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Geographical inequalities in global forest science: A bibliometric perspective

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ABSTRACT

This bibliometric study is situated in the context of increasing awareness of inequalities in forest science. It was led by a single, core question: What geographical inequalities structure global forest science and how do they align with the natural geographical distribution of forest areas? Bourdieu's field theory was used to investigate the inequalities, focusing on three types of capital considered important for participation in global science: scientific capital (products of knowledge and acts of recognition), collaboration capital, and funding capital. To operationalise the types of capital for bibliometric analysis, eight regional-level indicators and seven country-level indicators were developed. The Dimensions database served as the data source to extract relevant publications in forest science from 2000 to 2021 based on the database's publication-level field classification. Forest-related research needs were determined using non-bibliometric data, specifically the extent of cover per region and country. This enabled the calculation of disparity ratios between the world shares of forest publications and the world shares of forests. The results highlight persisting inequalities in the distribution of different forms of capital in global science, as well as (mis)alignment with the geographical distribution of forest areas. While the Bourdieusian assumption that "capital breeds capital" seems to apply to two dominant regions (Europe and Northern America), explaining their continued centrality as loci of forest science, it does not seem to apply more generally. The study points to a mismatch between research foci and needs, which is concerning given the importance of place and context in forest science.

1. Introduction

Inequalities in science have come under scrutiny in the last decade (Nature Editorial, 2016; Nielsen and Andersen, 2021). Scholars from various fields, including forest research, have called for the persistent imbalances in the structure of their workforces to be addressed, as revealed by recent studies (Giakoumi et al., 2021; Graves et al., 2022; Kozlowski et al., 2022; Macinnis-Ng and Zhao, 2022). In addition to skewed gender patterns, these studies show geographical asymmetries in authorship of scientific publications, as well as in international collaborations, networks and conferences (Boncourt et al., 2023; Engels and Ruschenburg, 2008; Koch and Matviichuk, 2021; Marks et al., 2023; Tolochko and Vadrot, 2021b).

Such geographical asymmetries cause concern due to mounting evidence that location influences the type of research undertaken (Tolochko and Vadrot, 2021a). For example, the intensity of discussion about the socio-economic implications of sustainable forest management research differs greatly between the Global South and the Global North (Sutterlüty et al., 2018). Science is not 'placeless' but 'situated' (Haraway, 1988; Harding, 1986) as it always reflects a "view from some particular location" (Livingstone, 2003, pp. 80–81), generated by particular actors. This perspective is empirically supported by studies investigating actors and dynamics in knowledge co-production and science-policy interactions on paradigms such as REDD+ or the circular bioeconomy (D'Amato et al., 2022; Kamelarczyk and Smith-Hall, 2014). At the same time, epistemic discourses as well as science collaboration

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on both topics have been shown to be dominated by scientists in the Global North (Jankovský et al., 2021; Koch, 2017; Mascarello et al., 2024). Such geographical inequalities not only risk narrowing scientific perspectives but also creating a misalignment between research outputs and societal needs (Ciarli and Ràfols, 2019; Kumar et al., 2023).

Several papers using bibliometrics as a main or complementary method point to geographical inequalities shaping forest science. They can be broadly grouped into four strands: Analyses focused on (1) specific journals with the purpose to map patterns in their authorship and themes (Grobbelaar and Oosthuizen, 2022; Uribe-Toril et al., 2019); (2) larger sets of journals to sketch and evaluate the publication landscape in forestry (Malesios and Arabatzis, 2012; Peteh, 2020); (3) specific countries or regions that seek to capture and compare forest research conducted in these places (Päivinen et al., 2023; Fazeli-Varzaneh et al., 2021; Santillán-Fernández et al., 2023; Soler et al., 2021); and (4) specific sub-fields (e.g. forest ecology research) or themes (e.g. community forestry research) (Bullock and Lawler, 2015; Gao et al., 2022; Jankovský et al., 2021; Lovrić et al., 2020; Ma et al., 2022; Song and Zhao, 2013; Sullivan, 2022). Most of these studies indicate a dominance of Northern America and Europe in the production and funding of forest research.

We aim to contribute to the existing literature with a bibliometric analysis showing the geography of forest science in a more comprehensive and theoretically grounded way. The analysis is led by a core question: What geographical inequalities structure global forest science and how do they align with the natural geographical distribution of forest areas? For this, we adopt a theoretical lens that provides a more nuanced picture of geographical inequalities than mere descriptive analyses that focus only on output. Following the French sociologist Pierre Bourdieu, we assume that relations of dominance and power in scientific fields are not constituted by productivity alone, but by the availability of different forms of capital that reinforce each other (Bourdieu, 1975, 1988, 1991, 2004). We therefore explore how different forms of capital – ranging from strict scientific capital (publications and citations) to economic capital (funding acknowledgements) and collaboration capital (co-authorships) – are geographically distributed and related. We use both sub-regions and countries as geographical units to capture inequalities between and within world regions.

Before proceeding, a conceptual clarification of our understanding of inequality is needed. A defining feature of what is meant by inequality, according to the Merriam-Webster Dictionary (Merriam-Webster Dictionary, 2023), is "disparity of distribution or opportunity". Consulting the same dictionary, distribution refers to "the position, arrangement, or frequency of occurrence […] over an area or throughout a space or unit of time" but also the "natural geographic range of an organism". Distributive inequality, in the context of this study, therefore, refers to disparities in the geographical distribution of different forms of capital in global forest science, which we present in relation to the natural geographical range of forests.

In the next section, we briefly outline how geographical inequalities have been examined in bibliometric studies (Section 2) before outlining Bourdieu's theory with a focus on capital (Section 3). After explaining how we operationalised this concept for the bibliometric study, we provide details of our data sources and methods of analysis (Section 4). In Section 5, we present bibliometric results on distributive inequalities in global forest science. We conclude by discussing the results and outlining directions for future research (Section 6).

2. Bibliometric scholarship on geographical inequalities in science

Bibliometric scholars study geographical patterns in science primarily through analyses of research production (publication counts), recognition and visibility of research (citation metrics), and international research collaboration (co-authorships and networks). One example is a study of Africa's contribution to global science (Tijssen, 2007), which shows, among other things, Africa's share of global publication output, the region's share of internationally co-authored publications, and the citation impact of the region's scientific output relative to the world as a benchmark. For about a decade, analyses of the funding acknowledgements reported in publications have been part of the bibliometric scene (e.g. Chankseliani, 2023), shedding light on the funding agencies that drive and dominate research activity.

Bibliometric studies dealing specifically with spatial aspects differ along several dimensions. These are the level of geographical localisation and comparison (country, region or world), the level of subject specialisation (all scientific fields or one or more selected fields, or selected topics within a scientific field), and the number and combination of parameters for intersectional analysis (space, time, field, organisation, language of publication and, in the case of an author analysis, gender, age, etc.). A prominent spatial perspective in bibliometrics is that of region and/or country, with the aim of identifying regions and countries in leading positions in knowledge production in selected scientific fields. There is also a broader spatial perspective on global inequalities in knowledge production, namely the so-called (and often contested) 'Global North' versus 'Global South'. What the bibliometric studies that include spatial aspects seem to provide is confirmation of global inequalities in practices of knowledge production and citation in different fields of scientific research. For example, in marine biodiversity research, the overwhelming share of scientific output was found to be produced by countries in the Global North, more specifically the US and European Union member states, and the average number of citations per paper was highest for the US, Sweden, and Canada (Tolochko and Vadrot, 2021b). However, it is important to remember that the leading positions of certain countries or regions in knowledge production are only indirectly actually spatial, as they reflect firstly the uneven distribution of different forms of resources and their broader contextual roots, which overlap with spatiality. Key expectations for any bibliometric study focusing on geographical inequalities would be that countries with higher research investments are more scientifically independent, that international collaboration is positively related to citation impact and that, despite increasing global participation in science, most international collaborations are asymmetrical, and the research system structured around a few dominant nations (Chinchilla-Rodríguez et al., 2019).

From a societal perspective, the risk arising from such inequalities is a misalignment between research foci and research needs. For example, in a bibliometric study of health research priorities in India, Kumar et al. (2023) found evidence of a mismatch between research output and disease burden in the country. The misalignment is explained in terms of the academic prestige of certain disease areas and funding opportunities in global health, among other factors. Yegros-Yegros et al. (2020, p. 1), in turn, examined the alignment between global health needs and research. The spatial aspect of their research led to the conclusion that "researchers in middle-income countries receive more citations when researching diseases more prevalent in high-income countries, [which] may divert the attention of researchers in these countries from diseases more prevalent in their contexts". Applied to global forest science, this could mean that the focus of forest research may be misaligned with the research needs of the countries in which it is conducted.

