

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

Myanna Lahsen¹, Roberto Sanchez-Rodriguez², Patricia Romero Lankao³, Pauline Dube⁴, Rik Leemans⁵, Owen Gaffney⁶, Monirul Mirza^{7,8}, Patricia Pinho^{1,6}, Balgis Osman-Elasha⁹ and Mark Stafford Smith¹⁰

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.

Addresses

¹ Center for Earth System Science, Brazilian Institute for Space Research (INPE), Av. dos Astronautas 1758, São José dos Campos 12227-010, SP, Brazil

² Department of Environmental Sciences, University of California, Riverside, CA 92521, USA

³ Climate Science and Applications Program, National Center for Atmospheric Research, 3450 Mitchell Lane, Boulder, CO 80301, USA

⁴ University of Botswana, Private Bag 0022, Gaborone, Botswana

⁵ Environmental Systems Analysis Group, Wageningen University, PO Box 47, 6700AA Wageningen, Netherlands

⁶ International Geosphere-Biosphere Programme, Box 50005, SE-104 05 Stockholm, Sweden

⁷ Environment Canada, 1265 Military Trail, Toronto, ON, M1C 1A4 Canada

⁸ African Development Bank, 13 Avenue de Ghana, BP 323-1002, Tunis Belvedere, Tunisia

⁹ Higher Council for Environment and Natural Resources, Gamma Street, Khartoum 10488, Sudan

¹⁰ CSIRO Climate Adaptation Flagship, PO Box 284, Canberra, ACT 2601, Australia

Corresponding author: Lahsen, Myanna (myannal@gmail.com)

Current Opinion in Environmental Sustainability 2010, 2:364–374

This review comes from the Open issue
Edited by Rik Leemans and Anand Patwardhan

Received 23 July 2010; Accepted 25 October 2010

1877-3435/\$ – see front matter
© 2010 Elsevier B.V. All rights reserved.

DOI 10.1016/j.cosust.2010.10.009

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^{**}].

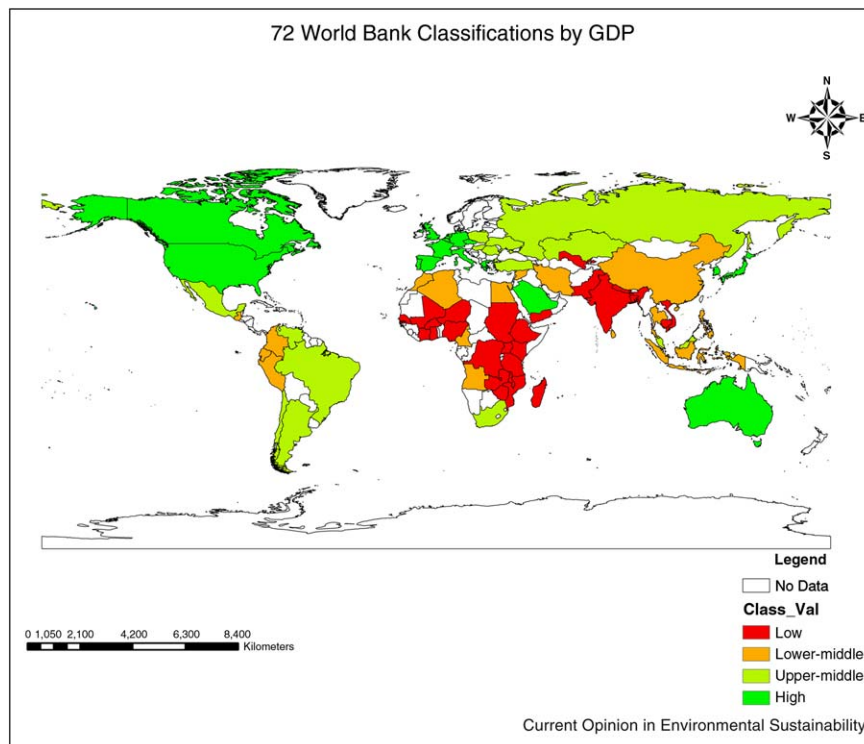
IAV researchers do not yet form a cohesive and organized community, partly because impact assessments have traditionally been conducted along disciplinary or sectoral lines (e.g. agriculture, hydrology or ecology) [15]. These issues are exacerbated by the genuine intellectual, cultural and organizational 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

1. Heltberg R, Siegel PB, Jorgensen SL: **Addressing human vulnerability to climate change: toward a 'no-regrets' approach.** *Global Environ Change* 2009, **19**:89-99.

