What secondary research evidence exists on the effects of forest management after disturbances: a systematic map protocol

Moritz Baumeister[1,2*] and Markus A. Meyer[1]

Abstract

Background Forest disturbances are projected to increase in intensity and frequency in the upcoming decades. The projected change in disturbance regimes is expected to alter the provision of ecosystem services and affect biodiversity. Both are critical for forest ecosystems to provide livelihoods for human societies. Forest management after natural disturbances shapes successional pathways of forest ecosystems. Therefore, the management of post-disturbance sites deserves critical attention to avoid negative effects of management interventions on ecosystem services and biodiversity. The two most common management interventions after natural disturbances are salvage logging (comparator: no salvage logging) and tree planting (comparator: natural regeneration). This planned systematic map of reviews aims to aggregate the existing evidence syntheses on the implications of common forest management interventions after natural disturbances on successional trajectories with regard to selected ecosystem services and biodiversity. Evidence-based post-disturbance management is highly relevant for protected area management as well as for the management of commercial forests.

Methods We will systematically search the databases Scopus, Web of Science Core Collection and the Forest Science Collection of the CABI Digital Library for reviews and meta-analyses (after 2003). We will apply eligibility criteria for review selection and assess the evidence synthesis validity of selected reviews using the most recent version of CEESAT (Collaboration for Environmental Evidence Synthesis Assessment Tool). The results will be displayed in topic subgroups in summary of scope and summary of findings tables.

Keywords Salvage logging, Afforestation, Tree planting, Biodiversity, Ecosystem services, Natural regeneration, Restoration, Evidence synthesis, Evidence review map, Meta-analysis

*Correspondence:
Moritz Baumeister
moritz.baumeister@hs-anhalt.de; moritz.baumeister@protonmail.com
[1] Department of Agriculture, Ecotrophology, and Landscape Development, National and International Nature Conservation, University of Applied Sciences Anhalt, Bernburg, Germany
[2] Ecosystem Modelling, Faculty of Forest Sciences and Forest Ecology, University of Göttingen, Göttingen, Germany

Background

Natural disturbances structure ecosystems worldwide. Due to climate change, rapid shifts in abiotic conditions are expected to change global disturbance regimes and thus alter ecosystems [1]. In forest ecosystems, disturbances are projected to be more frequent and intense in the future and also the likelihood of interactions of different disturbance types is expected to increase [2].

An increase in disturbance frequencies and intensities in forests also changes the provision of ecosystem services [3] and affects biodiversity [4]. Species diversity and, in particular, the functional diversity of species

are closely linked to the ability of ecosystems to provide a portfolio of ecosystem services [5]. Thus, the rapidly changing world causing biodiversity loss [6, 7] and increased disturbance intensities and frequencies result in great uncertainties regarding the provision of ecosystem services [8]. Human societies, however, are inseparably intertwined with their surrounding ecosystems [9] and are heavily dependent on a reliable provision of ecosystem services [10].

Forest management has the potential to mitigate negative disturbance impacts on ecosystem service provision [2]. After natural disturbances, current forest management is usually guided by two silvicultural management questions: Should forest management opt (i) for salvage logging [11] and (ii) for planting trees [12]? These two simple management questions entail more complex follow-up questions. For instance, the potential expansion of green tree retention harvest procedures [13, 14] to harvest procedures after natural disturbances [15].

In forestry, however, the evaluation of management decisions can only be evaluated after long time periods *ex post* [16]. Forest management has long-lasting and often unforeseen legacies far into the future [17] and may fundamentally affect the successional trajectories of forests [18]. Therefore, adequate forest management requires permanent and dynamic adaptation and evaluation of management decisions [19] and needs to embrace the complexity of forest ecosystems instead of seeing it as an obstacle to achieving clear management targets [20].

To embrace the complexity of forest ecosystems and to acknowledge the fact that we can never predict ecosystem dynamics over decades without considerable uncertainties strengthens the importance of forest management grounded in available ecological knowledge. Furthermore, it highlights the potential for severe consequences of incautious management decisions. To link management decisions with their consequences for ecosystems, systematic reviews and meta-analyses have been established as tools in ecology to aggregate the findings of individual studies as part of the "evidence-based conservation movement" [21, 22]. Systematic reviews and meta-analyses provide a powerful tool to guide forest management and estimate the impacts of certain management interventions on forest ecosystems. For example, meta-analyses were conducted to assess the effects of salvage logging on ecosystem services [23], biodiversity in general [24] and specific taxa [25].

It has first been recognised in medical sciences that decision-makers and scientists face difficulty reading the large number of systematic reviews published regularly [26]. Therefore, a new article type called overview of reviews (sometimes also referred to as umbrella review, review of reviews, synthesis of systematic reviews or summary of systematic reviews [27]) was established in recent years, and its methods are still under development [28]. Despite the infancy of the overview methodology in medical sciences [29], a similar methodology to aggregate existing secondary research has also been developed under the term "evidence review mapping" in environmental sciences [30]. Here, we refer to our methodology as a systematic map of reviews to be consistent with the established terms by the Collaboration for Environmental Evidence (CEE).

Management decisions are usually made shortly after natural disturbances occur [11], and environmental managers are unlikely to have the time to aggregate the fragmented knowledge from many different reviews. Thus, adopting methods that allow to map the evidence from secondary research regarding the effect of management decisions after natural disturbances with respect to ecosystem services and biodiversity provides an accessible knowledge base for environmental managers and political decision-makers.