While geographical inequalities and their (potential) implications have been addressed by bibliometric studies for quite some time, they are rarely examined and explained through a specific meta-theoretical lens. In this study, we adopt Bourdieu's field theory to investigate inequalities in global forest science, as it allows us to link different dimensions of inequality and show how they are interrelated.

3. Bourdieu's theory as conceptual lens to study inequality in science

Bourdieu's sociology of science is based on the premise that science, like any other societal sphere, is "a social field of forces, struggles, and

Table 1
Forms of capital and their corresponding bibliometric indicators.

Forms of capital	Bibliometric indicators	Level of analysis	
		Regions	Countries
Scientific capital (products of knowledge)	• *Publication contribution*: World share of forest publications	Table 3 & Fig. 2	Fig. 5
	• *Research disparity*: Disparity ratio between world share of forest publications and world share of forests	Table 3 & Fig. 2	Fig. 5
Scientific capital (acts of recognition)	• *Citation contribution*: World share of total citations of forest publications	Fig. 2	Fig. 5
	• *Mean citation count*: Average number of citations per forest publication	Fig. 3	–
	• *Publication visibility*: Share of forest publications among top 10% most cited	Fig. 3	–
Collaboration capital	• *Cross-regional collaboration*: Share of forest publications co-authored with other regions	Table 6	
	• *National collaboration*: World share of all forest publications with national co-authorship only	–	Fig. 7
	• *International collaboration*: World share of all internationally co-authored forest publications	–	Fig. 7
Funding capital	• *Internal funding*: Share of forest publications mentioning funding from own region / country	Table 7	Table 8
	• *External funding*: Share of forest publications mentioning funding from other regions / countries	Table 7	Table 8

Note: The table and figure names in the last two columns indicate where in the results section the discussion of each indicator can be found.

relationships" (Bourdieu, 1991, p. 3). In global science, the actors involved may be individuals, but also organisations, countries or world regions. They compete for the ascription of scientific authority as the "socially recognised capacity to speak and act legitimately (i.e. in an authorised and authoritative way) in scientific matters" (Bourdieu, 1975, p. 19). Actors' chances of success in this competition depend not only on their intellectual capacity but also on the amount and forms of capital they have at their avail. Three forms of capital are relevant to participating in global science.

Scientific capital refers to the products of knowledge and acts of recognition performed by scholars in a given field (Bourdieu, 2004). Scholars accumulate scientific capital through the publication of scientific work, for which they receive varying degrees of recognition through citation by peers. Both publications and citations function as a special form of symbolic capital that is "primarily, sometimes exclusively, valid within the limits of the field (although it can be converted into other kinds of capital, economic capital in particular)" (Bourdieu, 2004, p. 55).

Economic capital refers to the material resources that scholars have at their disposal: funds to buy equipment, build laboratories, travel for field research, or hire staff. This form of capital – perhaps better described as *funding capital* – is related to scientific capital, since more financial resources to carry out research are likely to increase research output. However, the relationship goes both ways: the availability of scientific capital in the form of publications and citations increases the accessibility of resources, as criteria such as productivity and citation impact inform funding decisions at both the individual and institutional levels (Brunet and Müller, 2023).

Collaboration capital refers to the collaborative ties that scholars have with others. Over the past decades, collaboration has become an important currency in today's scientific system (Olechnicka et al., 2019; Tolochko and Vadrot, 2021b). At both the individual and institutional levels, participation in transnational collaboration networks is often seen as an indicator of scientific capacity. Internationality has become a 'virtue' for individual scholars and a core criterion in academic assessment and promotion processes (Hamann and Zimmer, 2017). Universities adopt internationalisation strategies to make their organisations competitive in the academic market (Witjes and Sigl, 2015). While this form of capital played a subordinate role in Bourdieu's original writings, its importance has increased immensely with the globalisation of science.

Bourdieu's theory rests on two assumptions: first, that "capital breeds capital" (Bourdieu, 2008, p. 85), meaning that different forms of capital, whether material or symbolic, mutually reinforce each other. Second, that scholars' positions and relations in the scientific field depend on the amount of capital they have at their avail. Those with high levels of capital form the dominant group, which is able to decide on the 'rules of the game' and define what constitutes legitimate science – "doing quality work is doing work like theirs" (Albert and Kleinman, 2011, p. 266). In contrast, scholars with low levels of capital are in a subordinate position that limits their scope for action, i.e. their scope for setting the agenda, deciding on research topics and questions, and choosing the methods and approaches they consider appropriate is significantly reduced (Bourdieu, 1975). The social structure resulting from the distribution of capital in a given field therefore inherently affects the knowledge it produces.

A few bibliometric studies have used Bourdieusian theory to highlight asymmetrical power relations and various forms of inequality that structure global science. Schirone (2023) identified 183 documents in the bibliometric literature with an explicit reference to Bourdieu's concept. However, as he points out, "[occurrences] of more than one type of capital in the same text are rare" (Schirone, 2023, p. 8), and where they do occur, it is mainly scientific capital as a specific form of symbolic capital that is referred to. Our study differs in this respect by considering different forms of capital and their distribution in global forest science. Table 1 shows how we operationalised the concept for our analysis, indicating the bibliometric indicators used to examine the distribution of capital types, both for regions and countries.

The indicators presented in Table 1 are embedded in a broader bibliometric analysis of geographical inequalities in global forest science, presented in Section 5. To facilitate a clear understanding of these indicators, we first provide an explanation of the data source of the underlying publications, as well as the value added to the publication data for the construction of the indicators (e.g. establishing links with forest area and world region).

4. Data source and methods

4.1. Bibliometric data source

The data source was Dimensions, a publication and research database from Digital Science, and specifically the in-house version at the Centre for Science and Technology Studies (CWTS) at Leiden University. This version contained data up to June 2022, and the period of analysis was from 2000 to 2021. To create a set of publications in forest science, we used the so-called Fields of Research (FoR) classification in the Dimensions database, an article-based classification that follows the Australian and New Zealand Standard Research Classification. All publications in Dimensions are coded according to this classification using machine learning.[1] The FoR group applicable to our study was 'Forestry Sciences', which generated a dataset of 116,554 publications.[2] Of these,

[1] https://dimensions.freshdesk.com/support/solutions/articles/23000018826-what-is-the-background-behind-the-fields-of-research-for-classification-system-

[2] Given the name of the applicable FoR in Dimensions, we use the term 'forestry' instead of 'forest science' to describe the extracted publications in the methods and results sections.

81,223 had author addresses and country metadata and could be included for analysing. Six document types were used: articles, books, chapters, monographs, preprints and proceedings.

4.2. Classification of countries into regions

The dataset of 81,223 publications translated into an authorship dataset of 112,974 records. A publication was assigned to a country based on whether the name of a country appeared in the list of the addresses of the authors of the publication. We assigned the countries in the authorship dataset to regions, according to the seven regional groupings used by the United Nations (2023) in its work on the Sustainable Development Goals (SDGs). However, one region 'Europe and Northern America' was split into two, resulting in us having eight regions. Table 2 lists all the regions and their abbreviations.

The co-occurrence of regions in the author addresses of publications was used to calculate the degree of collaboration between regions. Similarly, by examining the co-occurrence of country names in the addresses of publications, we calculated the degree of both international and national collaboration. We also calculated the world shares of all publications produced by national and international co-authorship (i.e., national and international collaboration capital). For example, the world share of nationally co-authored publications was calculated by taking the global total of forestry publications produced through national collaboration only and expressing the number of nationally co-authored publications for each country as a share of this total. The underlying assumption was that publications with only national collaboration (i.e. no international collaboration simultaneously present) reflect a local research need.

4.3. Citation performance

For each forestry publication in the Dimensions database, the database has a record of the total number of citations it has received in all fields in the entire database, not just in forestry science. This allowed us to calculate three indicators of citation performance. The first was the contribution to global citations, calculated as a country or region's share of the total citations received by all forestry publications in the world. The second indicator was the average number of citations received by a region or country. The third, publication visibility, focused on the most cited forestry publications in the world (the top 10%), i.e., the percentage of publications from a given region included in this set of most cited publications.

