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Impacts, adaptation and vulnerability to global environmental change: challenges and pathways for an action-oriented research agenda for middle-income and low-income countries

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The socio-economic impacts of environmental stresses associated with global environmental change depend to a large extent on how societies organize themselves. Research on climate-related societal impacts, vulnerability and adaptation is currently underdeveloped, prompting international global environmental change research institutions to hold a series of meetings in 2009–2010. One of these aimed at identifying needs in middle-income and low-income countries (MLICs), and found that effective responses to the challenge of reducing vulnerability and enhancing adaptation will drive research and policy into challenging and innovative areas of research. Producing impacts, vulnerability and adaptation knowledge requires greater inclusion of MLIC researchers and a rethinking of the research structures, institutions and paradigms that have dominated global change research to date. Scientific literature discussed in this article suggests that governance issues need to become central objects of empirically based, detailed, multiscale and action-oriented research, and that this needs to address the politically sensitive and seemingly intractable issue of reducing global inequities in power and resource distribution. The scientific literature suggests that without effective action in those directions, current trends toward greater inequality will continue to both reflect and intensify global environmental threats and their impacts.

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Introduction

It sounds like a paradox: ‘catastrophic and irreversible damage to natural systems from climate change need not result in catastrophic and irreversible damage to humans. . . [even though] . . . catastrophic and irreversible damage to humans can result even from modest changes in natural systems’ ([1••], p. 89). The critical factor is how societies develop and organize themselves – whether they do so in ways that render them vulnerable or resilient to current and future environmental stresses caused by global climate change in interaction with other environmental, political and economic trends, both global and local [2].

Pathways toward effective strategies for enhancing societal resilience and adaptation¹ to environmental stresses in general, and climate change in particular, have received relatively little attention in research and policy thus far [4]. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC-AR4) [3] reflected an enhanced focus on climate-related societal impacts, adaptation and vulnerability (IAV).²

¹ Adaptation is the process of adjustment to experienced or anticipated negative climate-related impacts in order to reduce vulnerability to climate extremes [3]. It includes a wide range of activities, from direct adaptations such as dike construction to prevent inundation and relocation of plantation areas and populations away from vulnerable areas, to indirect adaptations associated with capacity building, institutional transformation and research.

² Direct impacts of climate change on geobiophysical dynamics have received more scientific attention than indirect effects on socio-ecological systems. The ‘impacts’ evoked under the ‘IAV’ label in this article refer particularly to the indirect effects on socio-ecological systems.

Box 1 MLICs: Why middle-income and low-income countries?
(Source: [50^{**}])

The use of classifications of countries as developing/developed or industrialized might be inaccurate and even misleading when used to explore the linkages between development and climate change. Many so-called developing nations are not actually developing. The reference to OECD countries as industrialized hides the reality that some Asian and Latin American countries belong to the world's major industrial producers and several have higher proportions of their labor force in industry than North America and most of Europe. Considering these points, Working Group 3 of IPCC includes countries with these alternative development pathways and emissions trajectories, such as the OECD90 region and the countries undergoing economic reform (REF), within the developed-nations group. The collapse of the REF countries' economies during the 1990s resulted in great decreases in GHG emissions, while changes within the OECD90 nations showed two tendencies: one subgroup with increasing carbon intensity, a second with a decreasing trend. Therefore the World Bank's classification of national economies is used here (Figure 1): this is based on 2006 gross domestic product per capita, used to define middle-income and low-income countries (MLICs).

Nevertheless, the main emphasis in climate change research and policy has been on defining the nature of present and future climate changes and their *direct* impacts on natural systems [1^{**}]. Such research was crucial for the emergence of climate change as a global policy problem, but improvements in scientific predictions of climate change are weakly correlated with effective adaptation measures, as is also the case in other policy arenas [5]. What is needed is human-system research that can identify and help address the *indirect* and cumulative effects of environmental stresses and global trends, including the human factors that drive them [6^{**}].