Stakeholder engagement

The increased frequency and intensity of extreme weather events as well as an increase in the extent, frequency and impacts of pests and diseases in forest ecosystems have been identified as essential challenges for the supply of ecosystem services in Europe [31]. Understanding the influence of forest management on the successional trajectories of forest ecosystems is key to making careful and considerate forest management decisions that include a broad portfolio of ecosystem services and consider biodiversity conservation. The idea to provide a reader-friendly systematic map of reviews relevant to forest management after natural disturbances originated from the Wald-Klima-Forum (Forest-Climate-Forum) in Jena, Germany, in June 2022 and the conference "Holznutzung in Krisenzeiten" (Timber use in Times of Crisis) in Göttingen, Germany, in April 2023. On both occasions, stakeholders from various backgrounds (forestry sector, nature conservation organizations, scientists) discussed urgent questions of current forest management. One of the overarching questions was how to manage forest sites after natural disturbances. The debate is not new [32] but was reinforced due to recent widespread bark beetle outbreaks and prolonged summer droughts negatively affecting the main economic tree species in Central Europe [33]. The discussion intensified in the last few years, spread beyond the scientific community and became also highly relevant for the management of disturbance sites within protected areas such as national parks [34].

Objective of the review

The objective of our systematic map of reviews is to summarize the evidence of recent reviews (after 2003) addressing how common management interventions after forest harvesting and natural disturbances (salvage logging and tree planting) affect forest successional trajectories. This systematic map aims to aggregate the key findings of previous reviews to guide forest management with respect to selected ecosystem services and biodiversity (Fig. 1). Systematic maps of reviews act as an entry point for a more detailed examination of certain aspects of a topic [26] and should be written as user-friendly documents to reach a broad audience of scientists and environmental decision-makers [29].

Our selection of ecosystem services is based on the list of forest ecosystem services mapped by Orsi et al. 2020 for the European Union: Wood supply, water supply, erosion control, pollination, soil formation, climate regulation (carbon sequestration) and recreation [35]. We do not consider "habitat provision" from their list as we
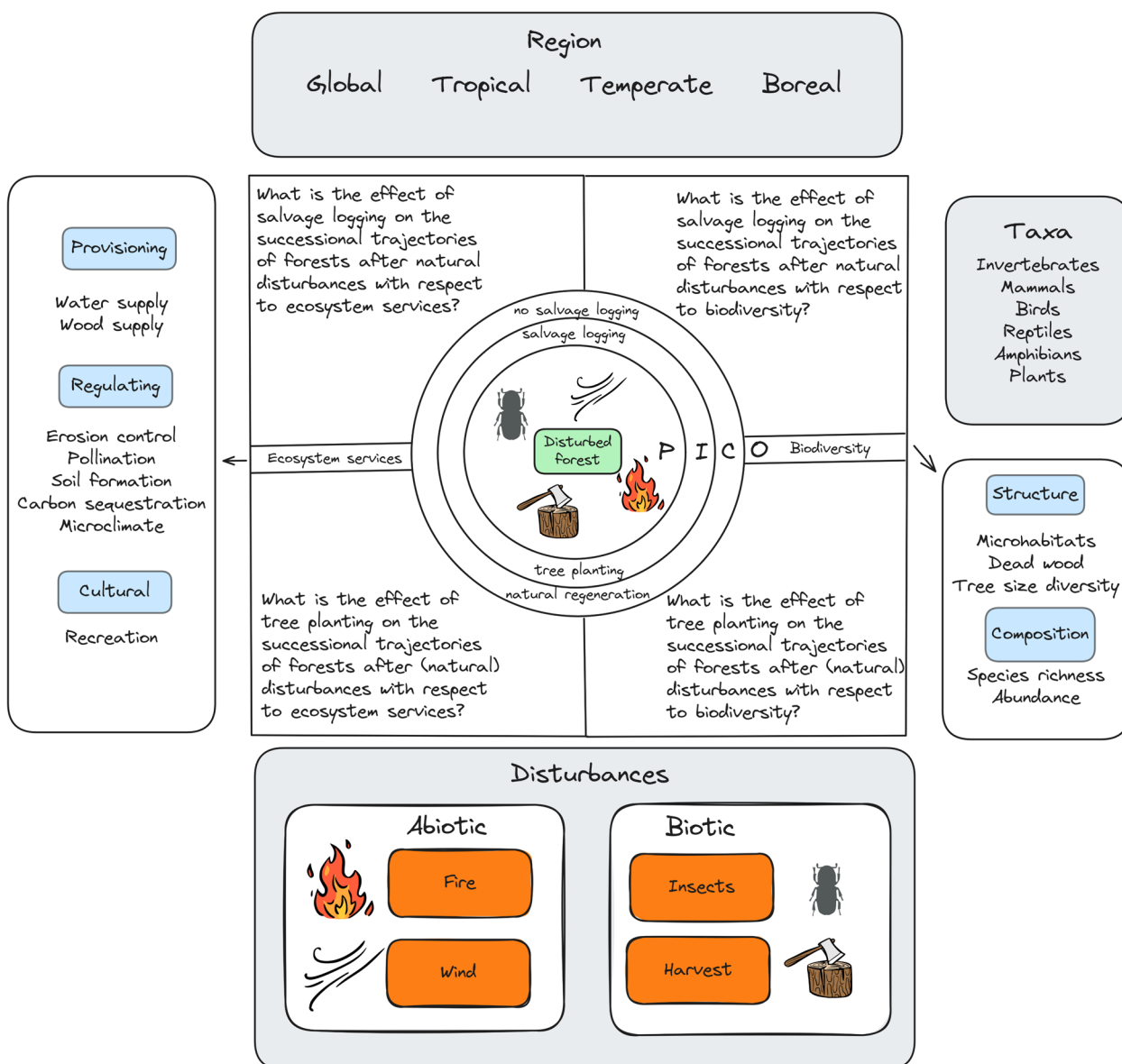

Fig. 1 Detailed visualization of Population, Interventions, Comparators and selected Outcomes of interest for the planned systematic map. The structure follows the PICO elements for question formulation in evidence syntheses following the CEE guidelines [45]. Grey boxes indicate additional categories by which the mapped reviews will be grouped. References for the illustrations: cocomaterial (https://creativecommons.org/publicdomain/zero/1.0/); bark beetle © Dorota Paczesniak (https://creativecommons.org/licenses/by-sa/4.0/); Link: ; no changes made

treat biodiversity as a separate entity within our analysis. Additionally, we consider forest microclimate regulation as an ecosystem service class [36]. We include microclimate because the effect of forest management on microclimate regulation and its potential to impact the climate on the landscape scale is a heavily debated current topic in forestry (e.g. [37]).

