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The Dynamic Relationships between Cities and Global Environmental Change

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Introduction

This paper has been commissioned for this Roundtable in order to provide an overview context for the more specific case-study presentations and the ensuing discussion. While not attempting to be a comprehensive literature review, it draws on diverse sources and work within the 10-year UGEC core project of the International Human Dimensions Programme on Global Environmental Change (IHDP), in order to address three key questions, namely

1. What is the extent of global warming in relation to cities and what broad challenges arise from this?
2. To what extent do cities contribute to climate change?
3. What are the impacts of climate change on cities in different regions of the world?

A fourth question, following logically from these three, is to be addressed mainly by the case study papers, namely,

4. In what ways can cities contribute to the mitigation of greenhouse gas emissions and how can climate change be integrated into urban planning and management?

Taken together, these four questions could be said to encompass the entire research agenda and policy discourse on the complex and bidirectional relationships between cities and climate change. The body of research relevant to each is growing rapidly, but our knowledge in relation to the final question is still quite modest. Clearly full justice cannot be done to the volume of work in a brief synthesis review like this. However, we attempt to avoid simplistic generalisations and to indicate areas of uncertainty and regional/local diversity. In view of the rapidly evolving state of scientific knowledge and our understanding of the dynamics, and the inevitable empirical diversity of conditions, we also do not claim to provide definitive answers to each question. Indeed, our first argument is that any search for a simple 'holy grail' will prove illusory. Generalisations will always be just that and it is vital to remain sensitive to real-world variations.

Accordingly, an appropriate analytical and policy formulation framework that poses appropriate questions and adapts policies and practices to local biophysical, environmental, socio-economic and cultural conditions will be more useful and robust than efforts to formulate a supposedly universally relevant master plan or technical fix based on values or experiences in one particular part of the world (as has happened so often in the past).

Before addressing the questions cited above, we wish to highlight three preliminary points. First, in common with much of the relevant literature and policy discussion, this session focuses on cities, where high population densities and concentrations of economic activities provide the clearest and often most pronounced concerns in relation to global warming. However, urban areas of all sizes are relevant to the debate and policy process; indeed, in many countries, intermediate and smaller urban areas have been growing most rapidly in recent years and may experience *relatively* more pronounced impacts and changes as a result.

Second, the term 'climate change' is rather narrow and we prefer the broader approach of global environmental change (GEC), which encapsulates more diverse changes and interactions bound up with increasing greenhouse gas (GHG) concentrations in the atmosphere, ocean warming and sea level rise. GEC can be defined as the set of biophysical transformations of land, oceans and atmosphere, driven by an interwoven system of human and natural processes. More formally, GECs are global changes that (i) alter the well mixed fluid envelopes of the Earth system (the atmosphere and the oceans) and hence are experienced globally and those that (ii) occur in discrete sites but are so widespread such as to constitute a global change (Vitousek 1992). Examples of the former include change in the composition of the atmosphere, climate change, decreased stratospheric ozone concentrations and increased ultraviolet input while of the latter, land use change, loss of biological diversity, biological invasions and changes in atmospheric chemistry.

The effects of GEC comprise two distinct but mutually reinforcing processes. These are an increase in the frequency and severity of extreme events (such as hurricanes, storm surges, floods and droughts), most of which arise suddenly and are of short duration, and changes of a semi-permanent or permanent nature but that arise more slowly, such as sea level rise and atmospheric warming. These latter changes distinguish GEC from ‘natural disasters’. Hence, although the disasters literature and policy lessons are relevant, they are not sufficient. Broader approaches and policy responses are necessary.

Finally, it is important to understand the very different ways that challenges of GEC/climate change have been approached in different parts of the world. In wealthy countries, where most of the research to date has occurred and where mitigation and perhaps now also adaptation policies are often most advanced, efforts have focused on assessing the likely extent of GEC impacts, identifying weak spots in sea defences or other infrastructure and seeking to ‘climate proof’ them. Efforts to reduce GHG emissions and other contributors to GEC are intensifying. Crucially, at least before the current global economic/banking crisis, resource constraints have been less of a limiting factor than political will.

