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Indigenous knowledge on climate change adaptation: a global evidence map of academic literature

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Abstract

There is emerging evidence of the important role of indigenous knowledge for climate change adaptation. The necessity to consider different knowledge systems in climate change research has been established in the fifth assessment report (AR5) of the Intergovernmental Panel on Climate Change (IPCC). However, gaps in author expertise and inconsistent assessment by the IPCC lead to a regionally heterogeneous and thematically generic coverage of the topic. We conducted a scoping review of peer-reviewed academic literature to support better integration of the existing and emerging research on indigenous knowledge in IPCC assessments. The research question underpinning this scoping review is: How is evidence of indigenous knowledge on climate change adaptation geographically and thematically distributed in the peer-reviewed academic literature? As the first systematic global evidence map of indigenous knowledge in the climate adaptation literature, the study provides an overview of the evidence of indigenous knowledge for adaptation across regions and categorises relevant concepts related to indigenous knowledge and their contexts in the climate change literature across disciplines. The results show knowledge clusters around tropical rural areas, subtropics, drylands, and adaptation through planning and practice and behavioural measures. Knowledge gaps include research in northern and central Africa, northern Asia, South America, Australia, urban areas, and adaptation through capacity building, as well as institutional and psychological adaptation. This review supports the assessment of indigenous knowledge in the IPCC AR6 and also provides a basis for follow-up research, e.g. bibliometric analysis, primary research of underrepresented regions, and review of grey literature.

1. Introduction

Adapting to climate change presents a major societal challenge, made all the more difficult by the uncertainty of future impacts and issues surrounding climate justice. Knowledge systems and practices of Indigenous peoples are recognised as a ‘major resource’ for climate change adaptation (Adger *et al* 2014), but they have not been used consistently in adaptation efforts and have often been neglected in policy and research (Adger *et al* 2014, Jones *et al* 2014, IPCC 2014b). In order to support an adequate engagement with the existing and emerging research on indigenous knowledge in the Intergovernmental

Panel on Climate Change (IPCC) assessments, this paper provides the first systematic global evidence map of peer-reviewed literature with evidence concerning indigenous knowledge on climate change adaptation, including a synthesis of geographic and thematic gaps and clusters.

The IPCC Special Report on Global Warming of 1.5 °C lays out the enormity of the challenge we face in limiting temperature rise to levels that are less dangerous to life (IPCC 2018b). Yet even if all parties to the Paris Agreement were to meet their Nationally Determined Contributions, global temperatures could still rise to over 3 °C above pre-industrial levels (UNEP 2019). The United Nations Conference of

Parties in 2021 (COP26) will be a sobering review of progress made and the steps needed to avert climate catastrophe. Even with future deep cuts to emissions, changes that have occurred and are occurring in the climate system will continue to impact human and natural systems, especially vulnerable and marginalised populations (IPCC 2018b). This means that effective adaptation to climate impacts will become increasingly important. Unfortunately, UNEP's adaptation gap report finds a growing gap between countries' preparedness for climate change and the actual measures needed to prepare communities for a future of increasing climate risks (UNEP 2018).

The higher the diversity of adaptation approaches in our repertoire, the greater our chances of finding responses that fit a particular situation. The value of diversity for decision-making has been long recognised in the literature on resource management (Berkes 2009, Norström *et al* 2020, van Bavel *et al* 2020). Likewise, in the IPCC's fifth assessment report (AR5), the utilisation of different forms of knowledge together with existing adaptation practices was recognised by both the climate research community and governments as not only increasing the effectiveness of adaptation (IPCC 2014b) but also critical for ethical and sustainable adaptation practices (Nakashima *et al* 2012, de Coninck *et al* 2018).

One such type of knowledge is indigenous knowledge. Indigenous knowledge refers to the understandings, skills and philosophies of Indigenous peoples, developed through long and multigenerational histories of interactions with the natural world and adapting to highly variable and changing ecological and social conditions including colonisation and globalisation (Adger *et al* 2014, UNESCO 2017). Despite the finding that indigenous knowledge has not been widely utilised in formal adaptation efforts by governments and has often been neglected in policy and research (Adger *et al* 2014, Jones *et al* 2014, IPCC 2014b), the AR5 does not explore the reasons for this omission. Despite this neglect, Indigenous peoples themselves have long recognised the importance of their knowledge systems for managing change (Ford *et al* 2020).

Various reasons have been proposed for this omission, including the positivistic framing of the IPCC, perceptions of indigenous knowledge as being of lesser value and legitimacy than knowledge deriving from dominant societies and cultures, and because some of the underlying belief systems and environmental ethics are at odds with capitalist economic systems. A further reason could be the accessibility of indigenous knowledge to scientists and policymakers involved in generating IPCC reports—how it is represented and discussed, and the associated lack of indigenous knowledge holders in IPCC assessment reports (Ford *et al* 2012b, 2016).

The literature dealing with indigenous knowledge and climate change adaptation in IPCC reports is heterogeneous and mostly generic (Ford *et al* 2016). This may contribute to the lack of consistency in its assessment to which the AR5 refers. The recent and ongoing IPCC special reports in the sixth assessment cycle acknowledge and highlight indigenous knowledge within their specific contexts (e.g. with a focus on Arctic communities, fishers, small islands, sustainable land management) (de Coninck *et al* 2018, Hurlbert *et al* 2019, Meredith *et al* 2019). Nonetheless, a consistent integration of the growing body of research on indigenous knowledge remains an important task for the upcoming AR6.

In response to this knowledge gap, we apply a systematic scoping review methodology to generate an evidence map that comprehensively engages with the existing and emerging research on indigenous knowledge. We seek to understand the geographical and thematic distribution of this research and ask the question: How is evidence of indigenous knowledge on climate change adaptation geographically and thematically distributed in the peer-reviewed literature? In examining this overarching question, we also investigate sub-questions, including:

- What is the typology of publications in which peer-reviewed papers are published?
- Which regions and populations are represented, and to what extent?
- How is indigenous knowledge defined and conceptualised?
- Which aspects of adaptation are included?
- Which attributes of indigenous knowledge are drawn upon, and for what purpose?
- In what way, if at all, is indigenous knowledge combined with scientific knowledge?

The evidence base for this topic is suitable for a scoping review since there is a growing range of literature available from various disciplines. Recent reviews relevant to the topic have a relatively narrower scope and/or specific thematic focus (see also Salick and Ross 2009), for example, on indigenous research methods (Drawson *et al* 2017), indigenous knowledge coupled with scientific knowledge (David-Chavez and Gavin 2018, Makondo and Thomas 2018), local knowledge (Reyes-Garcia *et al* 2016, Klenk *et al* 2017), specifically regarding mitigation (Brugnach *et al* 2017) or health (McDonald *et al* 2010), or focus on specific regions such as the Arctic (Ford and Pearce 2010, Ford *et al* 2012a). Most publications on indigenous knowledge deal with case studies or specific geographies, such as Arctic communities, aboriginal populations, pastoralists, and small island communities (Ford *et al* 2020).