With respect to biodiversity, we explicitly consider categories related to forest structure that are indicators for biodiversity: tree size diversity, microhabitats and dead wood [38, 39]. We will further group our results into different taxa: Plants, invertebrates, mammals, birds, reptiles and amphibians [40].

For this systematic map of reviews, we additionally differentiate between different natural disturbance agents (fire, wind and insects) and the geographical scale of the respective review (Fig. 1). Even though the systematic map is designed to summarize secondary evidence for forest management after natural disturbances, we decided to also include anthropogenic disturbances. Studies investigating successional trajectories after harvest may provide valuable insight for the questions at hand. Despite the focus on natural disturbance sites, excluding normal harvest procedures would decrease the body of evidence unjustifiably. Wood harvest is a very common anthropogenic disturbance and research on its effects on forest ecosystems has been conducted for decades [41].

The primary question is 'What is the effect of salvage logging (comparator: no salvage logging) and/or tree planting (comparator: natural regeneration) on the successional trajectories of forests after natural disturbances and forest harvesting with respect to ecosystem services and biodiversity? For detailed question elements see Fig. 1.

Methods

The general principles that guide the planning of a Systematic Map of primary studies are also applicable for mapping reviews[27]. Thus, this protocol is planned in accordance with the " CEE Guidelines and Standards for Evidence Synthesis in Environmental Management" [42]. A completed ROSES form (reporting standards for systematic evidence syntheses) for systematic map protocols for this protocol is provided as supplementary material (Additional file 1 following [22]).

Searching for articles

The search strings were defined based on population, intervention, and outcome [21, 43] and by comparison to existing systematic review protocols in the field of forest ecology [44–47]. The databases Scopus, Web of Science (core collection), and the Forest Science Collection of the CABI Digital Library will be searched (Table 1) for reviews and meta-analyses after 2003 in four distinct categories: (1) salvage logging and ecosystem services, (2) salvage logging and biodiversity, (3) tree planting (comparator: natural regeneration) and ecosystem services, (4) tree planting (comparator: natural regeneration) and biodiversity. These four categories result in four individual search strings (Table 2). As part of the methodology of systematically mapping reviews, the search intentionally aims to exclude primary research [28]. The search covers the two most widely used databases of the natural sciences [48] and a database with a forestry-specific collection. Additionally, the reference list of every fully read review will be screened for potentially relevant reviews that were not detected by the database search and we will also screen the websites of the following organizations for links or references to relevant publications and data, including grey literature:

European Environment Agency (http://www.eea.europa.eu).

Food and Agriculture Organization of the United Nations (http://www.fao.org).

International Union for Conservation of Nature (http://www.iucn.org).

Society for Ecological Restoration (http://www.ser.org).

International Union of Forest Research Organizations (https://www.iufro.org/

We do not search library databases to include grey literature. We acknowledge this as a potential limitation with respect to the comprehensiveness of our search.

The search terms will be searched within the title, abstract and keywords (TITLE-ABS-KEY). The search is restricted to research published in English as a

Table 1 The proposed databases to search studies

Database	Institutional subscription	Search fields
Web of science core collection • WoS—Science Citation Index Expanded (SCIE) • Journal Citation Reports (InCites JHCD) • Social Sciences Citation Index (SSCI) •Medline	Göttingen University	Topic (includes title, abstract, author keywords, and key-words plus)
Scopus	Anhalt University	Article Title, Abstract, Keywords
CABI digital library • Forest science collection	Göttingen University	Article Title, Abstract, Keywords

Table 2 Search strings for the systematic map of reviews

Category	Search string
Salvage logging and ecosystem services	TITLE-ABS-KEY((forest* OR woodl*) AND (disturb* OR succession* OR harvest* OR fire OR wildfire OR windthrow OR storm OR ((pest OR insect* OR beetle*) AND (outbreak OR attack))) AND ("snag remov*" OR ((salvag* OR post*) AND (log* OR harvest* OR cut* OR fell*))) AND ("ecosystem service*" OR "environmental service*" OR "ecosystem function*" OR "wood supply" OR "tree regenerat*" OR recov* OR "water supply" OR erosion OR pollinat* OR "soil formation" OR "climate regulation" OR "carbon sequestration" OR "carbon storage" OR recreat* OR microclimat*) AND (review OR "meta$analy*" OR synthes* OR datasets)) AND PUBYEAR > 2003 AND LANGUAGE(english) AND SRCTYPE(j OR b)
Salvage logging and biodiversity	TITLE-ABS-KEY((forest* OR woodl*) AND (disturb* OR succession* OR harvest* OR fire OR wildfire OR windthrow OR storm OR ((pest OR insect* OR beetle*) AND (outbreak OR attack))) AND ("snag remov*" OR ((salvag* OR post*) AND (log* OR harvest* OR cut* OR fell*))) AND (biodivers* OR diversity OR richness OR "species richness" OR "tree size diversity" OR microhabitat* OR "dead wood" OR invertebrat* OR vertebrat* OR flora OR vegetat* OR mammal* OR bird* OR avian OR reptile* OR amphibian*) AND (review OR "meta$analy*" OR synthes* OR datasets)) AND PUBYEAR > 2003 AND LANGUAGE(english) AND SRCTYPE(j OR b)
Tree planting (comparator: natural regeneration) and ecosystem services	TITLE-ABS-KEY((forest* OR woodl*) AND (disturb* OR succession* OR degrad* OR restorat* OR log* OR harvest* OR cut* OR fell* OR fire OR wildfire OR windthrow OR storm OR ((pest OR insect* OR beetle*) AND (outbreak OR attack))) AND (plant* OR seed* OR sowing OR "seed* establish*" OR grow* OR afforestat* OR restorat* OR "natural rejuvenation" OR regenerat* OR rejuvenat* OR "seed* establish*" OR seed* OR "young adj4 tree*") AND ("ecosystem service*" OR "environmental service*" OR "ecosystem function*" OR "wood supply" OR "tree regenerat*" OR recov* OR "water supply" OR erosion OR pollinat* OR "soil formation" OR "climate regulation" OR "carbon sequestration" OR "carbon storage" OR recreat* OR microclimat*) AND (review OR "meta$analy*" OR synthes*)) AND PUBYEAR > 2003 AND LANGUAGE(english) AND SRCTYPE(j OR b)
Tree planting (comparator: natural regeneration) and biodiversity	TITLE-ABS-KEY((forest* OR woodl*) AND (disturb* OR succession* OR degrad* OR restorat* OR replace* OR log* OR harvest* OR cut* OR fell* OR fire OR wildfire OR windthrow OR storm OR ((pest OR insect* OR beetle*) AND (outbreak OR attack))) AND (plant* OR seed* OR sowing OR "seed* establish*" OR grow* OR afforestat* OR restorat* OR "natural rejuvenation" OR regenerat* OR rejuvenat* OR "seed* establish*" OR seed* OR "young adj4 tree*") AND (biodivers* OR diversity OR richness OR "species richness" OR "tree size diversity" OR microhabitat* OR "dead wood" OR invertebrat* OR vertebrat* OR flora OR vegetat* OR mammal* OR bird* OR avian OR reptile* OR amphibian*) AND (review OR "meta$analy*" OR synthes*)) AND PUBYEAR > 2003 AND LANGUAGE(english) AND SRCTYPE(j OR b)