Middle-income and low-income countries (henceforth referred to as 'MLICs', see Box 1, Figure 1) have been variously unable or disinclined to actively pursue research focused on IAV issues and to integrate societal resilience and adaptation enhancements as elements of overall policy responses [7,8^{*},9–11], yet these countries are going to be especially exposed and vulnerable to the negative impacts of climate extremes [10,12]. In the context of the IPCC, global environmental change researchers have come to recognize that inadequate attention has been paid to defining research that might help understand and address vulnerability in these countries, including how to support successful adaptation activities and reconcile such efforts with aspirations for development. As stated in the IPCC-AR4 [3], many key knowledge gaps remain (e.g. about consequences of abrupt change; impacts of multiple drivers; costs of impacts and adaptation; key vulnerabilities; communicating risks to stakeholders; adaptive capacities and resilience of natural and human systems) and research needs (e.g. on integrated monitoring systems for natural and social aspects; on integrated modeling; and on better regional scenarios).

To overcome the knowledge and action gaps related to IAV, the global environmental change community co-sponsored a series of meetings in 2009–2010 on IAV issues [13^{**}] (see Box 2). These included a Brazil meeting in November 2009 with the explicit goals of: identifying IAV research and researchers from MLICs; integrating the science-policy assessments, such as IPCC; creating research networks among them; and, defining an international science agenda for action-oriented IAV research with their central participation and the benefit of their expert knowledge about natural and human systems in MLICs. Given their high level of vulnerability to climate-related stresses³ [3], MLICs would be well-served by enhancing IAV-relevant national research and policy capacity to the extent that responsibility for adaptation efforts, and vulnerability reduction more broadly, tend to be deferred to the local and national levels [6^{**}].

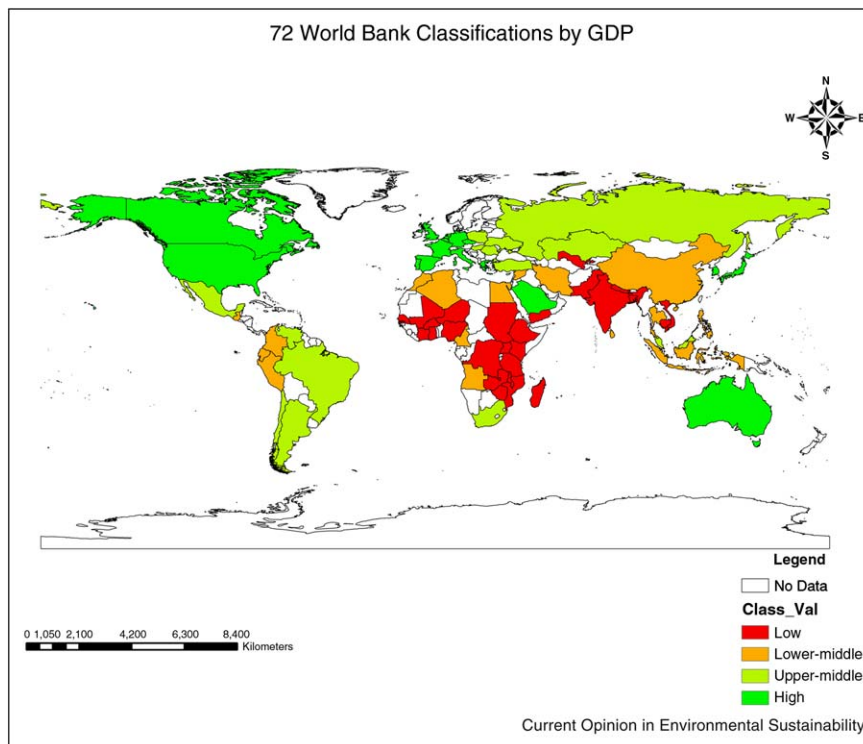
IAV researchers do not yet form a cohesive and organized community, partly because impact assessments have traditionally been conducted along disciplinary or sectoral lines (e.g. agriculture, hydrology or ecology) [15]. These issues are exacerbated by the genuine intellectual, cultural and organizational challenges of pursuing deeply interdisciplinary research. The result has generally been small and dispersed groups of researchers and research centers, lacking resources and coordination among agencies. This is true for the IAV community globally and further exacerbated in MLICs. More integrated and interdisciplinary approaches developed only when vulnerability assessment emerged a decade ago (e.g. [16]). A central challenge and achievement of the above-mentioned meetings has thus been the identification and engagement of relevant IAV researchers who focus more on adaptation and thus vulnerability. The Brazil workshop gathered 89 IAV scientists mostly from MLICs.⁴

Approaching climate change as part of a broader challenge of ensuring societal resilience to global environmental change and a transition to environmental sustainability, this article defines key themes and suggestions for research and policy directions for IAV research focused on MLICs, including both associated challenges and promising pathways.

