Climate Policy

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tcpo20

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To cite this article: Robbert Biesbroek, Sarah Judith Wright, Stefanie Korswagen Eguren, Anita Bonotto & Ioannis N. Athanasiadis (2022) Policy attention to climate change impacts, adaptation and vulnerability: a global assessment of National Communications (1994–2019), Climate Policy, 22:1, 97-111, DOI: 10.1080/14693062.2021.2018986

To link to this article: https://doi.org/10.1080/14693062.2021.2018986

CLIMATE POLICY
2022, VOL. 22, NO. 1, 97–111
https://doi.org/10.1080/14693062.2021.2018986

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RESEARCH ARTICLE

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Policy attention to climate change impacts, adaptation and vulnerability: a global assessment of National Communications (1994–2019)

Robbert Biesbroek [a], Sarah Judith Wright [a], Stefanie Korswagen Eguren [a], Anita Bonotto[a] and Ioannis N. Athanasiadis [b]

[a]Public Administration and Policy group, Wageningen University & Research, Wageningen, The Netherlands; [b]Geo-Information Science and Remote Sensing Laboratory, Wageningen University & Research, Wageningen, The Netherlands

ABSTRACT

Over the past 30 years countries across the globe have developed and implemented policies and measures on climate change impacts, adaptation, and vulnerability (IAV). This paper empirically explores whether and how policy attention around climate change IAV has shifted over time and across regions. We use structural topic modelling to analyse the main themes and regional differences reported by 196 countries in their UNFCCC National Communications over the period 1994–2019. Based on 612 documents, we find impact topics dominate policy attention (>50% of the topics), but this has decreased in recent periods. Attention to the topic on governance, adaptation, and vulnerability have increased over time and across all regions. We observe a more homogeneous spread of topics in recent time periods, and large differences across topic proportions across 6 regions. Results further suggest that the different IAV topic distributions between Annex I and non-Annex I countries continue to persist. Our findings and approach can help to gain a clearer picture of how policy attention to IAV is evolving globally.

Key policy insights:

- Policy attention in National Communications to adaptation has slowly increased but remained stable since 2013.
- Asia and Africa have paid more attention to adaptation compared to Europe and North America where focus on impacts dominates.
- Compared to earlier time periods, the topic distribution of impacts, adaptation and vulnerability in 2017–2019 is most different across regions.
- Large regional differences in attention to IAV suggest the need to tailor the global stocktaking under the Paris Agreement to better understand progress countries and regions make.

ARTICLE HISTORY
Received 6 November 2020
Accepted 12 December 2021

KEYWORDS
Climate change policy; policy attention; National Communication; policy analysis; quantitative text analysis; Natural Language Processing

1. Introduction

Climate change is at the top of political agendas of many governments across the globe. Whilst climate change mitigation still dominates climate policy agendas, climate change adaptation is slowly but surely emerging as an increasingly urgent policy response that is necessary to combat climate change impacts and reduce social vulnerabilities (Berrang-Ford et al., 2021; Dessler & Parson, 2019). Past decades have already witnessed an increase in the design and implementation of climate change adaptation policies and measures (Lesnikowski et al., 2016), resulting in a complex multi-level regime that is contrived of interdependent global, national, regional and local levels (Hall & Persson, 2018; Jordan et al., 2015; Maria et al., 2020).

CONTACT Robbert Biesbroek Robbert.Biesbroek@wur.nl
Supplemental data for this article can be accessed https://doi.org/10.1080/14693062.2021.2018986.

Previous studies have explored how climate change impacts, adaptation and vulnerability (IAV) emerged in the international arena, identifying and reflecting on critical moments, and exploring possible explanations of this emergence (Bankoff, 2019; O'Brien et al., 2006; Persson, 2019). Khan and Roberts (2013), for example, identify three discernible time periods, referring to the 'stumbling' and 'facilitative' first stage in the 1990s where adaptation received limited political attention and was considered by many a fatalist strategy that would distract from global mitigation efforts (Schipper, 2006). The second stage in the early 2000s followed with growing scientific evidence that climate impacts were already observed and may be unavoidable in the future. The topics discussed centred mostly around how to support least developed countries to deal with climate impacts through, for example, adaptation finance and knowledge sharing (Pielke et al., 2007). The third stage emerged from even stronger scientific evidence around the need for adaptation in the IPCC Fourth Assessment Report, resulting in a range of global arrangements, such as the 2010 Cancun Adaptation Framework. As Persson (2019) argues, the importance of adaptation continued to rise since then, with the Paris Agreement demarcating the start of an important fourth stage that placed adaptation – at least on paper – on more or less equal footing with mitigation. This led to a range of additional policy instruments, including the global goal on adaptation, enhanced commitments of Parties on adaptation through their Nationally Determined Contributions (NDCs), the Global Stocktake to assess progress, and the Adaptation Communications to be developed and made available by countries (Lesnikowski et al., 2017; Weikmans & Gupta, 2021).

Although these studies paint a general picture of how IAV has emerged, there is limited attention to more detailed questions. For example, have all countries followed this global pattern or are there regional differences given that climate hazards, impacts and adaptive capacity varies significantly cross the globe (IPCC, 2018)? Are there differences in how developed and developing countries have framed IAV as the academic literature suggests (O'Brien et al., 2007)? Are there specific topics and themes that have emerged or fallen from the global climate policy agenda? And what is driving this dynamic? Is there any empirical evidence that governments are indeed placing adaptation higher on the political agenda in the post-Paris stage than before? Does this come at the cost of other climate policy topics? Policy studies have explored and theorized these types of policy dynamics, notably on how issues emerge and rise on the policy agenda, on what makes these issues 'stick', and on when they fall off the agenda and why (Baumgartner et al., 2006). Only a select few studies have looked at these questions in the context of climate change adaptation, and those that do focus mostly on national and local levels (Keskitalo et al., 2012), failing to capture global trends.

The aim of this paper is to unpack some of these questions by empirically investigating whether and how policy attention around climate change IAV has shifted over time and across regions. It explores these questions using National Communications (NCs).

We take an empirical, data-driven approach by quantitatively analysing the content of all NCs submitted to the United Nations Framework Convention on Climate Change (UNFCCC) between 1994 and 2019. There are other data sources to investigate these questions, including the Biennial Reports, National Adaptation Programmes of Actions, National Action Plans, and more recently, under the Paris Agreement, the Adaptation Communications and NDCs that have been used by others to analyse adaptation (Hsu et al., 2020; Pauw & Klein, 2020; Schmidt & Fleig, 2018; Tørstad et al., 2020). However, the NCs offer the only publicly available data source that has a global coverage and allows for a longitudinal analysis of policy attention around climate change IAV.