The search strings displayed are for the search in the database Scopus (the search strings for the other databases are provided as Additional file seven). If any later changes are made in the search strings, the adjustments are disclosed in the methods section of the final publication

journal article or as a book chapter (SRCTYPE) after 2003 (PUBYEAR > 2003, the year when the Centre for Evidence-based Conservation was established.). The final publication of the systematic map will include dates of the searches and the full search strings modified for the different databases.

Test searches for the intervention categories of tree planting and natural regeneration pointed out that the removal of the terms "(disturb* OR succession)" resulted in the inclusion of studies that investigated the respective interventions after usual harvest procedures (e.g., clear-cut forestry, retention forestry). Despite the focus on natural disturbances, we want our systematic map to include this well-studied disturbance agent. Mapping the reviews conducted for anthropogenic disturbances most likely provides valuable additional insights (see also section *Objective of the review* for reasoning).

Review screening and review eligibility criteria

The search results will be imported into Excel and the removal of duplicates will be conducted using the statistical programming language R [49] within the integrated development environment RStudio. All search results within the four search categories will be screened based on predefined eligibility criteria (Table 3 after[50]) by two independent reviewers [51]. The inclusion or exclusion of studies follows the usual hierarchical approach of screening first only the title, second the abstract and third the full text of the respective review [50]. All hierarchical levels of the screening process will be managed with the software Excel.

After every hierarchical level of the screening process, the two reviewers discuss their differences in decisions and resolve them together. To reduce the risk of missing eligible studies, in the case of ambiguity of the usefulness of the respective review, the review is always transferred to the next hierarchical level of the screening process. If the inclusion or exclusion of a certain review remains unclear at the full-text stage, the two reviewers discuss in detail the respective review and document their final reasoning for inclusion or exclusion. The screening process will be documented with a flow diagram [22, 52] for each of the four categories (Additional file 3).

To assess agreement between reviewers and test if the eligibility criteria are applied consistently, the alignment is checked with a kappa value [53] based on the first 100 screened reviews at the title stage of all four categories (for more details on the kappa value see Additional File 6). If there is at least a substantial agreement between reviewers (agreement on 81 of the 100 reviews, kappa > 0.6; [54]), the entire screening process will be conducted as planned. If there is less than substantial agreement, the reviewers discuss the eligibility criteria and may modify for clarification.

A full list of all reviews retrieved by the original search (duplicates removed) will be made available as a CSV file together with review details (author(s), document title, year, DOI, abstract, author keywords and indexed keywords). A list of reviews that remain after title and abstract screening, respectively, will also be published together with the final publication. The list of reviews at full-text stage will include an additional column indicating the reason for exclusion. The CSV files will be permanently made available with the research management tool by the Center for Open Science (Open Science

Table 3 Eligibility criteria

Key element	Eligibility criteria	ID
Population Disturbed forest area	Included: explicit reference to a disturbed forest area (of boreal, temperate, tropical forest)	P
Intervention salvage logging, tree planting	Included: explicit reference to the interventions of interest	I
Comparator No salvage logging, natural regeneration	Included: explicit reference to the comparators of interest	C
Outcomes Ecosystem services *Water supply,* *Wood supply,* *Erosion control,* *Pollination,* *Soil formation,* *Carbon sequestration,* *Microclimate* *Recreation* Biodiversity *Invertebrates* *Mammals* *Birds* *Reptiles* *Amphibians* *Tree size diversity* *Microhabitats* *Dead wood*	Included: explicit reference to the ecosystem services OR biodiversity parameters of interest	O
Review design/methods Review, meta-analyses	Included: review with qualitative summary and/or meta-analyses. The review summarizes empirical studies Excluded: not a review article summarizing primary research	D

The ID column refers to the capital letter that will be used in the csv file to provide reasons for review exclusion. The number of studies excluded will also be displayed in the flow diagram (Additional file 3)

Table 4 Summary table of scope of included reviews and assessments of selected CEESAT categories

Review year	RI[1]	Aim primary objective	No. of stud	Region[2]	DA[3]	protocol? (2.1)[4]	Search comprehensive (3.2)[4]	Eligibility criteria defined (4.1)[4]	Critical appraisal (5.1)[4]	Limitations discussed (8.1)[4]
Name1 and Name2 (2012) [book icon][5]	1	Investigate the effect of salvage logging on tree regeneration	21	Global		⭐	🖐	🖐	✋	🔺!
Name 3 et al. 2019 [icon][5]	a	...								