³ In the decade of 1990–2000, developing countries have absorbed US\$ 35 billion a year in damages from natural disasters. On a per capita gross domestic product (GDP) basis, this is 20 times the cost in developed world [14].

⁴ Around 195 scientists were invited, mostly from developing nations. 89 persons were able to attend, representing 27 countries: 5 developed countries (England, Netherlands, Spain, Sweden, USA) and 22 developing countries (Argentina, Bangladesh, Botswana, Brazil, Chile, Colombia, Fiji, Ghana, India, Indonesia, Mexico, Mongolia, Mozambique, Nigeria, Philippines, Senegal, South Africa, Sudan, Tanzania, Venezuela, Vietnam, Zambia). The list of participants, itself one of the achievements of the meeting although far from sufficient, is available via <http://www.ess.inpe.br/iavbrazil/>.

Figure 1



Countries of the world classified by gross domestic product (GDP) according to the United Nations, showing the middle-income and low-income countries, or MLICs, referred to in this paper (middle-income countries are further subdivided in this map).

The causes of vulnerability and its links to economic inequality and development

Given the complex interlinkages among multirooted stresses, recent assessments suggest that IAV research should center on understanding the broader range of underlying causes of vulnerabilities [17,18], focusing analyses and policy efforts on societal and environmental stresses in general, not only on those associated with climate. Vulnerability analysis as a focus largely encompasses the areas of research needed, namely, those related to vulnerability (risk of a negative outcome), adaptation (adjustments to reduce vulnerability) and adaptive capacity (ability to adjust). Actual adaptation efforts are also an important area of study, which is relevant for identifying some proximate response options [19,20]. However, a focus and framing of vulnerability analysis which privileges adaptation can draw relatively greater attention to postimpact activities than to efforts to avoid impacts in the first place, whereas a focus on the causes of vulnerability helps draw attention directly to deeper structural factors that need to be addressed. The latter is helpful, provided that vulnerability analyses do not become ends in themselves.

The scientific literature on IAV identifies inequities in power and resource distributions as key obstacles to

achieving societal resilience, including successful adaptation to climate change [9,19–24,25,26,27]. Many of these inequities are currently increasing rather than decreasing [28,29]. Economic globalization and neoliberal reforms have resulted in marked income disparities and a weakened capacity of the nation state to respond to IAV challenges [9,20,30,31]. Global economic activity has had a significant role in environmental changes that, as illustrated by the Sahel, have led to large-scale human suffering and societal disruption during drought periods [32]. Both climate change impacts and adaptation potential are interdependent with such development-related social and environmental processes. For that reason, vulnerability and adaptation potential needs to be defined on the basis of careful analysis of the impacts of multiple factors on multiple scales, from the global to the local [26]. MLICs are especially vulnerable to multiple exposures in the form of the simultaneous impacts of climate change and economic globalization. In India, for example, both climate change and market liberalization for agricultural commodities are changing the context for agricultural production. Some farmers may be able to adapt to these changing conditions, including discrete events such as drought and rapid changes in commodity prices, while other farmers may not [33].

Box 2 A short history of meetings to develop an IAV community. (*Source: [17*]*)

Several meetings were convened in 2009 with and by the Impacts, Adaptation and Vulnerability (IAV) community, with the goal of better identifying and building that community.