While indigenous knowledge can be understood at its most basic as the knowledge of Indigenous

peoples, there is no single internationally accepted definition of Indigenous peoples, and indigenous groups are themselves heterogeneous. The AR5 Glossary identifies indigenous groups' common characteristics, such as: residence within or attachment to geographically distinct traditional habitats, ancestral territories, and their natural resources; maintenance of cultural and social identities, and social, economic, cultural and political institutions separate from mainstream or dominant societies and cultures; descent from population groups present in a given area, most frequently before modern states or territories were created and current borders defined; and self-identification as being part of a distinct indigenous cultural group, and the desire to preserve that cultural identity (IPCC 2014a). There are overlaps in meaning between indigenous knowledge and local, traditional and community knowledge (Nakashima *et al* 2012, Naess 2013). In the following section, we provide definitions for indigenous knowledge and Indigenous peoples, as used in this review.

The paper provides an updated and global review of the peer-reviewed literature on indigenous knowledge and climate change adaptation across disciplinary boundaries and geographies, and identifies knowledge clusters and gaps. As such, the review is targeted to support the IPCC assessment by presenting global evidence of indigenous knowledge on climate change adaptation, consistent with the aim and other papers in this Focus Issue. In so doing, we hope the review will support policymakers and practitioners in applying and engaging with indigenous knowledge to improve adaptation efforts.

2. Methods

For this scoping review, we build on the principles of the systematic map methodology (James *et al* 2016, Haddaway and Macura 2018) to describe the state of knowledge and map the available evidence of the role of indigenous knowledge for climate change adaptation in academic journal articles, book chapters, and conference papers. Scoping reviews are an established method for evidence synthesis, and are also increasingly applied in climate change adaptation research (Berrang-Ford *et al* 2015). The objective of scoping reviews is to provide a broad overview of the literature on a specific topic and identify patterns, trends, knowledge clusters, and gaps. In contrast to non-systematic approaches, their methodology for screening, selecting, and extracting data is transparent, allows for a highly comprehensive set of literature, creates the baseline for tracking progress on an identified gap, and aims at minimising researcher bias (James *et al* 2016). While a scoping review approach usually does not include a critical appraisal of individual studies' results and their impacts, it is 'particularly valuable for broad, multi-faceted questions' (James *et al* 2016), and provides the basis for in-depth

follow-up research on specific subsets of the identified evidence.

The methodology for this scoping review is explained in the following sections and with additional details in supplementary data 1 (available online at stacks.iop.org/ERL/15/113007/mmedia). The full dataset and results of the evidence map can be found in the evidence map database (see supplementary data 3).

2.1. Scoping

The scoping of the review is based on the coverage of indigenous knowledge in recent IPCC reports, including AR5 and SR1.5, as well as selected review articles with direct relevance to the research question (Nakashima *et al* 2012, Reyes-Garcia *et al* 2016, Brugnach *et al* 2017, Dawson *et al* 2017, David-Chavez and Gavin 2018). The scoping study lays the foundation for the development of the search strategy (see table 1) and definition of key terms (see table 2).

A pilot search in the Web of Science Core Collection gave 1689 results (search string: TOPIC: climate change OR global warming OR climate variability AND TOPIC: adaptation OR mitigation OR response AND TOPIC: indigenous knowledge OR traditional knowledge OR local knowledge), after which further search terms were added to the search string.

2.2. Searching and selecting publications

The topical search (title, abstract, and keywords) for this review was conducted in three databases: Web of Science Core Collection, Scopus, and CAB direct (see supplementary data 1, section 1 for the full search string). Additionally, we hand searched the IPCC WGII AR5 reference list for relevant publications on 'indigenous' issues. There was no time period limitation for the inclusion of publications. Monographs and grey literature were excluded, since they would compromise the systematic nature of a scoping review. Full texts for books are more difficult to retrieve, and they—similar to grey literature—usually have a very different structure compared to journal articles, book chapters, and conference papers, making it more difficult to systematically extract the actual empirical evidence on adaptation.

Related to the 'Population, Interest, Context' (PICo) framing that defines the key components of the research question and search strategy (see table 1), inclusion criteria were defined as publications that are:

- Studies to include indigenous knowledge system(s) (e.g. traditional ecological knowledge, native science) from indigenous community(ies) (see David-Chavez and Gavin 2018), either by self-definition or according to the working definition (see table 2)
- Explicit climate change adaptation context, i.e. dealing with human adaptation to climate-related

Table 1. ‘Population, Interest, Context’ (PICo) framing for this review.

Population (P)	Interest (I)	Context (Co)
Indigenous populations	Observed/documentated human adaptation responses to climate change	Any empirically documented climate change adaptation responses across the globe

Table 2. List of working definitions for key terms of this review.

Key term	Definition
Indigenous populations/ Indigenous peoples	‘Indigenous’ should be understood to reference a community of peoples sharing intergenerational ancestry and cultural aspects with original (pre-colonial) occupants of ancestral lands in a specific region of the world. Within this definition, membership to an Indigenous community should be understood as a sovereign right established both through self-determination and community acceptance (Anaya 2004).
Indigenous knowledge	Indigenous knowledge refers to the understandings, skills and philosophies developed by societies with long histories of interaction with their natural surroundings. For many Indigenous peoples, Indigenous knowledge informs decision-making about fundamental aspects of life, from day-to-day activities to longer term actions. This knowledge is integral to cultural complexes, which also encompass language, systems of classification, resource use practices, social interactions, values, ritual and spirituality. These distinctive ways of knowing are important facets of the world’s cultural diversity (UNESCO 2017).
Climate Change	Climate change refers to a change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use (IPCC 2018a).
Adaptation	The process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities (IPCC 2018a).

environmental changes (Berrang-Ford *et al* 2011). ‘Climate-related environmental research’ includes knowledge systems and biocultural relationships humans hold regarding long term weather patterns, their environmental impacts, and environmental adaptation in a particular place (see David-Chavez and Gavin 2018).

- Original field studies
- Published in English, French, German, or Spanish¹

Accordingly, papers not dealing with indigenous populations or climate change adaptation (e.g. focus only on impacts, only on perception of change, or mitigation, i.e. human interventions to reduce emissions or enhance the sinks of greenhouse gases (IPCC 2018a)), as well as review articles, discussion papers, or commentaries, are excluded. Studies are excluded if there is insufficient information on whether the population and their knowledge systems that are studied can be considered as ‘indigenous’ according to the working definition (see table 2).

The screening of the evidence was done in a two-step process, with double-screening, i.e. two reviewers

in parallel screening titles and abstracts and resolving conflicts. The full-text screening was done only by the principal reviewer. A full list of included literature and reasons for publications excluded at the full-text screening stage can be found in supplementary data 3. The screening was facilitated by using the web-based tool Covidence. Reviewers who have authored publications to be considered within this review have not been involved in inclusion decisions.

