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Current Opinion in Environmental Sustainability

Global patterns of adaptation to climate change by Indigenous Peoples and local communities. A systematic review

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Indigenous Peoples and local communities have implemented myriad responses to deal with and mitigate climate change impacts. However, little effort has been invested in compiling, aggregating, and systematizing such responses to assess global patterns in local adaptation. Drawing on a systematic review of 119 peer-reviewed publications with 1851 reported local responses to climate change impacts, we show that Indigenous Peoples and local communities across the world apply a diverse portfolio of activities to address climate change impacts. While many responses involve changes to natural resource based livelihoods, about one-third of responses involve other activities (e.g. networking, off-farm work). Globally, local responses to climate change impacts are more likely to be shaped by people's livelihood than by the climate zone where they live.

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Current Opinion in Environmental Sustainability 2021, **51/52**:55–64

This review comes from a themed issue on **Climate decision-making**

Edited by **Diana Reckien**, **Cathy Vaughan** and **Rachael Shwom**

Received: 30 September 2020; Accepted: 01 March 2021

https://doi.org/10.1016/j.cosust.2021.03.002

Introduction

There is a 'strong, credible body of evidence, based on multiple lines of research, documenting that the climate is changing and that the changes are in large part caused by human activities', mainly by fossil fuel combustion and industrial processes [1,2]. The ongoing manifestation of global warming results in local impacts such as an increase in the frequency of coastal flooding, droughts, wildfires, and a continuous decline in sea ice [2]. Social scientists have shown that communities are differentially affected by climate change; not only because climate change impacts are highly place-specific, but also because climate change affects communities through specific pathways, largely mediated by local economic systems and culture. Specifically, climate change threatens the livelihoods and well-being of Indigenous Peoples and local communities (IPLC) — groups who are descended from and identify with the original inhabitants of a region and maintain a deep connection to place and nature over generations [3,4]—who urgently need to minimize associated present and future harms [5].

Throughout history, IPLC have experienced and responded to environmental changes and climate variability based on intricate and complex systems of knowledge about the world around them [6••], broadly referred to as Indigenous and Local Knowledge (ILK) [7].

Despite two decades of research on climate adaptation, we know little of the diversity of responses led by IPLC, and of the extent to which ILK-based measures may be transferable and beneficial across regions, cultures and environmental conditions [8,9]. Research on IPLC climate adaptation has focused on understanding local, so-called 'autonomous' [10], responses through case studies [11,12•], with a few reviews focusing on specific livelihoods (e.g. Ref. [13••]), regions (e.g. Refs. [14•,15,16], or ethnic groups (e.g. Ref. [17]). Only a recently published scoping review [18••] represents a first step to reduce the degree of fragmentation of this literature [19].

Systematic literature reviews are a powerful tool for evidence-based decision-making due to their high level of transparency, objectivity and reproducibility compared to traditional reviews [20], and increasingly applied in adaptation studies [19,21]. Departing from previous works, this review does not focus on institutional and

governmental-driven adaptation [22,23••,24] or on participatory processes, such as community-based and co-produced adaptation strategies [22,23••,24] that do not primarily target community-driven responses [25]. Rather, we focus on community-driven responses to climate change as such an approach directly addresses the need to integrate ILK into adaptation strategies [2,26••], by strengthening bottom-up approaches [27] and contributing to the identification of the best adaptation practices and their potential transferability [8,9]. Specifically, with this review we aim at answering the following questions: What is the geographical extent of research on local responses to climate change impacts? What are frequently reported local response strategies? How do responses differ across climates, livelihoods and regions?

Beyond reviewing case studies, our work also aims to develop a detailed and comprehensive classification system of local adaptation strategies that overcomes challenges of previous classifications which are either too broad for in-depth analysis [2,28,29] or not exhaustive (e.g. Refs. [13••,29,30]). Classifying the documented local responses allows assessment of global response patterns and sheds light on the diversity, commonalities and particularities of IPLC climate adaptation strategies.

Specifically, here we i) review recent research on IPLC responses to climate change impacts, ii) propose a new and comprehensive classification of such responses, and iii) describe the global range, variability and commonalities of such local responses across different climatic zones, livelihood activities and world regions.

We adopt an inclusive definition of local responses to climate change as the adaptation of IPLC 'to actual and expected impacts of climate change in the context of interacting non-climatic changes, [. . .] [which] can range from short-term coping to longer-term, deeper transformations, aim to meet more than climate change goals alone, and may or may not succeed in moderating harm or exploiting beneficial opportunities' ([31], p. 22026). We use the term 'local response', instead of 'adaptation', when referring to both direct actions to address climate change impacts and indirect measures in the form of adaptive capacity building to increase the ability of IPLC to implement direct actions [19,32].