After the release of the Fourth Assessment report of the Intergovernmental Panel on Climate Change (IPCC), a workshop in Sydney, Australia, in October 2007 collated lessons from this report that should guide global change research ahead of the next proposed assessment. That workshop was dominated by the global environmental change biophysical community, and its report [106*] noted that inadequate attention had been paid to defining research needs for supporting adaptation. While the earth system and integrated assessment modeling communities tend to be dominated by a relatively small number of large-scale modeling groups, it became apparent that the IAV community is a loose collection of researchers and research centers, mostly small in scale, which lacks coherence and structure.

Consequently members of the IAV community associated with the International Geosphere–Biosphere Programme (IGBP), the Earth System Science Partnership (ESSP) and the Second Working Group of the IPCC circulated an email in August 2008 to more than 90 colleagues in the international IAV community, inviting participation in a process of self-organization and enhanced communication with the IPCC Working Groups. A series of meetings resulted. The first was convened at the National Center for Atmospheric Center in Boulder, CO, USA ('Workshop on Climate Change Impacts, Adaptation, and Vulnerability Community Coordination,' 8–9 January 2009), followed soon after by another in Amsterdam, convened by the ESSP ('Future Climate-Change Response Research: Learning from IPCC's AR4,' 21–23 January 2009). The report from these meetings [18] emphasized the need for equal attention to be paid to understanding the underlying causes of vulnerabilities and the adaptation options and constraints. These meetings highlighted the low involvement of MLIC country researchers in the discussions, leading to the third meeting in Brazil (4–6 November 2009), as reported in this paper. Subsequent to these, the first major international conference on adaptation was held in Australia in June 2010 ('2010 Climate Adaptation Futures Conference', Gold Coast, Australia, 29 June–1 July 2010; see <http://www.nccarf.edu.au/conference2010/>).

Connections between vulnerability and political economic structures demand that attention be focused on social and governance dynamics, including how structures perpetuate inequalities that increase societal vulnerability. Research addressing disasters and climate change suggests that effective vulnerability reduction requires going beyond current development efforts, adopting a two-tiered approach involving both direct action on reducing disaster risk and fundamental reform of economic and sociopolitical structures that shape the governance of this risk [34–39]. As McMichael *et al.* [28] write, 'changes in technologies, behaviors, amenities, and equity are only the means to attaining desired human experiential outcomes, including autonomy, opportunity, security, and health. These are the true ends of sustainability-and there has been some recognition that their attainment, and their sharing, will be optimized by reducing the rich-poor divide' (p. 1919). Supporting their conclusion, a synthesis of research identifying obstacles

to achievement of the environmental Millennium Development Goals (MDGs) identified global economic inequality as a primary reason for failures to reach the goals, along with the lack of political will and the dependent variables of lack of infrastructure and deficient management [40].

Efforts to address climate change therefore need to be closely integrated with reduced socio-economic inequality and poverty, and are intimately interlinked with development [41,42]. A vicious cycle is created to the extent that environmental degradation (including but not limited to that associated with climate change) is expected to aggravate socioeconomic inequities [43], thus further intensifying this key obstacle to reducing vulnerability and reaching development goals. High and unsustainable consumption rates create environmental risks in the form of pollution, declines in food production, ecosystem degradation and global climate change [2]; poor levels of human development constrain adaptive capacity and increase vulnerability [3].

Some inequities that undermine societal resilience result from power distribution among different social groups, which can be differentially affected by climate impacts across regions and population groups [44]. For example, because of their role in the gender division of labor, women are more vulnerable to the impacts of climate change. A few studies illustrate how unequal power relations between women and men can be a causal factor in their differential access to environmental resources, opportunities for income diversification, time spent on livelihood activities, and capacities to cope and adapt [45,46]. A key priority area for IAV research is to understand how men and women face different types of vulnerability to climate change, and the resulting gendered implications. However, inequities that reduce environmental sustainability occur not only within and between countries and population sectors, but also as a result of power distributions among institutions [21].