The final publication will also provide a table with the full CEESAT assessments for every included review and a table template is provided here as Additional file 4

[1] Review Identifier; number: reference with meta-analysis (quantitative synthesis), letter: reference with narrative synthesis (qualitative synthesis) following[30]

[2] Global, Tropical, Temperate, Boreal

[3] Disturbance Agent: all, drought, fire, wind, ice and snow, pathogens, insects, herbivores, harvest

[4] based on CEESAT. Number in brackets refers to the section in CEESAT (2020, Version 2.1): Is there an a-priori method/protocol document? (2.1); Is the search comprehensive? (3.2); Are eligibility criteria clearly defined? (4.1); Does the review critically appraise each study? (5.1); Have the authors considered limitations of the synthesis? (8.1)

[5] article access issues: open book indicates open access and closed book indicates some form of subscription

Table 5 Summary of findings table of individual outcomes for Ecosystem services

Region	Ecosystem service section	Outcome measure	review year	RI[1]	DA[2]	Outcome indicator	Results effect size + standard error	Key findings[3]
Global	Provisioning	Water supply	Name4 et al. (2011)	5	wind			
			Name5 (2021)	c	fire			
		Wood supply	Name1 and Name2 (2012)	1	all	Tree density and height	height: -0.19 + 0.17 Density: −0.18 + 0.3	No evidence for a general effect of salvage logging on tree density and regeneration
	Regulating	Erosion control						
		Pollination						
		Soil formation						
		Carbon sequestration						
		Microclimate						
	Cultural	Recreation						
Tropical	Provisioning	Water supply						
		Wood supply						
	Regulating	Erosion control						
		Pollination						
		Soil formation						
		Carbon sequestration						
		Microclimate						
	Cultural	Recreation						
Temperate	Provisioning	Water supply						
		Wood supply						
	Regulating	Erosion control						
		Pollination						
		Soil formation						
		Carbon sequestration						
		Microclimate						
	Cultural	Recreation						
Boreal	Provisioning	Water supply						
		Wood supply						
	Regulating	Erosion control						
		Pollination						
		Soil formation						
		Carbon sequestration						
		Microclimate						
	Cultural	Recreation						

Language of evidence [62] is used to describe the effect to avoid the use of the term "statistically significant" (for a discussion see for example [63–65])

[1] Review identifier, see summary table of scope (Table X)

[2] Disturbance agent: all, fire, wind, insects, harvest

[3] Language of evidence

Framework, https://osf.io/) according to the guidelines of open science [55] to support a transparent and repeatable screening process.

Review validity assessment

Despite good and thorough guidelines for conducting evidence syntheses [22, 52], the term systematic review

Table 6 Summary of findings table of individual outcomes for Biodiversity

	Ecosystem service type	Outcome measure	Review Year	RI[1]	DA[2]	Taxa[3]	Outcome measures	Results Effect size + standard error	Key findings[4]
Global	Structure	Microhabitats	Name4 et al. (2011)						
			Name5 (2021)						
		Dead wood							
		Tree size div							
	Composition	Species richn							
		Abundance							
Tropical	Structure	Microhabitats							
		Dead wood							
		Tree size div							
	Composition	Species richn							
		Abundance							
Temperate	Structure	Microhabitats							
		Dead wood							
		Tree size div							
	Composition	Species rich							
		Abundance							
Boreal	Structure	Microhabitats							
		Dead wood							
		Tree size div							
	Composition	Species rich							
		Abundance							

Language of evidence [62] is used to describe the effect to avoid the use of the term "statistically significant" (for a discussion see for example [63–65])

[1] Review identifier, see summary table of scope (Table X)

[2] Disturbance Agent: all, fire, wind, insects, harvest

[3] Taxa: All (all), Plants (P), Invertebrates (I), Mammals (M), Birds (B), Reptiles (R), Amphibians (A)

[4] Language of evidence [62] is used to describe the effect; avoidance of the term "statistically significant" (for a discussion see for example [63–65]))

is erroneously used for traditional, narrative literature reviews, which are in most cases not conducted on a priori defined systematic methodology and therefore much more susceptible to biases [56]. Thus, the assessment of review validity deserves central attention when conducting a systematic map of reviews [57]. The validity of every review included in the summary table of scope (see section "Data synthesis and presentation") will be assessed using a checklist based on the newest version of the Evidence Synthesis Appraisal Tool (CEESAT) by the Collaboration for Environmental Evidence (2022, Version 2.1, CEESAT for Evidence Reviews, can be downloaded at https://environmentalevidence.org/ceeder/about-cee-sat/) by two independent reviewers. In addition to the five selected CEESAT criteria included in the summary of scope table of the final publication (Table 4), the full assessment of all 16 CEESAT criteria for every included review is provided as supplementary material (Additional file 4). Disagreements between the assessments of the two reviewers will be discussed and if there is no agreement whether or not a criterion is met by the review, both categories are displayed in the respective table to emphasize the disagreement of reviewers. In case the respective review included in this systematic map has already been assessed by the network of the CEEDER data base (https://environmentalevidence.org/ceeder/), the available assessment from the data base will be used and no additional assessment will be conducted.

