services of trees, for example, noise abatement (Ahac et al., 2021) and air-pollution (Arantes et al., 2019), as well as health benefits from forest products (Asprilla-Perea et al., 2020). Similarly, a typical theme was that of environmental justice, for instance, distributional access to urban green spaces (including forests) benefits, for example, by exploring the relationship between green spaces and human mortality (Rojas-Rueda et al., 2019) or other vulnerability markers (Allegretto et al., 2022). Another class of documents addressed the disservices of forests and urban trees (e.g. related to pollen allergies) (Steckling-Muschack et al., 2021), occupational health risks related to woodwork (Alonso-Sardón et al., 2015; Engelsman et al., 2020) and firewood use, and health risks stemming from deforestation (Guégan et al., 2020; White and Razgour, 2020).

We identified additional topics during thematic coding. These are not necessarily new but represent topics not previously assigned to our expert-based classification. Some are cross-cutting but have garnered renewed interest in SLRs (e.g., perception of forests, heatwave attenuation); other themes reflect a rise in the policy or industrial profile (e.g., biomass for energy, waste from wood processing).

3.2. *Geographic patterns in the provenance of studies included in SLRs*

We find an uneven geographic distribution of the empirical papers included in SLRs, that is, of the data included in the reviews, although

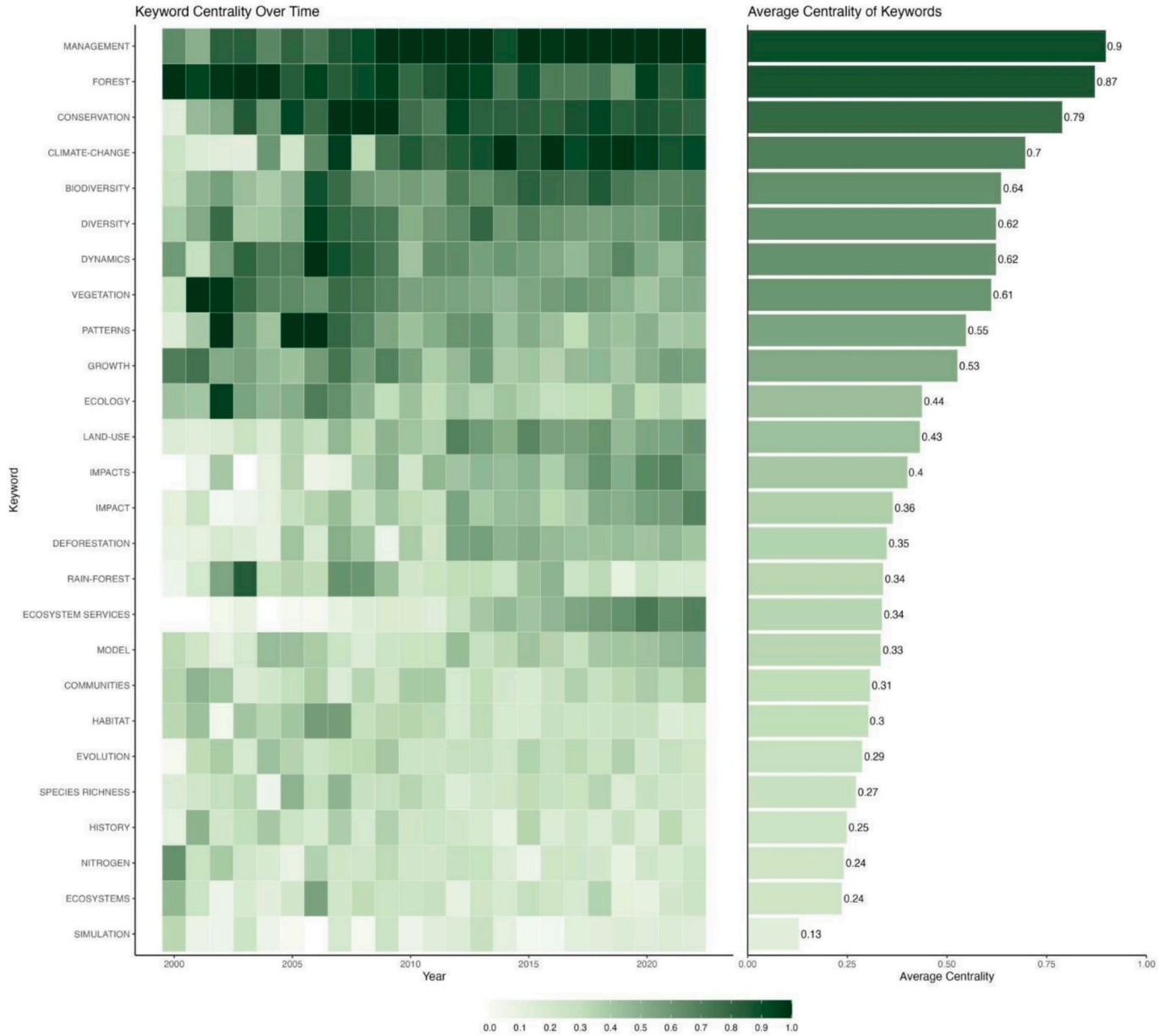

Fig. 6. Mapping emerging trends from 2000-2022. Based on Dataset 1. The centrality measure used is eigenvector centrality.

overarching theme patterns are similar across regions (Fig. 9). To explain this unevenness, we ran simple regressions using indicators of the importance of F&FS in each given country. The results showed modest correlation, for example, *between forest cover (ha)* (R^2=0.38, p<0.000), *European Innovation Scoreboard* (R^2=0.30, p<0.000), *R&D in % of GDP* (R^2= 0.26, p<0.007), and a much clearer pattern regarding the *economic contribution of value added in the forest sector* (R^2=0.713, p<0.000) (table of regressions in SM). The latter may reflect the economic importance of the forest sector in a country and may influence research priorities and funding. However, there may be no direct link to research funding, as despite high economic contributions under investments in the sector may still be the case. We found that forest technologies and forest products were the least represented themes in the SLRs, which may point to the private sector being a strong user of knowledge syntheses but a weak contributor. We note also that the indicator of *economic contribution of value added in the forest sector* does not correlate significantly with the *forest rents (%GDP)*, indicating that countries in the first category have more diversified economies. In terms of the relation between overarching topics and explanatory variables, only R&D was significant across the board. Further analysis with other proxies like share of urban population, GDP per capita, and a proxy for wellbeing like the world happiness score, only showed a significant relationship between this latter and the share of papers about the social aspects of forests.

Additionally, we found that the role of knowledge synthesizer is predominantly taken up by academic institutions. Examples of public agencies and private companies are rare in our datasets, despite common funder requirements for transdisciplinary research and public-private partnerships.

4. Discussion

Over time, the focus and methods of evidence synthesis in F&FS have undergone notable shifts. Early efforts were largely descriptive and discipline-specific, such as the Tamm and Acorn reviews, which provided expert commentary or brief assessments without systematic methodology. As the field matured, more structured approaches emerged, including scoping reviews and meta-analyses targeting