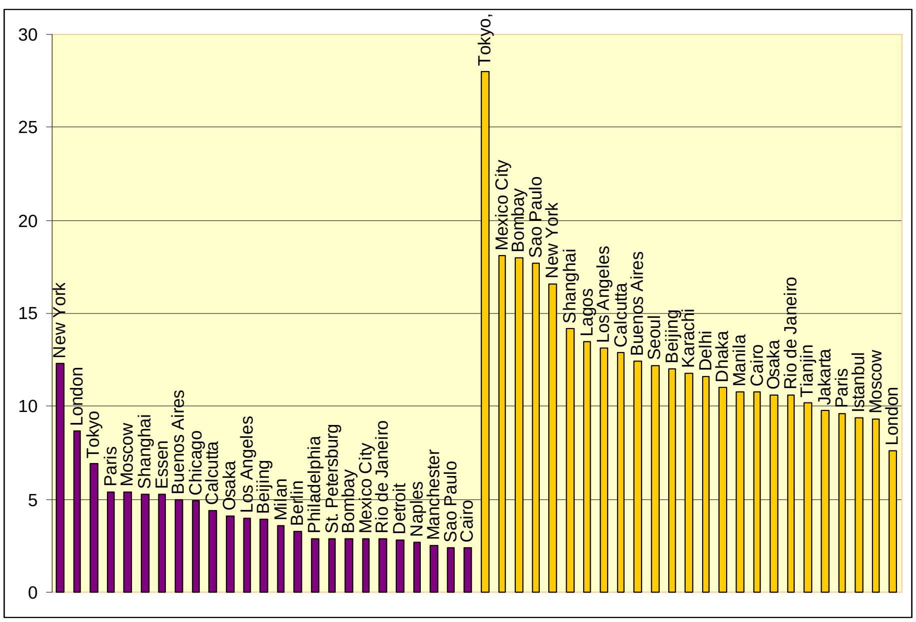
By contrast, in poorer countries, GEC mitigation and adaptation face severe resource constraints and have often been regarded as weak priorities at best, relative to the immediate pressures of hunger, poverty and the struggle to meet basic human needs, in short to ‘develop’. However, GEC impacts do pose a profound challenge, not least to the most vulnerable urban areas and groups. Hence, the challenge of GEC is necessarily finding a place within development discourses. Indeed, it is likely that only by being adopted within development policy and practice in order to avoid short-term projects from being undermined by longer term GECs, that the necessary political will and resources may be found to address them (Parnell, Simon and Vogel 2007).

What is the Extent of Global Warming in Relation to Cities and What Broad Challenges Arise from This?

Today we know that warming in the climate system is unequivocal and that most of the observed increase in globally averaged temperatures since the mid-20th century is *very likely* (with a 90-99% probability) due to human activity (IPCC 2007). Expected temperature increases range from 1.1-6.4 °C with a best estimate of 1.8 °C (3.2 °F). Due to thermal expansion and loss of mass from glaciers and polar ice caps, a sea-level rise of 18-59 cm is predicted during the 21st Century (*ibid*.). The annual frequency of natural catastrophes during the 1990s was three times higher than in the 1960s, causing a nine-fold increase in economic losses in real terms (*ibid*.). Other predictions by the IPCC AR4 (Fourth Assessment Report) suggest that it is v*ery likely* that hot extremes, warm spells and heat waves will continue to become more frequent over most land areas; that heavy precipitation events will become more frequent: the frequency (or proportion of total rainfall from heavy falls) will increase over most areas. Also, it is *likely* that the area affected by droughts will increase, that future tropical cyclones will become more intense, with higher peak wind speeds and heavier precipitation (but we have *less confidence in the estimates of change of total number).* Clearly, these predictions have significance for human security, safety, and health over the next century, particularly for urban areas.

Half of the world's population now lives in urban areas compared to 30% fifty years ago and 10% a century ago (Leitmann 2003). The populations of most (post)industrial countries are predominantly urbanised (>80%). Most of the world's future population growth is projected to occur in the rapidly growing cities of poor African and Asian nations as well as in Latin America (which has mostly already undergone its urban transitions and is today approximately 77% urban overall) (UN 2004). Between 1980 and 2030, urbanization levels in Africa are expected to increase from 20% to more than 50% (Leitmann 2003). While an increasing number of megacities, (population >10 million) is predicted, these are expected to contain approximately the same proportion of the world's urban population – around 15% as at present (Kahn 2006; UNCHS 2002); the majority of urbanites live in medium-sized or small cities. Furthermore, as already mentioned, the highest growth rates and associated urban challenges often occur in medium sized cities. The differences in identity and location of the world's largest cities between 1950 and 2000 are indicative of the changing global urban system (Figure 1).