This study presents and applies a conceptual framework to address human vulnerability to climate change. Drawing upon social risk management and asset-based approaches, the conceptual framework provides a unifying lens to examine links between risks, adaptation, and vulnerability. The integrated approach can help enhance societal capacity to manage climate risks, reduce the vulnerability of households and maintain or increase opportunities for sustainable development.

2. Rockstrom J, Steffen W, Noone K, Persson A, Chapin FS, Lambin EF, Lenton TM, Scheffer M, Folke C, Schellnhuber HJ *et al.*: **A safe operating space for humanity.** *Nature* 2009, **461**:472-475.
3. Parry ML, Canziani OF, Palutikof JP, Hanson CE, Van der Linden PJ: **Climate Change 2007. Impacts, adaptation and vulnerability.** *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge: Cambridge University Press; 2007.
4. Barnett J: **Adapting to climate change: three key challenges for research and policy — an editorial essay.** *WIREs Climate Change* 2010, **1**:314-317.
5. Dessai S, Hulme M, Lempert R, Pielke R Jr: **Climate prediction: a limit to adaptation?** In *Adapting to Climate Change: Thresholds, Values, Governance.* Edited by Adger WN, Lorenzoni I, O'Brien KL. Cambridge University Press; 2009:64-78.

6. Dovers SR, Hezri AA: **Institutions and policy processes: the means to the ends of adaptation.** *WIREs Climate Change* 2010, **1**:212-231.

Adaptation to increased climate change and variability will require policy interventions to change behaviors across multiple sectors. Institutional settings can constrain or enable policy processes. It discusses in detail how to redesign policy processes and institutions are especially rare at the crucial jurisdictional scales of national and subnational policy and planning.

7. Burton I, Huq S, Lim B, Pilifosova O, Schipper EL: **From impacts assessment to adaptation priorities: the shaping of adaptation policy.** *Climate Policy* 2002, **2**:145-159.

8. Mertz O, Halsnaes K, Olesen JE, Rasmussen K: **Adaptation to climate change in developing countries.** *Environ Manage* 2009, **43**:743-752.

This study presents the status of climate change adaptation in developing countries. Developing countries have to bear the large part of global costs of climate change, although these changes are caused mainly by industrialized countries. They are particularly vulnerable to climate change and have specific adaptation needs.

9. Eakin H, Lemos MC: **Adaptation and the state: Latin America and the challenge of capacity-building under globalization.** *Global Environ Change* 2006, **16**:7-18.

10. Mata LJ, Nobre C: **Impacts, Vulnerability and Adaptation to Climate Change in Latin America. Background Paper.** Bonn: The Secretariat of the United Nations Framework Convention on Climate Change; 2006.

11. Lahsen M, Öberg G: **The role of unstated mistrust and disparities in scientific capacity.** *CSPR Report.* Linköping: Centre for Climate Science and Policy Research, Linköping University; 2006.

12. Watson RT, Zinyowera MC, Moss RH (Eds): **Climate Change 1995. Impacts, Adaptations and Mitigation of Climate Change.** Cambridge: Cambridge University Press; 1996.

13. Leemans R, Asrar G, Canadell JG, Ingram J, Larigauderie A, Mooney H, Nobre C, Patwardhan A, Rice M, Schmidt F et al.: **Developing a common strategy for integrative global change research and outreach: the Earth System Science Partnership (ESSP).** *Curr Opin Environ Sustain* 2009, **1**:4-13.

