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Environmental Evidence

SYSTEMATIC MAP PROTOCOL

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What evidence exists on the effects of competition on trees' responses to climate change? A systematic map protocol

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Abstract

Background: Projections of climate change impacts upon forests are likely inaccurate if based on the premise that only climate controls tree growth. Species interactions control growth, but most research has ignored these effects on how trees respond to climate change. Climate change is inducing natural species selection. However, this selection does not occur at the community level. Species selection starts with competition amongst individual trees. Competition is an individual-to-individual antagonistic interaction that, if severe, can constrain the presence of trees within a particular environment. Thus, climate change impacts individual tree selection within forests. Projecting climate change impacts on forests should account for the effects of climate on tree growth and the effects of competition. The inclusion of competition can increase the predictive power of simulations.

Methods: We propose a protocol to systematically map the available literature on climate change impacts on forests and produce a comprehensive list of methods applied to measure competition and model the competition effects on tree growth responses to climate change. This systematic map is not limited to any country or continent or specific tree species or forest type. The scope of the search focuses on time (when the evidence was published), location (geographic location of the evidence) and research design (competition indices and modelling methods). We will evaluate articles at three levels: title, abstract and full text. We will conduct a full-text assessment on all articles that pass a screening at the title and abstract stages. We will report the extracted evidence in a narrative synthesis to summarize the evidence's trends and report knowledge gaps.

Keywords: Forestry, Global warming, Tree species interactions, Tree growth

Background

As climate change intensifies, there is concern about obtaining realistic projections of its impacts on forests worldwide. Climate change is a multi-faceted problem in forest sciences. A warmer climate affects tree species growth directly because heat induced by higher temperatures compromises physiological processes, such as photosynthesis and respiration [1–3]. A warmer climate also has indirect effects on the growth and survival of tree species. A warmer and changing climate alters disturbance regimes, exposing trees to more frequent extreme events, such as longer drought periods [4–6]. These events have serious repercussions for the seasonal availability of growth resources, and thus demand for resources starts to exceed resource supplies. The imbalance between resource supply and demand triggers competitive interactions that, if severe, can constrain the presence and competitive abilities of trees in a particular environment. Therefore, a warmer climate indirectly affects tree species' coexistence by altering the dynamics

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of competitive interactions [7–9]. As a result, novel communities may be created as species differ in traits that result in growth advantages when competing for resources [10, 11]. Therefore, to obtain realistic projections of climate change impacts on forests, it is essential to account for the effects of climate on tree growth and competition.

The importance of competition to forest stand development

Competition among plants is an old concept in plant ecology. Initially, competition was defined as an individual response manifested when two or more individuals' demand for resources exceeds resource supplies [12]. Later, the definition focused on the idea of an antagonistic interaction, usually triggered when neighbouring plants utilize the same quantum of light, ion of a mineral nutrient, molecule of water or volume of space [13]. This competition concept was later revised to include differences in growth resource acquisition from a common and limited supply [14].

When discussing forest stand development, competition is treated as the primary form of interaction among trees [15]. At the initial stages, tree growth is mediated by available resources, such as sunlight, water, nutrients and suitable temperature. Until one or more of these resources becomes limited, trees and species will continually grow in size and number. If a set of resources is amenable in allowing the growth of several species, their relative growth rate is then mediated by competition. Intra- and inter-specific competition occurs intensely among trees and other plants for all "growing space", which means growth resources at any given site (sunlight, moisture, nutrients) and other factors, including the physical space [15]. Intense competition for available growing space marks the beginning of the stem exclusion stage in forest stand development. At this stage, all growing space is being used (occupied sensu), and new plants are excluded from regenerating. If any stand-replacing disturbance occurs, the whole cycle begins again. Otherwise, the stand will gradually enter a stage where mature trees that no longer compete with other trees start to die, creating gaps that allow new plants to establish themselves in the understory. Stand initiation, stem exclusion, and understory reinitiation represent the first stages of natural succession in forest stands [15].