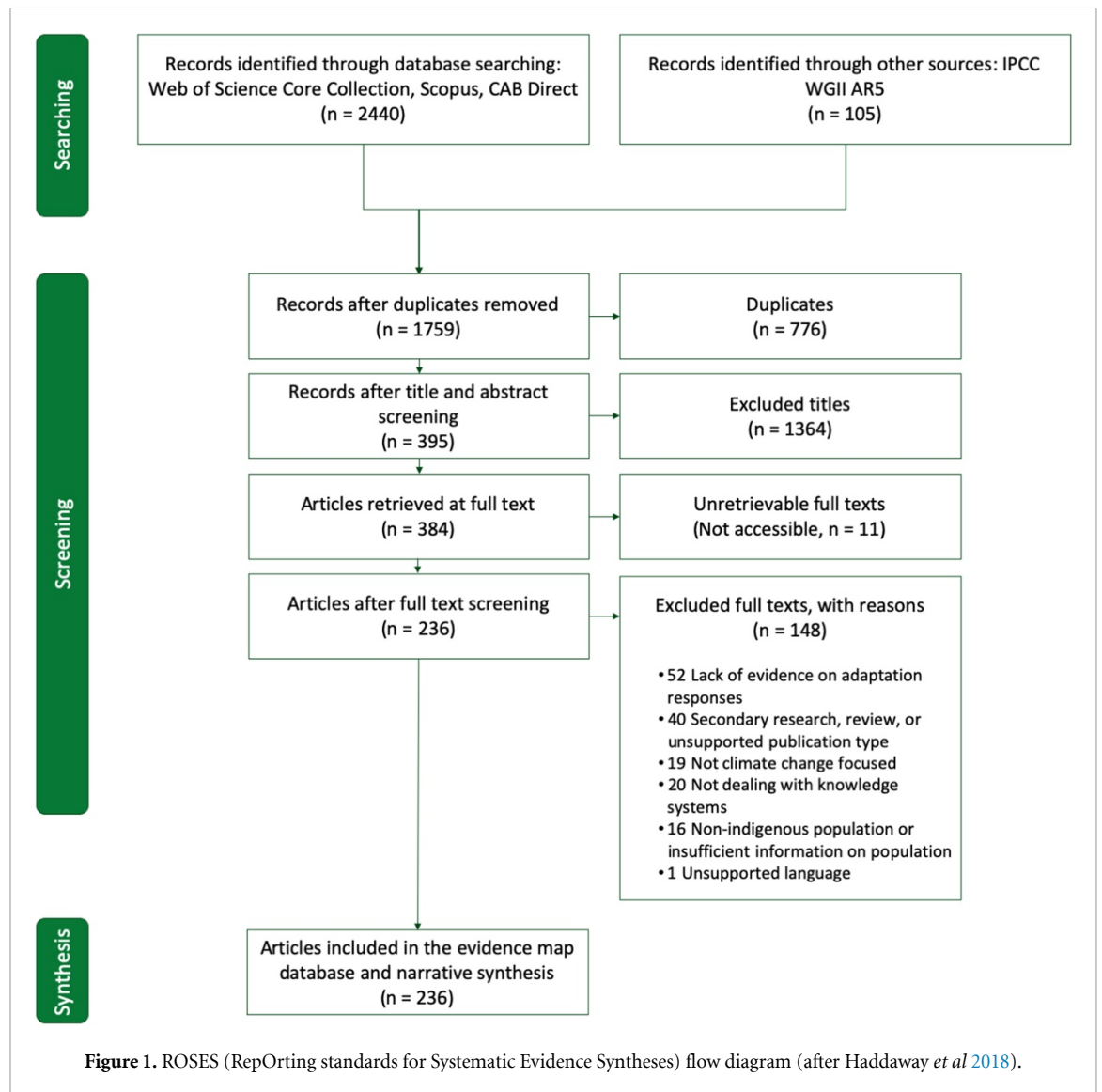
2.3. Coding and data extraction

The data extraction was done through coding the individual publications according to a set of subcategories on metadata, geographic, and thematic distribution. The individual codes for the geographic and thematic distributions build on concepts from climate change- and Indigenous people-specific literature (see supplementary data 1, section 2, for the full list of codes and labels). The coding and data extraction were done using the web-based tool SysRev.

2.4. IPCC AR5 review

We conducted an analysis of journal disciplines (according to the Essential Science Indicators by Web of Science) of all papers cited in the IPCC WGII Part A and B contribution to the fifth assessment report and listed in the ESI Web of Science in order to put the systematic literature review directly into context of the

¹According to researcher capacity at the search stage, only English keywords were used for the database search. However, it was possible to consider the limited number of French, German, and Spanish publications that were found through this search during the review stage.



IPCC assessment and compare the potential disciplinary bias (see supplementary data 2).

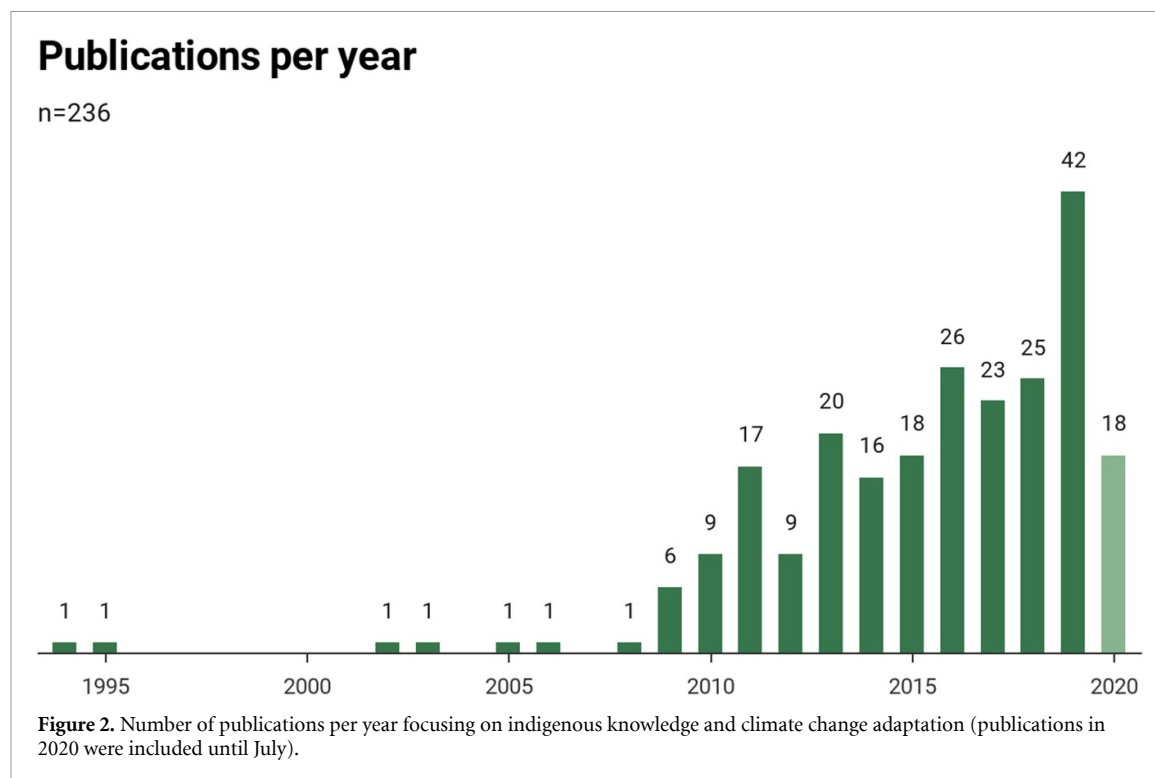
2.5. Limitations

Being a scoping review with the aim of broadly describing the evidence base, the paper has a number of limitations. Many of these limitations reflect our global focus and the associated trade-off of depth vs breadth, and inevitably we will not have captured all the relevant literature; this underscores the importance of future research to explore the findings in greater detail for specific regions and populations. Due to our focus on evidence of indigenous knowledge on climate change adaptation, we explicitly excluded studies on mitigation. Moreover, we excluded studies dealing only with the perception of climate or climatic change with no reference to adaptation. Regarding methods, more search terms identified at advanced stages of the review, such as ‘indigenous science’ or ‘ethnoscience’ could have produced more results. Due to researcher capacity and time constraints, we focused the coding on