Methods

We examined peer-reviewed publications that appeared after the Fifth Intergovernmental Panel on Climate Change (IPCC) report [2], from January 2015 to December 2019, including case studies documenting IPLC responses to climate change impacts. Our search encompassed, but was not limited to, responses derived from Indigenous and local knowledge (ILK) and covered a recent period of time to identify ongoing responses, that is, responses shaped by current assets, productive systems and institutions, from which we could draw lessons about how to support or mainstream local adaptations in the years to come. Detailed information on the review process, including search terms, article selection, data coding, and spatial and statistical analysis can be found in the Appendix A. Supplementary Materials 1 (SM1).

Drawing on previous classifications of 'adaptation' (e.g. Refs. [13••,22,33]) and through an iterative process that involved analyzing similarities and differences among documented responses, we developed a 3-level classification system defining response sectors, domains, and types (see Table SM9). The response *sector* encompasses the main natural resource dependent livelihood activities, for example, cultivation, livestock and fishing, as well as responses in other activities, such as housing, community life, and wage labor. The response *domain* captures whether changes relate to activities' timing, location, livelihood products, productive resource input, social and human capacity building, or the whole livelihood system. Finally, the response *type* identifies whether the response domain refers to quantitative changes, measurable in physical units (e.g. kg, ha, money) or to qualitative changes, such as changes in crop or livestock composition or in the cultivation methods applied. Each response strategy is further described by a direction (e.g. increase, decrease).

Results

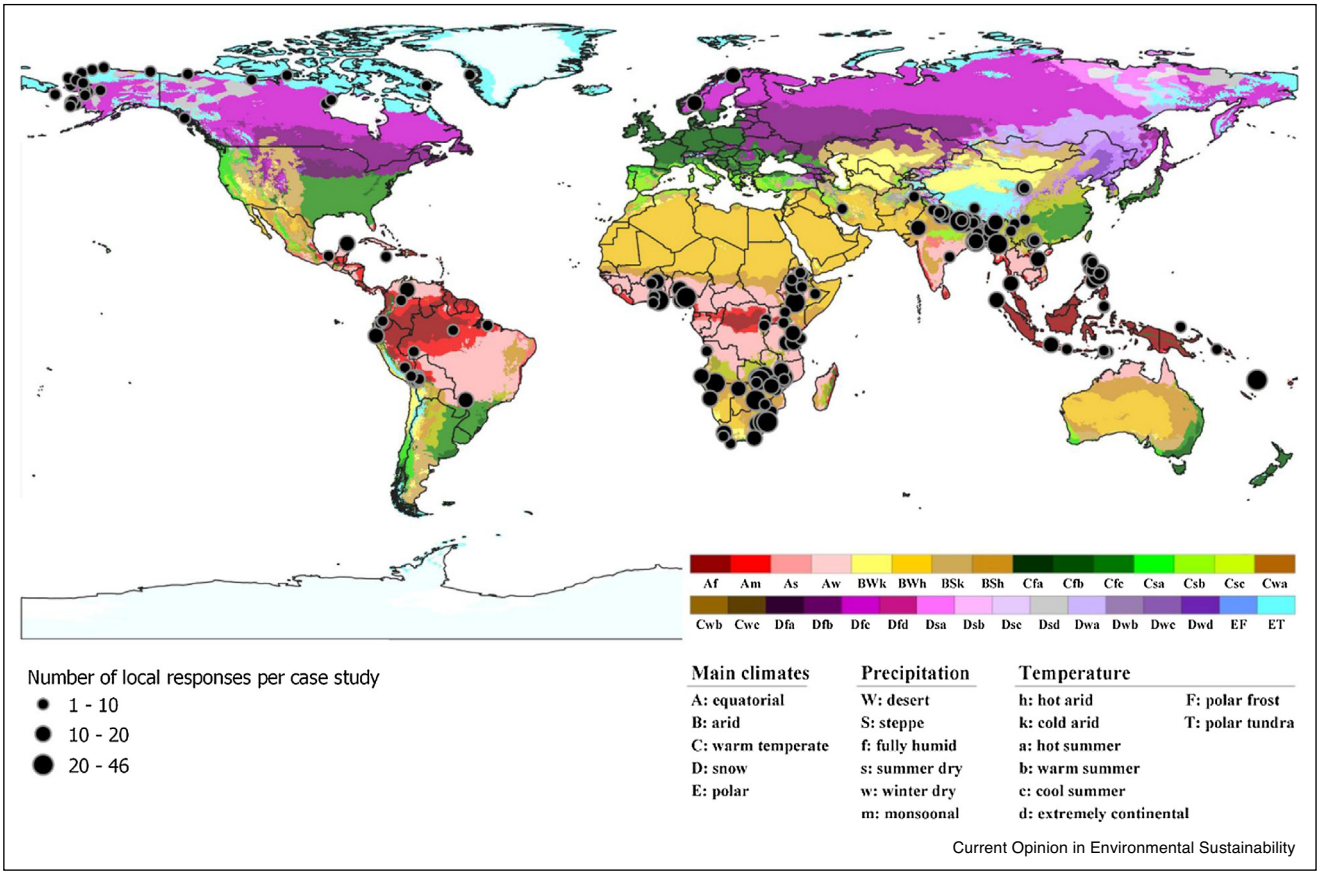
Geographical distribution of case studies