4.4. Funding source

Dimensions also includes the funding acknowledgements of publications (Herzog et al., 2020), which allowed us to generate a subset of forestry publications that mention funding. From our dataset of 81,223 forestry publications, 27,937 (34%) mentioned a funding organisation in their acknowledgements. Both the names and the countries of the funding organisations appear in the acknowledgements. Based on this information, we calculated, for each region, the percentage of forestry publications that mentioned funding from their own region (internal funding) and the percentage that mentioned a funder from other regions (external funding). For each country, we calculated the percentage of forestry publications with national and international funding, respectively (the two indicators of internal and external funding).

Table 2
Regions and abbreviations of regions.

Region	Abbreviation
Central and Southern Asia	CSA
Eastern and South-Eastern Asia	ESA
Europe	EUR
Latin America and the Caribbean	LAC
Northern America	NA
Northern Africa and Western Asia	NWA
Oceania	OCE
Sub-Saharan Africa	SSA

4.5. Forest areas

Forest cover data were obtained from the Food and Agriculture Organisation (FAO) of the United Nations (FAO, 2020). These data report the amount of forest land in each country, expressed in hectares, with 2020 as the most recent reporting year. The data were used to calculate the share of global forest area for each of the eight regions, as well as the percentage of a region's total land area that is forested. The same two indicators have also been produced for countries, together with a calculation of a country's contribution to the total forest area of the region in which it is located.

5. Results

5.1. Scientific capital (products of knowledge and acts of recognition)

The continued dominance of Europe in the production of forestry publications can be seen in Fig. 1, which shows the annual number of forestry publications in the different world regions during the period 2000 to 2021. Production levels are also relatively high in three other regions: Eastern and South-Eastern Asia, Northern America, and Latin America and the Caribbean. In 2017, Eastern and South-Eastern Asia (which includes China) overtook Northern America (which includes the US) as the world's largest producer of forestry research. Relatively small contributions to forestry publications were recorded for the remaining four regions. In 2021, the number of publications in these regions ranged from 427 (Central and Southern Asia) to 169 (Northern Africa and Western Asia).

Except for Latin America and the Caribbean and sub-Saharan Africa, all other six regions contribute a relatively larger share of the world's forestry publications than would be expected based on their share of the world's forest area. This is shown in Table 3, which presents the world shares of forestry publications, together with the disparity ratios between the world shares of forestry publications and the world shares of forests. For example, the share of forestry publications produced by Eastern and South-Eastern Asia are 2.0 times greater than its share of forest areas (24% versus 12%). Similarly, publications produced by Northern America have a disparity ratio of 1.7 (27% versus 16%). In contrast, the share of forestry publications produced by sub-Saharan Africa is relatively smaller than its share of forest area, with a disparity ratio of 0.3 (4% versus 15%). Table 3 also shows that the regional shares of forestry publications in the world, from 2000 to 2021, are generally in line with the regional shares of total publications worldwide. A notable exception is Latin America and the Caribbean, a region that produces 14% of the world's forestry publications, but only 5% of the world's publication output in all fields.

The ratios in the lower part of Table 3 were obtained by calculating the global average for each indicator and then using the average as the denominator in relation to a region's value for that indicator (the numerator). For example, Eastern and South-Eastern Asia accounts for 24% of the world's forestry publications, and the world average for this indicator is 15%. This means that the region produces 1.6 times more forestry publications than would be expected based on the world average. Europe, together with Latin America and the Caribbean, bears the 'burden' of forest area in the world (2.0 and 1.8 times more forest area, respectively, than expected based on the world average for the forest area indicator). In terms of forestry publications, Europe produces 2.6 times more publications than expected based on the world average, meaning that Europe's ratio of forestry publications exceeds its ratio of forest area. In the case of sub-Saharan Africa, its share of world forest area (15% – column B in Table 3) is close to the world average (13% –

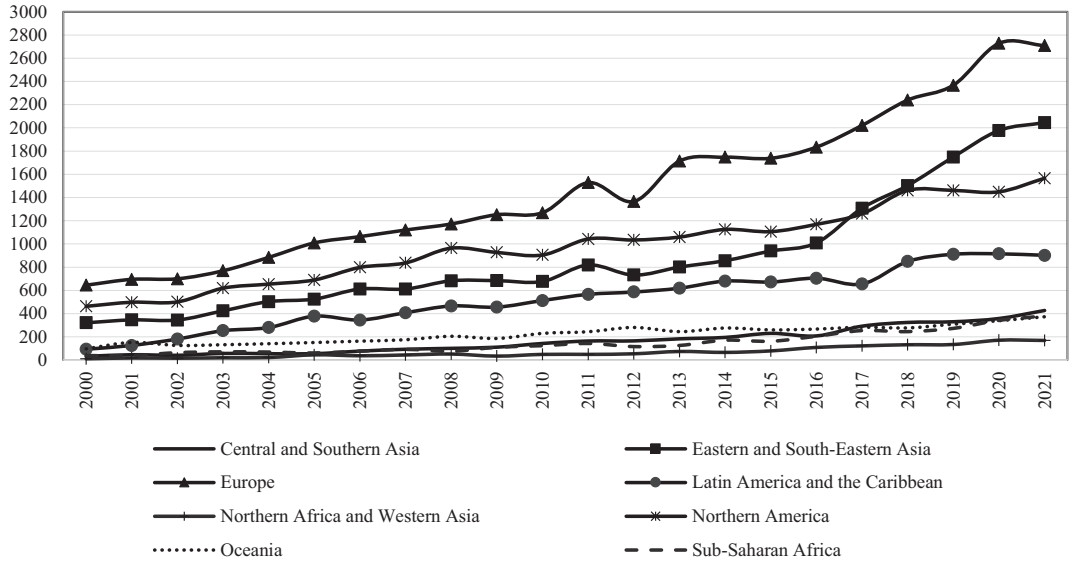

Fig. 1. Annual number of forestry publications by region, 2000 to 2021.

Table 3
Regional profile of global shares of forestry publications and forest areas.

Region	Publications, 2000–2021			Forest area, 2020		Disparity ratio (A/B)
	% world share of all publications	% world share of forestry publications (A)	% forestry publications out of all publications	% world share of forest area (B)	% land area that is forest	
Percentages						
Central and Southern Asia	6%	5%	0.1%	3%	11%	1.7
Eastern and South-Eastern Asia	27%	24%	0.2%	12%	29%	2.0
Europe	37%	40%	0.2%	25%	44%	1.6
Latin America and the Caribbean	5%	14%	0.5%	23%	46%	0.6
Northern Africa and Western Asia	4%	2%	0.1%	1%	5%	2.0
Northern America	30%	27%	0.1%	16%	30%	1.7
Oceania	4%	6%	0.3%	5%	22%	1.2
Sub-Saharan Africa	1%	4%	0.5%	15%	31%	0.3
Average for eight regions	*14%*	*15%*	*0.2%*	*13%*	*27%*	
Ratios						
Central and Southern Asia	0.4	0.3	0.5	0.2	0.4	
Eastern and South-Eastern Asia	1.9	1.6	0.6	1.0	1.1	
Europe	2.6	2.6	0.8	2.0	1.6	
Latin America and the Caribbean	0.4	0.9	2.0	1.8	1.7	
Northern Africa and Western Asia	0.3	0.1	0.3	0.1	0.2	
Northern America	2.1	1.8	0.6	1.3	1.1	
Oceania	0.3	0.4	1.1	0.4	0.8	
Sub-Saharan Africa	0.1	0.3	2.0	1.2	1.1	

≤0.5: below world average | 0.6-1.4: about world average | ≥ 1.5: above world average

column B), giving a ratio of 1.2 (column B in the "Ratios" section of Table 3). On the other hand, the world share of forestry publications in the same region (4% – column A) is below the world average (15% – column A), giving a ratio of 0.3 (column A in the "Ratios" section). Expressed differently, sub-Saharan Africa produces 3.8 times *less* forestry publications than would be expected from its share of the world's forest area (15% [column B] divided by 4% [column A]).

In terms of citations as scientific recognition, Fig. 2 shows substantial differences in the extent of citation distribution between the regions. Europe and Northern America stand out as the two regions that contribute most to global forestry citations (47% and 42% respectively), and therefore receive more scientific recognition than the other regions. Northern America's share of citations is 1.6 higher than its share of publications. In contrast, sub-Saharan Africa accounts for 15% of the world's forests, but only contributes 4% of the world's forestry publications and 4% of the world's forestry citations.