Promises and dangers of 'mainstreaming' IAV issues into current development agendas

Adaptation to climate change has become an increasingly prominent issue not only within the UNFCCC but also on the agendas of multinational and bi-national development agencies. Even so, adaptation is taking place on a limited basis in developing countries compared to mitigation [3], and 'mainstreaming' climate change adaptation into development agendas has been 'a challenge less urgently tackled' [42]. However, an emphasis on adaptation over mitigation for MLICs runs the danger of leaving the latter behind in the race to a new low carbon 21st century society. By contrast, a focus on the causes of human vulnerability to climate change may reveal opportunities for linking low-carbon development pathways and poverty alleviation. Research must help identify

how adaptation needs in MLICs can be closely integrated with efforts to enhance livelihoods, mitigate climate change, and move toward low carbon economies. Tropical MLICs have some comparative advantages that may facilitate this: bountiful solar and biomass energy resources, and cobenefit opportunities in building, transport and land use, among other sectors. Attention to such opportunities is also important given the finding that adaptive action exclusively focused on climate change seldom occurs [3,20,47]. Without a commitment to the transition to low carbon economies, economic development and addressing climate change will continue to be in fundamental conflict. Technological transfer has been insufficient, wherefore that approach needs to be rethought and replaced by processes emphasizing North–South cooperation around green technology development ([17], Appendix C). One ironic benefit of being less developed is that it is possible to leapfrog conventional technologies that developed nations may be locked into, just as has happened with mobile communications technologies in Africa (where the phase of investing in fixed copper telephone wires has been avoided in many regions). The equivalent development pathways which do not slavishly follow western development sequences need imagining for future green economies in MLICs.

Anticipatory societal responses to climate change must be ‘mainstreamed’ into existing national or subnational policies and practices, in areas such as development, and natural resource-use and land-use management [3,48,49]. However, fears that funds for adaptation measures might be drawn from extant development funds without a net increase in the latter are causing hesitance, if not resistance, to the need to mainstream adaptation and resilience measures into development. This highlights the necessity to mobilize new financial resources.

Moreover, mainstreaming adaptation efforts into development agendas is necessary but insufficient insofar as current development efforts have been unable to counter dominant trends toward increased inequality, with the resulting increased vulnerability to environmental stress [50]. Development projects have thus far seldom improved poverty alleviation [51] and have been prone to failure. Future research should learn from existing analyses of the failures of development to alleviate poverty, and approach poverty as a complex, multifaceted and multirooted problem [52,53,54]. There is a danger that current climate adaptation efforts, including those promoted under the UNFCCC, are repeating mistakes of development projects. These mistakes include failing to pay sufficient attention to local realities, failing to adopt bottom-up approaches to decision-making [55,56] and failing to harmonize programs with local realities and institutions [57]. Top-down decision-making has an important role to play, but the empirically informed

scientific literature stresses the crucial importance of participative, bottom-up and locally informed approaches to effective and legitimate decision-making and program implementation for climate-related projects [58]. The optimal design of such participative processes is under-explored in current social science research [59] and needs to become a stronger focus. Addressing the paradox that democratic institutions have to generate the same public attitudes on which they rely, it is necessary to go beyond a mere emphasis on deliberation and participation by developing deeper approaches, integrating policy effort to establish the economic, cultural, and institutional pre-conditions needed for informed, democratic and effective deliberation [59,60]. This requires careful, systematic analysis of ‘the ways in which globalization has transformed the key parameters of civil society and how such changes recursively affect how civil society impacts national, regional, transnational, and supranational bodies’ ([61], p. 419).

Overcoming inclinations toward the status quo in governance

Institutions are central to understanding and responding to global environmental challenges. In the New Institutional framework [62], institutions embody *rules* that encapsulate values, norms and views of the world, including rules that define roles and the ‘game’ of politics; these establish for players both the objectives and the range of appropriate tactics or moves. While they are never completely static, institutions take time to develop and to change, as they gradually become ingrained in ways of understanding and acting in the world [62].