Figure 1. Distribution of world's 25 largest cities (in millions of inhabitants), 1950 and 2000, in purple and yellow respectively (Source: UNCHS, 2002.)



Many of the most important changes associated with the impact of economic globalization and GEC are occurring in urban areas. These increasingly prominent (even dominant) interconnections between urbanization processes and GECs pose significant and urgent scientific and policymaking challenges.[1] In what follows, we review how issues of urbanization and environmental change have been analyzed in

[1] The need for further exploration of the intersection of those topics is promoted by the IHDP Urbanization and Global Environmental Change project (www.ugec.org), a 10-year international scientific programme positioned thematically at the intersection of these two major processes of global change (Sánchez-Rodríguez *et al.* 2005).

the past and the methods and frameworks currently being utilized.

One concept sometimes deployed to facilitate understanding of environmental problems and challenges as urban development occurs is that of the urban environmental transition (UET) (McGranahan *et al*. 2001; McGranahan 2007; Marcotulio 2007). While useful up to a point, and now being discussed in the plural to reflect the diversity of contexts and experiences, there is debate over whether the severity of environmental problems declines after a certain point as wealth increases (a bell-shaped curve on the graph) or continues to increase. Adapting the concept to accommodate GEC impacts will almost certainly also affect the situation and the shape of the graph, with some of the most severe impacts likely in low-income contexts.

To What Extent do Cities Contribute to GEC?

The increasing intensity and extent of urbanization are mirrored by increasingly complex interactions between environmental change and urbanization (Simon 2007). This complexity provides an argument for a focus on urbanization in the study of global environmental change and vice versa as well as a new conceptual framework of complex interactions (Sánchez-Rodríguez *et al*. 2005; Sánchez-Rodríguez 2008). To date, the principal emphasis in the relevant literatures has been on impacts originating in urban areas that have contributed to GECs.

Research into the relationships between urban areas and their surrounding 'natural' environments has identified several shaping factors (or dimensions) acting independently, or more often, in parallel. These are: (i) the level of economic development of a city, (ii) rapid demographic change, (iii) ecosystem factors, (iv) urban form (spatial structure) and function, and (v) the wider institutional setting (Anas, Arnott, and Small 1998; Leitmann 2003; Sánchez-Rodríguez *et al*. 2005; Simon 2007).

Table 1 represents a useful matrix of headings under which to assess the urban contributions to GEC. Constraints of space and time preclude discussion of more than a few illustrative examples.

Table 1. Sources of urban contributions to GEC

Transport	Waste	Habitat Destruction
Population	Industry	Sprawl/Growth
Consumerism	Highways	Commercial Buildings
Suburbs	Commuting	Water Use
Heat Islands	Weather Patterns	Energy Use

Of course, city size is not merely a function of population size but also of its density and distribution. An historically informed understanding of urban structure (spatial form) in particular places is therefore essential to beginning to address this aspect of the urban GEC nexus. Urban sprawl, facilitated by increasing access to private motor vehicles, has often created large, low-density suburban zones linked by congested commuting highways to city centres, industrial zones and other employment locations. In high-income countries, commuting car occupancy rates are characteristically low.

By contrast, in poorer countries, only the elites commute in this manner; most working people rely on congested public transport (with mass rapid transit lines under construction in a growing number of large cities) and increasingly ubiquitious minibuses and other forms of paratransit. Importantly, while private car ownership is positively correlated to per capita income, this relationship is neither linear nor constant; indeed some high income countries (e.g. Japan, South Korea, Netherlands) have comparatively modest car ownership rates due to a history of high density urban living with effective public transport systems (Simon 1996). Others, like Singapore, have adopted stringent policies to tackle congestion and vehicle emissions, again linked to effective public transport.