From a forest stand perspective, the more crowded stands are, the less growing space (resources such as light and water and the physical space for roots and branches expansion) is available to each tree in the stand. When it comes to individual trees, the distance and size of neighbouring trees directly influence how that tree secures growing space, especially light and water [16]. Larger tree species can disproportionally exploit greater amounts of growing space when competing with smaller species. For instance, the water competition mechanism is comparable to mechanisms of nutrient competition and favours individual trees with higher root length density [17]. Tree species might strategically place roots in the soil (e.g. contacting the roots of neighbours) so that they can preempt water access by competitors on a small scale [18]. Similar to light competition favouring taller trees, competition for water can select species with shallow root systems as they can intercept water from neighbours with deeper roots [19].

During the development of forest stands, a reduction in the number of trees results from competition and natural selection. In this regard, forest stands are dynamic and subject to continual changes resulting from developmental processes initiated by both endogenous (competition) and exogenous (natural disturbance) processes [20]. The most vigorous trees, or the best adapted to the environment, are likely to survive intense competition for growing space. Trees that can quickly secure the resources that are still available, or constrain resource availability, or continue to grow even with a limited supply of resources, are considered to have competitive advantages over neighbouring trees. Ultimately, these advantages may enhance the ability of trees to withstand climate change.

The role of competition in increasing the vulnerability of forest stands to climate change

High competition intensity reduces the adaptive capacity of tree species, increasing the vulnerability of forest stands to environmental stress, as illustrated in the conceptual framework [21] (Fig. 1). Climate change is an exogenous factor, causing stress on trees, a top-down environmental stressor expressed in terms of mean values, climate variability and extreme weather events. Vulnerability indicates the extent that forest stands are susceptible to environmental stressors, such as extreme drought events [22]. Vulnerability depends on two endogenous factors: (a) tree species' sensitivity to an environmental stressor and (b) individual trees' adaptive capacity to new climate conditions. First, sensitivity represents to what degree tree species can respond to environmental stressors [23]. Sensitivity is a function of species' traits and adaptation to the local conditions of the physical environment they live in. Second, adaptive capacity, or adaptability, corresponds to the degree of viable growth adjustments individual trees make in response to environmental stressors [23]. Adaptive capacity is inversely proportional to stand density, so the lower the stand density is, the more capacity the trees in that stand have to adjust to stressors, and thus the less