Existing social, economic, and political institutions currently limit actions within a narrow range, and a key question for research is how — and under what conditions — institutions can be transformed to enhance environmental sustainability and resilience. More specifically, New Institutionalists ask [62], how possible is it for dominant institutions to change themselves and to be changed by other social forces? The United Nations, the World Bank and other international organizations stress the importance of environmental sustainability and poverty alleviation. Development efforts to reduce poverty and social inequality are ongoing, yet the primary approach since the 1940s has been to promote macro-economic and political conditions deemed favorable to economic growth [63]. Rhetoric aside, equity and environmental issues are not currently the top priority in dominant institutions and policy agendas, for reasons that are structural in nature [64]. Market forces strive to maximize profits. States strive to protect national security, the conditions for economic growth and their own political legitimacy [64,65]. Neither of these two central contemporary forces include environmental protection among their driving concerns, and they also tend to perpetuate and even increase current inequalities. For

example, they are skewed toward disaster relief rather than long-term risk reduction, and they constrain vital technology transfer [66**]. While states generally are expected to override vested interests for the common good, states are, more often than not, 'entwined closely and sometimes indistinguishably with these same interests' ([66**], p. 203). These factors undermine the conditions needed for success in international agreements toward sustainable development, including the Kyoto Protocol and the MDGs [40].

International environmental treaties negotiated since the 1972 United Nations Conference on the Human Environment in Stockholm have arguably failed because they have integrated flawed ways of understanding the problem and its politics, reflecting inclinations toward the status quo by privileging states and market solutions and misrecognizing the underlying dynamics of development and economic globalization [67]. Approaching the world's environmental challenges as a matter of technical knowledge, to be integrated into existing institutional government arrangements, is a key part of the problem [68**]. Similarly, hazard management is increasingly a professional activity closely linked to existing bureaucratic and political power bases and, as such, resistant to tackling the institutional arrangements that restrict adaptability and resilience to environmental stresses [66**].

In light of the above, IAV research must do more to explore how to facilitate institutional arrangements that enhance social integration and accumulation of assets in more equitable and sustainable manners, building on insights in the current literature about how to empower the poor [1**,54*,69,70,71*,72,73,74*,75]. It should also seek to strengthen and give voice and impact to social movements, as democratic civic engagement is fundamental to successful social change. Albeit not always independent of elite interests [61,76], institutions of civil society are, as a whole, relatively less hindered by the limitations of institutions based in either the market or the state, wherefore they can help identify and propose actions to resolve social and environmental problems and infuse new thinking into public debates and decision-making [64**,77].

Recognizing the 'pattern of very deep-seated resistance to change' ([66**], p. 195) in dominant socio-economic and political systems at multiple scales, IAV research should seek to understand the factors that structure responses to risks. Using Handmer and Dovers [66**] typology of possible responses to resilience, they may explore what makes institutions more inclined to tackle the underlying causes of societal vulnerability and to possess greater preparedness to adopt new basic operating assumptions and institutional structures (see also [78]). In the current literature on climate adaptation, the need for change in institutions and policies is frequently men-

tioned but rarely specified [6**]. Yet efforts to ensure environmental sustainability and adapt to increased climate change and variability will require policy interventions to change behaviors across multiple sectors, involving policy processes that are constrained or enabled by current institutional settings. IAV research needs to provide detailed analysis of how to redesign policy processes and institutions, including at the crucial scale of national and subnational policy and planning which is very rarely analyzed [6**].

Though there are obvious possible political reasons for the limited focus on socio-political changes, a contributing nonpolitical reason is that there is little rigorous, in-depth, long-term and field-based research on the topic of vulnerability, including comparative studies of the causal structure of vulnerability [17*]. IAV research now needs to attend to the particularities of IAV-related response factors, places, and institutions. Such research should include attention to the politics of technical knowledge, both in its production and its (lack of) use in decision-making [79–85]. It is commonly assumed that relevant knowledge, once produced, will be used wherever possible. This assumption is not borne out by studies [7,86,87], suggesting that a deep understanding of MLICs' strategy choices in the area of climate-related research and action requires consideration also of the subjective, political, historical and cultural factors that shape the interpretive frameworks of decision makers [83,88*,89*], another crucial area that is little studied. Values, interests, and culturally inflected perceptions are intangible and methodologically difficult to access and predict, so that they are uncommon foci for analysis outside of anthropology [83,88*]. Yet they fundamentally shape decision-making that generates vulnerabilities [90,91]. Useful knowledge is therefore likely to emerge from interdisciplinary, empirical research on meaning-making, knowledge production and knowledge absorption at all levels of human societies, including institutions such as the IPCC and the World Bank [19,20,24,43,70,84,85,91,92].