The 119 articles reviewed reported 1851 local responses to climate change impacts. Results correspond to 181 case studies in 260 locations in 44 countries (Figure 1 and Table SM8). 70% (n = 126) of the case studies refer to locations in Asia (n = 68) and Africa (n = 58), and another 15% to locations in Latin America (n = 27). There were more case studies in the equatorial (n = 54), temperate (n = 53) and arid (n = 30) regions, than in the snow (n = 23) and polar regions (n = 21). About one-third of the studies were located along the coast (n = 67), in the low-lands and mid-lands (n = 62), and at altitudes above 1500 masl (n = 52), respectively.

Classifying local responses to climate change impacts

We classified the 1851 reported responses into 187 categories, of which 57 belong to cultivation, 33 to livestock, and 22 to fishery sectors. 46 categories refer to other activities. Two-thirds (63%) of reported local responses occur in natural resource dependent livelihood sectors, and particularly in the cultivation sector (40%) (Figure 2, sectors). This is consistent with agriculture being practiced in 80% of the case studies. In contrast, although 45% of the communities keep livestock and 38% practice fishing or aquaculture (Table SM8), proportionately fewer responses were documented in these sectors, that is, 13% and 5%, respectively. As much as 37% of the responses documented do not refer to a specific

Figure 1



Global distribution of case studies found in the literature across different main climates according to the Köppen-Geiger classification [34].

livelihood, but rather to changes in other household assets, such as social capital (e.g. sharing food and other resources), or infrastructure (e.g. building dykes).

With respect to domains, as much as one-quarter (24%) of local responses involved changes in practices (e.g. methods applied, weather forecast, biodiversity conservation), and almost one-quarter (22%) involved changes in productive resource inputs (e.g. water, fertilizer). Changes in location and time management corresponded to less than 10% of reported responses each (Figure 2, domains). Finally, 68% of the responses represented qualitative changes, while only 32% accounted for quantifiable changes (Figure 2, types).

Some of the responses reported draw from ILK, such as indigenous seasonal climate forecasts and farming practices [35,36]. Other responses, such as the use of GPS devices [37] or switching to early maturing hybrid varieties [38], draw from scientific knowledge (see Table SM10).

The five most frequent response categories describe 33% of all reported local responses. These include 'changes in the composition of cultivated crops and trees' (CU.PRODU.COMPS = 10%), 'changes in applied methods and techniques in cultivation' (CU.PRACT.METHD = 7%), 'changes in general social relationships & networks among community members' (OA.CAPAC.NETWK = 6%), 'changes in finances and incomes not derived from natural resource-dependent livelihoods' (OA.SYST.INCOM = 6%), and 'changes in the protection of natural ecosystems (incl. biodiversity conservation)' (OA.PRACT.NATUR = 4%).

Comparing adaptation strategies across climates

Documented responses are similar across climate zones, with larger diversity within each climate zone than across zones (Figure 3). With the exception of snow regions, the most reported sector-based responses in all climate regions relate to cultivation (30–50%) and other activities (23–42%). In the snow regions, most responses refer to changes in livestock rearing (42%) and other activities (24%). The few responses reported for the fishery sector are limited to the equatorial, arid and polar regions (Figure 3b).