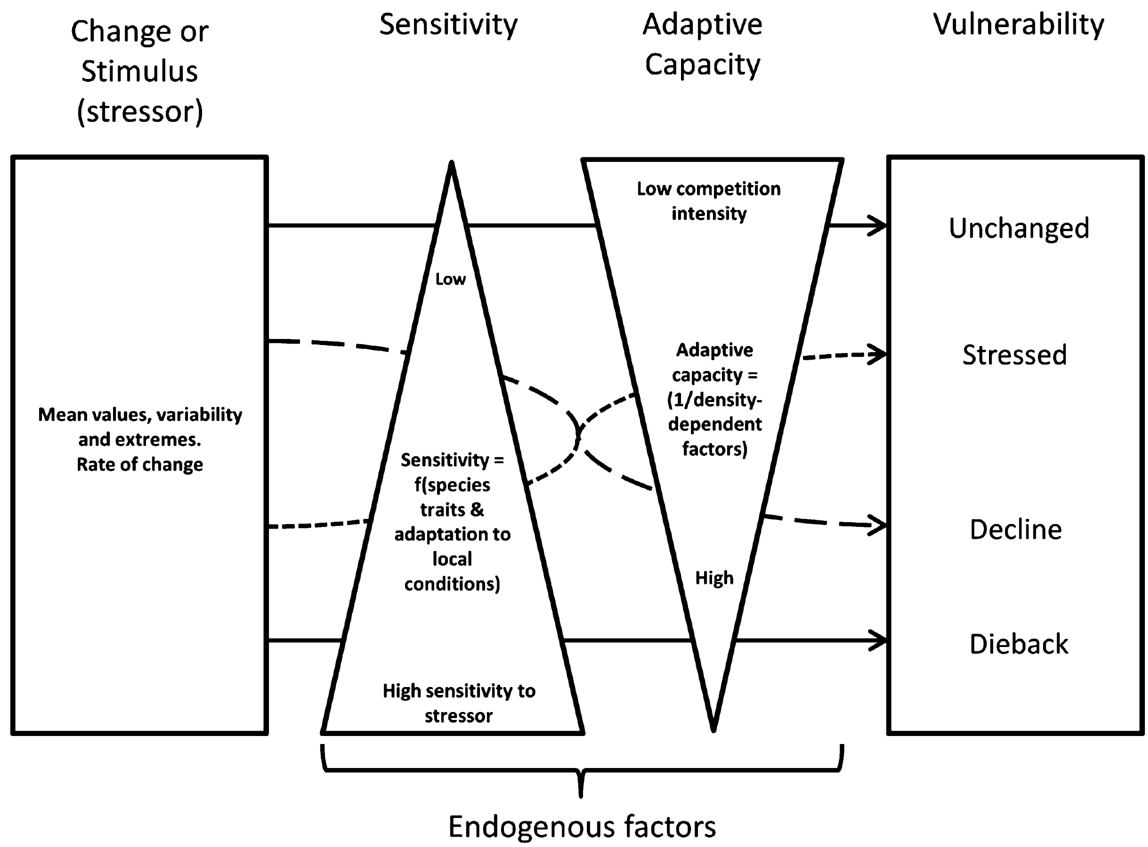

Fig. 1 A conceptual framework for the role of competition in increasing the vulnerability of forest stands to climate change. Adapted from [21]

vulnerable to climate change that stand is. According to [21], combining different levels of species' sensitivity and individual trees' adaptive capacity can lead forest stands to four paths: (1) unchanged, (2) stressed, (3) declined and (4) mortality. To illustrate, if less sensitive species grow in a low-density stand, that stand remains almost unchanged to exogenous stimulus, and thus it is considered less vulnerable to climate change. However, vulnerability increases if less sensitive species grow in higher density stands since those species are likely to decline in the face of environmental stressors. Highly sensitive species may experience stress if localized in lower-density stands, but if localized in high-density stands, mortality could happen, which increases vulnerability to environmental stressors. Therefore, the vulnerability of forest stands to climate change relates to the degree of stress that tree species can undergo, modulated by individual trees' adaptive capacity, which is an inverse function of the amount of competition.

Understanding the different capacities to respond to climate change can also be discussed within the concept of resilience. Climate change represents a continuing source of stress. A warmer and changing climate, for example, exposes trees to extreme weather events, such as increased heat waves or longer drought periods [24]. Modifications in the physical environment, like a decrease in water availability, are sources of stress to trees. If those sources persist or become frequent, there is a stress effect that negatively influences the resilience of forest stands. Here, resilience refers to the ability of forest stands to absorb changes and persist [25]. To illustrate, a study on three stable states of ecosystems in South America (forest, savanna, and grassland) portrays the negative influence of persistent stress on the resilience of forests. Compared to the other two ecosystems, forests were more sensitive to stress from climate variability because they have low adaptive capacity to conditions outside their optimum climate niche. A decrease in water availability induced by climate change can accelerate the resilience loss of of forests [26].

The necessity of including competition in climate change studies

Many studies have addressed the impacts of climate change on either independent tree species or a whole community's behaviour [27–30]. In these studies, emphasis was placed on simulating shifts in species' environmental envelope, which means accounting only for the impact of climate change on species' climatic range, also referred to as the species' fundamental niche. Climate change indeed shifts the climatic range in which trees are adapted to live [27]. First, the physical environment of forest stands is altered because changes in precipitation regimes and snowmelt timing affect the seasonal availability of water. Second, longer drought periods induce mortality by predisposing trees to water stress. Trees can respond positively to water stress by reducing transpiration or increasing leaf-specific hydraulic conductivity [31]. Nevertheless, longer drought periods tend to affect tree hydraulic conductivity negatively [32–34]. Mortality can occur when drought-induced hydraulic failure reduces trees' resistance to insect or pathogen attack, which population abundance usually increases during drought periods [35].