This study discusses the ESSP program which facilitates the study of the Earth's environment as an integrated system in order to understand how and why it is changing, and to explore the implications of these changes for global and regional sustainability. Joint research projects on carbon dynamics, food, water and health have been established. As a result of an independent review, the ESSP developed a new strategy that will provide an internationally coordinated and holistic approach to Earth system science. The approach integrates natural and social sciences from regional to the global scale.

14. Freeman PK: **Hedging natural catastrophe risk in developing countries.** *Geneva Pap Risk Insur: Issues Practice* 2001, **26**:372-385.

15. Leemans R: **Personal experiences with the governance of the policy-relevant IPCC and Millennium Ecosystem Assessments.** *Global Environ Change* 2008, **18**:12-17.

16. Metzger MJ, Leemans R, Schroter D: **A multidisciplinary multi-scale framework for assessing vulnerabilities to global change.** *Int J Appl Earth Observ Geoinform* 2005, **7**:253-267.

17. Lahsen M, Stafford Smith M, Pinho P: **Impacts, adaptation and vulnerability: research needs and priorities in developing countries.** *Workshop report.* São José dos Campos, Brazil: INPE; 2010. This work identifies research needed to understand and address vulnerability related climate change, including how to support successful adaptation activities, synthesizing discussions that took place in a November 2009 workshop in Brazil on the Impacts, Adaptation and Vulnerability (IAV) of developing countries. Workshop participants included a total of 89 top experts working on IAV issues, both from developed and developing countries.

18. Palutikof J, Romero-Lankao P: **Adapting to climate change: research challenges.** *EOS* 2009, **90**: doi: 10.1029/2009EO250009.

19. Sánchez-Rodríguez R: **Vulnerability and adaptation to climate change in urban areas: a role for urban planning.** In *Building*

Safer Settlements. Governance, Planning and Responses to Natural Hazards. Edited by Fra U. IOS Press; 2009:105-124.

20. Sánchez-Rodríguez R: **Understanding and improving urban responses to climate change. Reflections for an operational approach for adaptation in low and middle-income countries.** *5th Urban Research Symposium; The World Bank, Marseilles, 28-30 June: 2010:17.*

21. Adger NW, Arnell NW, Tompkins EL: **Successful adaptation to climate change across scales.** *Global Environ Change* 2005, **15**:77-86.

22. Schipper ELF: **Climate change adaptation and development: exploring the linkages.** *Tyndall Centre Working Paper No. 107.* Norwich: Tyndall Centre; 2007.

23. Bohle HG, Downing TE, Watts MJ: **Climate change and social vulnerability: toward a sociology and geography of food security.** *Global Environ Change* 1994, **4**:37-48.

24. Sánchez-Rodríguez R: **Learning to adapt to climate change in urban areas. A review of recent contributions.** *Curr Opin Environ Sustain* 2009, **1**:201-206.

25. Romero Lankao P: **Urban areas and climate change: review of current issues and trends.** *Commissioned Issues Paper for UN-Habitat "Cities and Climate Change: Review of Current Issues and Trends".* UN-Habitat, Boulder: NCAR; 2008. Available from <http://www.ral.ucar.edu/staff/prlankao-staff.php>. This Concept and Issues Paper serves as a basis for the 2011 UN Habitat Report on Human Settlements Urban Areas and Climate Change: Review of Current Issues and Trends. Extracting ideas and findings from policy and academic writings on the multiple interactions between urban centers and climate change, discussing major challenges urban areas are facing in terms of main sources and drivers of climate change, key climate risks, and the factors shaping adaptation and mitigation options.

26. Romero Lankao P: **Water in Mexico City: what will climate change bring to its history of water-related hazards and vulnerabilities?** *Environ Urban* 2010, **22**:157-178.

27. Ribot JC: **Vulnerability does not just come from the sky: framing grounded pro-poor cross-scale climate policy.** In *Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World.* Edited by Mearns R, Norton A. The World Bank; 2009:47-74.

28. McMichael A, Butler C, Folke C: **New visions for addressing sustainability.** *Science* 2003, **302**:1919-1920.

29. Milanovic B: **Worlds Apart: Measuring International and Global Inequality** Princeton: Princeton University Press; 2005.