Figure 2

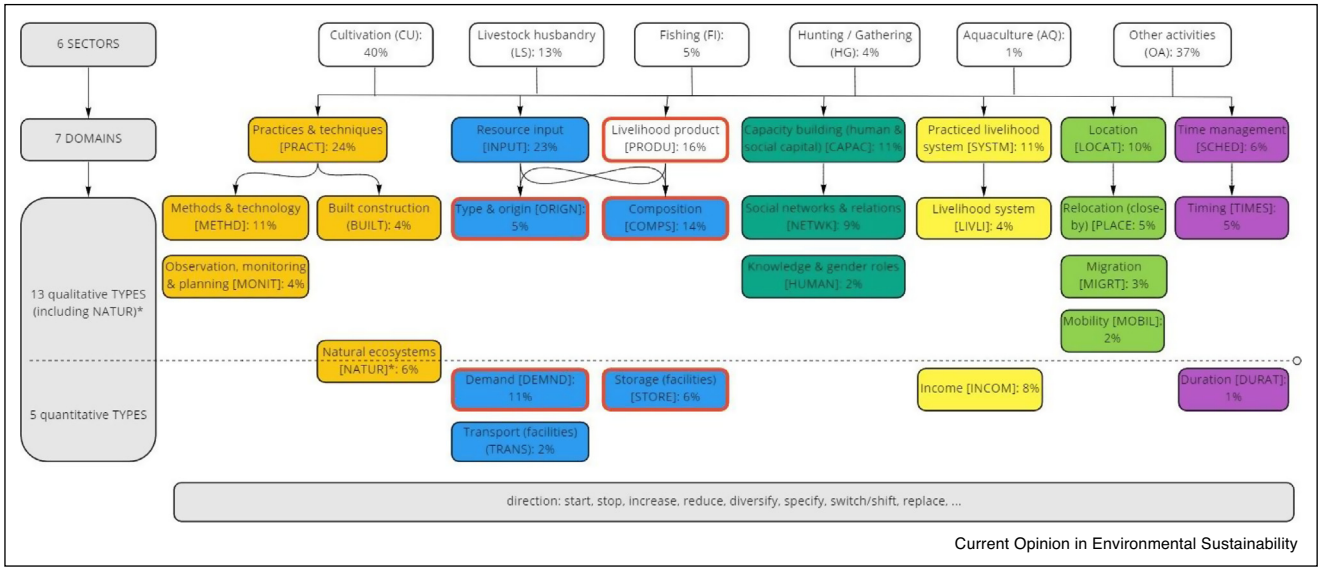


Diagram of the classification and coding system. Note that some strategies of the response type 'Natural ecosystems (incl. biodiversity conservation)' are qualitative, and some are quantitative. For the definitions of each response sector, domain and type see Table SM9.

Changes in practices are the most frequently identified local response domain (21–27%) (Figure 3c), except in the polar regions, where a shift in the main livelihood system and income sources is more frequently reported (19%) than changes in practices (18%). In the snow region, changes in location are the second most common response domain (20%), probably due to common livestock rearing in higher mountain regions, such as the Andes and the Himalayas. In the other climate regions, responses related to changes in productive resource inputs (13–20%), such as water and food, were more often reported than changes in locations (7–17%). Nuanced differences exist regarding livelihood products, including changes in crop composition, which are more frequent in the temperate zones (20%), and changes in income generation activities, which are more frequent in the arid (13%) and polar regions (14%) (Figure 3d).

Comparing local adaptation strategies across sectors

Local responses to climate change impacts largely vary across sectors (Figure 4). The largest number of local responses was documented within the cultivation sector (n = 736) (Figure 4a). The most common local responses in the cultivation sector involve changes in the livelihood products (30%) — mainly changes in crop composition — followed by changes in cultivation practices (21%), for example, soil conservation methods, and changes in the application of productive resources, such as irrigation (13%) and fertilizer use (8%) (Figure 4b). Responses in the livestock sector were dominated by changes in grazing location (21%) and changes in animal species and herd size (21%). Adjustments in feeding practices accounted for 13% of the responses in the livestock sector. In the fishing sector, the most common responses correspond to the adoption of new fishing techniques (31%), especially the use of improved methods and gear (20%), followed by changes in the location of fishing spots (19%) and the duration and timing of fishing activities (14%) (Figure 4b, c). Responses in 'other activities' focus on intensifying social relationships and networks (16%), income generation through wage labor or small businesses (16%), and biodiversity conservation (10%) (Figure 4c).