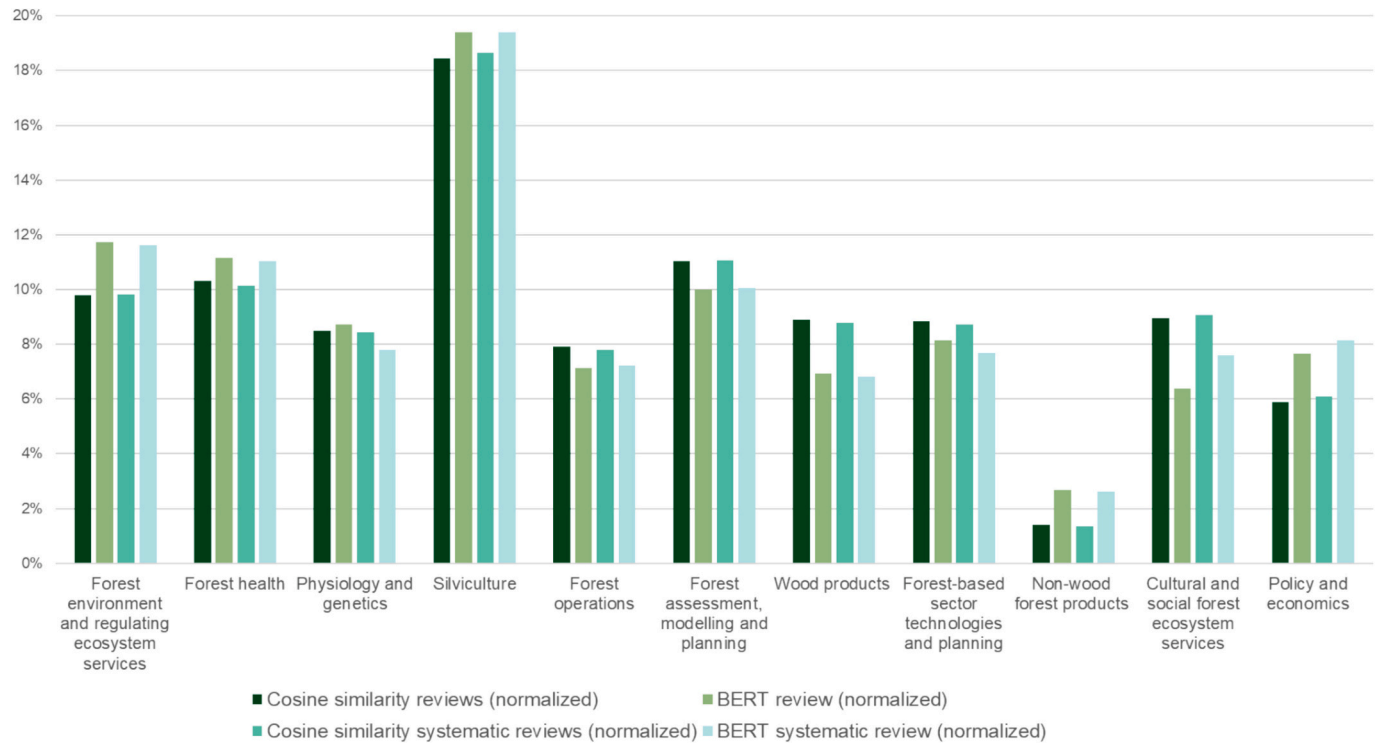

Fig. 7. Text similarity of abstracts and topical description. Based on Dataset 1 and 2.

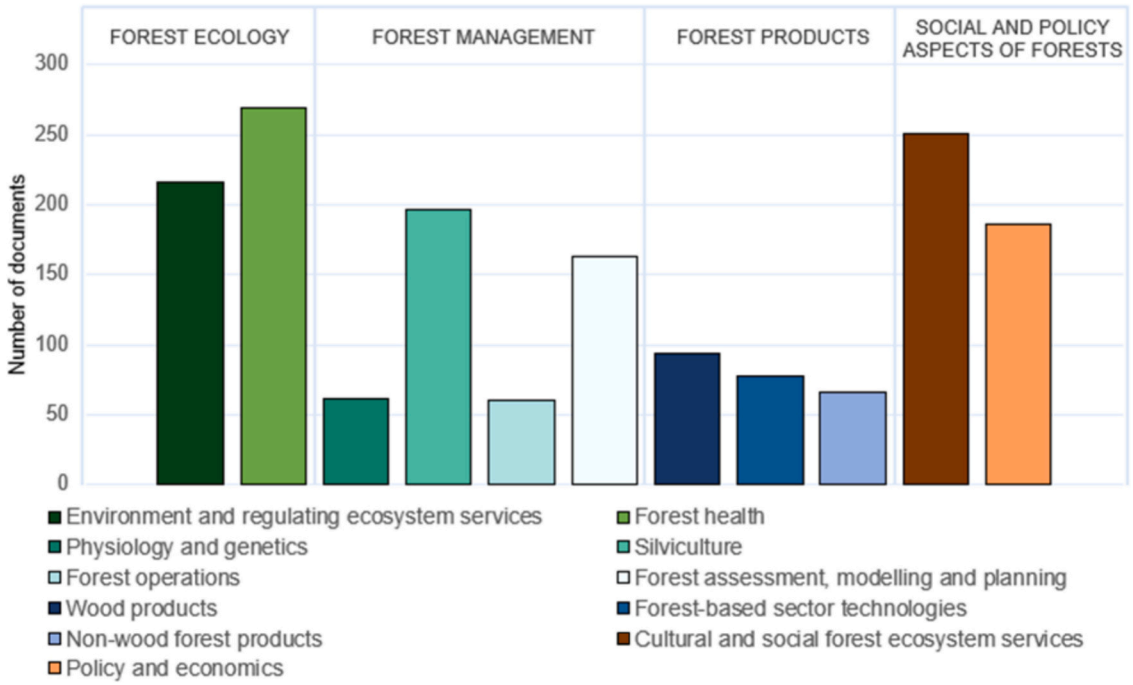

Fig. 8. Topical distribution of papers in dataset 2 (SLRs) following the expert-led classification.

specific sub-fields like forest ecosystems and bioeconomy (Lovrić et al., 2020). Recently, there has been a growing interest in interdisciplinary and policy-relevant themes, such as social innovation and AI applications (e.g. Holzinger et al., 2024), reflecting broader societal and technological changes. These shifts also mirror evolving policy priorities, from biodiversity and restoration to climate mitigation and circular bioeconomy. By mapping these transitions, this review aimed to capture not only the current state of evidence synthesis but also its trajectory and implications for future research and policy.

4.1. *Size, patterns and trends identified in the network analysis*

We found that the field ewas clustered around key topics, e.g., silvicultural themes, that pertain to more traditional forestry-related themes of managing forests as a natural resource, but it also sprawls into other non-traditional forestry topics, such as climate change or

Table 3
Summary of most common sub-categories and most common themes within them with an example. Note that the same document can be classified into multiple categories, so the Ns and percentages do not add to the total N. Dataset 2.

First level category	Second-level sub-category	Most common theme in sub-category	Example of reviewed document
Forest ecology (n = 342, 53%)	Forest environment and regulating ecosystem services (n=216, 34%)	Forest biodiversity and habitat provision (n=87, 14%)	"Manipulating ungulate herbivory in temperate and boreal forests: effects on vegetation and invertebrates. A systematic review" (Bernes et al., 2018)
	Forest health (n=269, 42%)	Climate change (n=92, 14%)	"Dynamic carbon-nitrogen coupling under global change" (Niu et al., 2023)
Forest management (n = 363, 57%)	Physiology and genetics (n=61, 9%)	Physiology (n=31, 5%)	"Parenchyma fractions drive the storage capacity of nonstructural carbohydrates across a broad range of tree species" (Zhang et al., 2022)
	Silviculture (n=197, 31%)	Nature-based solutions and ecosystem management-based approaches (n=42, 7%)	"Can retention forestry help conserve biodiversity? A meta-analysis" (Fedrowitz et al., 2014)
	Forest operations (n=60, 9%)	Forest operations ecology (n=24, 4%)	"What are the effects of even-aged and uneven-aged forest management on boreal forest biodiversity in Fennoscandia and European Russia? A systematic review" (Savilaakso et al., 2021)
	Forest assessment, modelling and planning (n=163, 25%)	Forest inventory, monitoring and modelling (n= 65, 10%)	"LiDAR as a Tool for Assessing Timber Assortments: A Systematic Literature Review" (Alvites et al., 2022)
Forest products (n = 195, 30%)	Wood products (n=94, 15%)	Wood construction (n=30, 5%)	"Wooden multi-storey construction market development – systematic literature review within a global scope with insights on the Nordic region" (Jussila et al., 2022)
		Biorefinery, new materials – mass commodities (n=30, 5%)	"A systematic review of densifed biomass products life cycle assessments" (Esquiaqui et al., 2023)
	Forest-based sector technologies (n=78, 12%)	Digitalization (n=27, 4%)	"A Systematic Review on Technologies and Industry 4.0 in the Forest Supply Chain: A Framework Identifying Challenges and Opportunities" (He and Turner, 2021)
	Non-wood forest products (n=66, 10%)	Wild forest products (n=59, 9%)	"Wild Edible Fruits: A Systematic Review of an Under-Researched Multifunctional NTFP (Non-Timber Forest Product)" (Sardeshpande and Shackleton, 2019)
Social aspects of forests and forest policy (n = 379, 59%)	Cultural and social forest ecosystem services (n=251, 39%)	Human health and wellbeing (n=148, 23%)	"Forests and emerging infectious diseases: unleashing the beast within" (Guégan et al., 2020)
	Policy and economics (n=186, 29%)	Forest policy, law and governance (n=84, 13%)	"Does the effectiveness of forest protected areas differ conditionally on their type of governance?" (Macura et al., 2013)

ecosystem services. Generally, reviewed topics (Dataset 1) are dominated by management, conservation, biodiversity and climate change, all important topics in the sustainability agenda. This may reflect the growing recognition and funding of forests' multifunctionality in policy design. Furthermore, they were core nodes with high degrees and eigenvector centrality. This means that they are essential components of the larger network of reviews and, thus, the existing knowledge base in F&FS.

The overall network structure of the research field, characterized by low density with pronounced hierarchy, is typical of large-scale social networks (Barabási and Albert, 1999). This means there is a very clear 'core' as to what forestry research is, but the boundaries of the field are numerous. This makes it practically difficult to 'draw' clear analytical boundaries as to what forest research is. On the other hand, the ratio between the average distance (i.e. average path length) and the network size is higher than what the situation is with other comparable (including scholarly) networks (Uzzi et al., 2007). This indicates the observed research field has a higher probability of becoming a more cohesive network (or field) than the average situation. As this was a static analysis, we cannot say at which stage of its life-cycle (Bettencourt et al., 2009) this field is, which warrants further inquiry. The way that degree and eigenvector centrality were closely aligned to one another means that there is no single topic that has an outsized global effect, or in other words, each topic contributed proportionally to the overall cohesiveness of the research field. We must note again that this is a static analysis, where the most interesting research question would be how innovative the research within each of these topics is. Future research could address this question by longitudinal semantic analysis akin to what was applied here (e.g. BERT model) when contrasted to quantitative network structure (e.g. Milojević, 2015).