key indicators of interest for geographic and thematic distribution. Additional codes such as on landscape type and research methods would give more detailed information on the case studies and research background. Furthermore, the evidence base of our evidence map is limited due to the exclusion of further databases, monographs, grey literature, and publications in other languages than English, French, German, or Spanish. For this scoping review, we did not include a separate validity and consistency check during the stage of coding and data extraction. However, this is a step that is more important for full systematic reviews that include a critical appraisal of study results.

3. Results

After the database search, title and abstract screening, and full-text screening, 236 publications were considered for review (see figure 1) and included in the evidence map database (see supplementary data 2 for the full list of publications included in the review, and



supplementary data 3 for the evidence map database, including all results and codes for the review analysis).

3.1. Typology of publications

Of the 236 publications reviewed, 210 are published in academic journals, 21 as chapters in edited books, and five as conference papers. The earliest publication was published in 1994. However, most publications were published between 2010 and 2020, with between 9 and 42 publications per year (see figure 2).

Journals with the highest number of publications are the *Indian Journal of Traditional Knowledge* (14 publications), *Climatic Change* (12), *Jamba-Journal of Disaster Risk Studies* (9), and *Climate and Development* (8). The *Indian Journal of Traditional Knowledge* (IJTK) is a relevant journal for topics regarding indigenous knowledge, and besides focusing on Asian studies, also covers case studies from other continents. In fact, four of the 14 publications published in the IJTK are about African case studies (Ethiopia, Zimbabwe, and two in Uganda). However, the IPCC WGII AR5 includes only references to four publications from this journal.

The journal discipline (according to the Scimago Journal & Country Rank database; see figure 3) most frequently represented is environmental sciences (133 publications), followed by social sciences (97), earth and planetary sciences (50), agricultural and biological sciences (36), medicine (22), and health professions (14). However, within these broad categories, multiple disciplines per journal are possible. Among edited books, the book series *Climate Change Management* is most represented (five chapters).

The top 10 keywords (excluding ‘climate change’, ‘knowledge’, ‘indigenous knowledge’, ‘traditional knowledge’, ‘traditional ecological knowledge’, ‘adaptation’, ‘climate change adaptation’) for the publications that included them are (see figure 4): Vulnerability (37), Resilience (35), Adaptive Capacity (18), Agriculture (17), Drought (16), Food Security (15), Management (15), Perception (13), Impact (13), and Community (13).

3.2. Geographic distribution

Most publications focussed on African case studies (92), followed by Asia (75) and North America (26). Some countries dominate the case studies within their respective region, such as Zimbabwe (17) and Kenya (12) in Africa, and India (23 publications, which is the highest number of publications of a single country), Nepal (11), and Bangladesh (10) in Asia. The North American case studies are mainly located in Canada (17 publications) (see figure 5).

Overall, most studies are located in tropical climates (92), followed by temperate (78), dry (47), continental (29), and polar climates (10) (after Köppen-Geiger climate classification; see figure 6). Going into more detail, the most common climate zones are ‘Aw: Tropical savanna climate with dry-winter characteristics’ (53), ‘Cwb: Dry-winter subtropical highland climate’ (37), and ‘Cwa: Dry-winter humid subtropical climate’ (30).

The vast majority of publications includes studies in rural settings (193), followed by ambiguous settlement forms (32), i.e. those that could be considered to be either rural or urban (see Satterthwaite 2016), six publications with rural and urban settlements, and

Publications per discipline

n=236

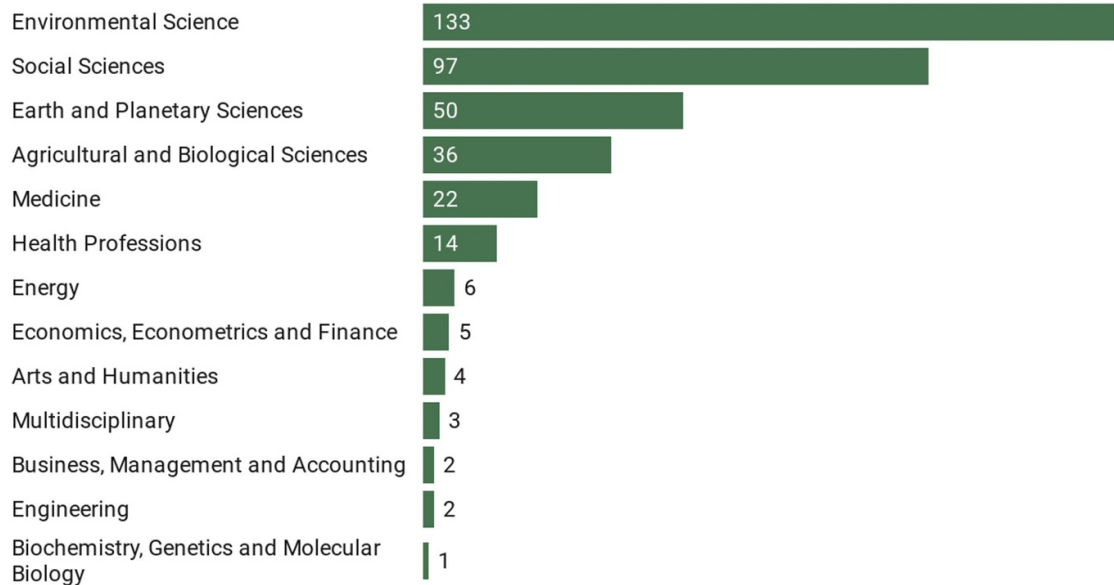


Figure 3. Distribution of publications per disciplines (according to journal disciplines as listed in the Scimago Journal & Country Rank database).



Figure 4. Wordcloud of author keywords (excluding 'climate change', 'knowledge', 'indigenous knowledge', 'traditional knowledge', 'traditional ecological knowledge', 'adaptation', 'climate change adaptation'; produced with www.wordart.com). Top ten keywords in green.