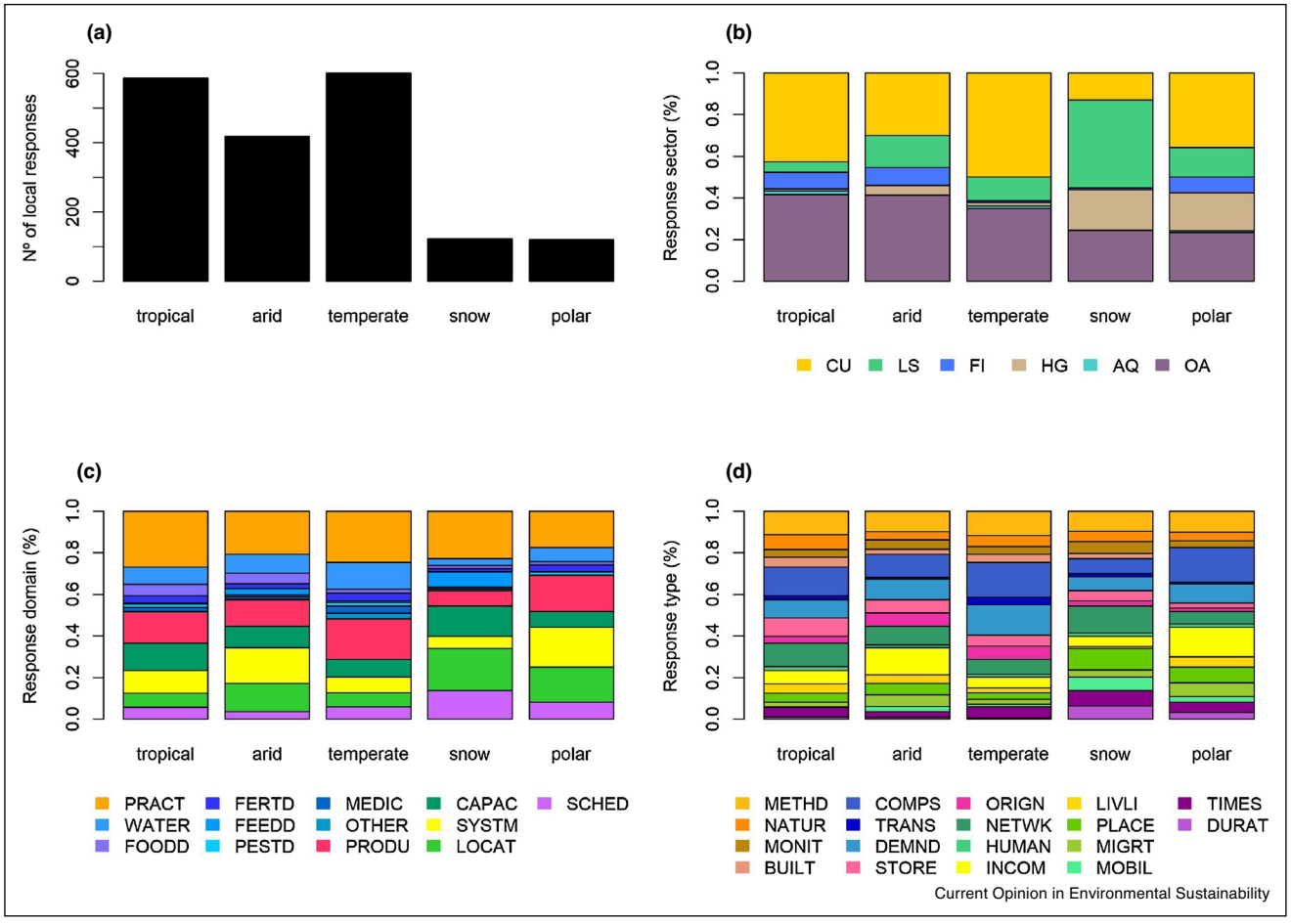
Comparing local adaptation strategies across world regions

To understand macro-regional patterns, we compared the local responses documented in regions with more data, namely Sub-Saharan Africa (AFR, n = 776), South Asia (SAS, n = 448), Latin America (LAM, n = 223) and the Asia-Pacific region (PAS, n = 203) (Figure 5a).

Sub-Saharan Africa and South Asia show similarities regarding the frequency of responses for the cultivation sector, 48% and 40%, and other activities, 33% and 38%, respectively (Figure 5b). Latin America and the Asia-Pacific region show different patterns. For example, in Latin America and the Asia-Pacific region, the share of local responses directly related to the fishing sector are higher than in other regions, 9% and 11% respectively. No responses related to livestock keeping are reported for the Asia-Pacific region.

Although Sub-Saharan Africa and South Asia show similar response pattern regarding the cultivation sector, differences exist with respect to the response domain and type

Figure 3



Frequency of local climate change responses across climate zones **(a)**, according to the response sector **(b)**, the response domain **(c)**, and the response type **(d)**.