Since 1992, the UNFCCC requests Parties of the Convention to submit NCs regularly to the Secretariat to communicate and provide information about the ambitions and implementation of policies and measures to achieve the objectives and commitments of the Convention (Article 12). To facilitate this process and ensure a methodologically comparable approach, the NCs follow standardized reporting guidelines. These guidelines have been updated infrequently, most notably after the Bali Action Plan (COP13), which introduced the principle of measurement, reporting and verification (MRV) to enhance quality and transparency of reporting. These reporting guidelines explicitly require governments to report on IAV, without prescribing in great detail what needs to be reported. This gives governments the freedom to decide what topics get prioritized and how much attention certain topics should have compared to others. Frequent reporting through NCs is an important modality that helps us to enhance understanding of the ambitions and of existing efforts to

combat climate change at national and international level. Subjected to a technical review process, these documents provide important input to the Conference of the Parties.

With over 600 NCs submitted, the UNFCCC's repository offers a unique dataset of self-reported activities of governments across the globe on climate change mitigation and adaptation policies and measures. NCs have been used in earlier studies to approach questions around adaptation. Previous studies have used manual content analysis methods to a subset of countries, for example, progress made by Annex I countries (Lesnikowski et al., 2016), Annex I and OECD countries (Gagnon-Lebrun & Agrawala, 2007), or a sample of vulnerable countries or sectors (Albrecht & Arts, 2005; Muchuru & Nhamo, 2019; Skelton et al., 2019). Those that did take a global approach focussed on one reporting period (Berrang-Ford et al., 2014; Lesnikowski et al., 2015), and no studies analysed more than three NC submissions (Gagnon-Lebrun & Agrawala, 2007; Lesnikowski et al., 2016). One of the main reasons for never fully utilizing the full set of data available from NCs is the large volume of text available, which requires significant resources if done manually. This study analyses the adaptation content of all NCs using Natural Language Processing tools; as such, it provides the first comprehensive, empirically driven assessment of the shifts in policy attention around climate change IAV.

Understanding these patterns of change in NCs can help to better understand the current global adaptation governance landscape and allows for critical reflections about why certain shifts have occurred and how further developments of global adaptation governance may evolve.

2. Methods

This section describes the methodology for collecting, processing, and analysing the NC documents using topic modelling. Details of the approach as well as supportive data can be found in the Supplementary Material (SM).

2.1. Data collection

NCs were used in this study to create a comprehensive, consistent, comparable and complete (Ford & Berrang-Ford, 2016) dataset of reported IAV by the Parties of the UNFCCC. The files were scraped from the UNFCCC online repository in June 2019, and the database was augmented manually in August 2020 for updates. Missing files were searched online using different search term configurations resulting in 41 additional documents. All reports submitted until 1 January 2020 were included to allow for longitudinal analysis (1994–2019). Files were downloaded in PDF format. Naming conventions for files were developed to enable spatial and temporal analysis. PDFs were converted to TXT files using a script in R. PDF files where pages were stored as scanned images were transformed to text using the Tesseract package in R, or PDFCandy, an online tool for optical character recognition. Files that could not be processed despite these steps were removed from the dataset ($n = 2$). The final database contained 612 documents from 196 countries, covering 25 years (1994–2019). The final version of the database contained NC1-NC7 for Annex I countries and NC1-NC6 for non-Annex I countries. Some countries and regions have submitted few NCs and are therefore underreported in our study (see section 2.5).

2.2. Data cleaning and corpus preparation

All TXT files were inspected manually and compared to the original PDF to ensure the quality of the conversion before further processing. Sections relevant to IAV, most often the chapter 'Vulnerability Assessment, Climate Change Impacts and Adaptation Measures', were extracted from the TXT. Non-relevant parts were removed, i.e. headers and footers, figures, figure captions, and numeric tables. Tables that used text were converted into plain text. NC documents submitted in a UN language other than English were translated via Google Translate. Although this approach might reduce the semantic meaning of sentences and paragraphs, we subsequently use the bag-of-words model that disregards word order, and has been used in similar type studies (Lesnikowski et al., 2019; de Vries et al., 2018).

Using the Quanteda text mining package in R (v2.1.2) (Benoit et al., 2018), the TXT files were transformed into a corpus. The corpus was cleaned using Quanteda's cleaning function: removing English stopwords,

punctuation, and symbols; converting all characters to lowercase; removing numbers and words with fewer than three characters; and stemming common terms with multiple suffixes. Country and location names were removed by creating a dictionary to allow for location-invariant topic modelling. Terms that occurred fewer than 150 times total or in fewer than 30 documents were excluded to increase topic coherence (Roberts et al., 2019). Finally, the ten most frequent terms of the corpus were removed, allowing for greater topic diversity rather than multiple topics dominated by the same few words.

2.3. Topic model

To analyse the data, we used Natural Language Processing tools, specifically topic modelling. Topic models are statistical models that use unsupervised machine learning algorithms to discover the existence and distribution of 'topics' across a body of documents based on word frequencies and co-occurrences (Hsu & Rauber, 2021; Lesnikowski et al., 2019). These models allow researchers to process large volumes of text-based data in a transparent manner to uncover the hidden semantic structures in texts. In the current information age, Natural Language Processing tools are increasingly important as the processing capacity through human coding has its limits. Although several types of topic models exist, we employed structural topic modelling, a technique that is able to discover topics and estimate their relationship to document metadata (Roberts et al., 2019). In our case, metadata include spatial and temporal dimensions incorporated in the document names. We used the STM package in R (v1.3.6). The number of topics (k) was identified by running STM for k-values of 20, 30, 40 and 50. The resulting topics were qualitatively assessed by the authors for coherence and diversity. The 30–40 *k*-value range was considered most appropriate as a lower k-value failed to yield unique topics on important sectors, and a higher *k* yielded redundant topics. The STM 'searchK' function was run to quantitatively explore the semantic coherence of each k-value between 30 and 40. The selected final value was 32, as it was the lowest value in this range with the highest semantic coherence and interpretable topics.