In addition, the network analysis revealed an increased emphasis on terms such as "dynamics," "land-use," and "ecosystem services" in recent years. This shift suggests a growing scholarly interest in understanding the complex interactions within ecosystems and the implications of land-use changes in forest environments. Collectively, these observations may point to a broader trend towards addressing complex global challenges within the international policy agenda. Concurrently, there is a discernible decline in the use of narrower disciplinary terms such as "vegetation" and "growth." This shift may reflect the maturation of earlier research themes and signal a transition toward more holistic and

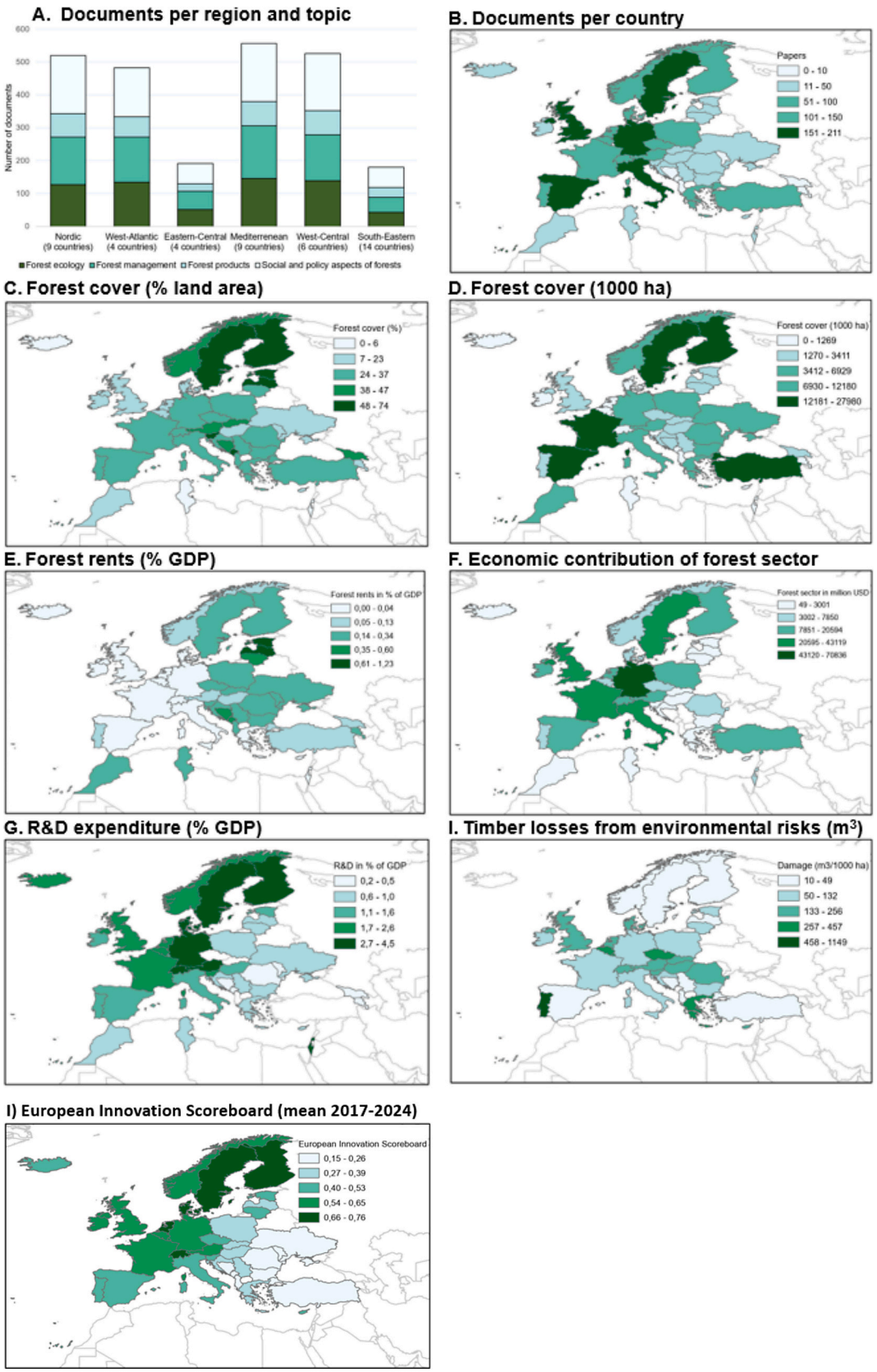

Fig. 9. Geographic patterns in the provenance of studies included in SLRs against different indicators. A) Number of SLRs reporting country-specific empirical research (distribution per region and main topic). B) Number of SLRs reporting country of empirical research (distribution per country). C) Forest cover by 2020 in percentage of land area. D) Forest cover by 2020 in 1000 ha. E) Forest rents (% of GDP) are estimated as roundwood harvest times the product of regional prices and a regional rental rate compared to GDP, average between 1990-2021. F) Economic contribution of value added in the forest sector in million USD. G) Research and Development expenditure (% of GDP), average 2010-2022. H) Volume of timber damages from environmental risk (yearly average 1950-2019) by 1000 ha forest cover. I) European Innovation Scoreboard (average between 2017-2024).

integrative approaches in forest research, aimed at addressing the complex challenges of climate change and ecological sustainability. Weiss et al. (2020) came to a similar conclusion on innovation research in forestry and forest-based industries, finding that innovation research has grown steadily in scope and complexity but is largely shaped by country-specific and sectoral case studies, with limited cross-national or cross-sectoral comparisons. While rapidly growing, systematic literature reviews (SLRs) (dataset 2) still account for under 1% of all scientific production in F&FS (~5% of all evidence synthesis). However, SLRs were distinctly more prolific in health-related and social science topics compared to non-systematic reviews, while syntheses of forest technologies and forest products were generally scarce.

Our results provide a structured approach to identifying trends and patterns in the evidence synthesis of the field of forestry and the forest-based sector, whether systematically reviewed or not. Through this, we can identify potential biases in the topics and geographic provenance of the documents that get synthesized and presumably contribute to shaping agendas at the science-policy interface. We found that most research in F&FS is not systematically reviewed. This comes with a host of potential biases—or at least a lack of transparency and replicability—and may also encompass redundant stocktaking formats. Evidence synthesis in F&FS has traditionally not followed a systematic approach, yet reviews make up about 20% of the scientific production in the field, which points to a high demand for evidence synthesis.

Comparing the salience of topics across datasets shows that the themes addressed in systematic reviews do not necessarily align with those examined in non-systematic reviews. The subcategory "Human health and wellbeing" is a good example of a strong SLR bias, possibly because of the tradition of meta-analyses in health sciences. Niche products and themes not covered in the description of our expert-led classification are a testament to a sprawling field. In the thematic analysis of both datasets, there is evidence of crosscutting, higher-level issues (e.g., bioeconomy, sustainability), and disciplinary crossovers (e.g., social scientists examining perceptions of construction wood products).

4.2. Geographic representation in the synthesized forestry evidence

In a mapping of forest-based bioeconomy research in Europe, Lovrić et al. (2020) found that the field is growing in funding but remains fragmented and unevenly distributed across regions. Furthermore, the research activity was concentrated in a few North-Western European countries and institutions, while Eastern Europe remains underrepresented and poorly integrated into the broader research network. We also find there is important geographical unevenness in scientific production and evidence synthesis. Within Europe, there are stark differences in where empirical production that ends up in SLRs takes place. These differences cannot be explained just by the distribution of forest cover, forest rent, or the distribution of environmental hazard impacts. Instead, the economic contribution of value added to the forest sector comes up as a significant variable with a large effect, as does the country's level of investment in R&D, suggesting that countries that have large forests, sophisticated value chains for forest products but also diversified economies are more represented in scientific literature about the sector. This is somewhat surprising because forest technologies and forest products were the least represented theme among SLRs, but a buoyant forest products sector might excite interest in associated themes (e.g. regulation and policy, stakeholder perception, forest risks, etc.). Additionally, the predominance of English in science might constrain the inclusion of empirical evidence in not-so-widely spoken languages into continent-wide or global reviews, thus increasing the chance of bias through false negatives.

4.3. Characteristics of topics included in Systematic Literature Reviews

Inclusion tends to favor topics with a substantial body of literature, whether due to their long-standing presence or recent rapid growth. Topics also need to be perceived as sufficiently important to merit synthesis, and ideally, supported by standardized methodologies. Given the multifunctionality of forests and the increasingly complex value chains associated with forest products, most evidence synthesis efforts are deliberately narrow in scope to ensure a manageable number of documents. This is especially true for SLRs dealing with qualitative findings, which require more intensive reading, interpretation, and synthesis than other types of reviews.