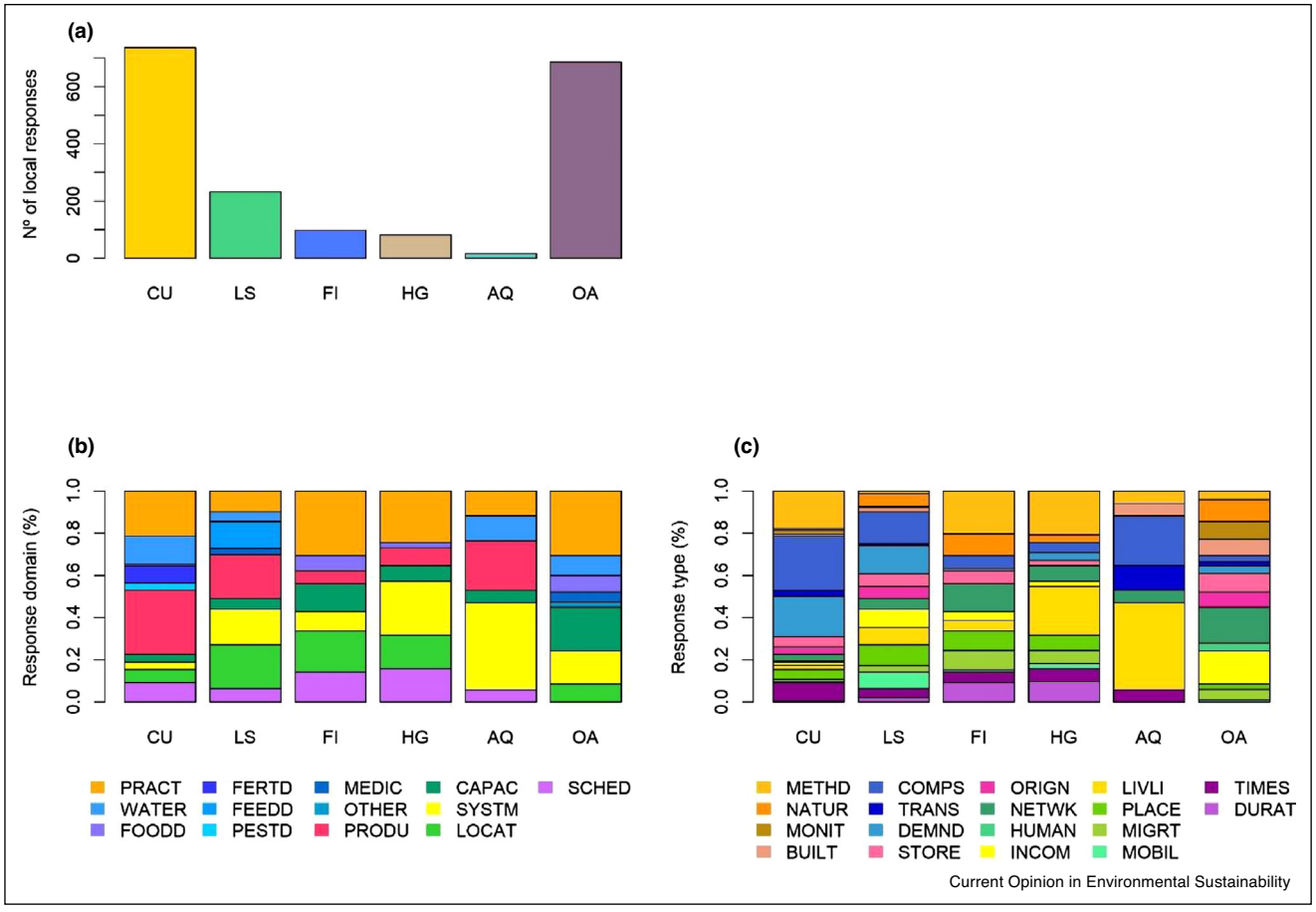
(Figure 5c,d). For example, while the demand for productive resource input, including water, fertilizer, pesticides and medicine is higher in South Asia (29%), more responses relate to relocation, including mobility, (12%) and income generation (9%) in Sub-Saharan Africa. Income generation is also a common response strategy in Latin America, while in the Asia-Pacific region a more common response is to strengthen social networks (19%) and rely on food storage (11%).

Discussion

IPLC across the world rely on a diverse portfolio of responses to face climate change impacts. While many responses involve changing natural-resources-based livelihood practices, about one-third of responses involve other activities (e.g. networking, off-farm labor, or biodiversity conservation). Globally, IPLC responses to climate change are more often shaped by livelihood activities than by the climate zone in which respondents live. We identified a geographic bias in the selected cases, which may be due to the uneven global distribution of research — also reported in other reviews on related topics [18••,26••,39,40] — the exclusion of grey literature [41] and non-English publications [42], and research investment patterns [43•].

Consistent with previous work [13••,14•], we found a large number and diversity of local responses to climate change impacts. In absolute terms, we have identified more responses than any previous systematic review and described a larger number of response categories [13••,14•,44]. Our 3-level approach is more comprehensive and detailed than previous classification systems [18••,45,46], thereby contributing to an improved understanding of local response strategies. Our classification system also allows manifold analysis by disentangling local responses into elementary units, that is, sector, domain and type. We found that IPLC generally respond to climate change impacts by changing aspects of their natural resource dependent livelihood system (63%), with

Figure 4



Frequency of local climate change responses across different response sectors **(a)**, according to the response domain **(b)** and the response type **(c)**. Sectors: cultivation (CU), livestock husbandry (LS), fishing (FI), hunting/gathering (HG), aquaculture (AQ) and other activities (OA).