Tree species' environmental envelope, besides climate sensitivity, depends on their competitive abilities. In this regard, climate change also impacts the limit of a species' realized niche [36]. This process is slow, as it comprises the death of more climate-sensitive species and the migration of less climate-sensitive species. To survive drought-induced mortality brought on by climate change, tree species must migrate [37, 38]. However, the ability of migrants to establish successfully depends on competition with existing trees, among other factors. The death of climate-sensitive species releases growth resources, but that initially favours the growth of already-established trees [15]. An example of climate change shifting the limit of species' realized niche was reported in Scandinavia [39]. Recent warming threatens the dominance of Norway spruces (*Picea abies*) while favouring the expansion of the European beech (*Fagus sylvatica*). Due to the impact of longer drought periods and bark beetle infestation, dominant spruce individuals died, decreasing canopy closure and allowing more sunlight to reach the forest floor. An increase in sunlight availability favoured the long-term growth of European beeches relative to that of spruce. Therefore, a warmer climate is narrowing the Norway spruce range while expanding the European beech range towards the north of Scandinavia.

The relevance of competition to simulate climate change impacts on forests lies in the effects of competition on tree growth surpassing that of climate [40]. For instance, in high-density oak (*Quercus* spp.) and pine (*Pinnus* ssp.) stands of the Iberian Peninsula, an increase in temperature indirectly benefits oak species because the death of pine trees releases growth resources. An increase in temperature implies higher water demand, causing greater drought stress, and ultimately, mortality of the water-demanding pine species [41]. Under low competition levels, tree growth is usually enhanced [42]. Conversely, tree growth is already close to the lower limit for survival under higher competition levels [43]. This negative effect of competition on tree growth performance, in some cases, exceeds that of higher temperatures [8, 44, 45]. To illustrate, the low-severity fire regime maintained the conifer forests of California at a lower density. In the past century, fire suppression practices allowed for the successful development of high-density stands. Nevertheless, those high-density stands have now become more vulnerable to drought-related stress, and as a result, tree mortality has increased [46]. Mortality increased because trees under competition stress are more vulnerable to climate change as their growth is already compromised. In these cases, competition intensity may be the critical driver of tree species growth under climate change.

Considering the ongoing warmer climate scenario worldwide, omitting the effects of competition on tree growth responses to climate change precludes the possibility that forest communities remain immutable. Beginning with intra and interspecific competition among individual trees, a warmer climate is slowly inducing natural selection in forests. In this regard, the climate envelope models are to be considered deficient. The projections of forests' vulnerability to climate change will likely be inaccurate if based on the premise that climate is the only factor controlling tree species distribution [36]. The critical point is ignoring that some tree species might be absent from those projections due to competitive exclusion. Tree species responses to climate change are likely to be individual and influenced by the competitive environment [47, 48]. This topic is worthy of a systematic map because it can raise awareness for reformulation of the model functions so that ecological bases of tree growth, such as competition, are accurately reflected in the projections of climate change impacts on forests.

Stakeholder engagement

The Ministry of Forests of British Columbia, Canada, is reviewing guidelines for Commercial Thinning (CT) in the province. The FLNRORD Commercial Thinning Research Working Group, a group of forestry experts and managers from government, industry and academia, whose mission is to provide a foundation for the development of a CT strategy for this province, requested advice to ensure a more rigorous and systematic approach to identifying the motivations for commercial thinning and how that silviculture practice could help forest stands adapt to a warmer climate scenario. The FLNROR group and the authors agreed to expand the search to the competition effects since understanding how to assess competition will contribute to the projections of tree growth under climate change and ultimately to the guidelines for commercial thinning of B.C.'s forests. This systematic map builds upon the initial request for advice by providing a database of available evidence to support delineating a CT strategy for this province. Some members of the FLNROR group provided support defining the key objectives and search terms to include in this map. The authors will allow the FLNROR group to review the final map.

Objective of the review

A systematic map of climate change competition tree growth linkages is a way to understand better how to assess the role of competition in individual tree growth responses to climate change. These linkages will serve as the scientific basis for forest management, providing information on the best silviculture practices to assist tree species in coping with a warmer climate. For instance, some authors have suggested thinning as the silviculture practice that can help forest stands adapt to a future climate warming scenario [47, 49, 50]. That suggestion is based on the higher importance of competition to tree growth compared to that of climate. A systematic map of climate change competition tree growth linkages can identify subsets or evidence gaps where future primary studies can add value to validate that thinning suggestion. Therefore, this systematic map aims to identify, among the current scientific knowledge of climate change impacts on forests, studies that accounted for the effects of species interactions on tree growth responses to climate change. The main objective is to provide a comprehensive overview of the available knowledge and methods used to assess the effects of competitive interactions.