2.4. Interpretation and analysis of topics

Based on coverage of the time periods in the dataset, the dataset was split into eight time periods of three years, with the first period covering four years. The dataset split was informed by reporting periods and to ensure an equally distributed document split between the different regions. The 'labelTopics' function in STM was used to view the most frequent, important and unique keywords, allowing researchers to label each topic. Clustering of the 32 topics was done using a mixed approach: qualitatively using frequent and exclusive keywords for each of the topics, and quantitatively using LDAvis (Sievert & Shirley, 2014) and Topic Correlations to ensure robustness of our qualitative clustering (see Figure SM1.2). Using group discussions among the authors, each topic was assigned into: (i) Adaptation; (ii) Vulnerability; (iii) Impacts; (iv) Governance; or (v) Other. The SM provides more detail of the steps taken to analyse and visualize the topics. The topics identified reflect the main issues countries report on and therefore offer a valuable proxy for climate policy attention (Lesnikowski et al., 2019).

2.5. Limitations

NCs may represent the most complete, standardized, systematic, national-level and digitally available datasets on climate change adaptation globally, and therefore are frequently used to assess progress and trends over time and to compare progress to a baseline (Berrang-Ford et al., 2014; Lesnikowski et al., 2016). Limitations of using NCs to track adaptation have been discussed elsewhere (Biesbroek et al., 2018; Ford, Berrang-Ford, Biesbroek, et al., 2015; Ford & Berrang-Ford, 2016), for example, NCs are not available for all countries, there are delays in NC submissions, there are other sources for adaptation whose content is not covered in the NCs, and there is negligible inclusion of marginalized and vulnerable groups. Moreover, the UNFCCC guidelines for NCs are critiqued for not being detailed enough to ensure consistent reporting between countries and over time (Ford & Berrang-Ford, 2016). For instance, some countries report some of their adaptation policies and actions in another chapter of the NC (e.g. the 'policies and measures' chapter contains both mitigation and

adaptation policy responses), while others include climate models and scenarios as a separate chapter. For NCs published before 2007, we determined the relevant chapter manually. For the more recent NCs that followed stricter reporting guidelines, we selected chapter 4.

Although our NC analysis at the 6 continents provides valuable insights, it does not capture sub-regional differences. Sub-regional differences in adaptation reporting have been identified before and can drive some of the findings. For example, Ford, Berrang-Ford, Bunce, et al. (2015) highlighted the dominance or absence of certain adaptation initiatives across regions in Asia and Africa. Similarly, Araos et al. (2016) showed how urban adaptation activity is heavily skewed within continents (e.g. certain cities drive the results at continent level, as is the case of New York representing over half of North America's initiatives). Triangulating with multiple data sources to allow for more fine-grained sub-regional assessments, such as a Biennial Report or NDC, could be a next step (Biesbroek et al., 2018).

3. Results

3.1. Attention to IAV and Governance in National Communications

Here we show how different topic classes on IAV have shifted over time. The streamgraph in Figure 1 illustrates the shifts in magnitude of the 32 topics across eight time periods for the full corpus of NC documents ($n = 612$). For each of the topics we determined the topic share: the topic proportion for the time period multiplied by the number of documents in that time period.

The Impacts class contains the most topics ($n = 16$) and is of the greatest magnitude across all time periods, suggesting that governments report on impact topics most substantively.

The Impacts class fluctuates in topic share over time, ranging from 31.0 (2002–2004) to 65.0 (1999–2001). Several prominent Impacts topics show a rapid decline over time, e.g. *agroforestry* (topic 18), *snow and ice* (t23), and *seasonal tourism* (t21) move from a collective topic share of 19.0 in 1994–1998 to a peak topic share of 30.3 in 1999–2001 and then majorly decline to 2.2 in 2017–2019. Some Impacts topics, however, have substantially increased in attention. For example, *rainfall projections* (t26), increases from a topic share of 0.2 to 6.4. Similar increases can be found in *health* (t17), *reefs* (t19), and *agricultural systems* (t29). *Lakes and inland seas* (t25) remains stable, except in 2005–2007, when it jumps to 9.6. Another notable topic of fluctuation is *livestock* (t30), which remains <0.4 for 1994–2004, jumps to a topic share of 9.2 in 2005–2007, and gradually decreases again to a final topic share of 2.4 by 2017–2019. The remaining Impacts topics remain relatively stable.

The Adaptation class, the smallest class for most of the analysed time periods, consists of five topics: *disaster management and implementation* (t12), *desertification* (t13), *water for agriculture* (t14), *deltas* (t15), and *tourism infrastructure* (t16). This class increases drastically over time from a topic share of 2.7 (1994–1998) to a topic share of 16.0 (2017–2019). This is driven by increases in four topics, with *deltas* (t15) and *water for agriculture* (t14) demonstrating especially notable growth from topic shares of 0.8–3.2 and 0.1–3.3, respectively. *Desertification* (t13) remains relatively constant across each time period with topic shares of about 1.0–3.0.

The Vulnerability class as a whole declines from a topic share of 8.1 in 1994–1998 to 4.1 in 2005–2007, significantly increases to a topic share of 18.9 in 2008–2010 and then re-stabilises by 2017–2019. Of the five topics in this class, three demonstrate noticeable growth over time: *regional productivity* (t07), *livelihoods* (t10), and *coastal disasters* (t11) (Figure 2a). *Regional productivity* (t07) generally increases across time, with a low topic share of 0.3 in 2002–2004 and a high topic share of 6.9 in 2011–2013. *Livelihoods (t10)* topic share grows from 0.1 in 1994–1998 to 6.2 in 2017–2019 (Figure 2b). *Coastal disasters* (t11) increases in prominence between the 2005–2007 and 2008–2010 periods, from a topic share of 0.3 to 3.1. Both *sea level rise* (t08) and *vulnerability assessment* (t09) are significant from the start and fluctuate across time.