30. Wade RH: **Is globalization reducing poverty and inequality?** *World Dev* 2004, **32**:567-589.

31. Hoffman K, Centeno M: **The lopsided continent: inequality in Latin America.** *Annu Rev Sociol* 2003, **29**:363-390.

32. Nyong A, Adesina F, Osman Elasha B: **The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel.** *Mitigat Adapt Strat Global Change* 2007, **12**:787-797.

33. O'Brien K, Leichenko R, Kelkar U, Venema H, Aandahl G, Tompkins H, Javed A, Bhadwal S, Barg S, Nygaard L et al.: **Mapping vulnerability to multiple stressors: climate change and globalization in India.** *Global Environ Change* 2004, **14**:303-313.

34. O'Brien G, O'Keefe P, Rose J, Wisner B: **Climate change and disaster management.** *Disasters* 2006, **30**:64-80.

35. Lemos MC, Boyd E, Tompkins EL, Osbahr H, Liverman D: **Developing adaptation and adapting development.** *Ecol Soc* 2007, **12**:26 [online].

36. Lemos MC, Finan TJ, Fox RW, Nelson DR, Tucker J: **The use of seasonal climate forecasting in policymaking: lessons from Northeast Brazil.** *Climatic Change* 2002, **55**:479-507.

37. Tompkins EL, Adger WN: **Does adaptive management of natural resources enhance resilience to climate change?** *Ecol Soc* 2004, **9**: NIL_190-NIL_203.