By building a systematic climate change competition tree growth map, we will address the following primary research question:

1. What evidence exists on the effects of competition on tree growth responses to climate change?

This question is worthy of a systematic map because the lack of comparable outcomes across studies will be a barrier to systematic review. We will search for different outcomes. Using the resulting evidence base, we aim to answer the following set of secondary research questions:

1.1 *What is the state of the evidence on the effects of competition on tree growth responses to climate change in terms of quantity of articles, tree species type, outcomes measured (a measure of tree growth) and geographical location?*

1.2 *What modelling methods have been applied to study the effects of competition on tree growth responses to climate change?*

1.3 *What kinds of indices are commonly used as measures of competition in those studies?*

1.4 *What are the major gaps in the evidence base from primary research studies?*

Components of the primary question

Population:	single and mixed-species stands in both planted and natural forests around the world.
Exposure factor:	competition is an individual tree response to limited growth resource availability. Considering that changes in climate will alter the availability of growth resources, such as water, trees will interact more competitively. Competition will mediate tree species growth responses to climate change altering resources availability (water, light and nutrients) and species' niche. Competition strongly affects the adaptive capacity of trees as high competition intensity reduces the capability of individual tree species to make growth adjustments in response to climate change [21].
Comparator:	single and mixed-species stands with low competition intensity; same study site before or after exposure.
Outcome:	the effects of competition on tree growth responses to climate change, with tree growth measured in terms of basal area, basal area increment, ring width, diameter at breast height (1.3 m above ground), biomass, height, and volume. Under a future with a warmer climate, forest stands can either remain unchanged, become stressed, decline or ultimately die, depending on different levels of species' sensitivity and individual trees' adaptive capacity. The vulnerability of forest stands to cli-

mate change relates to the capability of individual tree species to make growth adjustments (adaptive capacity) in response to climate change associated with their sensitivity to environmental stressors [21].

Methods

To build a systematic climate change competition tree growth map, we will employ a methodology of gathering and collating evidence adapted for environmental sciences [51]. Similar to systematic reviews, a predefined search strategy is necessary to explore the literature thoroughly, as outlined in Additional file 1. The search strategy for building a climate change competition tree growth evidence map includes two items: (a) the key search terms and (b) the inclusion and exclusion criteria.

Searching for articles

To select the proper search terms, we performed a preliminary inspection with two English terms in the ISI Web of Science, TOPIC: (forest*) AND TOPIC: ("climat* change") AND TOPIC: (competition) AND TOPIC: ("tree growth"). After this preliminary inspection, we used the word frequency query from NVivo®, a software for qualitative data analysis. We discovered repetitive keywords used among eligible studies (from the title, abstract and author-keyword list) that were synonyms for the topics of climate change, competition and tree growth (Additional file 2). We included those synonyms as well as alternative spellings into the final search string. To help develop and assess the final search string retrieval performance, we created a list of benchmark articles considered pertinent to answer the question of this evidence synthesis (Additional file 3). The final search string consisted of subject headings and keywords related to the processes whereby competition is thought to impact or alter individual tree species' responses to climate change worldwide. We will conduct a publication database and a topical database and organization search for links or references to eligible publications and data, including grey literature, using the engines listed in Table 1. We will tailor the search string to each electronic database's syntax. We will restrict the

Table 1 List of databases, platforms, search engines, and organizations for the climate change competition tree growth systematic map