In addition to the IAV classes, a separate Governance class was identified and assessed. This class fluctuates the most compared to IAV topics. It demonstrates a local peak in topic share of 12.3 in 2002–2004 before declining to a low topic share of 4.7 from 2008–2010 and then increasing again to 19.6 by the 2017–2019. *Policies and programs (t05)* starts with a topic share around 2.5 (1994–1998), grows to nearly 4.6 (2002–2004), shrinks to 0.1 (2011–2013) and rises again to a topic share of 1.0 in 2017–2019. In contrast, *planning (t04)* gradually increases

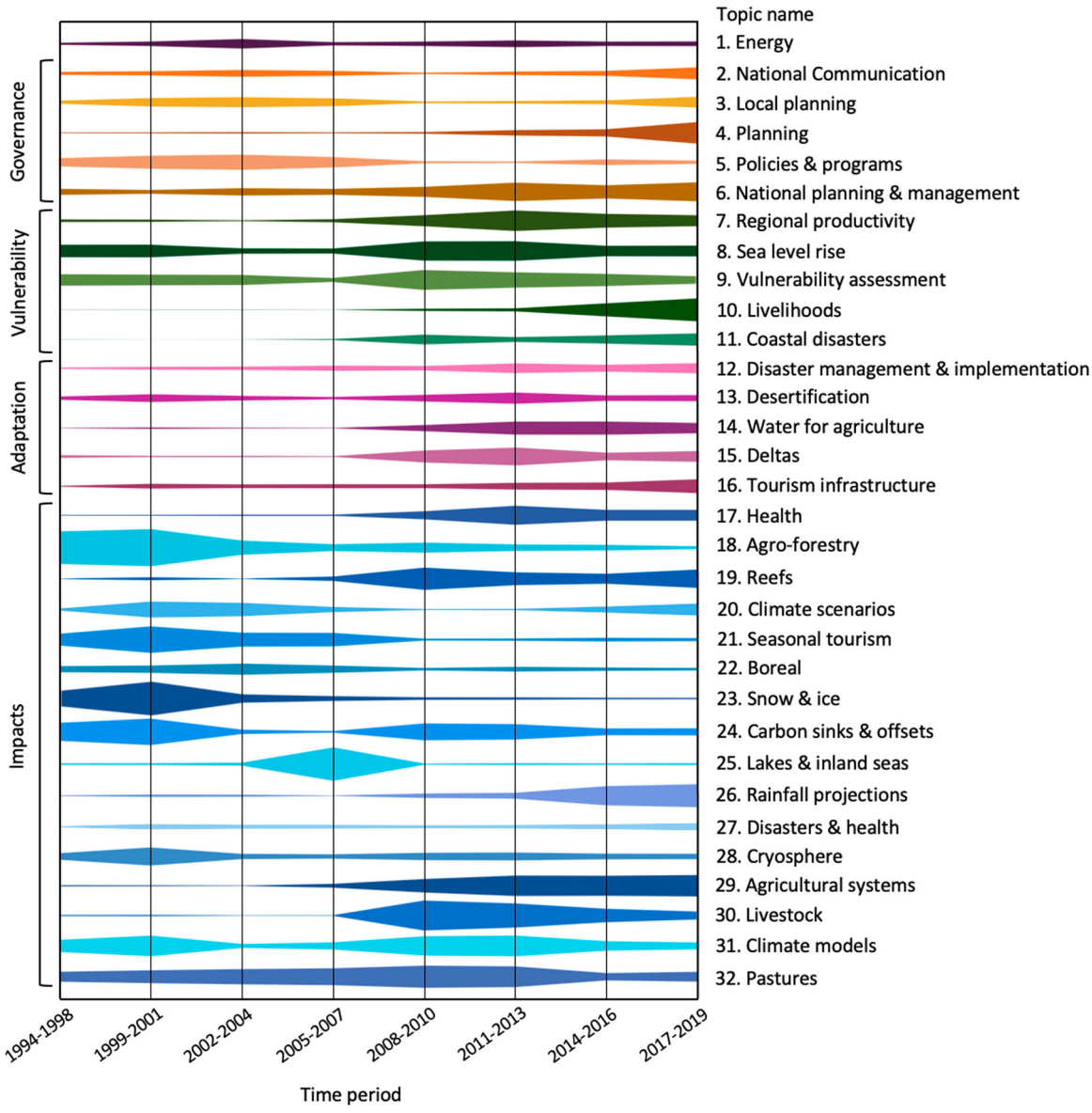

Figure 1. The streamgraph shows changes in topic magnitude of all 32 topics over the eight time periods for each of the five topic classes. The magnitude of each topic refers to the proportion of NC documents clustered to a topic in the corresponding time period. When referencing to Figure 1 in the main text we therefore report values as topic share for accuracy. The total number of documents per time period differs and can be found in Table SM.2.1. Alternative visualization of topic magnitude relative to document frequency can be found in Figure SM.1.3. The legend shows the topic classes, topic number assigned and topic label. More details can be found in Figures SM.1.1-SM.1.3. Topics in blue belong to the Impacts class, purple to the Adaptation class, green to Vulnerability, and yellow to Governance. The Energy topic (topic 1) belongs to its own 'Other' class.

from a topic share of 0.2 to 6.4 across the periods. *National Communication* (t2), *national planning and management* (t06), and *local planning* (t03) all fluctuate between topic shares around 1.0 and 4.0.

Finally, *energy* (t01), was identified as a discernible topic for which keywords did not allow grouping into one of the other classes. *Energy* (t01) topic share remains between 0.3 and 0.7 for all time periods except for 2002–2004 and 2011–2013, where it increases to 1.6 and 1.1, respectively.