38. Wisner B, Blaikie P, Cannon T, Davis I: *At Risk. Natural Hazards, People's Vulnerability and Disasters*. London: Routledge; 2004.
39. Pelling M (Ed): *Natural Disasters and Development in a Globalizing World*. New York: Routledge; 2003.
40. Castelló DL, Gil-González D, Alvarez-Dardet Diaz C, Hernández-Aguado I: **The environmental millennium development goal: progress and barriers to its achievement**. *Environ Sci Policy* 2010, **13**:154-163.
41. Agrawala S (Ed): *Bridge Over Troubled Waters: Linking Climate Change and Development*. Paris: OECD; 2005.
42. Murdiyasar D: **Climate and development — the challenges in delivering the promises: an editorial essay**. *WIREs Climate Change* 2010, **1**: doi: 10.1002/wcc.1019.
43. Thomas D, Twyman C: **Equity and justice in climate change adaptation amongst natural-resources-dependent societies**. *Global Environ Change* 2005, **15**:115-124.
44. Smith JB, Schellnhuber H-J, Qader Mirza M, Fankhauser S, Leemans R, Erda L, Ogallo LA, Pittcock BA, Richels R, Rosenzweig C et al.: **Vulnerability to climate change and reasons for concern: a synthesis**. In *Climate Change 2001. Impacts, Adaptation, and Vulnerability*. Edited by McCarthy JJ, Canziani OF, Leary NA, Dokken DJ, White KS. Cambridge University Press; 2001:913-967.
45. Masika R: **Editorial**. In *Gender, Development and Climate Change*. Edited by Masika R. Oxfam; 2002:2-9.
46. Alesina A, la Ferrara E: **Participation in heterogeneous communities**. *Q J Econ* 2000, **115**:847-904.
47. Romero Lankao P: **How do local governments in Mexico City manage global warming?** *Local Environ* 2007, **12**:519-535.
48. Huq S, Reid H: **Mainstreaming adaptation in development**. *Inst Dev Stud Bull* 2004, **35**:15-21.
49. Smit B, Wandel J: **Adaptation, adaptive capacity and vulnerability**. *Global Environ Change* 2006, **16**:282-292.
50. Romero Lankao P, Nychka D, Tribbia JL: **Development and greenhouse gas emissions deviate from the 'modernization' theory and 'convergence' hypothesis**. *Climate Res* 2008, **38**:17-29.
- This study shows that reduction of greenhouse gas emissions in developing countries will be far harder than many policymakers have predicted. This is due mainly to economic and technological disparities between rich and poor nations. The barrier will be a major barrier to the adoption of efficient and renewable forms of energy.
51. Few R, Tran PG: **Climatic hazards, health risk and response in Vietnam: case studies on social dimensions of vulnerability**. *Global Environ Change* 2010, **20**:529-538.
52. Krishna A: **For reducing poverty faster: target reasons before people**. *World Dev* 2007, **35**:1947-1960.
53. Zeller M, Sharma M, Henry C, Lapenu C: **An operational method for assessing the poverty outreach performance of development policies and projects: results of case studies in Africa, Asia, and Latin America**. *World Dev* 2006, **34**:446-464.
54. Davies M, Guenther B, Leavy J, Mitchell T, Tanner T: **Adaptive social protection: synergies for poverty reduction**. *IDS Bull Inst Dev Stud* 2008, **39**:105-112.
- This study examines the opportunities for linking social protection, adaptation and disaster risk reduction (DRR) in the context of agriculture and rural growth, as well as ways of linking these three approaches to help enhance resilience to shocks and stresses in agriculture-dependent rural communities.
55. Black JK: *Development in Theory and Practice: Paradigms and Paradoxes* Boulder, CO: Westview Press; 1999.
56. Scott JC: *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed* New Haven: Yale University Press; 1998.
57. Clements P: **An approach to poverty alleviation for large international development agencies**. *World Dev* 1993, **21**:1633-1646.