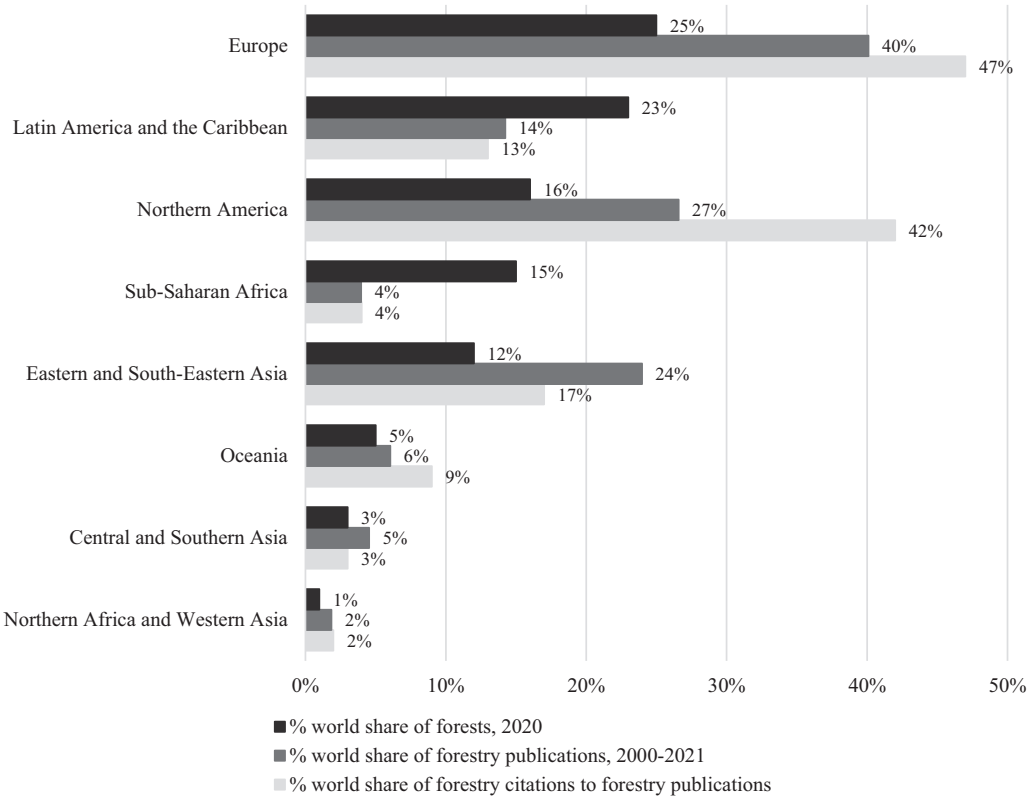

Fig. 2. Shares of forest area and forestry publications and citations, by region.

Forestry publications from Northern America and Oceania have the highest average citation scores of 27.5 and 27.2, respectively (Fig. 3). In addition, 19% and 18% of forestry publications from these two regions, respectively, are in the top 10% of most cited forestry publications worldwide. Although sub-Saharan Africa contributes little to the global pool of forestry publications (4%, as shown in Table 3), publications from this region are not the least cited. A relatively high average citation score of 17.7 is observed for the region, and 12% of the region's forestry publications are among the top 10% most cited worldwide.

Fig. 4 compares the shares of forest area and forestry publications, at the country level, using world maps. By placing the two maps close together, the discrepancy between the two indicators becomes clear. In 2020, two countries (Russia [20.2%] and Brazil [12.3%]) each had >400 million hectares of forest area, which together accounted for about 33% of the world's forest area. In terms of forestry publications, three countries (US, Brazil and China) each produced >5000 publications between 2000 and 2021 (21%, 9.9% and 11.1%, respectively). These three countries account for 40% of all forestry publications worldwide. The other top five producers of forestry publications worldwide are Japan (7.7%), Canada (6.7%), Germany (6.5%), Australia (4.9%) and Sweden (4.5%). Except for South Africa, all countries on the African continent had <500 publications in total during the period considered. This is even though five countries on the continent (Angola, Mozambique, Tanzania, the Democratic Republic of the

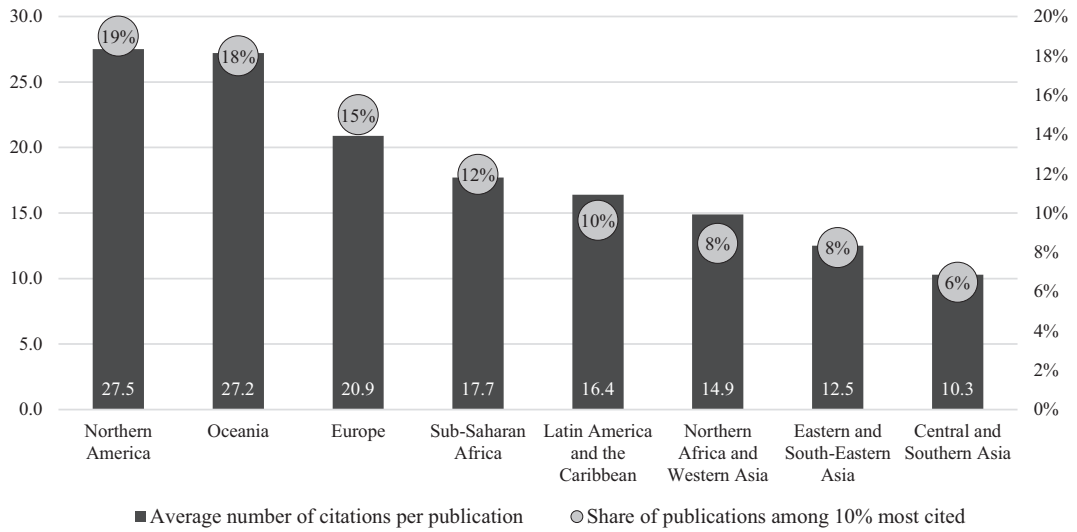

Fig. 3. Two citation indicators for forestry publications, 2000–2021, by region.