Literature databases and platforms*	Web URL
Academic Search Premier	https://web.a.ebscohost.com
Agricultural & Environmental Science Database (AESD)	https://www.proquest.com/agricenvironm
arXiv	https://ui.adsabs.harvard.edu
BioOne	https://bioone.org
CAB Direct (Includes CAB Abstracts, CAB Abstracts Archives and Global Health)	https://www.cabdirect.org/cabdirect
Directory of Open-Access Journals	https://doaj.org
Web of Science Core Collection	https://www.webofscience.com/wos/woscc/advanced-search
JSTOR: Journal Storage	https://jstor.org
Scopus	https://www.scopus.com
SciELO	https://www.scielo.org
ProQuest (Thesis)	https://about.proquest.com/en/libraries/academic
Search engines**	
Google Scholar	https://scholar.google.com
Microsoft Academic	https://academic.microsoft.com
Scirus	https://www.scirus.com
Specialist websites	
Centre for International Forestry Research/CIFOR	https://www.cifor.org
Environment Canada/EC	https://www.ec.gc.ca
European Forest Institute/EFI	https://www.efi.int
International Union of Forest Research Organization/IUFRO	https://www.iufro.org
Food and Agriculture Organization/FAO	http://www.fao.org/home/en
Society of American Foresters/SAF	https://www.eforester.org
Tropical Agronomic Center for Research and Teaching/CATIE	https://www.catie.ac.cr

*Searches will be conducted using subscriptions of the University of British Columbia, Canada

**In each case, we will examine the first 100 hits (based on relevance) for appropriate data study inclusion eligibility to the English language. The final search string must contain the following English terms:

Population terms ("forest*")

AND

Exposure factor terms (("climat* change" OR "global warming" OR "changing climate" OR "extreme weather event*" OR "climat* warming" OR "climat* variability") AND ("tree species interaction" OR "competiti*"))

AND

Outcome terms ("tree growth" OR "tree ring growth" OR "tree radial growth" OR "tree basal area" OR "tree ring width" OR "biomass" OR "volume" OR "diameter" OR "height" OR "tree survival" OR "tree dieback" OR "die back" OR "tree mortality" OR "stress")

Article screening

We will upload the library of all search results to EndNote [43] and use this reference management tool to remove duplicates before the screening. We will perform the eligibility criteria at three successive levels. First, the reviewers will observe the inclusion of competition, or tree species interactions, on the title. Next, each article potentially eligible based on the title will be judged for inclusion based on the abstract. In cases of uncertainty, the reviewers will tend towards inclusion. Finally, articles that meet the inclusion criteria at the title and abstract levels will be judged for inclusion. Again, the reviewers will tend towards inclusion in cases of uncertainty. Full-text assessment will be conducted on all articles that pass a screening at title and abstract, but articles must pass each of the three-level criteria in this systematic map. As a check of consistency in the interpretation of the selection criteria, a subset consisting of 100 studies will be assessed at each level (title, abstract and full-text) by all reviewers. A Cohen's kappa statistic relating to the assessments will be calculated, and a minimum value of 0.6 will be required to pass the abstract assessment. If this statistic indicates that those reviewers are inconsistent in their assessment ($\kappa < 0.6$), discrepancies will be discussed and the inclusion criteria will be clarified or modified. Then, another subset of the same size will be tested, and a minimum value of 0.6 will be required to pass the abstract assessment. Replicability of the selection criteria will be reported, and all disagreements between reviewers will be discussed so that the resolutions can inform subsequent assessments. An impartial reviewer will screen these papers at both stages if a reviewer is an author on any included article. A list of articles rejected based on full-text assessment will be provided in the appendix of the final manuscript together with the reasons for exclusion.

Study eligibility criteria

To be included in the map, an article needs to fulfill each of the following criteria at both stages of the screening process:

- Eligible population(s)

  The study considers any forest stand around the world.
- Eligible exposure(s)
  The study acknowledges competition as an exposure factor affecting tree growth responses to climate change.
- Eligible comparator
  The study includes forest stands with low competition intensity (e.g. low density stands).
- Eligible outcome
  The study focuses on the vulnerability of forest stands to climate change. Vulnerability indicates whether a forest stand can remain unchanged, decline, become stressed or die as potential outcomes of the effects of competition on tree growth responses to climate change. Tree growth should be measured in terms of: basal area, basal area increment, ring width, diameter at breast height (1.3 m above ground), biomass, height and volume.
- Eligible study designs
  The study assesses climate change through metrics, e.g. precipitation and temperature, and competition through a distant-dependent or a distant-independent index. We will only evaluate studies published in or translated to English. We will not apply any date restrictions.
- Ineligible population(s)
  The study's methodology has garden experiments or provenance tests.
- Ineligible exposure(s)
  The study focuses on other exposure factors besides competition (e.g. pollution effects on tree growth responses to climate change).
- Ineligible comparator
  The study includes forest stands at an early stage of development (e.g. germination or saplings). Thus, growth resource availability has not become limited, so tree species interactions are not be classified as competition.
- Ineligible outcome (s)
  The study's outcomes are unrelated to the effects of competition and climate change on tree growth (e.g. climate change and competition effects on wood quality).
- Ineligible study design

This study does not measure competition and does not include competition in the tree growth model. The study's objective is tree-ring dating or dendroclimatology.