We find an uneven distribution of systematic reviews across expert-led classifications which may reflect broader epistemic structures. SLRs are less common in areas related to industrial innovation. Much of the relevant research in these domains may remain inaccessible due to its proprietary nature, particularly when conducted by private entities aiming to protect economically valuable results. This is particularly true for forest product development. Despite growing support for transdisciplinary approaches, academia continues to dominate in terms of evidence synthesis. Additionally, niche or newly emerging topics often fall outside the scope of SLRs, either because the literature base is still too limited or too recent to have been systematically reviewed. Emerging topics may also lack the momentum to attract early synthesis efforts, increasing the likelihood of oversight.

5. Implications and outlook for research and policy

Hetemäki (2019) highlights the growing demand for evidence-based policy. Literature reviews can play a crucial role in bridging the gap between scientific research and policymaking. They can help policymakers understand the current state of knowledge, identify gaps, and make evidence-based decisions. By using evidence-based methods to maximize rigor and minimize bias, systematic reviews can become a more reliable source for informing policymaking (Tranfield et al., 2003). This becomes particularly valuable in fields like F&FS where increasing complexity of forest-related challenges (e.g., climate adaptation, multifunctionality, socio-ecological resilience) and interactions between environmental, economic, and social factors demand integrated approaches to policy and management that blur the boundaries between traditional forestry and other disciplines.

Our results clearly show that the patterns and trends in evidence synthesis in F&FS are non-random. Instead, they point to structural biases that make some topics more or less "systematizable". The choice of the literature that gets reviewed responds both to the characteristics of such literature (e.g. quantitative vs qualitative, extent of sub-field, tradition in evidence synthesis), as well as an expectation of its policy appeal. Furthermore, we find that the geographic provenance of studies included in SLRs is also non-random. We found that while the extent of forest cover in a country matters, nations whose economies are highly dependent on the forest sector tend to be underrepresented. Instead, measures of investment in research, innovation and value added of forest products are more strongly correlated with inclusion in SLRs. Altogether, our results suggest that the portion of the literature in F&FS that gets synthesized and presumably informs policy and management is a partial and possibly skewed representation of the true wealth of knowledge in the field. This suggests that the literature informing policy is disproportionately shaped by countries with robust research infrastructures, rather than those most reliant on forests economically or socially.

The current analysis does not address whether evidence synthesis truly influences agenda-setting, which would be valuable to explore in future research. Scientific reviews in the F&FS field, particularly those published in academic journals, may be difficult to connect to practical or policy-oriented forestry-related knowledge needs unless linked to broader agendas. Undoubtedly, "hot policy topics" linked to climate change, biodiversity and sustainability agendas have dominated the type of evidence that is synthesized, as seen in our results. A feedback loop perpetuating the choice of topics and their policy relevance via

securement of funding has been suggested in the literature and should be further studied for the F&FS field (Hu et al., 2024; Sun et al., 2021). These findings may highlight a critical tension in the science-policy interface. Although systematic reviews are designed to minimize bias, they are themselves subject to systemic influences, such as funding priorities, disciplinary norms, and institutional capacities that shape what knowledge is synthesized and used. The dominance of the aforementioned hot policy topics and their high visibility may attract more funding and synthesis, thereby perpetuating their centrality in policy discourse. This is particularly important given that the literature selected for synthesis is incomplete in several respects, as discussed earlier, which means that policy decisions may ultimately rely on a limited and potentially biased body of knowledge that emphasizes certain topics and geographic regions over others. In other fields, such as medicine, psychology, and education, systematic reviews have been shown to summarize research robustly and inform policy and practice (Borrego et al., 2014). Whether this is the case for fields like F&FS is still unclear. This difficulty in tracking the effectiveness of scientific reviews on decision-making may indeed stem from the complexity, and transdisciplinary nature of the F&FS field.

A related challenge in the science-policy interface is the sheer volume of both empirical research and reviews even when robustly conducted, leading to an oversupply of information that can be overwhelming for knowledge users (McNie, 2007). This can make it difficult for policymakers to discern which data is most relevant and reliable for their needs (see e.g. Yin et al., 2021). The growing volume of scientific output, the sometimes-contradictory findings on certain topics, and the growing complexity of modern scientific methods (i.e. black box models) can increase the burden and reduce confidence in science-driven policymaking (Maeda et al., 2021). Experience has shown that access to more information or "better evidence" does not necessarily guarantee better decision-making (Hetemäki, 2019). Policy decisions are "political" (Ibid.), and political and value-based considerations often outweigh scientific evidence in decision-making processes (Colglazier, 2016). In this context of too much information, even when summarized, understanding the systematic biases in how this information is synthesized is a crucial input for decision-making.

To move beyond the current outlook on strengthening the science-policy interface in the F&FS, future research and policy should not only prioritize systematic literature reviews (SLRs) but also address six key areas that are critical for building a more inclusive, transparent, and actionable evidence base. First, methodological diversity must be expanded to include synthesis approaches that accommodate qualitative, practice-based, and emerging research, allowing for a broader and more representative knowledge base. Second, underrepresented topics, such as industrial innovation and forest technologies, and regions with high forest dependency should be actively supported through targeted funding, inclusion of non-English and grey literature, and integration of local and indigenous knowledge systems. Methodological advances and AI-assisted tools may assist in identifying underexplored areas, guiding research priorities, automating literature search, including grey and non-English literature, and improving inclusivity. Despite this development of new tools for synthesizing evidence, there is still a need for in depth manual interpretation of the data and quality assessment. Third, institutional infrastructure should be strengthened by establishing dedicated evidence synthesis units within research and policy institutions, embedding synthesis requirements into publicly funded projects, and fostering cross-sectoral collaboration in review design. Fourth, capacity building is essential: training programs should equip researchers, policymakers, and practitioners with the skills to conduct, interpret, and apply systematic reviews, particularly in transdisciplinary contexts. Fifth, synthesized evidence must be made more usable and accessible through tailored communication formats such as policy briefs, visual summaries, and interactive platforms that meet the needs of diverse knowledge users. Finally, mechanisms to monitor and evaluate the uptake and impact of synthesized evidence in policy decisions should be developed to ensure that reviews contribute meaningfully to decision-making. Together, these areas form a comprehensive framework for advancing evidence-informed policymaking in F&FS and addressing the structural biases that currently shape what knowledge is synthesized and used.

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work the author(s) used Microsoft Co-Pilot in a few parts of the text to improve the language. After using this tool/service, the corresponding author reviewed and edited the content as needed and take full responsibility for the content of the published article.

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Declaration of competing interest

The authors declare that they have no competing interests.

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Appendix A. Appendix

Final query RoR. Revised keywords after round of feedback with partners. The keywords are categorized according to EUFORE scoping document.

Review terms

Review*
"systematic review*"
"systematic literature review*"
"systematically review"

Core forest and tree terms

"*forest*"
"tree*"
"*wood*"
"*timber*"
+ All European tree species scientific and common names

Additional Forestry and the Forestry sector terms

1. Forest ecology

"ecosystem service*"
"ecolog*"
"provisioning"
"anthropogenic disturbance*"
"old-growth"
"old growth"
"natural disturbance*"
"fires"
"drought*"
"species diversity"
"genetic variance"
"extinction"
"endangered"
"biodiversity"
"resilien*"
"functional diversity"
"management"
"habitat*"
"degradation"
"fragmentation"
"regulat*"
"ventilation"
"transpiration"
"humidity"
"air quality"
"carbon sink*"
"carbon stock*"
"carbon storage*"
"carbon off-set*"
"carbon credit*"
"carbon offset*"
"carbon sequestration"
"carbon captur*"
"carbon fixation"
"carbon accounting"
"carbon allocation"
"carbon balance"
"carbon budget"
"carbon emission*"
"carbon cycl*"
"REDD plus"
"carbon neutrality"
"carbon footprint"
"mitigation"
"redd +"
"net ecosystem exchange"
"ecosystem function*"

"atmospheric"
"chemical composition"
"Water supply"
"water flow"
"watershed protection"
"groundwater"
"ground water"
"sub-surface"
"freshwater"
"coastal water"
"waterway*"
"ecohydrology"
"riparian"
"infiltration"
"evaporation"
"runoff"
"wetland*"
"flood prevention"
"flood management"
"floodplain*"
"water purification"
"sediment dynamics"
"sedimentary balance"
"stabilization"
"stabilisation"
"erosion"
"eutrophication"
"pollution"
"neopollutant*"
"*organic contamina*"
"*organic pollut*"
"humus"
"soil processes"
"decontamination"
"nutrient cycling"
"soil formation"
"buffer*"
"attenuation"
"mass flow*"
"mass-flow*"
"sediment*"
"nitrogen cycling"
"nitrogen fix*"
"plant pathology"
"phytopathology"
"parasitic"
"ectoparasite*"
"disease etiology"
"disease cycle*"
"plant disease* epidemiology"
"disease resistan*"
"insect resistan*"
"pathosystem"
"fung*"
"infectious disease*"
"saproxylic"
"oomycete*"
"Phytoplasma*"
"entomology"
"biomechanics"
"arthropod*"