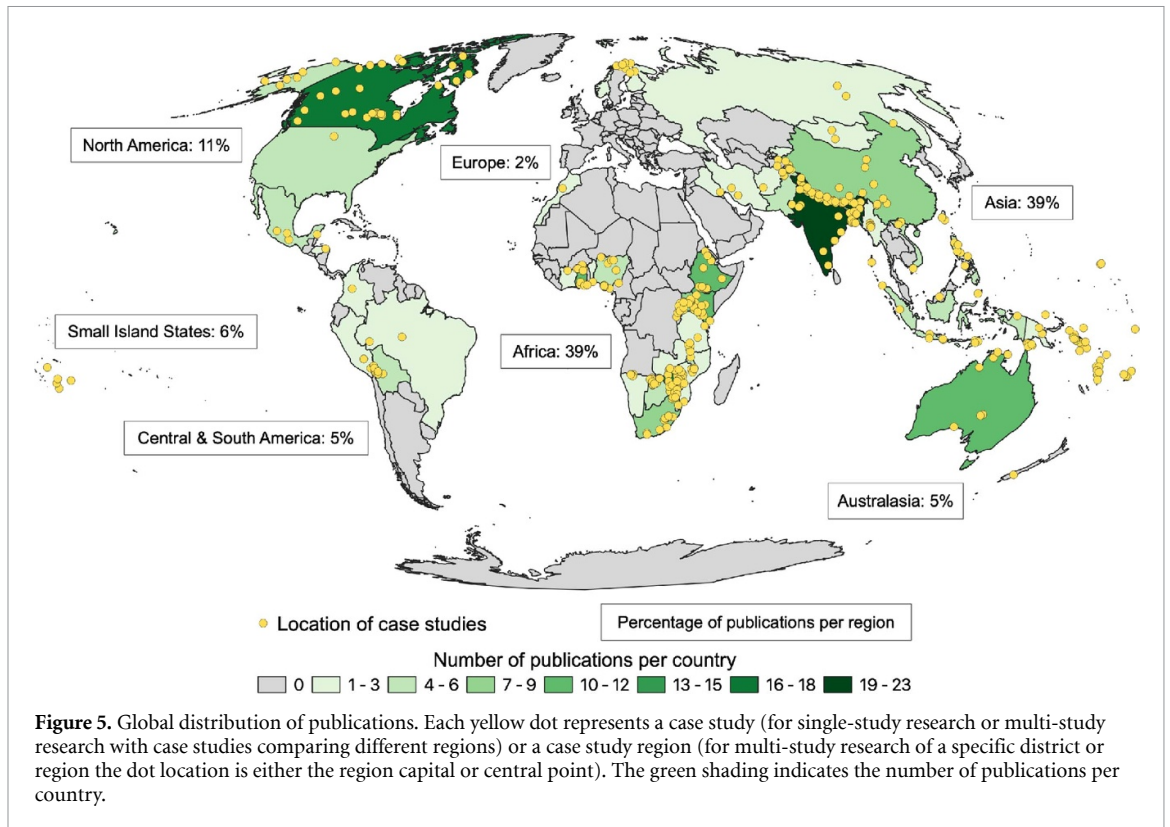
five with only urban case studies (see figure 7). The urban case studies are located in sub-Saharan Africa (Ghana, Namibia, Ivory Coast, Zambia), Asia (India, Philippines, Iran, Myanmar, Vietnam), and one in a Small Island State (Fiji).

The publications referred to Indigenous peoples in a variety of ways. The majority of publications did not provide the name of the Indigenous peoples that were involved in the field study, but

referred to them by their type of livelihood or made generic references such as islander or villager (see figure 8).

3.3. Concepts used

First, we looked at terminology and definitions of indigenous knowledge. As noted earlier, the distinction between indigenous knowledge and other forms of knowledge such as local or traditional knowledge is



Climate groups

n=236

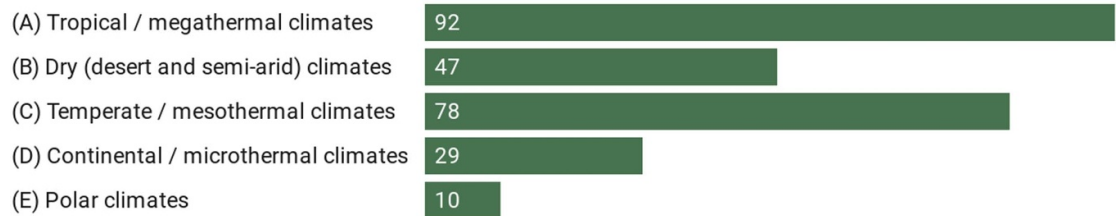


Figure 6. Distribution of publications across climate groups (after Köppen–Geiger climate classification).

Type of settlement

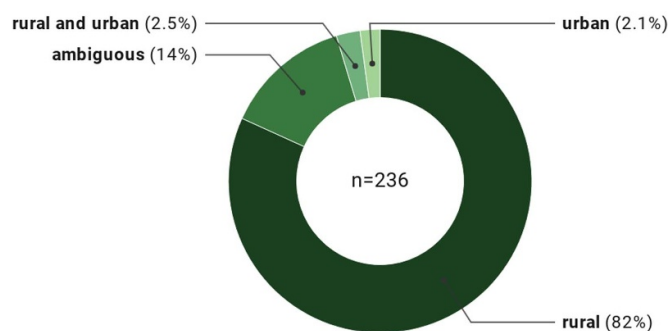


Figure 7. Number of publications per type of settlement (after Satterthwaite 2016).

Indigenous people

n=236



Figure 8. Number of publications per Indigenous peoples. Note that ‘Named Indigenous peoples’ may also include one of the other types, e.g. pastoralists or islanders.

Terms and concepts

n=236



Figure 9. Number of publications per terms and concepts for indigenous knowledge used in publications.

not always clear (Nakashima *et al* 2012). The publications included in this review also use a range of terms and concepts to describe indigenous knowledge. The most commonly used term is indigenous knowledge (151 publications). However, the terms or concepts of traditional knowledge (68), local knowledge (48), and traditional ecological knowledge (39) are also used in many of the publications dealing with Indigenous peoples and their knowledge systems. In some cases, different concepts are used in the same paper, e.g. traditional knowledge and indigenous knowledge (e.g. Negi *et al* 2017), or indigenous knowledge and local knowledge (e.g. Kpadonou *et al* 2012). Moreover, other concepts such as Inuit knowledge (Ford *et al* 2006), aboriginal knowledge (Newton 1995), traditional environmental knowledge (Janif *et al* 2016), indigenous technical knowledge (Rautela 2005), ethnoscience (Jerie and Matanga 2011), or local wisdom (Sulistiyawati *et al* 2017) were also used—these are included in the category ‘Other’ because they are less widely used in the literature and/or are regionally specific, in contrast to the more commonly used terms (see figure 9). More than half of the publications (119) do not provide definitions of indigenous knowledge or any of the other concepts used.