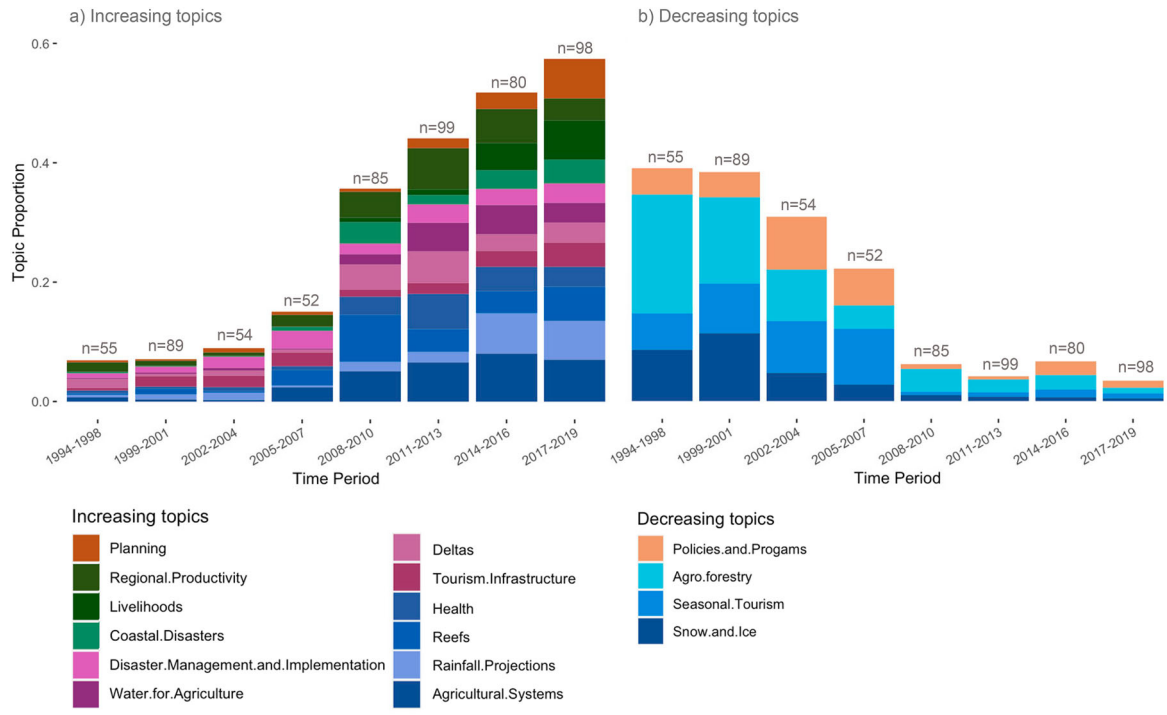

Figure 2. Overview of topics that decrease (left panel, a) or increase (right panel, b) across the eight time periods for the whole dataset. Colours represent the classes and topics as identified in Figure 1. This figure is not adjusted for the number of documents in each time period and therefore includes the number of documents for each time period. Topic in blue belong to the Impacts class, purple to the Adaptation class, green to Vulnerability, and yellow to Governance.

3.2. Differences in policy attention between Annex I and non-Annex I countries in National Communications

Topics were analysed by comparing countries labelled as Annex I or non-Annex I under the Kyoto Protocol (Figure 3). The findings show that some topics belong more strongly to either Annex I or non-Annex I countries, and several topics are more neutral.

Annex I dominant topics include topics from the Impacts class (e.g. *pastures* (t32), *lakes and inland seas* (t25) and *agroforestry* (t18)), and the Governance class (e.g. *local planning* (t03) and *policies and programs* (t05)). Some of these topics demonstrate a large shift in orientation over time, with *pastures* (t32) and *lakes and inland seas* (t25) becoming more Annex I oriented in the most recent time period (2011–2019), and historically more Annex I topics becoming more neutral (e.g. *agroforestry* (t18)). Non-Annex I dominant topics include those from the Impacts class (*reefs* (t19), *agricultural systems* (t29), *livestock* (t30)) and Vulnerability class (*regional productivity* (t07) and *coastal disasters* (t11)). Here too a shift between time periods is noticeable across topics dominant to non-Annex I countries. For example, *rainfall projections* (t26) and *planning* (t04) have become more non-Annex I, whereas topics such as *livestock* (t30) have shifted to a more neutral position in 2011–2019. A large range of topics have a more neutral position, including *National Communication* (t02), *desertification* (t13), *tourism infrastructure* (t16) and *disasters and health* (t27), which all remain relatively stable across time.

When comparing the shifts over time, Impacts topics show the most substantial movement, with *lakes & inland seas* (t25) and *pastures* (t32) moving significantly from neutral (or balanced attention in both groups of countries) towards more attention in Annex I countries. By comparison, *agro-forestry* (t18), *snow & ice* (t23), and *carbon sinks and offsets* (t24) move from more Annex I attention towards neutral. *Reefs* (t19) and *livestock* (t30) move away from non-Annex I attention towards neutral, while *rainfall projections* (t26) shifts from neutral towards more non-Annex I attention. Through the analysed time, topics in the Adaptation class tend