2. Forest management

"xylem"
"xylogenesis"

“shoot growth”
“canopy”
“forest stand”
“root physiology”
“root cell anatomy”
“root anatomy”
“root architecture”
“root system”
“mycorrhiza*”
“rhizosphere*”
“ion absorption”
“hardiness”
“physiology”
“flowering”
“hydraulic architecture”
“dehydration
“frost hardening”
“stomatal closure*”
“chilling requirement”
“dorman*”
“earlywood”
“latewood”
“provenance trail*”
“allele* frequenc*”
“population genetics”
“population differentiation”
“ecological genetics”
“conservation genetics”
“genetic conservation”
“breeding value*”
“breeding strateg*”
“progeny”
“objective trait*”
“DNA marker*”
“dispersal”
“ecological niche*”
“adapt*”
“post-genomic”
“microenvironment*”
“selection criteria”
“evolution”
“gene expression”
“vegetative propagation”
“range shift*”
“radiation conversion”
“dry matter conversion”
“process-based model*”
“growth prediction*”
“genetic variability”
“molecular marker*”
“molecular tool*”
“functional genomics”
“metabolomics”
“breeding program*”
“hybridization”
“hibridisation”
“water use efficiency”
“tree improvement”
“plasticity”
“spatial trend*”
“spatial heterogeneity”
“reforestation stock”
“seed orchard*”
"allometric equations"
“somatic embryogenesis”
“SE technolog*”

“genetically improved”
“larch-breeding”
“vegetative propagatino”
“vegetative deployment”
“cryopreserv*”
“genetic stability”
“boreal”
“conifer*”
“temperate”
“Mediterranean”
“broadleaf’
“broadleave*”
“evergreen”
“deciduous”
“schlerophyll”
“grove*”
“plantation*”
“monoculture”
“short rotation*”
“short-rotation”
“rotation age*”
“rotation period*”
“optimal rotation*”
“stand age”
“SRWCs”
“*biomass”
“bioenerg*”
“silviculture”
“phytotechnolog*”
“phytoremediation”
“ecological restoration”
“mine reclamation”
“agroforestry”’
“perennial*”
“intercropping”
“multi-strata”
“dehesa”
“montado”
“silvo*”
“*even-aged”
“*continuous cover”
“multiaged”
“close-to-nature”
“rehabilitation”
“stand management”
“multi-objective”
“multi-varietal”
“pruning”
“tending”
“thinning”
“fertilization”
“fertilisation”
“vegetation transition*”
“biotic disturbance*”
“abiotic disturbance*”
“biotic risk*”
“abiotic risk*”
“temporal scales”
“global change”
“global environmental change”
“climate change”
“pasture*”
“land-use change”
“LULUC*”
“heterogeneous”
“mosaic*”

"nature-based solution*"
"nature conservation*"
"PES schem*"
"ecological restoration"
"forest restoration"
"ecosystem* restoration"
"ecosystem-based"
"natural regeneration"
"mixture*"
"rewilding"
"TREM"
"triad management"
"retention forestry"
"understory"
"overstory"
"alpha diversity"
"gamma diversity"
"vulnerability*"
"temporal scale*"
"harvesting engineering"
"*harvest*"
"transportation engineering"
"logging operation*"
"felling"
"logs"
"logs and limbs"
"round wood"
"yarding"
"stump*"
"landing"
"loading"
"mill*"
"sawmill*"
"hauling"
"trucking"
"machinery"
"stand establishment"
"stand treatment"
"juvenile forest*"
"nursery seedling*"
"ergonomics"
"human-factor engineering"
"forest operation management"
"communication technolog*"
"ICT"
"GIS"
"GPS"
"phone networks"
"production waste"
"small-scale"
"communit*"
"maneuverability"
"processing plant*"
"inventory"
"monitoring"
"planning"
"simulation*"
"mensuration"
"ground position*"
"aerial photograph*"
"remote* sens*"
"landsat"
"liDAR"
"MODIS"
"SPOT"
"imagery"

“dendrochronolog*”
“dendrometr*”
“tree-ring analys*”
“net primary productivity”
“NPP”
“leaf-area index”
“LAI”
“indices”
“on-site indicator*”
“off-site indicator*”
“leaf-litter decomposition”
"levulinic acid*"
“biometrics”
“Nearest neighbour”
“Nearest neighbor”
“scenario modelling”
“system extensibility”
“analytical engines”
“distant-dependent model*”
“Decision-support-system*”
“DSS”
“uncertaint*”
“nonlinear models”
“optimization”
“optimisation”
“risk analysis”
“data integration”
“data transformation”
“horizontal dimension*”
“landscape model*”
“landscape planning”
“landscape management”
“machine learning”
“natural hazard*”
“risk management”
“die-back*”
“dieback*”
“wildfire*”
“bark beetle*”
"mountain pine-beetle"
“maximum sustainable yield*”
“revegetat*”
“landslides”
“avalanche*”
“extreme temperature*”
“radioactive contamination”
“storm*”

3. Forest products

“fiber*”
“cell wall*”
“extractives”
“modulus of elasticity”
“grain pattern*”
“wood grain”
“texture*”
“porosity”
“density*”
“stiffness”
“end-product”
“quality”
“toughness”
“hardness”
“morphological characteristics”
“construction”

“light-frame”
“framing”
“skeletal framework”
“prefabrication”
“stick-built”
“post-and-beam”
“façade*”
“insulation”
“building code*”
“civil engineering*”
“civil structure*”
“cross-laminated”
“CLT”
“EWP”
“building information model*”
“BIM”
“computer numerical control*”
“CNC”
“wood-base panel*”
“wood wool”
“Eurocode*”
“solid wood treatment”
“sanding”
“temperature pressing”
“planks”
“wood boards”
“pallet*”
“parquet*”
“furniture”
“fixture*”
“upholster*”
“carpent*”
“biophilic”
“finger-jointed blank*”
“life-cycle analys*”
“durability”
“rot”
“moisture”
“varnish*”
“lasure*”
“preservative*”
“coating*”
“sealer*”
“fire retardant*”
“chemical conversion”
“mechanical conversion”
“slurr*”
“catalyst*”
“enzym*”
“microorganism*”
“*cellulos*”
“*polymer*”
“reactive extrusion”
“extractive extrusion”
“ultrasound assisted extrusion”
“microwave assisted extrusion”
“mechanical treatment*”
“semi-finished products”
“debarking”
“bucking”
“chipping”
“chips”
“shavings”
“scraps”
“sawing”
“paper”

“packaging”
“biodegradable”
“nanomaterial*”
“corrugated”
“European Standardization committee*”
“biofuel*”
“biorefin*”
“biotechnolog*”
“biobased plastic*”
“bio-based plastic*”
“biobased material*”
“bio-based material*”
“biofilm*”
“bio-film*”
“bio-plastic*”
“bioplastic*”
“pharmaceutical*”
“cosmetics”
“aerospace*”
“automobile”
“hygiene”
“myrrh production”
“niche market*”
“bioeconomy”
“resource availability”
“pre-treatment*”
“steam explosion”
“mechanical treatment”
“chemical treatment*”
“biological treatment*”
“*mechanical”
“bio-pulping”
“wood particle*”
“pulp*”
“manufactur*”
“lignin”
“cellulose”
"pectin*"
“tannins”
“terpene
“digester”
“bleaching”
“organosolve”
“torrefaction”
“pyrolysis”
“gasification”
“primary process*”
“secondary process*”
“downstream process*”
“veneer*”
“hybrid building*”
“adhesive*”
“glulam”
“glue-laminated”
“medium-density fiberboard*”
“MDF”
“particle board”
“OSB”
“oriented strand board”
“LVL”
“plywood”
“pre-fabricat*”
“prefabricat*”
“composite*”
“laminated”
“centrifug*”

"*filtration"
"sieve*"
"chromatography"
"distillation"
"non-volatile solute*"
"volatile liquid*"
"chemical separation"
"mechanical separation"
"physical separation"
"digitalization"
"digitalisation"
"traceability"
"parametric design"
"3d print*"
"product passport*"
"scanners"
"sensors"
"lifecycle assessment*"
"material bank*"
"energy performance"
"non-wood forest product*"
"non-wood product*"
"fruit*"
"leaf"
"leaves"
"seed*"
"bark"
"root*"
"resin*"
"cork"
"ecomaterial*"
"genetic material*"
"nuts"
"berries"
"lumber"
"sawdust*"
"mushroom*"
"truffles"
"herb*"
"medicinal"
"scents"
"essential oil*"
"sap*"
"ornament*"
"Christmas"
"decorat*"
"fertilizers"
"soil microbes"
"mulch"
"pinecone*"
"pine kernel*"
"game species"
"hunt*"
"deer"
"rabbit*"
"wild boar*"
"fodder"
"firewood*"
"fuelwood*"
"dried"
"processed"
"added-value"
"value added"
"territorial marketing"