58. Panel on Strategies and Methods for Climate-Related Decision Support: *National Research Council: Informing Decisions in a Changing Climate* Washington, DC: National Academies Press; 2009.
59. Lövbrand E, Pielke R, Beck S: **A democracy paradox in studies of science and technology**. *Sci Technol Human Values* 2010 doi: 10.1177/0162243910366154.
60. Brown MB: *Science in Democracy: Expertise, Institutions and Representation* Cambridge, MA: MIT Press; 2009.
61. Cohen JL: **Civil society and globalization: rethinking the categories**. *Dados* 2003, **46**:419-459.
62. O'Riordan T, Jordan A: **Institutions, climate change and cultural theory: towards a common analytical framework**. *Global Environ Change* 1999, **9**:81-93.
63. Hjorth P: **Knowledge development and management for urban poverty alleviation**. *Habit Int* 2003, **27**:381-392.
64. Brulle RJ: **From environmental campaigns to advancing the public dialog: environmental communication for civic engagement**. *Environ Commun* 2010, **4**:82-98.
- Critical analysis of claims that more effective environmental messages developed through the application of cognitive science by professional communications experts can favorably influence public opinion, and thus support legislative action to remedy this issue.
65. Schlosberg D, Rinfret S: **Ecological modernization, American style**. *Environ Polit* 2008, **17**:254-275.
66. Handmer J, Dovers S: **A typology of resilience: rethinking institutions for sustainable development**. In *The Earthscan Reader on Adaptation to Climate Change*. Edited by Schipper LF, Burton I. Earthscan; 2008:187-210.
- An exceptionally clear and to the point analysis of three broad types of possible institutional responses in the face of environmental risks: resistance to change; change at the margins; openness and adaptation. Highlighting the prevalence and the dangers of, systemic tendencies to resist change. It is part of a valuable, edited volume joining especially significant contributions in IAV research.
67. Park J, Conca K, Finger M: **Death of Rio environmentalism**. In *The Crisis of Global Environmental Governance. Towards a New Political Economy of Sustainability*. Edited by Park J, Conca K, Finger M. Routledge; 2008:228.
68. Park J, Conca K, Finger M (Eds): *The Crisis of Global Environmental Governance. Towards a New Political Economy of Sustainability*. London: Routledge; 2008.
- A compilation of analyses which identify, and seek to move beyond, current institutional tendencies to resist changes needed to address the structural causes of global environmental problems.
69. Moser CON, Anis AD: *Assets, Livelihoods, and Social policy*. Washington, DC: World Bank; 2008.
70. Stern N: *A Blueprint for a Safer Planet. How to Manage Climate Change and Create a New Era of Progress and Prosperity*. London: The Bodley Head; 2009.
71. Tschakert P: **Views from the vulnerable: understanding climatic and other stressors in the Sahel**. *Global Environ Change* **17**:381-396. An interesting case study for a better understanding of vulnerability.
72. Carolini G: **Organizations of the urban poor and equitable urban development: process and product**. In *The New Global Frontier: Urbanization, Poverty and Environment in the 21st Century*. Edited by Martine G, McGranahan G, Montgomery M, Fernandez-Castilla R. Earthscan; 2007:133-150.
73. Satterthwaite D, Huq S, Reid H, Pelling M, Romero Lankao P: **Adapting to climate change in urban areas: the possibilities and constraints in low- and middle-income nations**. *Human Settlements Discussion Paper Series*. London: IIED — Human Settlements Programme; 2007.
74. Moser C, Satterthwaite D: **Towards pro-poor adaptation to climate change in the urban centres of low- and middle-income countries**. *Human Settlements Discussion Paper Series*. London: IIED — Human Settlements Programme; 2008. This study provides a useful approach to integrate the reduction of