Critical analysis of current information-structures

Research institutions and the dominant paradigms and priorities within them are similarly inclined toward the status quo, for example by viewing adaptation narrowly as a largely scientific and technical problem, and in their tendency to seek to estimate and quantify impacts rather than identify options to reduce vulnerabilities to climate change [4]. Most of this research has lacked effective engagement with the public, private, and other social sectors. The effect of this research on decision-making is thus still slim [93], encompassing relatively few studies about adaptation potential that integrate current understanding of how social–ecological systems respond to change [4,26]. This state of affairs reflects the minimal

participation of social scientists in vulnerability and adaptation research [4], as in global environmental change research generally.

Defining and reducing current global environmental threats, including their interactions with other human-driven dynamics, is not a priority at the level of research and major sponsors [94–96]. GEC research has thus far tended to focus on projections, on the above-mentioned erroneous assumption that knowledge, if available, necessarily will be used by national and local-level decision-makers. Social science research needs to further understand the conditions under which different types of scientific information are effectively brought to bear on environmental decision-making, building from existing insights, frameworks and research agendas.

To the limited extent that the social sciences are engaged in GEC research, they have tended toward familiar, disciplinary approaches and local case studies that are difficult to compare and insufficiently connected macro-structures and macroanalyses [89[•],97,98]. Yet interdisciplinary approaches are needed which address the multiple processes and multiscale nature of the causes of environmental risks, of vulnerability, and of the necessary solutions [28,90,99].

In its next phase, the IAV literature must identify obstacles to the creation of resilience-relevant science and to the impact of such science on decision-making at all scales. It must press beyond its current level of abstraction and generalities, and do more to help create the knowledge and conditions needed for democratic economic and sociopolitical reform by which to ensure environmental sustainability and societal resilience for all of the world's population segments. To do so, IAV research must grow more interdisciplinary, specific, and action-oriented. Adaptation to increased climate change and variability will require policy interventions to change behaviors across multiple sectors, requiring policy processes to reshape institutional settings. Yet in current discussions of climate adaptation, insufficient and insufficiently informed consideration is given to the necessary institutional changes [6^{••}]. Similarly, the literature often refers to justice concepts but remains highly unspecific as to how these concepts may best be reconciled not only with impacts and vulnerability, but also with policies and power politics [100]. The current regime recognizes the need for 'distributive justice between the rich and poor countries ... [but] it has not provided a basis to sufficiently upset the underlying forces and abiding structures of global inequality' [91].

The under-inclusion of MLIC researchers has thus far kept global environmental research from fully living up to its 'global' label [47]. Their under-inclusion can undermine the national and foreign environmental policies of

MLICs [19,91]. It may also have limited the application of systemic approaches to vulnerability identification and reduction, inasmuch as systemic changes are more frequently advocated by groups who are disadvantaged by current arrangements [66^{••}], and to the extent that MLIC researchers tend to focus on the socio-economic conditions and associated consequences marking their own region. At least in these respects, greater inclusion of researchers from MLICs may help increase attention to the causes of societal vulnerability in IAV research and policy. Their locally grounded experiences can also help to blend different knowledge sources and facilitate more locally relevant and effective efforts to enhance adaptation and resilience. Finally, by helping integrate new insights, data and publications that currently only exist in the local gray literature and in languages other than English, inclusion of new sets of researchers can help enrich and expand the IAV literature away from increasing self-referentiality, another factor currently limiting its policy impact [6^{••}].

Improved governance structures along the lines defined above also require critical analysis of current information (and associated power) structures. While calls for improved communication and information transfer have become commonplace, the causes of failures in communications and governance in developing and developed countries alike are deeper and more systemic than commonly recognized, including in current IAV research discourse. Limited data suggest that national and regional variations in media systems' political context, financial resources, institutional characteristics and journalistic practices produce regional differences in climate change coverage, affecting popular understanding of the nature of the threat [101–103]. There is a need for investigation into such variations and the associated effects of media in the processes of political (dis)engagement in relation to climate change. Analyses focused on the structural causes of vulnerability should seek to identify the deeper, systemic roots of all governance failures, including the roles of the political economy and of the mass media in undermining thorough, critical public understanding and political engagement with IAV-relevant politics and activities.⁵ Research needs specifically to advance knowledge of how information structures can be designed and used to reduce the power of entrenched, parochial, conflicting interests and overcome apathy, inertia, fatalism and the lack of political will.