4. Social aspects of forests and forest policy

“recreation”
“human health”
“well-being”
“wellbeing”
“amenit”
“hiking”
“trekking”
“outdoor*”
“forest bathing”
“shinrin-yoku”
“leisure”
“nature-based tourism”
“ecotourism”
“parks”
“urban green*”
“urban trench*”
“urban biodiversity”
“natural place*”
“natural area*”
“nature area*”
“wilderness”
“biosphere reserve”
“wildlife reserve*”
“protected area*”
“sacred”
“holy”
“religious”
“spiritual”
“ritual*”
“heritage”
“cultural site*”
“socio-cultural”
“historical site*”
“aesthetic”
“identity”
“symbolic”
“urban green*”
“gender”
“feminis*”
“inequalit*”
“justice”
“vulnerable communit*”
“vulnerable population”
“vulnerable group*”
“education*”
“rural”
“livelihood*”
“natural resource*”
“ownership”
“*tenure”
“legislation”
“standards”
“institution*”
“economics”
“circular economy”
“circular-by-design”
“disassembl*”
“deconstruction”
“reuse”
“remanufacture”
“recycl*”
“eco-design”
“sustainab*”
“policy”
“policies”
“governance”

“funding”
“trade-off*”
“market*”
“supply”
“demand”
“economic transformation*”
“new products”
“value chain”
“production portfolio*”
“property right*”
“certification*”
“marketing”
“innovat*”
“emerging”
“entrepren*”
“startup*”
“start-up*”
“enterpris*”

NOT terms (confounding)

“*bronchial tree*”
“*biliary tree*”
“meta-analysis tree*”
“vascular tree*”
“artery tree*”
“pulmonary tree*”
“deciduous teeth”
“deciduous tooth”
“deciduous molar*”
“deciduous canine*”
“bacterial cellulose”
“optical fiber*”
“fiber optic*”
“multicore fiber*”
“crystal fiber*”
“glass fiber*”
“muscle fiber*”
“helical fiber*”
“myocardial fiber*”
“Wood units”
“Wood U”
“bypass lime*”
“forest and funnel plot*”
“norwood”
“tree-based extreme gradient boosting”
“tree-in-bud”
“tree in bud”
“Bournewood case*”
“nerve branch*”
“fault tree analys*”
“Quad Tree”
“quad-tree”
“coding tree unit”
“partition tree*”
“Dual Tree Complex”
“inference tree model*”
“Tree man syndrome”
“underwood”
“cawood”
“Semliki Forest vectors”
“semliki forest virus”
“Englewood”
“Engelwood”
“Dixon-Woods”
“Mediterranean diet”

"Woodward"
"Rockwood"
"Forestier* disease*"
"Elwood"
"tree of life"
"Westwood"
"Woodside"
"decision analysis tree*"
"random forest classification"
"RF-KDE"
"blood count"
"diabetes"
"android"
"applied computing"
"soft computing"
"computational intelligence"
"naive bayes"
"extraintestinal manifestation*"
"perinatal"
"OMBUs"
"fetal fibronectin"
"villous tree"
"placenta*"
"crohn's disease"
"obstetri*"
"colectomy"
"*platelet*"
"stroke"
"*cerebral"
"aneurysm*"
"maxillar*"
"Newtonian"
"cosmic"
"carotid"
"periodontal"
"vessel tree"
"oral frailty"
"oral hygiene"
"TinyML"
"anaesthe*"
"surgery"
"surgical procedure*"
"surgical treatment*"
"Cochrane Handbook"
"l'Abbe plot*"
"coronary tree"

Query 1
TS= **((**review**) AND (((**Core forest + tree terms**) AND (**Additional forestry sector terms**)) NOT (**confounding terms**))) + category and geographical refinements**
Query 2
TS= **((**systematic review**) AND (((**Core forest + tree terms**) AND (**Additional forestry sector terms**)) NOT (**confounding terms**)))**

TS=(("review*") **AND** (((*forest*" OR "tree*" OR "*wood*" OR "*timber*" OR "Abies alba" OR "silver fir*" OR "abies spp*" OR "circum-Mediterranean fir*" OR "acer campestre" OR "field maple*" OR "acer platanoides" OR "norway maple*" OR "acer pseudoplatanus" OR "sycamore maple*" OR "aesculus hippocastanum" OR "European horse-chestnut*" OR "ailanthus altissima" OR "tree of heaven" OR "alnus cordata" OR "italian alder*" OR "alnus glutinosa" OR "common alder*" OR "alnus incana" OR "grey alder*" OR "alnus viridis" OR "green alder*" OR "betula spp*" OR "birch*" OR "carpinus betulus" OR "common hornbeam*" OR "carpinus orientalis" OR "oriental hornbeam*" OR "castanea sativa" OR "sweet chestnut*" OR "celtis australis" OR "nettle tree*" OR "chamaecyparis lawsoniana" OR "lawson cypress*" OR "cornus mas" OR "cornelian cherr*" OR "cornus sanguinea" OR "common dogwood*" OR "corylus avellana" OR "common hazel*" OR "cupressus sempervirens" OR "mediterranean cypress*" OR "eucalyptus globulus" OR "tasmanian blue gum" OR "eucalypt*" OR "euonymus europaeus" OR "spindle tree*" OR "fagus sylvatica" OR "european beech" OR "frangula alnus" OR "alder buckthorn*" OR "fraxinus angustifolia" OR "narrow-leaved ash*" OR "fraxinus excelsior" OR "Common ash*" OR "fraxinus ornus" OR "manna ash*" OR "ilex aquifolium" OR "european holl*" OR "juglans regia" OR "common walnut*" OR "juniperus communis" OR "common juniper*" OR "juniperus oxycedrus" OR "prickly juniper*" OR "juniperus phoenicea" OR "phoenician juniper*" OR "juniperus thurifera"