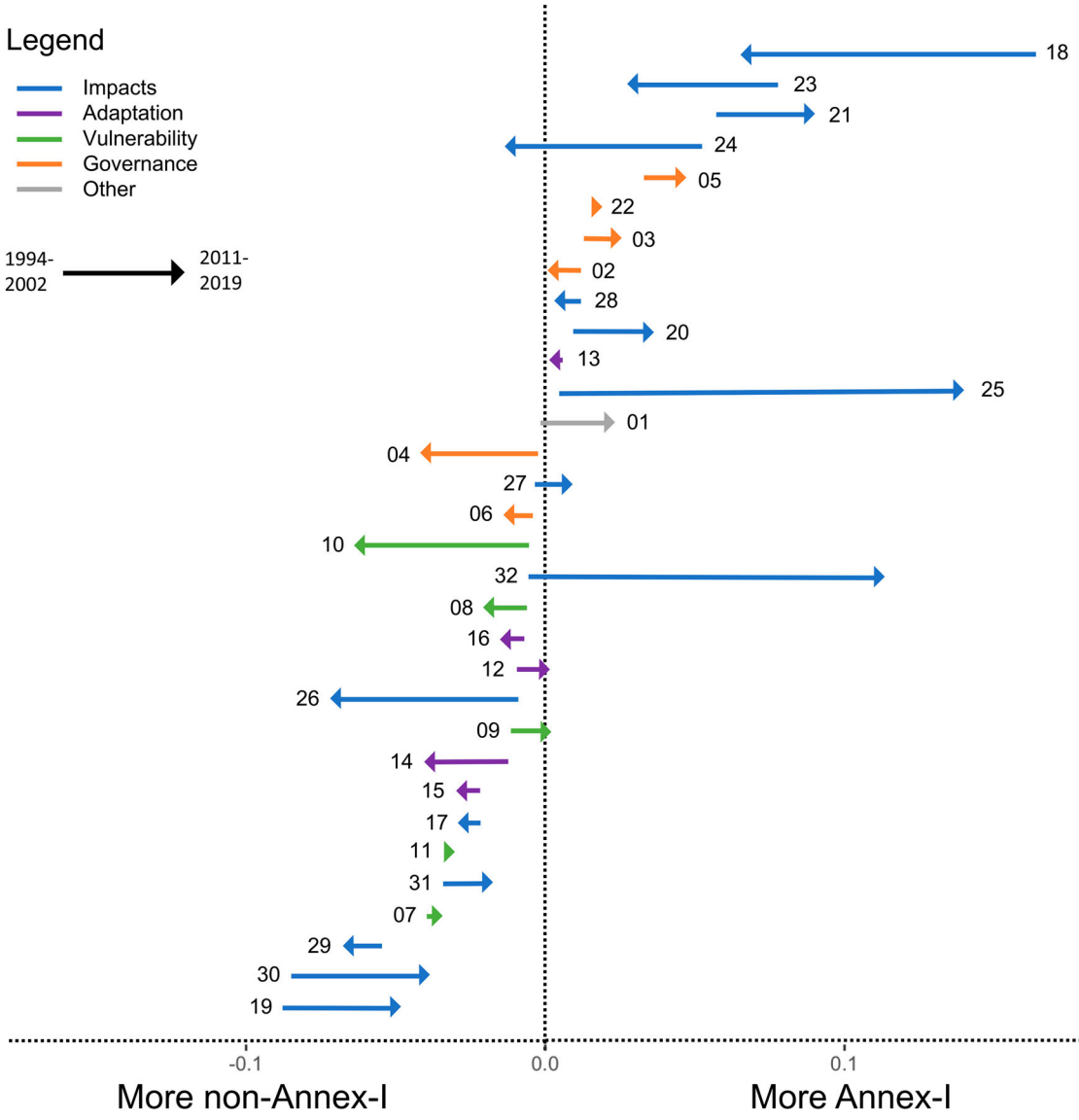

Figure 3. Differences in topic proportion by Annex I and non-Annex I countries for two time periods, 1994–2002 and 2011–2019. These periods were used for analysis due to scarcity of early NCs and the desire to show shifts between early and recent years. Each horizontal line represents the magnitude of shift in proportion between the two time periods for a topic, as quantified on the x-axis. Start of the horizontal line is 1994–2002 and the end of the arrow is 2011–2019. Direction of change is signalled by the direction of the arrow, signalling how the weight of policy attention is shifting across Annex I and non-Annex I countries. Colours of the lines represent the classes and numbers represent the topics as identified in Figure 1. Distance from the y-axis represents how strongly the topic is linked to Annex I (right) or non-Annex I (left) countries. SM 1.4 provides a different visualization.

to be fairly neutral near the axis, most notably *disaster management and implementation* (t12), *tourism infrastructure* (t16), and *desertification* (t13). Topics in the Vulnerability class skew towards non-Annex I throughout, especially *livelihoods* (t10), though some like *vulnerability assessment* (t09) move towards neutral. Governance topics are relatively neutral, but four of the five move away from the axis over time, with *local planning* (t03) and *policies & programs* (t05) shifting towards Annex-I and *National Communication* (t02) and *planning* (t04) shifting towards non-Annex I.

3.3. Regional assessment of policy attention to IAV and Governance

The distribution of NC topic portion across regions (Figure 4) generally reflects global trends presented in section 3.1: dominance of the Impacts class but a decreasing trend over time; an increase in Adaptation and Vulnerability classes over time; and fluctuations in the Governance class. The topic distribution is most different across regions in the latest period of study, 2017–2019.

Although the Impacts topics show a decline in all four regions, the topic composition across regions differs. For Africa, four relatively stable topics dominate the impacts discourse: *climate models* (t31), *livestock* (t30), *agricultural systems* (t29), and *rainfall projections* (t26) comprise 65% of topic share in 1994–1998 and 41% in 2017–2019. In Europe and Asia, more diversity in Impacts topics is noticeable, with both regions reporting significantly on *agroforestry* (t18), *climate models* (t31) and *pastures* (t32). Additional key topics in Europe include *climate scenarios* (t20) and *seasonal tourism* (t21), while in Asia *carbon sinks and offsets* (t24) is considered a key topic. North America notably reports less on Impacts than all other regions, reaching a minimum of 20% by 2017–2019, although similar topics are identified (*climate models* (t31), *carbon sinks and offsets* (t24), *rainfall projections* (t26)).

The Vulnerability class stands out in North America, where it not only dominates attention in some time periods, but also increases across time from 19% (1994–1998) to 42% (2017–2019). *Coastal disasters* (t11)