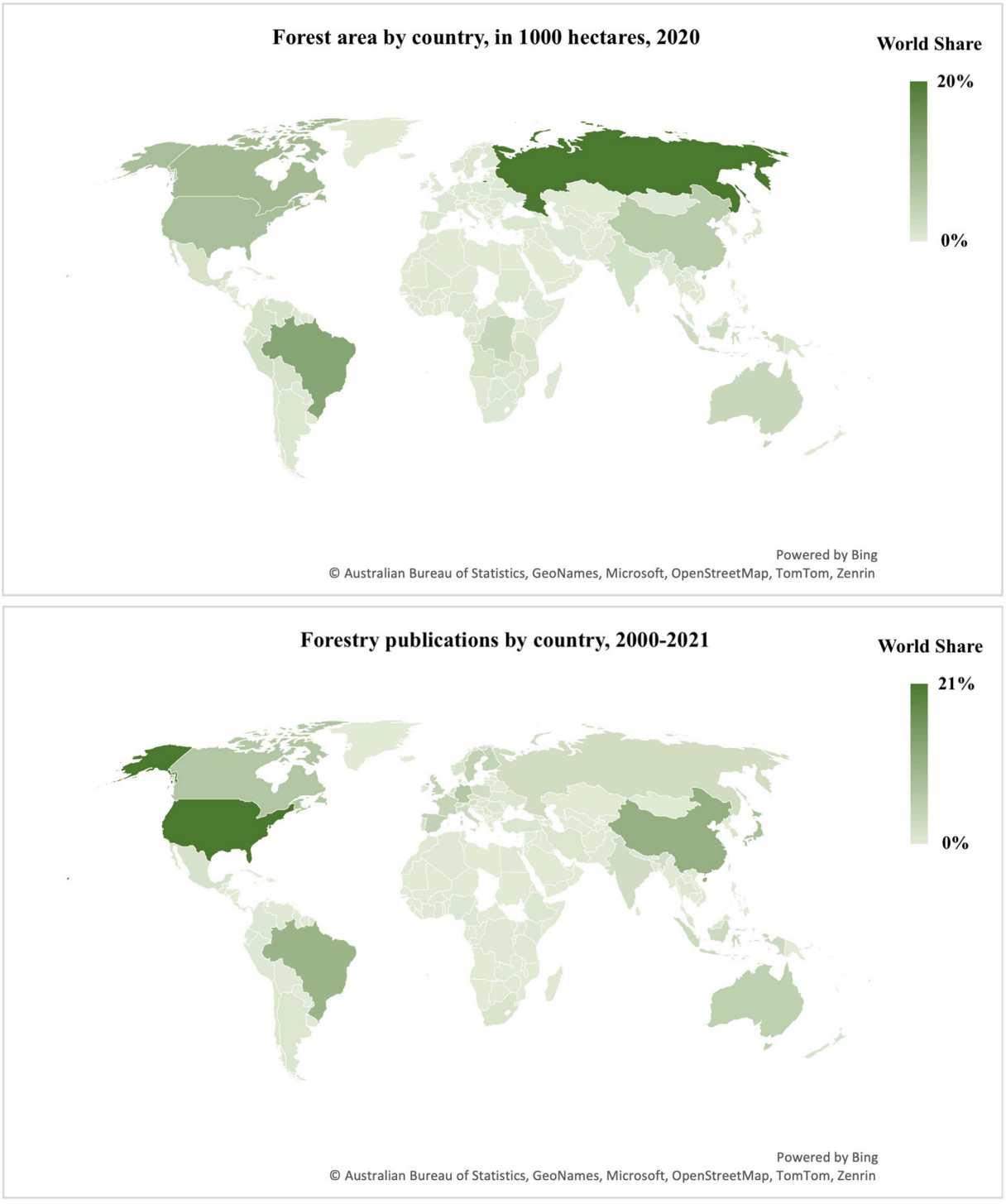

Fig. 4. World maps of forest area and forestry publications.

Congo [DRC] and Zambia – see Fig. 5) have relatively large shares of forest area.

For five of the twenty countries with the largest forest area, the share of world forestry publications exceeds the share of world forest area (US, China, Australia, Indonesia, and India – Fig. 5), with substantial differences in the case of the US (21% versus 8%) and China (11% versus 5%). For the remaining countries, mainly in the developing world, the share of world forestry publications is smaller than the share of world forest area. Russia shows the most striking difference – despite having about 20% of the world's forest area, it contributes only 2% of the world's forestry publications.

In terms of the share of citations related to forestry, three countries (US, Australia, and Canada) receive more recognition than the others (Fig. 5). Their citation shares exceed their contributions to global forestry publications: US (35% compared to 21%), Australia (8% compared to 4.9%), and Canada (10% compared to 6.7%). Argentina, although relatively low in total contributions, also receives significant recognition compared to other countries, with its share of citations exceeding its contribution to global forestry publications (1.5% versus 0.9%). In contrast, countries such as China, Brazil, and Russia receive

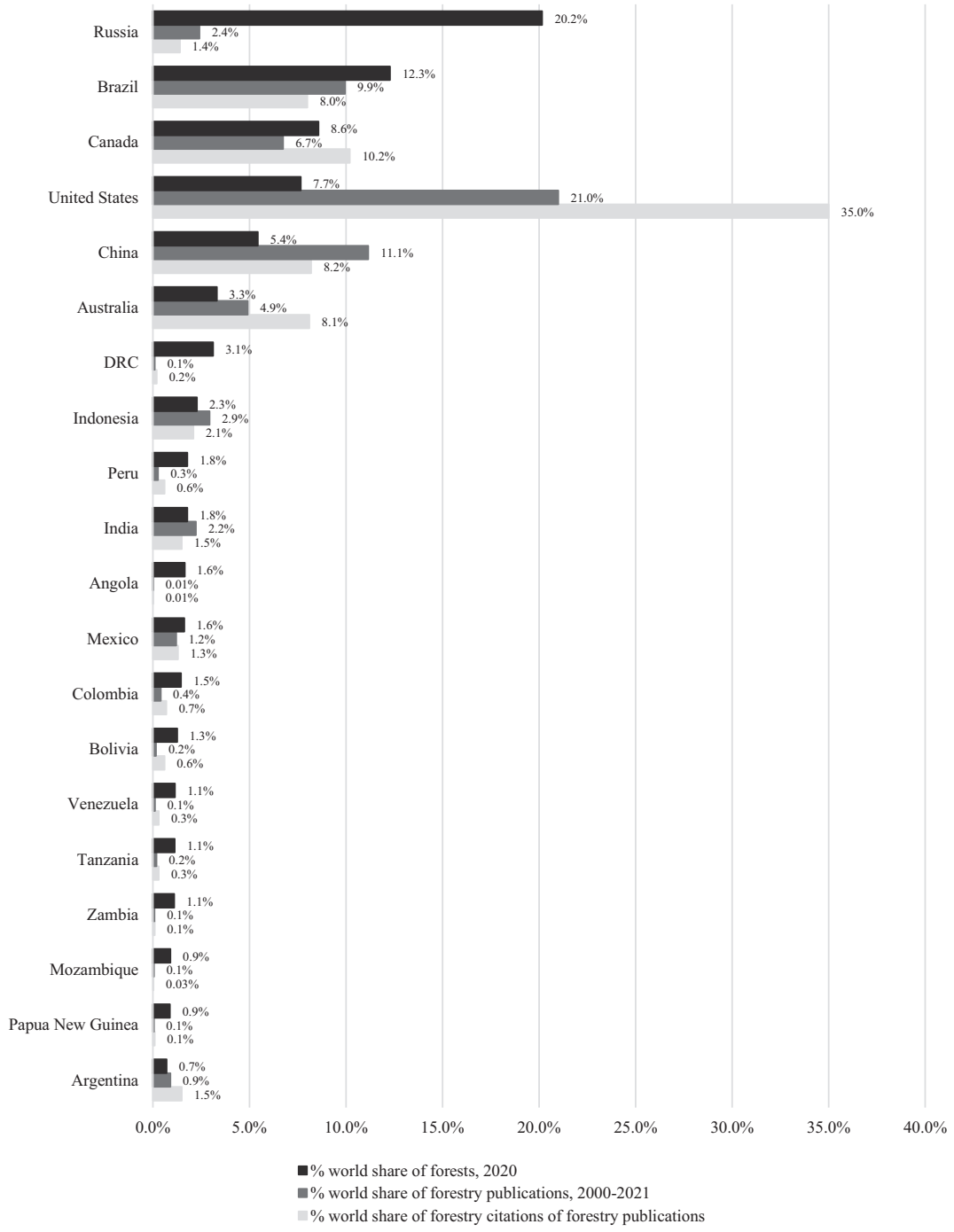

Fig. 5. Shares of forest area and forestry publications for 20 countries with largest forest areas.

fewer citations relative to their share of forestry publications. For the remaining countries, all of them in the developing world, the difference between the share of forestry publications and the share of forestry citations is less pronounced but not always trivial (e.g. in the case of Peru, Colombia and Bolivia).

Tables 4 and 5 provide an alternative perspective to that presented in Fig. 4, as the shares of forest area and forestry publications per country are based on the respective regional totals, rather than the world total. Table 4 is organised around the three countries with the largest forest area in each region. A disparity ratio >1 indicates that a country's share of forest area is less than its share of forest publications. For example, in Europe, the three countries with the largest forest areas are Russia (80%), Sweden (3%) and Finland (2%) (Table 4). With a disparity ratio of 0.1, Russia's forest area is about 13.3 times larger than its share of forestry publications (6% versus 80%). In contrast, Sweden and Finland, with disparity ratios of 3.7 and 5.0 respectively, have smaller shares of forest area than their shares of forestry publications (3% versus 11%, and 2% versus 10%). Table 5 is arranged according to the three countries with the highest shares of forestry publications in the different regions. The table shows that the three European countries with the highest regional shares of forestry publications are Germany (16%), Sweden (11%) and the UK (11%). It is noteworthy that the shares of regional forestry publications produced by these three countries are substantially higher than their shares of forest area, as indicated by the respective ratios of 16.0, 3.7 and 36.7.

As another example, in sub-Saharan Africa, the three countries

Table 4
Shares of forest area and forestry publications for selected countries, by region (three countries with the largest forest area in each region).