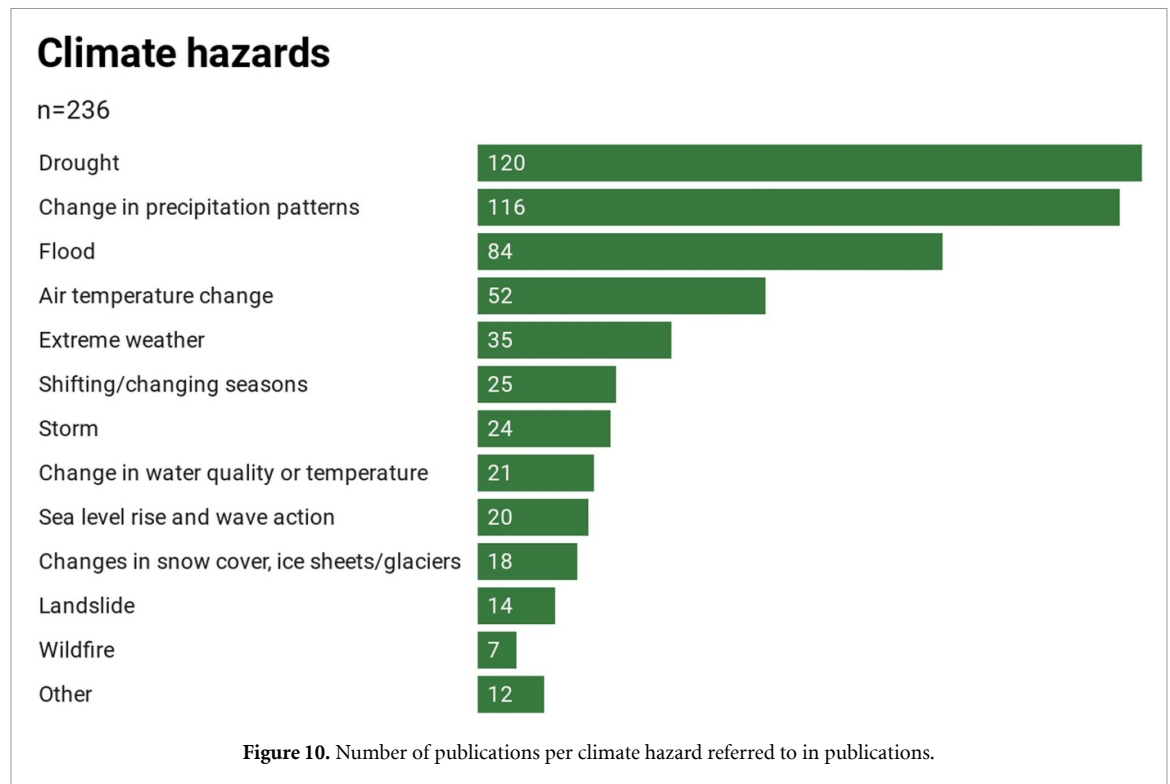
Next, we considered in what way indigenous knowledge was combined, if at all, with scientific knowledge. Most studies (120) focus only on the role

of indigenous knowledge for climate change adaptation. However, many studies (116) also analysed indigenous knowledge in combination with scientific knowledge for adaptation, among other purposes, for the improvement of weather forecasting (e.g. Kalanda-Joshua *et al* 2011), warning systems (e.g. Paul and Routray 2013) and of farming/land management (e.g. Newsham and Thomas 2011).

3.4. Indigenous knowledge and adaptation

Adaptation refers to the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities (IPCC 2018a). The publications included in this review cover adaptation to a range of climate impacts or hazards. More than half of the publications refer to drought (120), followed by precipitation change (116), flood (84) and air temperature change (52) (see figure 10).

Practice and behavioural responses are the most common type of adaptation documented. They are considered in 166 publications (representing more than two-thirds of the publications) and involve, for example, land management techniques, climate-resilient crops or livestock practices, and mobility/migration. The next type of adaptation is management and planning (109), followed by warning and observation systems (54) and physical infrastructure



(47) (see table 3). The analysis of types of adaptation per region shows that practice and behavioural adaptation is the most common type across regions except Australasia and Small Island States, where management and planning is more often referred to in the reviewed studies (figure 11).

Finally, we looked at different attributes of indigenous knowledge that were drawn upon in the studies. The most common attribute mentioned is the factual knowledge about the environment and environmental changes (170), followed by factual knowledge about the use of the environment (143). However, governance and social capital (61), and cultural values and worldviews (61) also played a role in many studies (see table 4). The analysis of attributes of indigenous knowledge drawn on for adaptation per region shows that factual knowledge about the environment and environmental changes is mostly (in relative terms) referred to in African and North American studies, and factual knowledge about the use of the environment especially mostly in Asian and Central & South American studies. Cultural values and worldviews are relatively most prominent in Australasian studies and governance and social capital particularly in studies from Small Island States (figure 12).

4. Discussion

The aim of this evidence map was to analyse the geographic and thematic distribution of evidence of indigenous knowledge on climate change adaptation in the peer-reviewed literature to support ongoing

and future assessments and research on this topic. This analysis includes the type of publications and disciplinary background, usage of specific concepts for dealing with indigenous knowledge and its various attributes, and an overview of different types of adaptation.

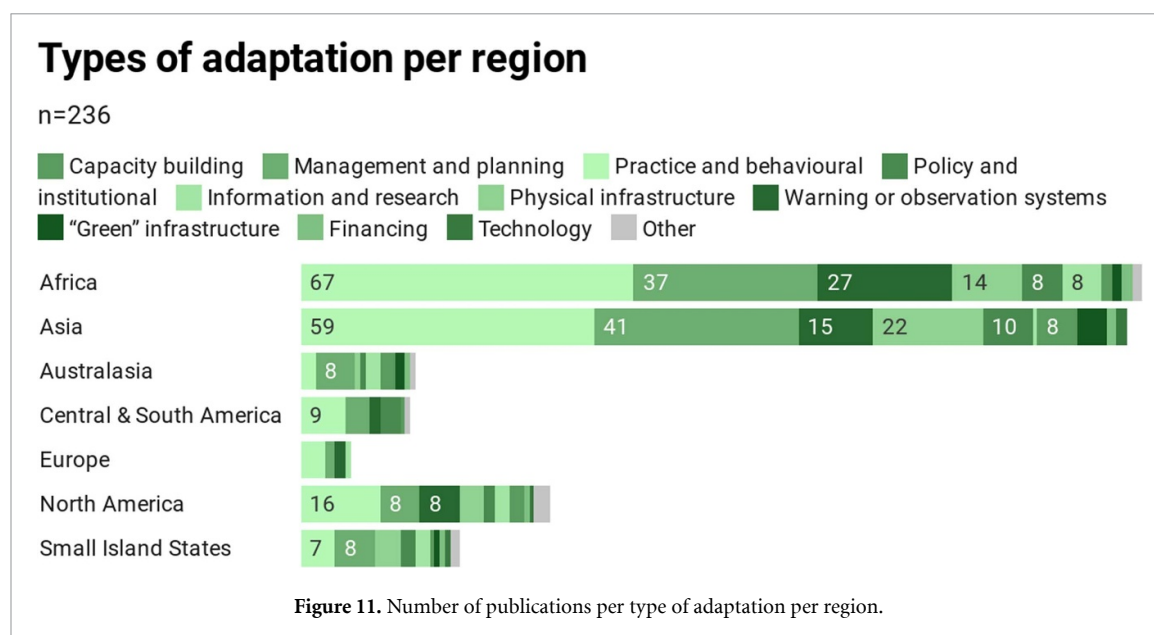
4.1. Typology of publications

The analysis indicates that the number of published original peer-reviewed research articles on indigenous knowledge and climate change adaptation has been growing over time. The typology of publications by journal discipline by Scimago Journal & Country Rank (SJR) shows a predominance of publications in environmental science (35%) and social sciences (26%) journals, followed by earth and planetary sciences (13%) and agricultural and biological sciences (10%).