- vulnerability and adaptation to climate change with poverty reduction efforts.
75. Stern N: *Key Elements of a Global Deal on Climate Change*. London: London School of Economics and Political Science; 2008
 76. Vogel A: **Who's making global civil society? Philanthropy and US empire in world-society**. *Brit J Sociol* 2006, **57**:635-655.
 77. Alcamo J, Kreileman GJJ, Leemans R: **Global models meet global policy – how can global and regional modellers connect with environmental policy makers? what has hindered them? what has helped?**. *Global Environ Change* 1996, **6**:255-259.
 78. Brewer GD, Stern PC (Eds): *Panel on Social and Behavioral Science Research Priorities for Environmental Decision Making*. Washington, DC: Committee on the Human Dimensions of Global Change, National Research Council; 2005.
 79. Goldman M: **The birth of a discipline: Producing authoritative green knowledge, world bank style**. *Ethnography* 2001, **2**:191-217.
 80. Ericksen PJ, Ingram JSI, Liverman DM: **Food security and global environmental change: emerging challenges**. *Environ Sci Policy* 2009, **12**:373-377.
 81. Lahsen M: **Transnational locals: Brazilian experiences of the climate regime**. In *Earthy Politics, Worldly Knowledge: Local and Global in Environmental Politics*. Edited by Jasanoff S, Martello ML. MIT Press; 2004:151-172.
 82. Lahsen M: **Seductive simulations? Uncertainty distribution around climate models**. *Soc Stud Sci* 2005, **35**:895-922.
 83. Lahsen M: **Distrust and participation in international science and environmental decision making: knowledge gaps to overcome**. In *The Social Construction of Climate Change*. Edited by Pettinger M. Ashgate Publishing; 2007:173-196.
 84. Lahsen M: **Experiences of modernity in the greenhouse: a cultural analysis of a physicist "trio" supporting the backlash against global warming**. *Global Environ Change* 2008, **18**:204-219.
 85. Kandlikar M, Sagar A: **Climate change research and analysis in India: an integrated assessment of a South-North divide**. *Global Environ Change* 1999, **9**:119-138.
 86. Sarewitz D, Pielke Jr RA, Byerly R (Eds): *Prediction: Science, Decision making and the Future of Nature*. Washington, DC: Island Press; 1999.
 87. Rosenzweig C, Parry ML: **Potential impact of climate change on world food supply**. *Nature* 1994, **367**:133-138.
 88. Lahsen M: **A science-policy interface in the global south: the politics of carbon sinks and science in Brazil**. *Climatic Change* 2009, **97**:339-372.
This article illustrates problems in the science-policy interface, revealing how history, culture and politics influence interpretations of scientific data and can limit its uptake in decision-making in MLICs.
 89. Lahsen M: **The social status of climate change knowledge: an editorial essay**. *WIREs Climate Change* 2010, **1**:162-171.
Many dimensions and implications of climate change remain uncertain and imprecise. Stakeholders clash and converge in their attempts to shape how societies understand the threat and what should be done about it, variously dismissing, downplaying or exaggerating the uncertainties and the sociopolitical and economic implications of action to reduce carbon emissions in ways that undermine policy. The article explains and discusses why more research needs to explore the social status of climate change.
 90. Cash DW, Moser SC: **Linking global and local scales: designing dynamic assessment and management processes**. *Global Environ Change* 2000, **10**:109-120.
 91. Okereke C: **Climate justice and the international regime**. *WIREs Climate Change* 2010, **1**:462-474.
 92. Nobre C, Joly C, Cerri C, Hogan D, Rocha H, Marcovitch J, Cortez LAB, Artaxo P, da Silva Dias PL: *FAPESP Research Programme on Global Climate Change (FRPGCC)*. São Paulo: The State of São Paulo Research Foundation (FAPESP); 2008.
 93. Eakin H, Patt A: **Are adaptation studies effective, and what can enhance their practical impact?** *WIREs Climate Change* 2010, in press.
 94. Lever-Tracy C: **Global warming and sociology**. *Curr Sociol* 2008, **56**:445-466.
 95. McMichael AJ, Butler CD: **Climate change, health, and development goals**. *Lancet* 2004, **364**:2004-2006.
 96. Nagel J, Dietz T, Broadbent J: **Summary of the proceedings of the Sociological Perspectives on Global Climate Change**. *Workshop on Sociological Perspectives on Global Climate Change; National Science Foundation, Arlington, Virginia, May 30-31, 2008*: 2009:156.
 97. Brosius P: **What counts as local knowledge in global environmental assessments and conventions?** In *Bridging Scales and Epistemologies: Linking Local Knowledge and Global Science in Multi-Scale Assessments*. Edited by Reid W, Berkes F, Capistrano D, Wilbanks T. World Resources Institute; 2006:129-144.
 98. Rhoten D: **Interdisciplinary research: trend or transition**. *Items Issues* 2005, **5**:6-11.
 99. Martens P, McEvoy D, Chang C: **The climate change challenge: linking vulnerability, adaptation, and mitigation**. *Curr Opin Environ Sustain* 2009, **1**:14-18.
 100. Gupta J: **Climate change and development cooperation: trends and questions**. *Curr Opin Environ Sustain* 2009, **1**:207-213.
 101. Eskjaer MF: **Communicating climate change in regional news media**. *Int J Climate Change Strat Manage* 2010, **1**:356-367.
 102. Carvalho A: **Media(ted) discourses and climate change: a focus on political subjectivity and (dis)engagement**. *WIREs Climate Change* 2010, **1**:172-179.
 103. Moser SC, Dilling L (Eds): *Creating a Climate for Change: Communicating Climate Change and Facilitating Social Change*. Cambridge: Cambridge University Press; 2007.
 104. Asociación por los Derechos Civiles (ADC): *The Price of Silence: The Growing Threat of Soft Censorship in Latin America* New York: Open Society Institute; 2009.
 105. D'Almeida Martins R, da Costa Ferreira L: **The research on human dimensions of global environmental change in Latin America: looking back, moving forward**. *Int J Climate Change Strat Manage* 2010, **2**:264-280.
 106. Doherty S, Bojinski S, Henderson-Sellers A, Noone K, Goodrich D, Bindoff N, Church J, Hibbard K, Karl T, Kafajez-Bogatay L et al.: **Lessons learned from IPCC AR4: scientific developments needed to understand, predict, and respond to climate change**. *Bull Am Meteorol Soc* 2009, **90**:497-513.
This work discusses future scientific developments needed to understand, predict and respond to climate change, in light of two classes of recommendations that emerged from the IPCC's 4th Assessment Report of Working Group I and II: the need to improve climate models, observational and climate monitoring systems, and our understanding of key processes, and the need to extend the framework for climate research and observations to document impacts and guide adaptation and mitigation efforts.