‘Modern’ (i.e. mainly western-derived) building materials, architectural styles and especially the increasing reliance on high-rise development are often unsuited to local tropical and sub-tropical conditions, necessitating reliance on energy-intensive power and air conditioning systems, exacerbating per capita GHG emissions. This quest for modernity also often involves the loss of locally appropriate designs, technologies and traditions. Possibilities of developing interesting and effective hybrids are rarely pursued, even/especially where resource constraints are not a factor, as in the competitive reach for the sky now so prominent in Dubai and Abu Dhabi.

Urban land use change can affect biogeochemical cycles through altered disturbance regimes, landscape management practices, urban spatial structure, and changes in the local environment; these changes have created novel urban ecosystems, which have the potential to affect biogeochemical cycles at local, regional, and global scales significantly (Pouyat *et al*. 2007). Urban morphology affects natural ecosystem functions through the displacement or removal of flora and fauna (or loss of biodiversity), net primary productivity, nutrient and material cycling and disturbance regimes (Alberti 2005). It is important to emphasize, however, that while worldwide urbanization processes have been studied on a case-by-case basis, we do not have a good understanding of the aggregate impacts.

Nevertheless, much evidence shows that cities cause atmospheric and microclimatic changes: urban lifestyles reduce atmospheric quality with the introduction of a variety of air pollutants – by-products of urban lifestyle and consumption patterns. These give rise to the urban heat island effect (Oke 1982; Grimmond 2007); and city size is statistically associated with changes in rainfall patterns (Kaufmann *et al*. 2007).

Other complex interactions between urbanization and global environmental change are understudied. Less attention has been paid to GECs that have a negative effect on urban areas (e.g., impacts on the socioeconomic situation and health of the people who live in cities), the resulting interactions and responses within urban systems due to those GECs and the feedback of those responses to GEC.[2]

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[2] Research in these unexplored areas is promoted and supported by the UGEC core project. This project provides the framework for co-ordination of research that analyzes interactions between global environmental change and urban processes. In short, the framework seeks an answer to the following question: What are the interactions between GEC and urban processes and the results of these interactions across spatial and temporal scales and for different social groups (social groups defined as appropriate in any particular context: in terms of age, gender, ethnicity, class, migration status, degree of empowerment etc.) It suggests a focus on the rate, intensity and scale of

Four themes that emerge from a conceptual framework of interactions between the urban and the global environment components of the Earth system have been identified (Sánchez-Rodríguez *et al*. 2005; Simon 2007; Sánchez-Rodríguez 2008), conceptually distinguishing the earth system into an urban sub-system and a global environment sub-system. *First*, the conceptual framework starts with processes within the urban system that contribute to global environment change. *Second*, it focuses on the pathways through which specific global environmental changes affect the urban system. *Third*, once these pathways and points of intersection are identified, the framework addresses the interactions and responses within the urban system which result. *Finally*, it centres on the consequences of the interactions within the urban system on global environmental change, or feedback processes (Sánchez-Rodríguez *et al*. 2005; Simon 2007; Sánchez-Rodríguez 2008).

What are the Impacts of GEC on Cities in Different Regions of the World?

As documented in the Stern Review Report (2006, 2007) and Fourth Assessment Report of the IPCC (2007), many of the profound impacts of climate change will be felt in different combinations everywhere, with poor countries and urban areas suffering particularly severely. Inland and coastal urban areas face different challenges but low-lying areas of coastal cities, and low elevation coastal zones (LECZs) as a whole, are generally regarded as being the most vulnerable. Some 13% of the world's urban population lives in LECZs, often in high spatial concentrations; the ten countries with the most people living in LECZs account for about 73% of those who live in the zone globally and most are also low- or middle-income countries (McGranahan, Balk and Anderson 2007, 2008: 172-4).

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urban and environmental change and their mutual impacts; the examination of pathways of transformations of urban systems and a look at the challenges for sustainability of urban areas. The framework focuses on processes and people: seeing urban areas as part of wider geopolitical, socio-economic processes and environmental systems that operating at various spatial and temporal scales and both the nature of different impacts and possible adaptations and coping strategies. It is an integrative interdisciplinary science framework: it seeks to bring closer together the social and natural sciences that can have an input on these issues; to enhance the connection between theoretical and applied approaches, seeing urban areas as part of wider geopolitical, socio-economic processes and environmental systems that operating at various spatial and temporal scales.