Region	Country	% regional share of forestry publications	% regional share of forest area	Disparity ratio
Central and Southern Asia	India	49%	64%	0.8
	Iran	21%	9%	2.3
	Nepal	14%	5%	2.8
Eastern and South-Eastern Asia	China	47%	46%	1.0
	Indonesia	12%	19%	0.6
	Myanmar	0.002%	6%	0.0003
Europe	Russia	6%	80%	0.1
	Sweden	11%	3%	3.7
	Finland	10%	2%	5.0
Latin America and the Caribbean	Brazil	70%	5%	14.0
	Peru	2%	8%	0.3
	Mexico	8%	7%	1.1
Northern Africa and Western Asia	Turkey	44%	39%	1.1
	Sudan	3%	32%	0.1
	Morrocco	6%	10%	0.6
Northern America	Canada	25%	53%	0.5
	US	79%	47%	1.7
	Bermuda	0.0001%	0.0002%	0.5
Oceania	Australia	81%	72%	1.1
	Papa New Guinea	1%	19%	0.1
	New Zealand	20%	5%	4.0
Sub-Saharan Africa	DRC	3%	21%	0.1
	Angola	0.003%	11%	0.0003
	Tanzania	5%	8%	0.6

Table 5
Shares of forest area and forestry publications for selected countries, by region (three countries with the most forestry publications in each region).

Region	Country	% regional share of forestry publications	% regional share of forest area	Disparity ratio
	India	49%	64%	0.8
Central and Southern Asia	Iran	21%	9%	2.3
	Nepal	14%	5%	2.8
	China	47%	46%	1.0
Eastern and South-Eastern Asia	Japan	32%	5%	6.4
	Indonesia	12%	19%	0.6
	Germany	16%	1%	16.0
Europe	Sweden	11%	3%	3.7
	UK	11%	0.3%	36.7
	Brazil	70%	53%	1.3
Latin America and the Caribbean	Mexico	8%	7%	1.1
	Argentina	6%	3%	2.0
	Turkey	44%	39%	1.1
Northern Africa and Western Asia	Israel	11%	0.2%	55.0
	Algeria	6%	3%	2.0
	US	79%	47%	1.7
Northern America	Canada	25%	53%	0.5
	Greenland	0.005%	0.00003%	166.7
	Australia	81%	72%	1.1
Oceania	New Zealand	20%	5%	4.0
	Papua New Guinea	1%	19%	0.1
	South Africa	25%	3%	8.3
Sub-Saharan Africa	Ethiopia	13%	3%	4.3
	Kenya	10%	1%	10.0

responsible for most forestry publications in the region are South Africa (25%), Ethiopia (13%) and Kenya (10%) (Table 5). The shares of forest area for these countries are much smaller compared to their shares of forestry publications (8.3, 4.3, and 10.0 times smaller). In contrast the three countries with the largest forest areas in the region are the DRC (21%), Angola (11%) and Tanzania (8%) (Table 4). Their regional shares of forest area exceed the corresponding shares of forestry publications, with ratios of 0.1, 0.0003 and 0.6, respectively.

5.2. Collaboration capital

In this section, we look at the distribution of collaboration capital in global forest science as manifesting in co-authorship. On average, 66% of all forestry publications during the period involved only national collaborations, while 26% involved international collaborations (with or without concurrent national collaborations). A substantial percentage of forestry publications therefore have a national focus. Out of all eight regions, sub-Saharan Africa is the only region that produces >50% of its publications in collaboration with other regions (Table 6). Specifically, 41% of sub-Saharan articles are co-authored with Europe and 15% with Northern America. Three regions (Eastern and South-Eastern Asia, Europe, and Northern America) are most likely to appear as co-authors in forestry publications from other regions. For example, looking at the rows, Northern America collaborates with Central and Southern Asia in 10% of the latter's publications, with Eastern and South-Eastern Asia in 13% of its publications, and with Europe in 11% of its publications.

Forestry publications from the five countries that contribute most to the world's forest area tend to reflect mainly national collaboration (Brazil [75%], China [64%], Russia [59%], the US [53%] and Canada [50%]). This can be seen in Fig. 6, which shows the relationship between

Table 6
Extent of cross-regional co-authorship in forestry, 2000–2021.

Region	% of CSA publications co-authored with …	% of ESA publications co-authored with …	% of EUR publications co-authored with …	% of LAC publications co-authored with …	% of NA publications co-authored with …	% of NWA publications co-authored with …	% of OCE publications co-authored with …	% of SSA publications co-authored with …
CSA	--	2%	2%	0%	2%	2%	3%	3%
ESA	11%	--	7%	2%	11%	8%	15%	9%
EUR	19%	11%	--	18%	17%	30%	20%	41%
LAC	2%	1%	6%	--	8%	3%	7%	9%
NA	10%	13%	11%	15%	--	14%	17%	15%
NWA	1%	1%	1%	0%	1%	--	1%	1%
OCE	4%	4%	3%	3%	4%	3%	--	6%
SSA	3%	1%	4%	2%	2%	2%	4%	--
Any of the 7 regions	37%	26%	28%	32%	36%	49%	46%	59%

Note: Highlighted cells indicate cases of cross-regional co-authorship of 10% or more.

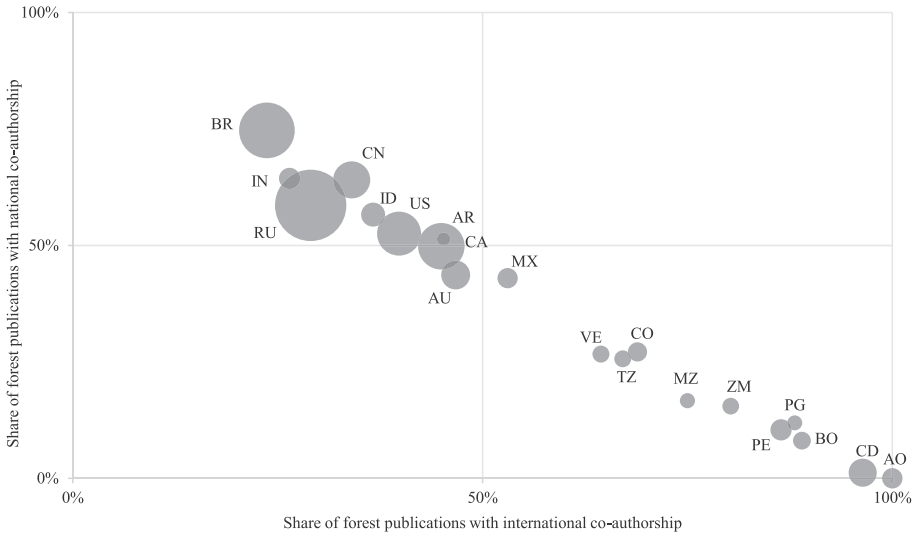

Fig. 6. Relationship between shares of national and international co-authored forestry publications for 20 countries with the largest forest areas.
AO (Angola), AR (Argentina), AU (Australia), BO (Bolivia), BR (Brazil), CA (Canada), CD (DRC), CN (China), CO (Colombia), ID (Indonesia), IN (India), MZ (Mozambique), MX (Mexico), PE (Peru), PG (Papua New Guinea), RU (Russia), TZ (Tanzania), US (United States), VE (Venezuela), ZM (Zambia).

the shares of national and international co-authored forestry publications for the 20 countries with the largest forest area in the world, and where the size of the bubbles corresponds to the actual forest area in hectares for each country. As for the other countries in Fig. 6, those with the highest levels of international collaboration (>50%) are also those with the smaller forest areas. Most of these countries are in the developing world. Angola (AO) and Zambia (ZM) are two such cases – with international collaboration rates of 100% and 75% respectively, and accounting for 1.6% and 1.1% of the world's forest area. The general pattern in Fig. 6 suggests that developing countries, even if they are among the 20 countries with the largest forest area in the world, rely on international collaboration for their forestry research.

Fig. 7 illustrates the relationship between national and international collaboration capital, through a scatterplot of the world shares of national and international co-authorship for the 20 countries with the largest forest area in the world. Four countries – Canada, Brazil, China and the US – have a global share of both national and international co-authored articles above 5%. These four countries have, to some extent, more national and international collaboration capital than the other countries. Thus, forestry publications from each of these four countries have both national and international interest. For example, the US contributes 16.8% to the global pool of national co-authored publications in forestry and 32.1% to the global pool of international co-authored publications.

5.3. Funding capital

A total of 27,937 forestry publications mentioned a funder in their acknowledgements. Among the eight regions, Europe (41%), Northern America (39%), and Eastern and South-Eastern Asia (25%) were the most likely to do so. In contrast, sub-Saharan Africa (3%), Central and Southern Asia (2%) and Northern Africa and Western Asia (1%) were the least likely to mention a funder. Latin America and the Caribbean (13%) and Oceania (6%) fell somewhere in between in terms of funder mentions. However, it is not only the percentage of publications mentioning a funder that is relevant, but also the location of the funders mentioned and the extent of cross-regional funding. Table 7 provides this information.