OR “Spanish juniper*” OR “larix decidua” OR “European larch*” OR “olea europaea” OR “olive tree*” OR “ostrya carpinifolia” OR “european hophornbeams” OR “picea abies” OR “Norway spruce*” OR “picea omorika” OR “Serbian spruce*” OR “picea sitchensis” OR “sitka Spruce*” OR “pinus cembra” OR “arolla pine*” OR “pinus halepensis" OR “pinus brutia” OR “aleppo pine*” OR “turkish pine*” OR “pinus mugo” OR “dwarf mountain pine*” OR “pinus nigra” OR “black pine*” OR “pinus pinaster” OR “maritime pine*” OR “pinus pinea” OR “stone pine*” OR “pinus sylvestris” OR “Scots pine*” OR “populus alba” OR “white poplar*” OR “populus nigra” OR “black poplar*” OR “populus tremula” OR “Eurasian aspen*” OR “prunus avium” OR “wild cherr*” OR “prunus cerasifera” OR “cherry plum*” OR “prunus mahaleb” OR “mahaleb cherr*” OR “prunus padus” OR “bird cherr*” OR “prunus spinose” OR “blackthorn*” OR “pseudotsuga menziesii” OR “douglas fir*” OR “quercus cerris” OR “Turkey oak*” OR “quercus frainetto” OR “Hungarian oak*” OR “quercus ilex” OR “Holm oak*” OR “quercus palustris” OR “pin oak*” OR “quercus pubescens” OR “downy oak*” OR “quercus pyrenaica” OR “pyrenean oak*” OR “quercus robur” OR “quercus petraea” OR “pedunculated oak*” OR “sessile oak*” OR “quercus suber” OR “cork oak*” OR “robinia pseudoacacia” OR “black locust*” OR “salix alba” OR “white willow*” OR “salix caprea” OR “goat willow*” OR “sambucus nigra” OR “black elderberr*” OR “sorbus aria” OR “common whitebeam*” OR “sorbus aucuparia” OR “rowan*” OR “sorbus domestica” OR “service tree*” OR “sorbus torminalis” OR “wild service tree*” OR “tamarix spp*” OR “tamarisk*” OR “taxus baccata” OR “european yew*” OR “tilia spp*” OR “limes” OR “ulmus spp*” OR “elms”) **AND** (“ecosystem service*” OR “ecolog*” OR “provisioning” OR “anthropogenic disturbance*” OR “old-growth” OR “natural disturbance*” OR “fires” OR “drought*” OR “species diversity” OR “genetic variance” OR “extinction” OR “endangered" OR “biodiversity” OR “resilien*” OR “functional diversity” OR “management” OR “habitat*” OR “degradation” OR “fragmentation” OR “regulat*” OR “ventilation” OR “transpiration” OR “humidity” OR “air quality” OR “carbon sink*” OR “carbon stock*” OR “carbon storage*” OR “carbon off-set*” OR “carbon credit*” OR “carbon offset*” OR “carbon sequestration” OR “carbon captur*” OR “carbon fixation” OR "carbon accounting" OR "carbon allocation" OR "carbon balance" OR "carbon budget" OR “carbon emission*” OR “carbon cycl*” OR “REDD plus” OR “carbon neutrality” OR “carbon footprint” OR “mitigation” OR “redd +*” OR "net ecosystem exchange" OR “ecosystem function*” OR “atmospheric” OR “chemical composition” OR “Water supply” OR “water flow” OR “watershed protection” OR “groundwater” OR “ground water” OR “sub-surface” OR “freshwater” OR “coastal water” OR “waterway*” OR “ecohydrology” OR “riparian” OR “infiltration” OR “evaporation” OR “runoff” OR “wetland*” OR “flood prevention” OR “flood management” OR “floodplain*” OR “water purification” OR “sediment dynamics” OR “sedimentary balance” OR “stabilization” OR “stabilisation” OR “erosion” OR “eutrophication” OR “pollution” OR “neopollutant*” OR “*organic contamina*” OR “*organic pollut*” OR “humus” OR “soil processes” OR “decontamination” OR “nutrient cycling” OR “soil formation” OR “buffer*” OR “attenuation” OR “mass flow*” OR “mass-flow*” OR “sediment*” OR “nitrogen cycling” OR “nitrogen fix*” OR “plant pathology” OR “phytopathology” OR “parasitic” OR “ectoparasite*” OR “disease etiology” OR “disease cycle*” OR “plant disease* epidemiology” OR “disease resistan*” OR “insect resistan*” OR “pathosystem” OR “fung*” OR “infectious disease*” OR “saproxylic” OR “oomycete*” OR “Phytoplasma*” OR “entomology” OR “biomechanics” OR “arthropod*” OR “xylem” OR “xylogenesis” OR “shoot growth” OR “canopy” OR “forest stand” OR “root physiology” OR “root cell anatomy” OR “root anatomy” OR “root architecture” OR “root system” OR “mycorrhiza*” OR “rhizosphere*” OR “ion absorption” OR “hardiness” OR “physiology” OR “flowering” OR “hydraulic architecture” OR “dehydration” OR “frost hardening” OR “stomatal closure*” OR “chilling requirement” OR “dorman*” OR “earlywood” OR “latewood” OR “provenance trail*” OR “allele* frequenc*” OR “population genetics” OR “population differentiation” OR “ecological genetics” OR “conservation genetics” OR “genetic conservation” OR “breeding value*” OR “breeding strateg*” OR “progeny” OR “objective trait*” OR “DNA marker*” OR “dispersal” OR “ecological niche*” OR “adapt*” OR “post-genomic” OR “microenvironment*” OR “selection criteria” OR “evolution” OR “gene expression” OR “vegetative propagation” OR “range shift*” OR “radiation conversion” OR “dry matter conversion” OR “process-based model*” OR “growth prediction*” OR “genetic variability” OR “molecular marker*” OR “molecular tool*” OR “functional genomics” OR “metabolomics” OR “breeding program*” OR “hybridization” OR “hibridisation” OR “water use efficiency” OR “tree improvement” OR “plasticity” OR “spatial trend*” OR “spatial heterogeneity” OR “reforestation stock” OR “seed orchard*” OR "allometric equations" OR “somatic embryogenesis” OR “SE technolog*” OR “genetically improved” OR “larch-breeding” OR “vegetative propagatino” OR “vegetative deployment” OR “cryopreserv*” OR “genetic stability” OR “boreal” OR “conifer*” OR “temperate” OR “Mediterranean” OR “broadleaf” OR “broadleave*” OR “evergreen” OR “deciduous” OR “schlerophyll” OR “grove*” OR “plantation*” OR “monoculture” OR “short rotation*” OR “short-rotation” OR “rotation age*” OR “rotation period*” OR “optimal rotation*” OR “stand age” OR “SRWCs” OR “*biomass” OR “bioenerg*” OR “silviculture” OR “phytotechnolog*” OR “phytoremediation” OR “ecological restoration” OR “mine reclamation” OR “agroforestry”’ OR “perennial*” OR “intercropping” OR “multi-strata” OR “dehesa” OR “montado” OR “silvo*” OR “*even-aged” OR “*continuous cover” OR “multiaged” OR “close-to-nature” OR “rehabilitation” OR “stand management” OR “multi-objective” OR “multi-varietal” OR “pruning” OR “tending” OR “thinning” OR “fertilization” OR “fertilisation” OR “vegetation transition*” OR “biotic disturbance*” OR “abiotic disturbance*” OR “biotic risk*” OR “abiotic risk*” OR “temporal scales” OR “global change” OR “global environmental change” OR “climate change” OR “pasture*” OR “land-use change” OR “LULUC*” OR “heterogeneous” OR “mosaic*” OR “nature-based solution*” OR “nature conservation*” OR “PES schem*” OR “ecological restoration” OR “forest restoration” OR “ecosystem* restoration” OR “ecosystem-based” OR “natural regeneration” OR “mixture*” OR “rewilding” OR “TREM” OR “triad management” OR “retention forestry” OR “understory” OR “overstory” OR “alpha diversity” OR “gamma diversity” OR “vulnerability*” OR “temporal scale*” OR “harvesting engineering” OR “*harvest*” OR “transportation engineering” OR “logging operation*” OR “felling” OR “logs” OR “logs and limbs” OR “round wood” OR “yarding” OR “stump*” OR “landing” OR “loading” OR “mill*” OR “sawmill*” OR “hauling” OR “trucking” OR “machinery” OR “stand establishment” OR “stand treatment” OR “juvenile forest*” OR “nursery seedling*” OR “ergonomics” OR “human-factor engineering” OR “forest operation management” OR “communication technolog*” OR “ICT” OR “GIS” OR “GPS” OR “phone networks” OR “production waste” OR “small-scale” OR “communit*” OR “maneuverability” OR “processing plant*” OR “inventory” OR “monitoring” OR “planning” OR “simulation*” OR “mensuration” OR “ground position*” OR “aerial photograph*” OR “remote* sens*” OR “landsat” OR “liDAR” OR “MODIS” OR “SPOT” OR “imagery” OR “dendrochronolog*” OR “dendrometr*” OR “tree-ring analys*” OR “net primary productivity” OR “NPP” OR “leaf-area index” OR “LAI” OR “indices” OR “on-site indicator*” OR “off-site indicator*” OR “leaf-litter decomposition” OR "levulinic acid*" OR “biometrics” OR “Nearest neighbour” OR “Nearest neighbor” OR “scenario modelling” OR “system extensibility” OR “analytical engines” OR “distant-dependent model*” OR “Decision-support-system*” OR “DSS” OR “uncertaint*” OR “nonlinear models” OR “optimization” OR “optimisation” OR “risk analysis” OR “data integration” OR “data transformation” OR “horizontal dimension*” OR “landscape model*” OR “landscape planning” OR “landscape management” OR “machine learning” OR “natural hazard*” OR “risk management” OR “die-back*” OR “dieback*” OR “wildfire*” OR “bark beetle*” OR "mountain pine-beetle" OR “maximum sustainable yield*” OR “revegetat*” OR “landslides” OR “avalanche*” OR “extreme temperature*” OR “radioactive contamination” OR “storm*” OR “fiber*” OR “cell wall*” OR “extractives” OR “modulus of elasticity” OR “grain pattern*” OR “wood grain” OR “texture*” OR “porosity” OR “density*” OR “stiffness” OR “end-product” OR “quality” OR “toughness” OR “hardness” OR “morphological characteristics” OR “construction” OR “light-frame” OR “framing” OR “skeletal framework” OR “prefabrication” OR “stick-built” OR “post-and-beam” OR “façade*” OR “insulation” OR “building code*” OR “civil engineering*” OR “civil structure*” OR “cross-laminated” OR “CLT” OR “EWP” OR “building information model*” OR “BIM” OR “computer numerical control*” OR