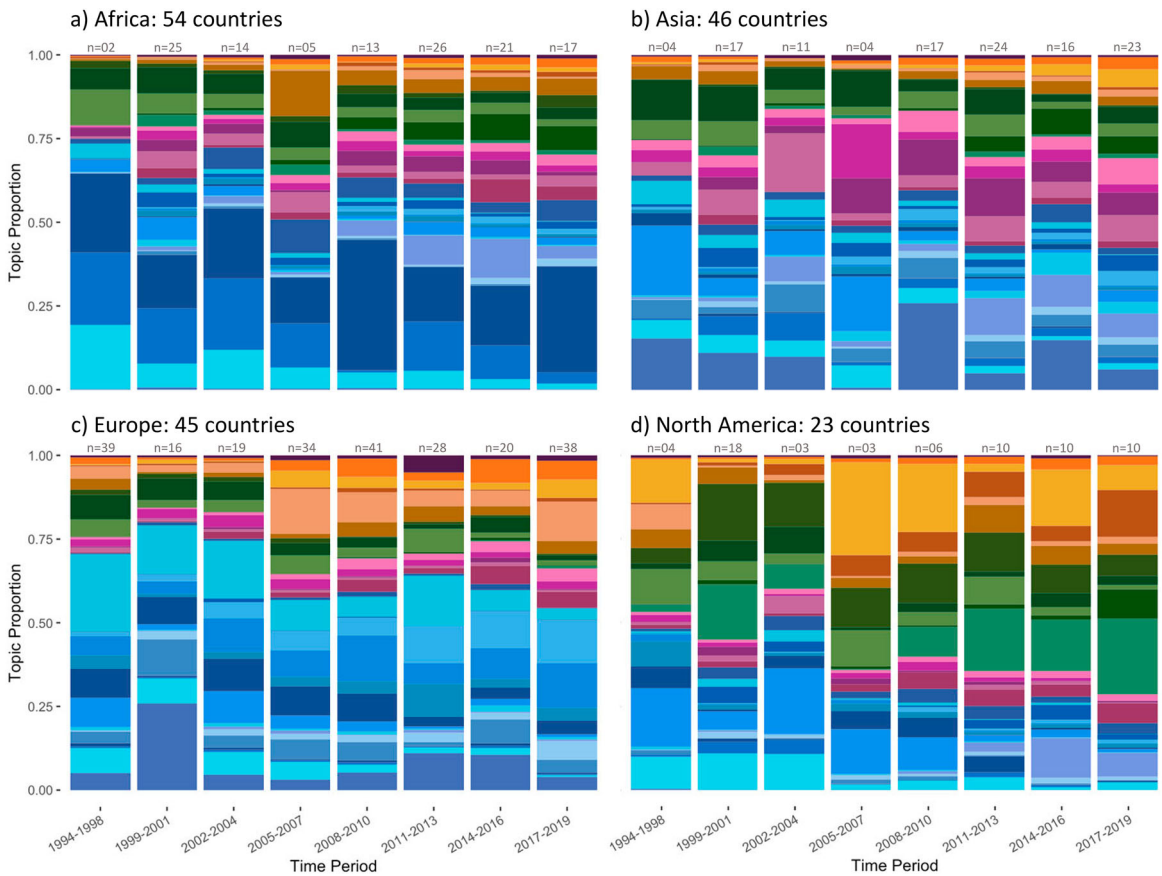

Figure 4. Topic proportion clustered by the six regions as defined under 2020 ISO world regions (ISO, 2020). The figure and analysis excludes South America (SOAM) and Oceania (OCEA) due to document sparsity (for SOAM and OCEA see Figure SM.1.5). Countries in Central America and The Caribbean are included in panel (d). Colours represent the classes and topic labels as in Figure 1: yellow are Governance topics, green are Vulnerability topics, purple are Adaptation topics, and blue are Impacts topics. It should be noted that the submission of NCs is different across time periods, so that document number can vary between time periods. Number of documents per period is reported at the top of each bar and available in the SM.

and *regional productivity* (t07) are key topics in North America, especially *coastal disasters* (t11) after 2011, reaching 23% in 2017–2019. In contrast, the three other regions emphasize *sea level rise* (t08) and *vulnerability assessment* (t09). *Livelihoods* (t10) is a key vulnerability topic for Africa in all time periods (up to 7% in 2014–2019) and for Asia in the last three time periods (reaching a maximum of 8% in 2014–2016), but is less frequently mentioned for other regions.

The Adaptation class is large in Asia compared to the three other regions (up to 27% in 2017–2019), though all regions see some growth in this class over time. In Asia, major topics include *water for agriculture* (t14) and *deltas* (t15), although there is a diversified reporting on all Adaptation topics. *Desertification* (t13) is a steady topic in Africa and Europe, also showing a major peak in Asia in 2005–2007. *Tourism infrastructure* (t16) gains marked attention in Europe and North America after 2008, while also experiencing a peak in Africa in 2014–2016. *Disaster management and implementation* (t12) is constant in all regions and time periods, at around 2–3%.

Governance shows fluctuations and tends to increase overall, although topic proportions differ across regions. Governance reporting is dominant in North America, with *local planning* (t03) standing out as a major topic (up to 28% in 2005–2007), followed by *planning* (t04). Main topics in Europe include *National Communication* (t02) and *policies and programs* (t05) (6% and 12%, respectively, by 2017–2019). In Africa, *national planning and management* (t06) gains prominence after 2005–2007. Governance tends to account for the smallest class in Africa and Asia, except for an increase in *national planning & management* (t06) in Africa in 2005–2007 and a gentle rise in *local planning* (t03) across the last four time periods in Asia.

4. Discussion

Our analysis of all NCs published between 1994 and 2019 allows us to make several important observations.

Our first observation revolves around the emergence of adaptation. We find an overall increase in the Adaptation class globally, particularly in 2007–2011. As noted by others, this time period is important as adaptation was considered more explicitly in the global arena, such as at the influential COP meetings (e.g. COP 13 and its resulting Bali Action Plan), as well as with the 2007 IPCC AR4 (Ford & King, 2015; Khan & Roberts, 2013). Perhaps more surprisingly, we find stabilization of the Adaptation class afterwards. This is interesting, as research has suggested that the extent of adaptation seems to have grown considerably since 2010 (Lesnikowski et al., 2015; Tompkins et al., 2018). Yet our findings are more in line with Schmidt and Fleig (2018) who note that worldwide national legislation on adaptation increased substantially around 2008 but stabilized around 2015. Evidence of the 'fourth stage' of adaptation policy that supposedly started after the Paris Agreement is therefore limited. Calls for accelerated and transformative climate adaptation by, amongst others, the Global Commission on Adaptation (2019) have not (yet) resulted in changes in issue attention in the reporting by governments. This might be a reflection of the time it takes to change policy attention. It is remarkable that the influence of the Paris Agreement is not more strongly visible in our data and analysis. We also find that some policy relevant issues that have been at the centre of adaptation scholarly debates for the past years, including, for example, maladaptation (Eriksen et al., 2021; Magnan et al., 2016), transitions and transformative adaptation (Few et al., 2017; Nalau & Handmer, 2015), and transboundary risks and adaptation (Benzie & Persson, 2019), were not found as topics in our analysis. Although a more detailed qualitative analysis would be needed to firmly conclude this, it seems some of the key insights from recent adaptation research are not translating easily into the policy attention of national governments.

Our second observation is that attention to the 32 topics identified here is more evenly distributed in NCs in recent time periods compared to early NCs where just a few topics dominate. This may suggest that the magnitude and extent of IAV are increasingly being felt, studied, and reported on by governments, therefore focussing on a range of topics rather than a selected few. This could also be a reflection of the increased awareness, ambition and preparedness of countries, however it could also reflect well known mechanisms such as policy mimicry, diffusion and convergence (Massey et al., 2014); in this context, topics and ideas are increasingly shared across different countries and reporting periods, resulting in more heterogenic topic distribution over time. More surprising is that regional differences in topic *class* distribution have grown over time.

Third, although we expected to find differences across the six world regions as the climate impacts and vulnerabilities differ by region, the regional differences are even larger than initially expected. Whilst our analysis is reporting policy attention only, it does suggest that adaptation topics in Asia and to lesser extent in Africa are much more present compared to Europe or Northern America. This likely represents the early needs of the most vulnerable countries to invest in adaptation, but could also reflect the early experiences with adaptation in these regions (Berbés-Blázquez et al., 2017; Ford, Berrang-Ford, Bunce, et al., 2015; Sovacool et al., 2012), or even indications of transformational adaptation or the transition to longer-term resilience. Concerningly, recent studies on where research on adaptation is conducted have found that these regions are not well studied; the vast majority of adaptation studies have a strong European and Northern American focus (Blicharska et al., 2017; Nalau & Verrall, 2021; Wang et al., 2018).