Despite the convenience to rate the overall confidence of the included reviews and a method for scoring an evidence synthesis was provided by the original publication of CEESAT [58], we do not plan to provide the reader with an overall score. It would prevent the reader from carefully considering the individual review and checking which of the CEESAT criteria are more important for their environmental management question. To provide scores may seem desirable for a systematic map of reviews to estimate the overall

Fig. 2 Matrix summarizing the total number of reviews considering each question with respect to ecosystem services. The matrix dimensions are based on the key characteristic outlined with Fig. 1. The matrix can be read using combinations from the left and top headings to form the question of interest, e.g. "What is the number of reviews that were conducted for the temperate region that considered the outcome pollination?". The diagonals indicate the total number of reviews conducted for the respective category. For further explanation regarding this visualization see [30]

risk of bias and the overall confidence in the results. It disguises, however, the potential relevance of a review for a reader behind a single number. Nevertheless, if a review has a majority of amber and red CEESAT assessments (deficient and seriously deficient in conduct and/or reporting) the confidence in the finding can be expected to be critically low. Therefore, if 13 or more CEESAT criteria are graded amber/red (over 80%), the respective review is excluded from the summary of findings table (Tables 5 and 6) and not visualized in the matrix (Figs. 2 and 3) but only listed in the summary of scope table (see flow diagram Additional file 3). A review is also immediately excluded from the findings table if the choice of synthesis approach is inappropriate and graded red (e.g., the review uses vote-counting: "most studies found", "three out of ten indicated" [59], see also Problem 7 Inappropriate synthesis in [60]).

Data coding strategy

There will be no data extraction from primary studies, and all the gathered information originates from quantitative and qualitative data summarized in the reviews. Table templates for each of the four forest management questions are provided to systematically extract data for every eligible review in the same way (Tables 4, 5, and 6). Two review authors will extract the data from the reviews independently. After the independent extraction process, the content of every table entry is directly compared, differences discussed and resolved together.

There is no risk that the persons planned to extract the data has (co-)authored one of the reviews included.

Review mapping and presentation

The systematic map will include the results of all eligible reviews and tabulate them in a summary of scope and summary of findings table [26]. The systematic map will include one summary table of scope of reviews (Table 4)

Fig. 3 Matrix summarizing the total number of reviews considering each question with respect to biodiversity. The matrix dimensions are based on the key characteristic outlined with Fig. 1. The matrix can be read using combinations from the left and top headings to form the question of interest, e.g. "What is the number of reviews that were conducted for the disturbance agent fire that considered the taxa of reptiles?". The circled diagonals indicate the total number of reviews conducted for the respective category. For further explanation regarding this visualization see [30]

and one summary of findings table per forest management question (Tables 5 and 6). The summary of findings table is subdivided into the different outcome types for ecosystem services (Table 5) and biodiversity (Table 6).

We expect that more than one review exists to investigate the effects of one of the interventions, and the likely overlap in primary research studies included in different reviews needs to be recognized as a limitation. Assessing the degree of overlap between evidence syntheses is anticipated to be a complex and time-consuming task [26]. Therefore, there is no aggregation of effect sizes from different reviews and the synthesis in this systematic map can be classified as an "evidence review map" [30]. To complement the tables we visualize the scope of our systematic map as a matrix that locates the number of reviews within our covered review landscape (Figs. 2 and 3 following [30, 40]).

In line with the PRIOR items 19b and 19c [61], we will also provide a table as supplementary material that presents the results of testing for causes of heterogeneity and

if a meta-analysis was conducted, it shortly presents the results of a sensitivity analysis (Additional file 2). For this purpose, we use the information and results presented in the respective review and do not carry out any further analyses ourselves.

Supplementary Information

Supplementary material 1. ROSES form for systematic map protocols.

Supplementary material 2. Assessment of meta-analysis results of included studies.

Supplementary material 3. Flow Diagram.

Supplementary material 4. CEESAT categories and full CEESAT assessment table template.

Supplementary material 5. Test of comprehensiveness of the search results.

Supplementary material 6. Cohens Kappa Reviewer Agreement.

Supplementary material 7. Search Strings Web of Science and CABI Abstracts Forest Science Library.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests. Procedural independence is guaranteed, as none of the authors has (co-)authored studies that could be included in this systematic map.