We will document all inclusion/exclusion decisions in the full-text stage and make them publicly available together with the literature reference archive and search records.

Study validity assessment

We will not critically appraise or assess the quality of included studies directly. The heterogeneity in outcomes included in the scope of the map does not support consistent criteria for evaluating studies. We will record descriptions of the studies' methods and replicates to identify subtopics to help future systematic reviews.

Data coding strategy

We will extract data from the eligible articles and synthesize that data according to three themes: (1) study characteristics, (2) tree growth model specifications and (3) evidence of the competition effect on tree growth under climate change, as outlined in Table 2. Study characteristics theme describes: 1. (a) study identification details, such as author, year of publication, subject area and 1. (b) methodology, such as study area location and size, and tree species scientific name. Tree growth model specifications theme describes the model type, dependent variables, modelling technique, prognostic factors and outcomes. The third theme focuses on the method used for competitor identification and quantifying the level of competition and the evidence of competition effect on tree growth and recommendation of thinning. We will report in the systematic map any changes to these themes and variables. During free text data extraction, we will use the codes "UA" (unattainable) for any metadata that cannot be obtained and all metadata that is not available in the abstract, "NA" (not applicable) for any metadata category that does not apply to a study, and "NO" (not available) for studies which full text is not available after contacting the author. To ensure consistency and repeatability of data extraction, we will check the results of ten studies or 10% of studies, whichever is the larger, extracted by two reviewers. We will discuss discrepancies and provide additional specifications, which will be recorded and reported in the systematic map.

Table 2 Coding variables for the climate change competition tree growth systematic map

Coding variables	Information recorded
1. Research characteristics	
Full reference	Author(s), title, date, publisher
Date	Date of publication in years
Publication type	Name of the scientific journal
Purpose	Objective of the study
Jurisdiction	Country(s) name and coordinates
Species	Study species' scientific name
Forest	Type of forest assessed
2. Tree growth model specifications	
Model type	Type of tree growth model applied (linear regression, linear mixed effect model, generalized linear model, Bayesian statistics, correlation methods or not specified)
Response variable	Measure of tree growth
	• Basal area (BA)
	• Basal area increment (BAI)
	• Ring width (RW)
	• Diameter at breast height (DBH)
	• Biomass
	• Height (H)
	• Volume (V)
Predictors	Precipitation, temperature, other climatic variables
3. Evidence of the competition effect on tree growth under climate change	
Competition index	Type of indices (distant dependent, or distant independent)
Influence	Effect of competition on tree growth (free text; extract information for each tree species)
Management recommendations	Thinning (yes, no or no recommendation)

Study map and presentation

We will create heat maps of study frequencies to identify trends, knowledge gaps and clusters (study question 1). We will relate the studies' methodology (study questions 2 and 3) to the reported findings of competition's influence on tree growth. Then, we will cross-reference the meta-data from the three themes (study question 4). We will publish the final database as an Excel spreadsheet. We will report the extracted evidence, as well as knowledge gaps in a narrative synthesis form. Any additional subtopic or questions identified through the course of the systematic map process will be described in detail in the resulting systematic map manuscript. Finally, we will make recommendations for priorities in future research on individual tree growth responses to climate change. For instance, we may assess the feasibility of a systematic review to address the effect of competition on individual tree growth responses to climate change (Additional file 4).

Supplementary Information

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Additional file 1. ROSES form.

Additional file 2. Search string.

Additional file 3. Benchmark studies.

Additional file 4. ROSES for systematic map protocols. Version 1.0.

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Authors' contributions
All authors participated in formulating the questions and the drafting, revision, and approval of the protocol. All authors read and approved the final manuscript.

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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.

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