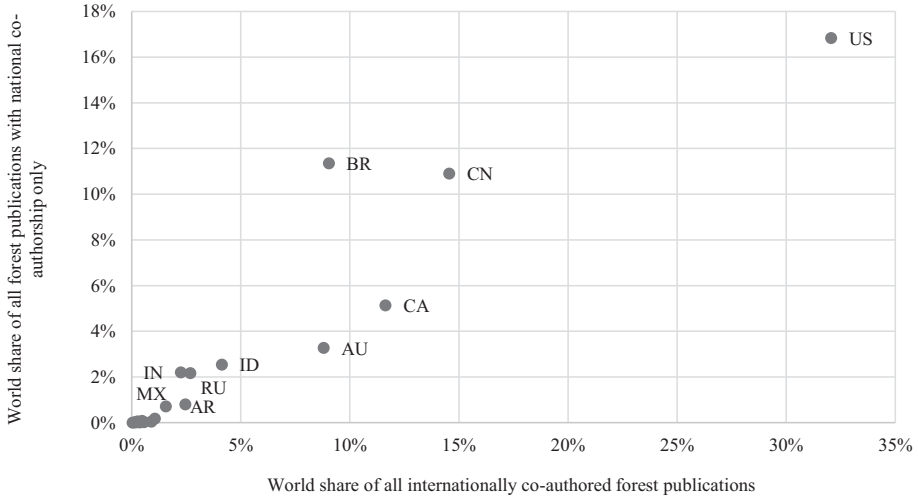

Fig. 7. Relationship between world share of nationally and internationally co-authored forest publications for 20 countries with largest forest areas.

Table 7
Extent of cross-regional funding in forestry, 2000–2021.

Region	% of CSA publications with funding mention by …	% of ESA publications with funding mention by …	% of EUR publications with funding mention by …	% of LAC publications with funding mention by …	% of NA publications with funding mention by …	% of NWA publications with funding mention by …	% of OCE publications with funding mention by …	% of SSA publications with funding mention by …
CSA	51%	0.2%	0.3%	0.1%	0.2%	1%	0.2%	2%
ESA	17%	87%	6%	1%	10%	12%	12%	9%
EUR	23%	10%	86%	20%	11%	46%	21%	69%
LAC	1%	1%	5%	74%	5%	3%	5%	5%
NA	13%	8%	10%	20%	82%	17%	17%	21%
NWA	0%	0.04%	0.2%	0.03%	0.2%	32%	0.1%	0.1%
OCE	3%	2%	1%	1%	1%	1%	60%	4%
SSA	0.2%	0%	0.03%	0%	0%	0%	0%	2%
Any of the 7 regions	53%	19%	22%	39%	26%	72%	48%	98%

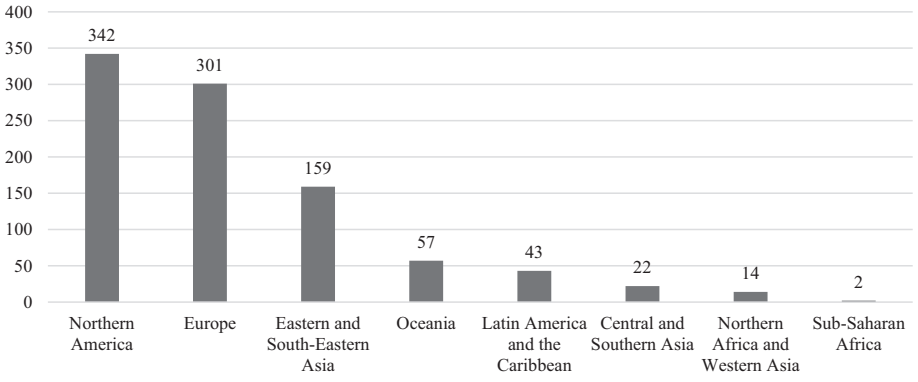

Fig. 8. Number of funding organisations in forestry, by region.

Except for sub-Saharan Africa and the Northern African and Western Asian region, the other regions overwhelmingly mentioned a funder from their own region. For example, in Table 7, only 26% of publications from Northern America, 22% from Europe, and 19% from Eastern and South-Eastern Asia, mentioned a funder from other regions. This suggests that these regions have a high level of internal funding, as a large percentage of their forestry publications mentioned funders from their own region. In sub-Saharan Africa, on the other hand, 98% of all

Table 8
Funding mention profile of 20 countries with the largest forest areas.

	Funding mentions			
	Number of forestry publications with funding mentions	Forestry publications with funding mentions as % of all forestry publications	Share of publications with national funding mentions	Share of publications with international funding mentions
Russia	380	19%	56%	61%
Brazil	2282	28%	85%	29%
Canada	2797	51%	74%	35%
United States	8550	50%	81%	29%
China	4259	47%	91%	17%
Australia	1461	37%	61%	47%
DRC	43	52%	0%	100%
Indonesia	333	14%	0%	100%
Peru	99	45%	0%	100%
India	412	23%	77%	28%
Angola	4	44%	0%	100%
Mexico	436	44%	71%	42%
Colombia	119	36%	24%	86%
Bolivia	78	57%	0%	100%
Venezuela	36	40%	25%	83%
Tanzania	41	27%	0%	100%
Zambia	20	28%	0%	100%
Mozambique	16	33%	0%	100%
Papa New Guinea	18	43%	0%	100%
Argentina	336	46%	68%	46%

publications with an acknowledgement of funding mentioned a funder from other regions, with only 2% mentioning a funder from their own region. Most funders mentioned in publications from sub-Saharan Africa were in Europe (69%). Europe, Northern America, and Eastern and South-Eastern Asia are also consistently acknowledged as funders in publications from other regions. For example, in addition to its funding mentions in publications from sub-Saharan Africa, Europe was mentioned as a funder in 23% of publications from Central and Southern Asia, 10% from Eastern and South-Eastern Asia, 20% from Latin America and the Caribbean, and 46% from Northern and Western Africa.

Fig. 8 shows the number of funding organisations in each region. Most funding organisations are in Northern America (342), closely followed by Europe (301), with Eastern and South-Eastern Asia also recording a good number of funders (159).

In four of the 20 countries with the largest forest area – Bolivia (57%), the DRC (52%), Canada (51%), and the US (50%), >50% of their forestry publications mention a funding source in the funding acknowledgement (Table 8). In the remaining 16 countries, less than half of their forestry publications mention funding. In terms of local and international funding, there is a notable trend: most publications with an acknowledgement of funding, especially those from the developing countries, mention a foreign funder. This could be related to international collaboration (see Fig. 6), as international partners are more likely to bring funding.

6. Discussion and conclusion

Against the background of a growing awareness of inequalities in forest science, our study set to answer the following question: Which geographical inequalities structure global forest science and how do they correspond to the natural geographical distribution of forest areas? In the light of the bibliometric results presented, a brief answer is as follows: global forest science is structured by geographical inequalities in terms of scientific, collaboration and funding capital, with a disparity between regions and countries endowed with high levels of capital and those endowed with natural forest resources. The specific form of inequality to which our results point at is a mismatch between forest research capital and forest research needs. In this final section, we discuss our results in more detail, highlighting aspects that have come to the fore due to the specific theoretical and methodological approach adopted.

One feature that distinguishes our analysis from previous bibliometric studies of forest science is its theoretical perspective. Drawing on Bourdieusian theory, we conceptualised bibliometric indicators – including research output, citations, collaboration and funding – as different types of capital and examined their geographical distribution in relation to their forest cover. The fact that there are specific sub-regions and countries – most notably Northern America and Europe, with countries such as the US or Germany – that lead in terms of these indicators is not surprising and confirms patterns found by previous studies focusing on specific sub-fields of forest science (e.g., Gao et al., 2022; Jankovský et al., 2021; Polinko and Coupland, 2021). Their dominance but also the rise of Eastern and South-Eastern Asia, including China, is not particularly specific to forest science but in line with spatial patterns and shifts in global science reflecting geopolitical and economic relations (Gui et al., 2019). However, our study shows the centrality of applying a relational perspective to understand persisting inequalities and their implications in the field of forest science.