"CNC" OR "wood-base panel*" OR "wood wool" OR "Eurocode*" OR "solid wood treatment" OR "sanding" OR "temperature pressing" OR "planks" OR "wood boards" OR "pallet*" OR "parquet*" OR "furniture" OR "fixture*" OR "upholster*" OR "carpent*" OR "biophilic" OR "finger-jointed blank*" OR "life-cycle analys*" OR "durability" OR "rot" OR "moisture" OR "varnish*" OR "lasure*" OR "preservative*" OR "coating*" OR "sealer*" OR "fire retardant*" OR "chemical conversion" OR "mechanical conversion" OR "slurr*" OR "catalyst*" OR "enzym*" OR "microorganism*" OR "*cellulos*" OR "*polymer*" OR "reactive extrusion" OR "extractive extrusion" OR "ultrasound assisted extrusion" OR "microwave assisted extrusion" OR "mechanical treatment*" OR "semi-finished products" OR "debarking" OR "bucking" OR "chipping" OR "chips" OR "shavings" OR "scraps" OR "sawing" OR "paper" OR "packaging" OR "biodegradable" OR "nanomaterial*" OR "corrugated" OR "European Standardization committee*" OR "biofuel*" OR "biorefin*" OR "biotechnolog*" OR "biobased plastic*" OR "biobased material*" OR "bio-based plastic*" OR "biofilm*" OR "bio-film*" OR "bio-plastic*" OR "bioplastic*" OR "bio-based material*" OR "pharmaceutical*" OR "cosmetics" OR "aerospace*" OR "automobile" OR "hygiene" OR "myrrh production" OR "niche market*" OR "bioeconomy" OR "resource availability" OR "pre-treatment*" OR "steam explosion" OR "mechanical treatment" OR "chemical treatment*" OR "biological treatment*" OR "*mechanical" OR "bio-pulping" OR "wood particle*" OR "pulp*" OR "manufactur*" OR "lignin" OR "cellulose" OR "pectin*" OR "tannins" OR "terpene" OR "digester" OR "bleaching" OR "organosolve" OR "torrefaction" OR "pyrolysis" OR "gasification" OR "primary process*" OR "secondary process*" OR "downstream process*" OR "veneer*" OR "hybrid building*" OR "adhesive*" OR "glulam" OR "glue-laminated" OR "medium-density fiberboard*" OR "MDF" OR "particle board" OR "OSB" OR "oriented strand board" OR "LVL" OR "plywood" OR "pre-fabricat*" OR "prefabricat*" OR "composite*" OR "laminated" OR "centrifug*" OR "*filtration" OR "sieve*" OR "chromatography" OR "distillation" OR "non-volatile solute*" OR "volatile liquid*" OR "chemical separation" OR "mechanical separation" OR "physical separation" OR "digitalization" OR "digitalization" OR "traceability" OR "parametric design" OR "3d print*" OR "product passport*" OR "scanners" OR "sensors" OR "lifecycle assessment*" OR "material bank*" OR "energy performance" OR "non-wood forest product*" OR "non-wood product*" OR "fruit*" OR "leaf" OR "leaves" OR "seed*" OR "bark" OR "root*" OR "resin*" OR "cork" OR "ecomaterial*" OR "genetic material*" OR "nuts" OR "berries" OR "lumber" OR "sawdust*" OR "mushroom*" OR "truffles" OR "herb*" OR "medicinal" OR "scents" OR "essential oil*" OR "sap" OR "ornament*" OR "Christmas" OR "decorat*" OR "fertilizers" OR "soil microbes" OR "mulch" OR "pinecone*" OR "pine kernel*" OR "game species" OR "hunt*" OR "deer" OR "rabbit*" OR "wild boar*" OR "fodder" OR "firewood*" OR "fuelwood*" OR "dried" OR "processed" OR "added-value" OR "value added" OR "territorial marketing" OR "recreation" OR "human health" OR "well-being" OR "wellbeing" OR "amenit" OR "hiking" OR "trekking" OR "outdoor*" OR "forest bathing" OR "shinrin-yoku" OR "leisure" OR "nature-based tourism" OR "ecotourism" OR "parks" OR "urban green*" OR "urban trench*" OR "urban biodiversity" OR "natural place*" OR "natural area*" OR "nature area*" OR "wilderness" OR "biosphere reserve" OR "wildlife reserve*" OR "protected area*" OR "sacred" OR "holy" OR "religious" OR "spiritual" OR "ritual*" OR "heritage" OR "cultural site*" OR "socio-cultural" OR "historical site*" OR "aesthetic" OR "identity" OR "symbolic" OR "urban green*" OR "gender" OR "feminis*" OR "inequalit*" OR "justice" OR "vulnerable communit*" OR "vulnerable population" OR "vulnerable group*" OR "education*" OR "rural" OR "livelihood*" OR "natural resource*" OR "ownership" OR "*tenure" OR "legislation" OR "standards" OR "institution*" OR "economics" OR "circular economy" OR "circular-by-design" OR "disassembl*" OR "deconstruction" OR "reuse" OR "remanufacture" OR "recycl*" OR "eco-design" OR "sustainab*" OR "policy" OR "policies" OR "governance" OR "funding" OR "trade-off*" OR "market*" OR "supply" OR "demand" OR "economic transformation*" OR "new products" OR "value chain" OR "production portfolio*" OR "property right*" OR "certification*" OR "marketing" OR "innovat*" OR "emerging" OR "entrepren*" OR "startup*" OR "start-up*" OR "enterpris*")) **NOT** ("*bronchial tree*" OR "*biliary tree*" OR "meta-analysis tree*" OR "vascular tree*" OR "artery tree*" OR "pulmonary tree*" OR "deciduous teeth" OR "deciduous tooth" OR "deciduous molar*" OR "deciduous canine*" OR "bacterial cellulose" OR "optical fiber*" OR "fiber optic*" OR "multicore fiber*" OR "crystal fiber*" OR "glass fiber*" OR "muscle fiber*" OR "helical fiber*" OR "myocardial fiber*" OR "Wood units" OR "Wood U" "bypass lime*" OR "forest and funnel plot*" OR "norwood" OR "tree-based extreme gradient boosting" OR "tree-in-bud" OR "tree in bud" OR "Bournewood case*" OR "nerve branch*" OR "fault tree analys*" OR "Quad Tree" OR "quad-tree" OR "coding tree unit" OR "partition tree*" OR "Dual Tree Complex" OR "inference tree model*" OR "Tree man syndrome" OR "underwood" OR "cawood" OR "Semliki Forest vectors" OR "semliki forest virus" OR "Englewood" OR "Engelwood" OR "Dixon-Wood*" OR "Mediterranean diet" OR "Woodward" OR "Wood-Werkman" OR "Kirkwood" OR "Rockwood" OR "Forestier* disease*" OR "Elwood" OR "tree of life" OR "Westwood" OR "Woodside" OR "decision analysis tree*" OR "random forest classification" OR "RF-KDE" OR "blood count" OR "diabetes" OR "android" OR "applied computing" OR "soft computing" OR "computational intelligence" OR "naive bayes" OR "extraintestinal manifestation*" OR "perinatal" OR "OMBUs" OR "fetal fibronectin" OR "villous tree" OR "placenta*" OR "crohn's disease" OR "obstetri*" OR "colectomy" OR "*platelet*" OR "stroke" OR "*cerebral" OR "aneurysm*" OR "maxillar*" OR "Newtonian" OR "cosmic" OR "carotid" OR "periodontal" OR "vessel tree" OR "oral frailty" OR "oral hygiene" OR "TinyML" OR "anaesthe*" OR "surgery" OR "surgical procedure*" OR "surgical treatment*" OR "Cochrane Handbook" OR "l'Abbe plot*" OR "coronary tree")))

Web of science category refinements

The aim was to refine the selection of studies to Web of Science categories which were found most relevant for the field. Six forest sciences experts marked individually the categories they found most relevant within the scope of F&FS. After a few rounds searching for consensus the applied refinement categories ended up being: "Environmental Sciences" OR "Forestry" OR "Ecology" OR "Plant Sciences" OR "Biodiversity Conservation" OR "Materials Science Paper & Wood" OR "Soil Science" OR "Environmental Studies" OR "Remote Sensing" OR "Entomology" OR "Chemistry Multidisciplinary" OR "Biology" OR "Agriculture Multidisciplinary" OR "Mycology" OR "Polymer Science".

Geographical refinement

In addition a geographical refinement was applied to ensure that only documents associated with European countries—either through author affiliation, research location, or publication metadata—are included in the results. The country refinement covered the following: "Denmark" OR "Finland" OR "Iceland" OR "Norway" OR "Sweden" OR "Estonia" OR "Latvia" OR "Lithuania" OR "Greenland" OR "France" OR "Germany" OR "Austria" OR "Belgium" OR "Netherlands" OR "Luxembourg" OR "Switzerland" OR "Ireland" OR "United Kingdom" " OR "England" OR "Scotland" OR "Wales" OR "Northern Ireland" " OR "Andorra" OR "Spain" OR "Portugal" OR "Italy" OR "Greece" OR "Malta" OR "Cyprus" OR "Albania" OR "Bosnia and Herzegovina" OR "Croatia" OR "North Macedonia" OR "Montenegro" OR "Serbia" OR "Slovenia" OR "Poland" OR "Czech Republic" OR "Slovakia" OR "Hungary" OR "Romania" OR "Bulgaria" OR "Moldova" OR "Ukraine" OR "Armenia" OR "Georgia" OR "Czechoslovakia" OR "Yugoslavia" OR "Federal Republic of Germany" OR "West Germany" OR "German Democratic Republic" OR "East Germany" OR "Bundesrepublik"

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.forpol.2025.103693.

Data availability

We share link to github and attach 3 supplementary information files

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