Conclusion

Efforts need to centrally examine and address the *causes* of vulnerability in MLICs, enhance resilience and adap-

⁵ For instance, a 2008 report identifies a growing threat of soft censorship in Latin America, which it ties to the political economy of the media, in particular their dependence on government funds and access to government officials for information [104].

tation efforts in ways that harmonize with development needs and practices, and attend to multiple scales and multiple (and potentially also multiscale) sources of stress. Varied, multiple-scale causes of vulnerability must be identified, and adaptation must be addressed in a similarly broad fashion while pressing beyond the current IAV literature's tendencies toward abstraction and generalities. To do so, research now must produce more detailed and context-sensitive knowledge of a wide complex of socio-environmental factors and dynamics, including the interplay of the divergent values of various socio-economic groups and societies, interests, meaning-making and inequities in power and resource distributions. This will drive research and policy into difficult, exciting, and even entirely new, areas of research. On the basis of the current scientific literature, we suggest that research must focus on how to best inform and design effective and democratic Earth system governance institutions capable of responding to the global environmental challenges of the 21st century. This research must include the institutional restructuring needed to alter current environmental trends and ensure improved decision-making in line with the MDGs and United Nations-defined human rights-related and equity-related imperatives. These suggestions resonate with an important strand of the current IAV literature, yet continue to be insufficiently heeded in practice, highlighting the need to also research causes of inertia in IAV-related research and policy.

Scientific knowledge is fundamental for interventions aimed at reconciling environmental sustainability and climate-change challenges with development goals. However, IAV and development research needs to grow more interdisciplinary, specific, and action-oriented if it is to help create the knowledge and conditions needed for successful, democratic, economic and sociopolitical reform for all parts of the world's population. Producing such knowledge requires greater inclusion of MLIC researchers, a rethinking of research structures, institutions and paradigms that thus far have dominated global change research, as well as critical analysis of current decision-making processes and associated information-structures and power-structures.

Synthesis studies involving in-depth, long-term and empirically based research should be produced to identify causal factors through the analysis of dynamics at multiple dimensions and scales. Such analyses should be sufficiently complete to highlight the concrete links between vulnerability and development, and the dynamics and decision-making structures that maintain inequality. They should draw from, and integrate, currently fragmented fields of knowledge spanning many disciplines. Reducing vulnerability and adapting to climate change in MLICs requires a dynamic and multidimensional process in which scholars strengthen and participate in efforts

aimed at local development through the involvement of public, private, and social sectors.

MLIC IAV researchers need to gain a stronger voice in international activities, not least in the global environmental change research programs and the IPCC. South-south networking should aim at creating shared conceptual frameworks for MLIC-relevant IAV research, as such unity can help researchers gain a stronger voice. However, south-south collaboration should also integrate south-north partnerships that maintain and build MLIC IAV capacity at the levels of both research and action.

The GEC research community is strongly dominated by the natural sciences. A key challenge is to find ways of training and engaging more social scientists in GEC-related research, including (but not limited to) IAV issues. Social science engagement with GEC is especially weak in MLICs; even in countries like Brazil, Mexico, and Argentina, which have strong natural science research communities, so-called 'human dimensions' research of GEC is highly underdeveloped [25*,92,105]. That said, it bears noting that there already is considerable capacity in MLICs, including many brilliant researchers and scholars who do not lack capacity but, rather, the *opportunity* to engage in GEC-focused and sustainability-focused interdisciplinary research and, thus, to develop their skills as researchers. It is of global benefit to reach and fully engage such talent.

References and recommended reading

Papers of particular interest, published within the period of review, have been highlighted as:

- of special interest
- of outstanding interest

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