Dominance in a scientific field is not based on the availability of one type of capital alone but must be understood as the manifestation of a complex interrelationship between different types of capitals. This is illustrated by the cases of Europe and Northern America in Table 9, which provides a comparative view of the indicators of capital for regions. These two regions have high shares of forest publications that are supported by exceptionally high shares of citations and internal funding capital. One could say that their 'performance' on the three indicators is

Table 9
Summary of bibliometric indicators of capital for regions.

Regions	Scientific capital 1 (products of knowledge)		Scientific capital 2 (acts of recognition)			Collaboration capital	Funding capital	
	World share of forest publications	Disparity ratio between world share of forest publications and world share of forests	World share of total citations of forest publications	Average number of citations per forest publication	Share of forest publications among top 10% most cited	Share of forest publications co-authored with other regions	Share of forest publications mentioning funding from own region	Share of forest publications mentioning funding from other regions
CSA	5%	1.7	3%	10.3	6%	37%	51%	53%
ESA	24%	2.0	17%	12.5	8%	26%	87%	19%
EUR	40%	1.6	47%	20.9	15%	28%	86%	22%
LAC	14%	0.6	13%	16.4	10%	32%	74%	39%
NA	27%	2.0	42%	27.5	19%	36%	82%	26%
NWA	2%	1.7	2%	14.9	8%	49%	32%	72%
OCE	6%	1.2	9%	27.2	18%	46%	60%	48%
SSA	4%	0.3	4%	17.7	12%	59%	2%	98%

Table 10
Summary of bibliometric indicators of capital for 20 countries.

Countries	Scientific capital 1 (products of knowledge)		Scientific capital 2 (acts of recognition)	Collaboration capital		Funding capital	
	World share of forest publications	Disparity ratio between world share of forest publications and world share of forests	World share of total citations of forest publications	World share of all forest publications with national co-authorship only	World share of all internationally co-authored forest publications	Share of forest publications mentioning funding from own country	Share of forest publications mentioning funding from other countries
AO	0.01%	0.0007	0.01%	0.0%	0.0%	0%	100%
AR	0.9%	1.3	1.5%	0.7%	1.6%	68%	46%
AU	4.9%	1.5	8.1%	3.3%	8.8%	61%	47%
BO	0.2%	0.1	0.6%	0.0%	0.6%	0%	100%
BR	9.9%	0.8	8.0%	11.3%	9.0%	85%	29%
CA	6.7%	0.8	10.2%	5.1%	11.6%	74%	35%
CN	11.1%	2.0	8.2%	10.9%	14.6%	91%	17%
CO	0.4%	0.3	0.7%	0.2%	1.1%	24%	86%
DRC	0.1%	0.03	0.2%	0.0%	0.4%	0%	100%
ID	2.9%	1.2	2.1%	2.5%	4.1%	0%	100%
IN	2.2%	1.3	1.5%	2.2%	2.3%	77%	28%
MX	1.2%	0.7	1.3%	0.8%	2.5%	71%	42%
MZ	0.1%	0.1	0.03%	0.0%	0.2%	0%	100%
PE	0.3%	0.2	0.6%	0.0%	0.9%	0%	100%
PG	0.1%	0.1	0.1%	0.0%	0.2%	0%	100%
RU	2.4%	0.1	1.4%	2.2%	2.7%	56%	61%
TZ	0.2%	0.2	0.3%	0.1%	0.5%	0%	100%
US	21.0%	2.7	35.0%	16.8%	32.1%	81%	29%
VE	0.1%	0.1	0.3%	0.0%	0.3%	25%	83%
ZM	0.1%	0.1	0.1%	0.0%	0.3%	0%	100%

well matched. Eastern and South-Eastern Asia, on the other hand, has similarly high shares in terms of output and internal funding, but receives significantly less capital in terms of citations as acts of recognition. While the Bourdieusian assumption that "capital breeds capital" seems to apply to the two dominant regions, explaining their continued centrality as loci of forest science, it does not seem to apply more generally.

At the other end of the spectrum in Table 9 is sub-Saharan Africa. Despite its low contribution to publications, it has comparatively high citation-related scientific capital, with a relatively high average citation score and share in the top 10% of most cited publications. Moreover, its high share of co-authored publications could be seen as a sign of collaboration capital and integration into global science. Looking at the bigger picture, however, we see that the region has significantly low levels of capital in the form of world share of total citations and internal funding. The high share of external funding cannot necessarily be seen as a positive asset, but also as a potential dependence, which is also reflected in the share of forest publications co-authored with other regions. Whether international collaboration is a form of capital that enhances a region's position and power needs to be assessed against other capital indicators, especially in relation to national collaboration and internal funding. Without the latter, it is questionable to what extent the type of science carried out reflects a region's research priorities.

Assumptions about dependence or independence in the interpretation of an indicator should therefore always be made with considerations of context in mind. Further insight into this can be gained from Table 10, which provides a comparative overview of capital indicators for the 20 countries with the largest forest area. The nine countries that reported only international funding are also the countries with low 'performance' on the other capital indicators. In this context, a specific form of funding capital, namely exclusive reliance on international funding, can be interpreted as an indication of both dependence and enablement – dependence because of the lack of any complementary internal funding, and enablement because external funding enables the countries in question to maintain a minimum level of publication output. Thus, from the perspective of developing countries in particular, international funding could be seen as an enabling form of capital.

This study also assumed that publications involving only national collaboration reflect research that addresses a local research need. The crux of this assumption is that the absence of international researchers in knowledge production leads to more attention being paid to a local research agenda and priorities. Clearly, this assumption requires further investigation, and the extent and context of its validity would need to be established through non-bibliometric methods, such as interviews with article authors in different settings. Empirical support for the assumption underlying the relevant indicator ("world share of all forest publications with national co-authorship only") would bring a theoretically informed bibliometric study such as ours closer to the study of epistemic inequality. Location and its relation to aspects of knowledge production is important given the growing trend towards geographically specific research in forest science (Polinko and Coupland, 2021).

However, as this study has focused on geographical inequalities in global forest science without looking at the knowledge that is mediated by the publications studied, we cannot assess epistemic inequalities at this stage. What is clear from this study, though, is a disparity in the distribution of capital and the distribution of forest area, which we interpret as a mismatch between the location of forest research and research needs. Again, this is a relational perspective: the inequality we wish to highlight here is one that relates the question of where/by whom forest science is produced, recognised and funded to where forests – as a common subject of concern in the field under study – exist. In contrast to studies that provide figures on general indicators such as publication output, citations or funding, we bring a spatial element into the picture, based on the premise that forest science is likely to be most needed in countries and regions endowed with forest cover. Our study shows strong discrepancies in this respect, as indicated by the different disparity ratios between the world shares of forest and the bibliometric indicators. Following studies by Ciarli and Ràfols (2019) and Kumar et al. (2023), we see here a mismatch between research foci and needs, which is particularly concerning when considering the importance of place and context in forest science.

As noted above, a major limitation of this study is its exclusive focus on the geographical distribution of capital in global forest science and the resulting inequalities, without examining how this shape the knowledge produced. While such an examination was beyond the scope of this paper, we see a need to bring these dimensions together and to trace if and how the question of where and by whom forest science is produced affects epistemic perspectives. Bourdieusian theory suggests

there is such a link, but an assessment can only be made based on empirical study.

Finally, the study used the Dimensions database as its primary source to investigate the extent of geographical inequalities in global forest research. However, it is important to acknowledge that inequalities may already be embedded in this data source, like in any other data source, as the scholarly literature reports substantial differences between data sources in terms of coverage, completeness, and accuracy (Visser et al., 2021), with some scholars recommending the inclusion of multiple data sources (Guerrero-Bote et al., 2021). To address this potential bias, a follow-up study should be conducted to explore how geographical inequalities manifest when more than one bibliometric data source is used.

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CRediT authorship contribution statement

Nelius Boshoff: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Similo Ngwenya:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Conceptualization. **Susanne Koch:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Funding acquisition, Conceptualization. **Jonathan Dudek:** Writing – review & editing, Visualization, Methodology, Formal analysis, Data curation, Conceptualization. **Olena Strelnyk:** Writing – review & editing, Writing – original draft. **Rodrigo Costas:** Writing – review & editing, Visualization, Methodology, Formal analysis, Data curation, Conceptualization. **Amani J. Uisso:** Writing – review & editing.

Declaration of competing interest

One of the authors (Susanne Koch) is a member of the Editorial Advisory Board of Forest Policy and Economics.

Data availability

The authors do not have permission to share data.

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