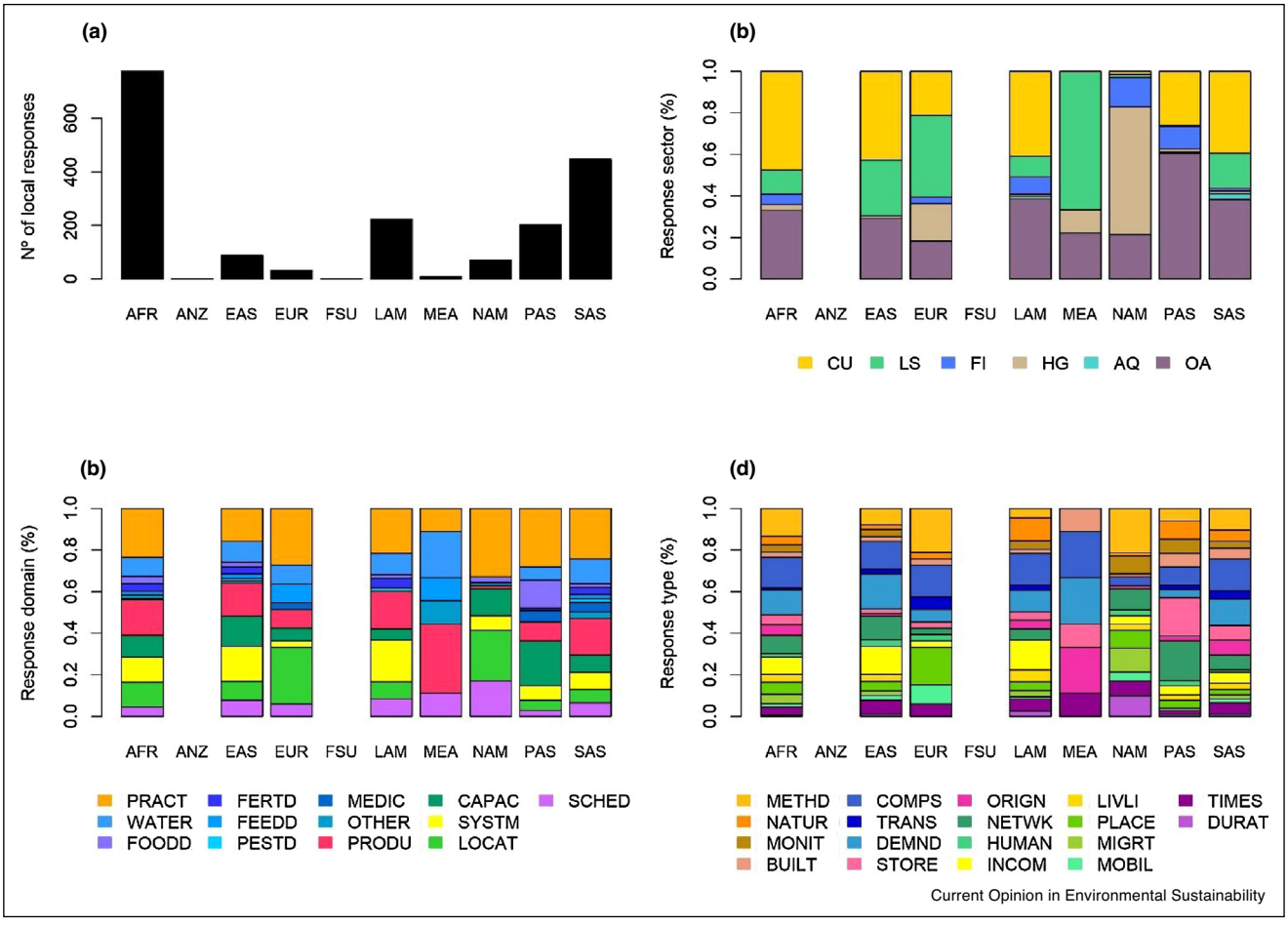
cultivation being the most represented sector in the sample. While this predominance can be partially explained by the relative global importance of small-scale agriculture [47–49], the share of responses in other livelihood sectors is disproportionately low compared to the number of communities that engage in other livelihoods in our sample. The apparent predominance of responses in the cultivation sector may also be due to the direct and strong impacts of changing rainfall patterns on cultivation and the resulting urgent need to adapt [23••].

Similar to previous work [18••,28,50], our findings show a high proportion of local responses related to behavioral changes, especially in the methods and techniques applied. However, contrary to previous work (e.g. Ref. [28]), we did not find that management, planning and knowledge transfer are important local adaptation strategies, probably because our review captures more spontaneous and reactive activities such as coping, adjusting or securing [51•].