This distribution across journal categories can be compared with the distribution of articles on climate change adaptation more generally. The analysis of journal disciplines (according to the Essential Science Indicators by Web of Science) of all papers cited in the IPCC WGII Part A and B contribution to the fifth assessment report (see supplementary data 2) shows a similar pattern. Here too, environmental sciences (29%) and social sciences dominate (23%), followed by geosciences (20%). Plant and animal science with agricultural sciences and biology & biochemistry form a fourth category (12%) that is comparable to the SJR category of agricultural and biological sciences. This comparison confirms a disciplinary bias towards environmental and social sciences and

Table 3. Overview of types of adaptation and examples from the reviewed literature.

Type of adaptation	Number of publications	Example
Practice and behavioural	166	Traditional farming techniques (e.g. Swe <i>et al</i> 2015); livestock practices (e.g. Rybråten and Hovelsrud 2010); mobility/migration (e.g. Morrison 2017; Rasmussen <i>et al</i> 2009)
Management and planning	109	Livelihood diversification (e.g. Ayeri <i>et al</i> 2012); management of grazing land (e.g. Singh <i>et al</i> 2018)
Warning or observation systems	54	Weather and climate forecasting systems (e.g. Balehegn <i>et al</i> 2019); drought forecasting (e.g. Chisadza <i>et al</i> 2013); cyclone forecasting (e.g. Paul and Routray 2010)
Physical infrastructure	47	Climate-resilient buildings (e.g. Mercer <i>et al</i> 2012); traditional temporary flood protection (e.g. Chowdhoree 2019)
Policy and institutional	28	Local institutions, rules and support schemes, food sharing (e.g. Mavhura 2017; Pearce <i>et al</i> 2010)
Information and research	19	Dissemination and communication of climate information (e.g. Chambers <i>et al</i> 2019; Gichangi <i>et al</i> 2015)
Capacity building	18	Knowledge sharing networks (e.g. McNamara and Westoby 2011)
'Green' infrastructure	11	Local plants for flood protection (e.g. Paul and Routray 2010); Revegetation of abandoned land (e.g. Tiwari and Joshi 2013)
Financing	7	Farm loans through microfinancing (e.g. Ebhuoma and Simatele 2017)
Technology	4	Technologies to improve water use (e.g. Paul and Routray 2010)
Other	9	Influencing weather through will and faith (e.g. Boillat and Berkes 2013)



relatively little attention paid to indigenous knowledge in the agricultural and biological sciences.

4.2. Geographic distribution

The representation of Indigenous peoples and their knowledge in climate change adaptation literature has implications for justice, as well as for the effectiveness of adaptation efforts.

By region, we have shown that a large proportion of the publications are African and Asian studies and that India, Zimbabwe, and Canada dominate by country, and accordingly tropical and subtropical

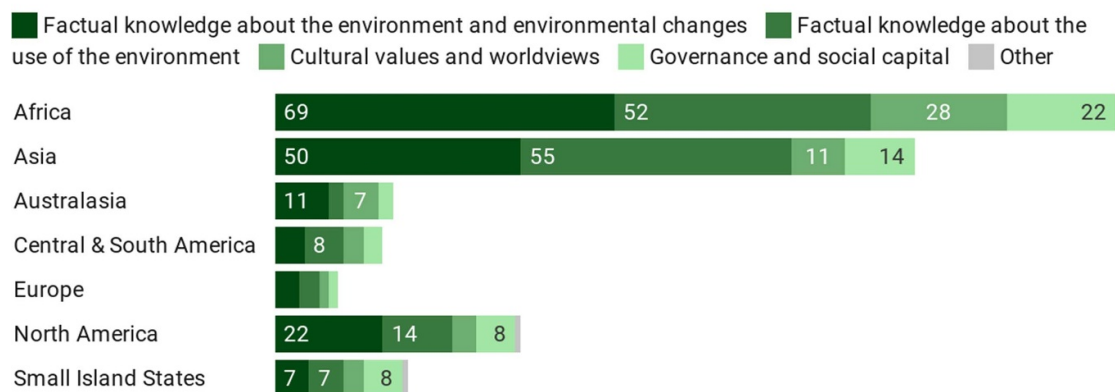
by climate zones. It is difficult to assess how representative this coverage is of Indigenous peoples across the world, for two main reasons. Firstly, as we have demonstrated, in many publications, the Indigenous peoples that were part of the research are not named. Secondly, there is no accepted list of all the Indigenous peoples worldwide. However, a comparison of our results (see figure 5) to the overview of Indigenous peoples by the International Work Group for Indigenous Affairs (IWGIA 2019) and the spatial analysis of indigenous lands worldwide by Garnett *et al* (2018) suggests some geographical gaps: in northern and

Table 4. Overview of attributes of indigenous knowledge drawn on for adaptation and examples from the reviewed literature.

Attributes of indigenous knowledge	Number of publications	Example
Factual knowledge about the environment and environmental changes	170	Observations of regional precipitation changes (e.g. Fassnacht <i>et al</i> 2018); changes in ice thickness (e.g. Newton 1995); knowledge of cloud and wind patterns, response of plants to temperature change (e.g. Belle <i>et al</i> 2017)
Factual knowledge about the use of the environment	143	Use of local material for flood/storm protection (e.g. Rasmussen <i>et al</i> 2009; Hazarika <i>et al</i> 2016); traditional crops and cropping mixes (e.g. Rankoana 2016)
Cultural values and worldviews	61	Relationship to land and stewardship (e.g. Golden <i>et al</i> 2015); values of reciprocity, collectiveness, equilibrium, and solidarity (e.g. Walshe and Argumedo 2016)
Governance and social capital	61	Food sharing networks (e.g. Bridges and McClatchey 2009); social networks and informal safety nets (e.g. Mavhura 2017)
Other	2	Traditional clothing (Giles <i>et al</i> 2013) and housing (Fujieda and Kobayashi 2013)

Attributes of indigenous knowledge per region

n=236

**Figure 12.** Number of publications per attributes of indigenous knowledge per region drawn on for climate change adaptation.

central Africa, northern Asia, Greenland, Australia, parts of South America and Polynesia. These findings confirm the patterns of distribution of evidence in similar systematic review approaches, e.g. with respect to clusters in the North American Arctic (Ford *et al* 2015), Sub-Saharan East Africa and the Tibetan Plateau (David-Chavez and Gavin 2018) and limited evidence from Greenland (Ford *et al* 2014, Canosa *et al* 2020).

It is also noteworthy that Indigenous people living in urban environments are hardly represented in the adaptation literature—only 11 publications include urban case studies. The few publications including urban case studies are all mainly located in Africa and Asia (in addition to one in Fiji). Hence, none of the Australasian, South or North American publications deal with adaptation of indigenous communities in cities, despite a large and growing number of indigenous populations living in urban areas (Minority Rights Group International 2015, IPMG 2019).

4.3. Conceptual approaches

We included a range of search terms relating to indigenous knowledge and found that multiple terms are often used in the same paper, for example indigenous, traditional and local knowledge, and that these terms appear to be used interchangeably. This reflects the approach in IPCC reports, where a clear distinction between these different forms of knowledge is avoided (e.g. Field *et al* 2014). Determining what the authors actually mean by the terms they use is more difficult because most (119 publications) do not provide definitions, highlighting a need for authors to more clearly define what they mean by the terms they use.