References

1. Turner MG. Disturbance and landscape dynamics in a changing world. Ecology. 2010;91:2833–49.
2. Seidl R, Thom D, Kautz M, Martin-Benito D, Peltoniemi M, Vacchiano G, et al. Forest disturbances under climate change. Nat Clim Change. 2017;7:395–402.
3. Seidl R, Schelhaas M-J, Rammer W, Verkerk PJ. Increasing forest disturbances in Europe and their impact on carbon storage. Nat Clim Change. 2014;4:806–10.
4. Viljur M-L, Abella SR, Adámek M, Alencar JBR, Barber NA, Beudert B, et al. The effect of natural disturbances on forest biodiversity: an ecological synthesis. Biol Rev. 2022;97:1930–47.
5. Winfree R. How does biodiversity relate to ecosystem functioning in natural ecosystems. In: Dobson A, Holt RD, Tilman D, editors. Unsolved problems in ecology. Princeton: Princeton University Press; 2020. p. 338–54.
6. Hooper DU, Adair EC, Cardinale BJ, Byrnes JE, Hungate BA, Matulich KL, et al. A global synthesis reveals biodiversity loss as a major driver of ecosystem change. Nature. 2012;486:105–8.
7. Isbell F, Balvanera P, Mori AS, He J-S, Bullock JM, Regmi GR, et al. Expert perspectives on global biodiversity loss and its drivers and impacts on people. Front Ecol Environ. 2023;21:94–103.
8. Ives AR, Carpenter SR. Stability and diversity of ecosystems. Science. 2007;317:58–62.
9. Folke C, Polasky S, Rockström J, Galaz V, Westley F, Lamont M, et al. Our future in the anthropocene biosphere. Ambio. 2021;50:834–69.
10. Cardinale BJ, Duffy JE, Gonzalez A, Hooper DU, Perrings C, Venail P, et al. Biodiversity loss and its impact on humanity. Nature. 2012;486:59–67.
11. Leverkus AB, Lindenmayer DB, Thorn S, Gustafsson L. Salvage logging in the world's forests: interactions between natural disturbance and logging need recognition. Glob Ecol Biogeogr. 2018;27:1140–54.
12. Ammer C. Unraveling the importance of inter- and intraspecific competition for the adaptation of forests to climate change. In: Canovas FM, Lüttge U, Matyssek R, editors. Prog Bot. Berlin: Springer; 2016. p. 345–67.
13. Gustafsson L, Baker SC, Bauhus J, Beese WJ, Brodie A, Kouki J, et al. Retention forestry to maintain multifunctional forests: a world perspective. Bioscience. 2012;62:633–45.
14. Fedrowitz K, Koricheva J, Baker SC, Lindenmayer DB, Palik B, Rosenvald R, et al. Can retention forestry help conserve biodiversity? A meta-analysis. J Appl Ecol. 2014;51:1669–79.
15. Thorn S, Chao A, Georgiev KB, Müller J, Bässler C, Campbell JL, et al. Estimating retention benchmarks for salvage logging to protect biodiversity. Nat Commun. 2020;11:4762.
16. von Detten R. Sustainability as a guideline for strategic planning? The problem of long-term forest management in the face of uncertainty. Eur J For Res. 2011;130:451–65.
17. Munteanu C, Nita MD, Abrudan IV, Radeloff VC. Historical forest management in Romania is imposing strong legacies on contemporary forests and their management. For Ecol Manag. 2016;361:179–93.
18. Thorn S, Chao A, Bernhardt-Römermann M, Chen Y-H, Georgiev KB, Heibl C, et al. Rare species, functional groups, and evolutionary lineages drive successional trajectories in disturbed forests. Ecology. 2020;101:e02949.
19. Bolte A, Ammer C, Löf M, Madsen P, Nabuurs G-J, Schall P, et al. Adaptive forest management in central Europe: Climate change impacts, strategies and integrative concept. Scand J For Res. 2009;24:473–82.
20. Filotas E, Parrott L, Burton PJ, Chazdon RL, Coates KD, Coll L, et al. Viewing forests through the lens of complex systems science. Ecosphere. 2014;5:1.
21. Pullin AS, Stewart GB. Guidelines for systematic review in conservation and environmental management. Conserv Biol. 2006;20:1647–56.
22. Haddaway NR, Macura B, Whaley P, Pullin AS. ROSES reporting standards for systematic evidence syntheses: pro forma, flow-diagram and descriptive summary of the plan and conduct of environmental systematic reviews and systematic maps. Environ Evid. 2018;7:1–8.
23. Leverkus AB, Rey Benayas JM, Castro J, Boucher D, Brewer S, Collins BM, et al. Salvage logging effects on regulating and supporting ecosystem services—a systematic map. Can J For Res. 2018;48:983–1000.
24. Thorn S, Bässler C, Brandl R, Burton PJ, Cahall R, Campbell JL, et al. Impacts of salvage logging on biodiversity: a meta-analysis. J Appl Ecol. 2018;55:279–89.
25. Basile M, Krištín A, Mikusiński G, Thorn S, Żmihorski M, Pasinelli G, et al. Salvage logging strongly affects woodpecker abundance and reproduction: a meta-analysis. Curr For Rep. 2022;9:1–14.
26. Smith V, Devane D, Begley CM, Clarke M. Methodology in conducting a systematic review of systematic reviews of healthcare interventions. BMC Med Res Methodol. 2011;11:1–6.
27. Hunt H, Pollock A, Campbell P, Estcourt L, Brunton G. An introduction to overviews of reviews: planning a relevant research question and objective for an overview. Syst Rev. 2018;7:1–9.
28. McKenzie JE, Brennan SE. Overviews of systematic reviews: great promise, greater challenge. Syst Rev. 2017;6:1–4.
29. Pollock M, Fernandes RM, Becker LA, Featherstone R, Hartling L. What guidance is available for researchers conducting overviews of reviews of healthcare interventions? A scoping review and qualitative meta-summary. Syst Rev. 2016;5:1–15.
30. O'Leary BC, Woodcock P, Kaiser MJ, Pullin AS. Evidence maps and evidence gaps: evidence review mapping as a method for collating and appraising evidence reviews to inform research and policy. Environ Evid. 2017;6:1–9.
31. Hernández-Morcillo M, Torralba M, Baiges T, Bernasconi A, Bottaro G, Brogaard S, et al. Scanning the solutions for the sustainable supply of forest ecosystem services in Europe. Sustain Sci. 2022;17:2013–29.
32. Lindenmayer DB, Foster DR, Franklin JF, Hunter ML, Noss RF, Schmiegelow FA, & Perry D. Salvage harvestingpolicies after natural disturbance. Science. 2004; 303:1303–03. https://doi.org/10.1126/science.1093438.
33. Obladen N, Dechering P, Skiadaresis G, Tegel W, Keßler J, Höllerl S, et al. Tree mortality of European beech and Norway spruce induced by 2018–2019 hot droughts in central Germany. Agric For Meteorol. 2021;307:108482.