Our results also validate other research showing that initiatives in low- and middle-income countries in the Global South prioritize disaster risk management and water issues, including concerns about precipitation, drought, flooding and low-lying deltas (Berbés-Blázquez et al., 2017; Burch et al., 2017). The strong focus on vulnerability and governance topics in North America is surprising and may be the result of the focus on extreme weather events and disaster risk management (Ford & King, 2015). Although it has only a small fraction of policy attention, adaptation is increasingly important in NCs from Europe, perhaps due to incentives by the EU for the inclusion of adaptation policies in national climate policy frameworks of EU Member States (Biesbroek et al., 2010; De Roeck et al., 2018). Nevertheless, recent NCs from European countries continue to prioritize impacts over adaptation. These regional observations raise the question of what the 'optimal' balance is between IAV in policy attention, of the implications for policy design and of how this translates to policy action on the ground.

Fourth, we find some topics are more strongly linked to Annex I or non-Annex I countries, empirically demonstrating the persistence in different IAV topics between these clusters of countries (O'Brien et al., 2007). Topic modelling allowed us to recognize these differences and visualize less visible framings as has been pointed out by O'Brien et al. (2007): 'the human-security framing of climate change has been far less visible in formal, international scientific and policy debates (…)'. For instance, our results demonstrate the major focus on impacts in Annex I countries, especially before 2010, with a stronger focus on disaster risk approach and addressing compounded social vulnerabilities in non-Annex I countries (Bankoff, 2019; Cannon & Müller-Mahn, 2010). Despite efforts to converge these different framings on IAV in the global arena, we find different framings continue to exist in our analysis of recent NCs, and in some cases, such as *rainfall projections* (t26), are growing. This observation is particularly relevant in the context of the Global Stocktake and monitoring and evaluating progress, since understanding these regional differences will require context specific data, methods and approaches for credible and transparent stocktaking (Magnan & Ribera, 2016; Tompkins et al., 2018).

Finally, the question of what is driving global and regional shifts is difficult to answer. At the global level, we find critical junctures as suggested by Khan and Roberts (2013), which imply that there may be numerous drivers of topic shifts, e.g. the increasing confidence in scientific evidence provided by international organizations and the IPCC; the role of the US in early stages of global debates; political turmoil around the Copenhagen accord; growing societal calls for policy actions due to growing public awareness of climate change; and success of knowledge sharing across contexts in recent years (Khan et al., 2020; Khan & Roberts, 2013; Persson, 2019; Pielke et al., 2007; Rayner, 2010). At regional levels, similar drivers have likely influenced regional policy attention, but also more region-specific policy dynamics. These might include: the experience of regional climate impacts and extreme events; regional interests in global negotiations on IAV; path dependency and different political cultures of policy making around climate change; and policy convergence and mimicry between countries in the same region. However, further hypothesis testing would be needed to understand and identify the key drivers for global and regional shifts in policy attention reported in NCs.

Any analysis using documents based on self-reporting should interpret the results carefully. First of all, NCs represent national-level self-reporting and thus reflect national priorities and are not necessarily representative of sub-national and local scales, which tend to be underreported, as are initiatives by the private sector and civil society (Hsu & Rauber, 2021; Lesnikowski et al., 2016). In addition, reporting countries are well aware that their NCs can give place to global rankings of countries' progress (or lack thereof), and may therefore be selective in

the information they provide, for example, to highlight innovative approaches to demonstrate global leadership or expose critical vulnerabilities. Especially for developing countries, and particularly for Least Developed Countries, such framings matter as there could be financial consequences and accountabilities attached to the NCs. Studies have shown that showing off higher vulnerability may attract greater adaptation funds by donors (Betzold & Weiler, 2017). In addition, the more recent NCs contain chapters with detailed constraints and gaps to allocate potential aid, particularly technical and capacity needs, as well as knowledge, education or training needs. Financial aid not only supports vulnerable countries to implement adaptation, but also influences IAV research priority and policy attention.

NCs are not designed with a Global Stocktake purpose (Tompkins et al., 2018), nor are NDCs or Biennial Reports. UNFCCC guidelines for countries are not (yet) detailed enough to allow for tracking a set of meaningful indicators over time to look at what and how different kinds of actions contribute to the global goal on adaptation, or Sustainable Development Goal 13 on Climate Action (SDG13). Yet national self-reporting will play a critical role – in combination with other scientific and independent sources – to provide information for the Global Stocktake (UNFCCC Adaptation Committee, 2020). Clearer IAV terminology in UNFCCC guidelines, and stricter reporting guidelines, could increase the usefulness of NCs in tracking progress.

Whilst Natural Language Processing tools, such as quantitative text analysis used in this study, have their weaknesses, tracking progress on climate change IAV globally can benefit from some of its strengths. These strengths include dealing with the rapidly developing new sources of data and evidence (velocity), the bias, noise and conflicting results that will come from different data sources (veracity), the ability to triangulate and check the validity of data (validity), and the frequent update of data in order to keep track of the adaptation gap (volatility) (Ford et al., 2016). These tools could thus support the UNFCCC to quickly and comprehensively understand whether we are making progress, for example, to assess if countries are reporting on the key impacts and are planning to adapt to the key risks. Such an approach could be used as a rough proxy for what Boutang et al. (2020) call 'fitness', and Berrang-Ford et al. (2019) call 'alignment' between climate risk and policy actions.

5. Conclusion

Understanding policy attention to IAV is important to realize if and how governments across the globe are planning and implementing climate change policies. This study shows that policy attention has become more diversified in recent time periods, which suggests there is increased awareness and action on climate change impacts, adaptation and vulnerability. In particular, countries in Asia and Africa have reported substantively more on adaptation compared to other regions. Although policy *attention* cannot be equated with policy *action*, it does offer an additional line of evidence to inform the Global Stocktake under the Paris Agreement on how we are advancing globally on climate change IAV.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

Contributions by RB are financed by the Dutch Research Council (NWO-VENI grant no: 451-117-006 4140).

Data availability

The underlying data used for the analysis is available upon request.

ORCID

Robbert Biesbroek http://orcid.org/0000-0002-2906-1419

Sarah Judith Wright http://orcid.org/0000-0003-3341-216X
Stefanie Korswagen Eguren http://orcid.org/0000-0003-2306-9329
Ioannis N. Athanasiadis http://orcid.org/0000-0003-2764-0078

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