As much as 36% of the documented responses do not directly relate to natural resource dependent livelihoods but to other household and community assets, for example, social networks, spirituality or biodiversity conservation [6••,25,52]. A strong link between ILK and social capital and biodiversity conservation has also been reported in other studies [53,54]. The importance of social relations in adaptation derives largely from its interaction and cascading benefits with other forms of capital (e.g. Refs. [55••,56]). For example, social institutions such as customary laws support coastal forest protection as adaptation measures to climate change impacts [52].

Although our search specifically targeted responses to climate change impacts by IPLC, not all reported responses could be unequivocally described as Indigenous or local [7], indeed some were externally driven and/or scientifically based. For example, the use of chemical fertilizers and pesticides, the adoption of hybrid varieties

Figure 5



Frequency of local climate change responses across world regions **(a)**, according to the response sector **(b)**, the response domain **(c)**, and the response type **(d)**. For the definitions of each world region see Table SM7.

or the shift towards off-farm work [57,58] were common responses. This finding shows that IPLC respond to climate challenges by using information from different knowledge systems [25,59], but it also raises questions about the long-term viability of some responses, due to their financial capital requirements [60,61] or potential negative ecological impacts [62•]. Other responses are more transformative and imply the potential loss of culture, tradition and social bonding [63]. In that sense, it is important to note that responses cannot be considered successful 'adaptation strategies' until their long-term viability, effectiveness, sustainability and potential impacts have been examined [64].

Our results on global patterns of local responses to climate change impacts show that ILK is relevant and transferable beyond the local context and scale of communities [9]. While the similarities in response strategies across climates may seem surprising, we argue that the patterns reflect the fact that people use similar strategies, rather than identical responses. For example, in different climates, changes in the cropping patterns and the adoption of irrigation might be a common response to climate change impacts in the cultivation sector. However, the selected species and varieties and the amount of required irrigation likely differ [65]. Thus, applying our findings at the local level requires accounting for local conditions and peculiarities.

Our classification system of local responses to climate change impacts provides a new tool for future analyses on the topic. For future work, we have the following recommendations: the consideration of additional literature, including grey literature, could further improve the classification system and our understanding of local responses to climate change. Future research could also apply this classification system to related topics such as assessments of adaptation drivers, adaptation enablers and barriers,

evaluations of adaptation feasibility, success, future viability, long-term sustainability and potential socio-cultural impacts of local responses to climate change impacts. Those are relevant topics for which our classification system presents a supportive tool for in-depth understanding.

Conclusion

Our systematic literature review constitutes a first attempt to consolidate and structure the scattered findings from many case studies on IPLC local responses to climate change impacts. The classification framework presented permits manifold analysis and comparisons of local responses within and between communities from different climates, world regions and with different natural resource dependent livelihoods, at local, regional and global levels. Our study shows that IPLC local responses to climate change are diverse, covering social, ecological and economic adjustments. Synthesizing such a wide range of local responses can help researchers, governments and other decision makers to understand the diversity of activities undertaken by IPLC, which could be used as a platform for informing future policies that support bottom-up approaches.

Author contribution

AS and VRG conceptualized the research questions and design. AS conducted the online literature search and the data analysis and was mainly responsible for developing the classification system. AS, VRG and SG were the main contributors to the writing of the manuscript. AM, IMS, PB and AS were responsible for the final selection, coding and quality check of the included and analysed publications. EC contributed conceptually to the manuscript, commented on several drafts and provided advice on the conceptual framework of climate change adaptation. RS contributed the online visualization of the developed classification system, namely the collapsing tree.

All co-authors commented on and contributed to several versions of the manuscript and the classification system, thereby considerably improving the final version.

Conflict of interest statement

Nothing declared.

Acknowledgments

Research leading to this work has received funding from the European Research Council (ERC) under grant agreement No 771056-LICCI-ERC-2017-COG. The authors acknowledge the financial support of the Laboratory for the Analysis of Social-Ecological Systems in a Globalized world (LASEG), Universitat Autònoma de Barcelona and Generalitat de Catalunya (2017-SGR-775). This work contributes to the "Maria de Maetzu" programme for Units of Excellence funded by the Spanish Ministry of Science, Innovation and Universities (CEX2019-000940-M).

Special thanks to Isha Thapa, Vanesse Labeyrie, Faustine Ruggieri, Xiaoyue Li, David Garcia del Amo and Miquel Mallo for their contribution to substantially improve this manuscript. Anna Schlingmann thanks the researchers of the Instituto de Ecología Regional in Tucumán, Argentina, for their contribution to the classification of local adaptation in the agricultural system.

We also thank the editor and anonymous reviewers for their useful comments and suggestions that helped to further improve the manuscript.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.cosust.2021.03.002.

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- •• of outstanding interest

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