34. Müller J, Noss RF, Thorn S, Bässler C, Leverkus AB, Lindenmayer D. Increasing disturbance demands new policies to conserve intact forest. Conserv Lett. 2019;12:e12449.
35. Orsi F, Ciolli M, Primmer E, Varumo L, Geneletti D. Mapping hotspots and bundles of forest ecosystem services across the European Union. Land Use Policy. 2020;99:104840.
36. De Frenne P, Lenoir J, Luoto M, Scheffers BR, Zellweger F, Aalto J, et al. Forest microclimates and climate change: importance, drivers and future research agenda. Glob Change Biol. 2021;27:2279–97.
37. Blumröder JS, May F, Härdtle W, Ibisch PL. Forestry contributed to warming of forest ecosystems in northern Germany during the extreme summers of 2018 and 2019. Ecol Solut Evid. 2021;2:e12087.
38. Dieler J, Uhl E, Biber P, Müller J, Rötzer T, Pretzsch H. Effect of forest stand management on species composition, structural diversity, and productivity in the temperate zone of Europe. Eur J For Res. 2017;136:739–66.
39. Larrieu L, Paillet Y, Winter S, Bütler R, Kraus D, Krumm F, et al. Tree related microhabitats in temperate and Mediterranean European forests: a hierarchical typology for inventory standardization. Ecol Indic. 2018;84:194–207.
40. Woodcock P, O'Leary BC, Kaiser MJ, Pullin AS. Your evidence or mine? Systematic evaluation of reviews of marine protected area effectiveness. Fish Fish. 2017;18:668–81.
41. Meyer P, Ammer C. Waldnutzungen. In: Wohlgemuth T, Jentsch A, Seidl R, editors. Störungsökologie. utb GmbH; 2019. p. 290.
42. Pullin AS, Frampton G, Livoreil B, Petrokofsky G. Guidelines and standards for evidence synthesis in environmental management: version 5.1. 2022;
43. Livoreil B, Glanville J, Haddaway NR, Bayliss H, Bethel A, de Lachapelle FF, et al. Systematic searching for environmental evidence using multiple tools and sources. Environ Evid. 2017;6:1–14.
44. Leverkus AB, Gustafsson L, Rey Benayas JM, Castro J. Does post-disturbance salvage logging affect the provision of ecosystem services? A systematic review protocol. Environ Evid. 2015;4:1–7.
45. Bernes C, Jonsson BG, Junninen K, Lõhmus A, Macdonald E, Müller J, et al. What are the impacts of manipulating grazing and browsing by ungulates on plants and invertebrates in temperate and boreal forests? A systematic review protocol. Environ Evid. 2016;5:1–6.
46. Gan JL, Grainger MJ, Shirley MDF, Pfeifer M. How effective are perches in promoting bird-mediated seed dispersal for natural forest regeneration? A systematic review protocol. Environ Evid. 2023;12:1–11.
47. Savilaakso S, Johansson A, Häkkilä M, Uusitalo A, Sandgren T, Mönkkönen M, et al. What are the effects of even-aged and uneven-aged forest management on boreal forest biodiversity in Fennoscandia and European Russia? A systematic review. Environ Evid. 2021;10:1–38. https://doi.org/10.1186/s13750-020-00215-7.
48. Singh VK, Singh P, Karmakar M, Leta J, Mayr P. The journal coverage of Web of Science, scopus and dimensions: a comparative analysis. Scientometrics. 2021;126:5113–42. https://doi.org/10.1007/s11192-021-03948-5.
49. R Core Team. R: A Language and Environment for Statistical Computing. Vienna, Austria: R Foundation for Statistical Computing. 2023. https://www.R-project.org/.
50. Frampton GK, Livoreil B, Petrokofsky G. Eligibility screening in evidence synthesis of environmental management topics. Environ Evid. 2017;6:1–13.
51. Edwards P, Clarke M, DiGuiseppi C, Pratap S, Roberts I, Wentz R. Identification of randomized controlled trials in systematic reviews: accuracy and reliability of screening records. Stat Med. 2002;21:1635–40.
52. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. Int J Surg. 2021;88:105906.
53. Cohen J. A coefficient of agreement for nominal scales. Educ Psychol Meas. 1960;20:37–46.
54. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics. 1977;33:159–74.
55. Haddaway NR. Open synthesis: on the need for evidence synthesis to embrace open science. Environ Evid. 2018;7:1–5.
56. Haddaway NR, Land M, Macura B. A little learning is a dangerous thing": a call for better understanding of the term 'systematic review. Environ Int. 2017;99:356–60.
57. Pollock A, Campbell P, Brunton G, Hunt H, Estcourt L. Selecting and implementing overview methods: implications from five exemplar overviews. Syst Rev. 2017;6:1–18.
58. Woodcock P, Pullin AS, Kaiser MJ. Evaluating and improving the reliability of evidence syntheses in conservation and environmental science: a methodology. Biol Conserv. 2014;176:54–62.
59. McKenzie JE, Brennan SE. Synthesizing and presenting findings using other methods. In: Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, Welch VA, editors. Cochrane Handb Syst Rev Interv. Hoboken: Wiley; 2019. p. 321–47.
60. Haddaway NR, Bethel A, Dicks LV, Koricheva J, Macura B, Petrokofsky G, et al. Eight problems with literature reviews and how to fix them. Nat Ecol Evol. 2020;4:1582–9.
61. Gates M, Gates A, Pieper D, Fernandes RM, Tricco AC, Moher D, et al. Reporting guideline for overviews of reviews of healthcare interventions: development of the PRIOR statement. BMJ. 2022. https://doi.org/10.1136/bmj-2022-070849.
62. Muff S, Nilsen EB, O'Hara RB, Nater CR. Rewriting results sections in the language of evidence. Trends Ecol Evol. 2022;37:203–10.
63. Martínez-Abraín A. Statistical significance and biological relevance: a call for a more cautious interpretation of results in ecology. Acta Oecol. 2008;34:9–11.
64. Halsey LG. The reign of the p-value is over: what alternative analyses could we employ to fill the power vacuum? Biol Lett. 2019;15:20190174.
65. Wasserstein RL, Schirm AL, Lazar NA. Moving to a world beyond "p< 0.05." Am. Stat. Taylor & Francis; 2019. p. 1–19. https://doi.org/10.1080/00031305.2019.1583913.

Publisher's Note

Moritz Baumeister   has a background in forest conservation and environmental sciences and is mainly trained as an ecologist.

Markus A. Meyer   research focusses on sustainable land management and ecosystem services. He holds a PhD in landscape ecology and is a professor for National and International Nature Conservation at Anhalt University of Applied Sciences.