More than half of the publications examine indigenous knowledge only, rather than exploring how indigenous knowledge is being integrated with scientific knowledge, or comparing research findings about indigenous knowledge with scientific knowledge. Given the findings of the AR5 that indigenous knowledge tends to be neglected or inconsistently applied in adaptation efforts and that

integrating such forms of knowledge with existing practises increases the effectiveness of adaptation, studies that already integrate indigenous knowledge with scientific knowledge may be most helpful in promoting and supporting effective use of indigenous knowledge in policy and practice. This is because integrating different knowledge systems, with differing rules of production, acquisition and shareability as well as different ontologies, poses considerable conceptual challenges (Brugnach *et al* 2017).

There are inherent ethical sensitivities and power imbalances in collecting and using indigenous knowledge data in mainstream research contexts (e.g. see IPHRC 2004, Burnette and Billiot 2015; Briggs 2016). To further the agenda of decolonizing research, it would therefore be useful if publications were explicit about the extent and nature of involvement of Indigenous peoples in the research process. This includes the production of new integrated knowledge as presented in the published articles, and whether a knowledge-sharing process had been agreed (Brugnach *et al* 2017, Dawson *et al* 2017, David-Chavez and Gavin 2018). The vast majority of climate studies using indigenous knowledge have been found to use an extractive model (David-Chavez and Gavin 2018). As the number of publications grows, lack of reflexive research practices that consider how research processes can be decolonized is an issue that must be addressed by climate researchers, academic journals, and research institutions. ‘Co-production of knowledge’ is considered as crucial for understanding the complex challenges social-ecological systems face under climate change and addressing these challenges in a way that serves those who are affected (Norström *et al* 2020). David-Chavez and Gavin (2018), therefore, argue that journals and funding agencies could improve research standards by requiring reporting on responsible engagement and providing incentives for knowledge co-production in climate adaptation research projects (see also Dilling and Lemos 2011).

4.4. Thematic distribution

The keyword analysis showed that agriculture, drought and food security were top themes, along with perceptions and management. Around half of the publications dealt with drought and precipitation change, more than two thirds with practice and behavioural adaptation and just under half with adaptation management and planning. Only very few publications explicitly focused on health concerns (4), one of these on mental health, one on ethnomedicine, and none focussed on psychological adjustment to climate impacts, for example, emotion regulation. Eco-anxiety and mental wellbeing more generally are starting to receive more media attention though it is still an area that is under-researched in climate science (see Nature Climate Change special issue on mental health, 2018, issue 8).

With regards to the attributes of indigenous knowledge, most studies draw upon factual knowledge—about the natural environment and how it is changing, and about the use and management of the natural environment. Factual knowledge is embedded in worldviews and can emerge from the cultural practices of particular Indigenous peoples and communities (Brugnach *et al* 2017, David-Chavez and Gavin 2018), but these attributes of indigenous knowledge feature less often in the reviewed publications. This seeming imbalance of different attributes of indigenous knowledge considered in the literature warrants further investigation, given the history and ongoing legacies of colonial subjugation, discrimination and suppression of Indigenous peoples and their cultures.

Of the 68 references included in this review published before 2013, which could have been included in AR5, only 21 (31%) were assessed in WGII AR5 Part A or B. With only one publication, respectively, especially Central & South America and urban studies are underrepresented in AR5. Looking at the 6566 references in Part A (‘Global and Sectoral Aspects’), 105 references (1.6%) are about indigenous issues. Of these, 18 publications are original research articles specifically about observed adaptation (and therefore also included in this evidence map) (see supplementary data 2). Hence, future reports, including the AR6, could draw upon a wider and more diverse body of literature, especially with respect to the existing adaptation-focussed evidence in the peer-review literature. Ford *et al* (2016) suggest that a more representative and meaningful assessment of this body of literature could be facilitated by creating a dedicated space in IPCC reporting on this topic, e.g. across chapters, in a specific chapter or even special report, as well as the engagement of indigenous knowledge holders and more scholars with expertise on indigenous knowledge as lead authors.

4.5. Critical reflection

The results presented here have limitations in terms of scope and depth, since only existing journal articles have been examined. Therefore, we do not claim to provide a comprehensive assessment of *all* of the available evidence, since research with indigenous communities on adaptation matters are also documented in other formats, such as books and non-peer-reviewed (grey) literature. Nonetheless, systematically mapping the literature in this format has value, because many assessments (such as the IPCC) and research projects build on the body of literature in formal academic publishing. The scoping review methodology also does not allow for an assessment of the quality of evidence in individual publications or the validity of their results. These steps are usually included as part of the critical appraisal in systematic reviews that have a narrower scope and research question.

5. Conclusions

The evidence map provided by this scoping review contributes a variety of outcomes that can support the assessment of indigenous knowledge in the IPCC AR6 and potentially also other future assessments (e.g. IPBES) and institutional programmes (e.g. UNESCO). We provide a systematic and transparent overview of the growing number of academic publications over time and the evidence of indigenous knowledge on adaptation across regions, including a categorisation of the most relevant concepts related to indigenous knowledge and their contexts used in the climate change literature, across disciplines.

The evidence map allows us to identify the strongest clusters in the existing academic literature on indigenous knowledge and climate change adaptation. Geographically, these were: rural areas in the tropics, subtropics, and drylands, especially East and Southeast Africa and the Himalaya. Thematically, there was an emphasis on drought or precipitation change. The strongest forms of adaptation represented in the literature were practice and behavioural measures, followed by planning and management. Gaps in the academic literature that warrant further primary research include research in northern and central Africa, northern Asia, South America, Australia, and Greenland. Urban areas were also underrepresented. Nor did the literature strongly represent adaptation from the perspective of capacity building and institutional and psychological adaptation.

In highlighting knowledge clusters and gaps in academic publishing we wish to stress the need for two types of action. For researchers to look at other forms of publications, including grey literature and monographs, in further studies that aim at systematically reviewing these gaps and clusters, and for academic publishers to address gaps in their own journals by pro-actively encouraging other types of submissions.

Recommendations for further research include primary research with a focus on specific underrepresented regions. For a more in-depth coverage of existing research, we also suggest an evaluation of existing adaptation policies that attempt to integrate indigenous and scientific knowledge; and existing reports or evaluations of how indigenous communities can be empowered to meaningfully influence adaptation policy development and decision-making processes. Such reviews could be complemented by a systematic bibliometric analysis to uncover disciplinary and research bias. Future primary research with Indigenous peoples and about indigenous knowledge should engage with the decolonization agenda, in order to avoid an extractive approach to knowledge generation.

Finally, we see a need for international assessments such as the IPCC to consistently assess the

existing evidence across regions, acknowledge the diversity of types of adaptation, attributes of indigenous knowledge, and include research approaches with diverse conceptual backgrounds relevant to indigenous knowledge. Such an assessment of the evidence base laid out by this evidence map could be implemented, for example, across the sectoral and regional chapters in the WGII contribution to AR6.

Declarations

We declare that none of the authors has any financial or non-financial competing interests.

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Data availability statement

All data that support the findings of this study are included within the article (and any supplementary information files).

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