Table 2 below lists the different aspects of climate change, the evidence for current impact, projected future impacts and the zones or groups most affected. It highlights the different kinds of impacts that arise from changes in extremes and changes in means; it also notes the need to consider the impacts of abrupt climate change, while also noting that its significance is less clearly established.

Table 2. Selected examples of current and projected impacts of climate change on industry, settlement and society and their interaction with other processes

Climate-driven phenomena	Evidence for current impact/ vulnerability	Other processes/ stresses	Projected future impact/ vulnerability	Zones, groups affected
a) Changes in extremes				
Tropical cyclones, storm surge	Flood and wind casualties & damages; economic loses; transport, tourism, infrastructure (e.g. energy, transport), insurance	*Land use/ population density in flood-prone areas; flood defences; institutional capacities*	*Increased vulnerability in storm-prone coastal areas; possible effects on settlements, health, tourism, economic and transportation systems, buildings & infrastructures*	*Coastal areas, settlements, and activities; regions and populations with limited capacities and resources; fixed infrastructures; insurance sector*
Extreme rainfall, riverine floods	Erosion/landslides; land flooding; settlements; transportation systems; infrastructure	*Similar to coastal storms plus drainage Infrastructure*	*Similar to coastal storms plus drainage infrastructure*	*Similar to coastal storms*
Heat- or cold-waves	Effects on human health; social stability; requirements for energy, water and other services (e.g. water or food storage), infrastructures (e.g. energy transport)	Building design and internal temperature control; social contexts; institutional capacities	Increased vulnerabilities in some regions and populations; health effects; changes in energy requirements	*Mid-latitude areas; elderly, very young, and/or very poor populations*
Drought	Water availability, livelihoods, energy generation, migration, transportation in water bodies	*Water systems; competing water uses; energy demand; water-demand constraints*	Water-resource challenges in affected areas; shifts in locations of population & economic activities; additional investments in water supply	*Semi-arid and arid regions; poor areas and populations; areas with human-induced water scarcity*
b) Changes in means				
Temperature	Energy demands and costs; urban air quality; thawing of permafrost soils; tourism and recreation; retail consumption; livelihoods; loss of meltwater	Demographic and economic changes; land-use changes; technological innovations; air pollution; institutional capacities	Shifts in energy demand; worsening of air quality; impacts on settlements and livelihoods depending on melt water; threats to Settlements / infrastructure from thawing permafrost soils in some regions	Very diverse, but greater vulnerabilities in places and populations with more limited capacities and resources for adaptation

Precipitation	Agricultural livelihoods, saline intrusion, tourism; water infrastructures, tourism, energy supplies	*Competition from other regions/ sectors; water-resource allocation*	*Depending on the region, vulnerabilities in some areas to effects of precipitation increases (e.g. flooding, but could be positive) and in some areas to decreases (see drought above)*	Poor regions and populations
Saline intrusion	Effects on water infrastructures	Trends in groundwater withdrawal	Increased vulnerabilities in coastal areas	Low-lying coastal areas, especially those with limited capacities and resources
Sea-level rise	Coastal land uses: flood risk, water logging; water infrastructures	*Trends in coastal development, settlement and land uses*	*Long-term increases in vulnerabilities of low-lying coastal areas*	*Same as above*
c) Abrupt climate change	Analyses of potentials	Demographic, economic, and technological changes; institutional developments	Possible significant effects on most places and populations in the world, at least for a limited time	Most zones and groups

Dark shading with text in italics indicates very significant in some areas and/or sectors; light shading indicates significant; no shading indicates that significance is less clearly established.

Source: Satterthwaite, D., Huq, S., Reid, H., Pelling, M. and Romero Lankao, P. (2007) *Adapting to climate change in urban areas: the possibilities and constraints in low and middle income nations*, Human Settlements Discussion Paper Series, Climate Change and Cities 1, IIED, London, Table 4, pp.16-17, (online at http://www.iied.org/pubs/display.php?o=10549IIED). Based on Wilbanks, T. & Romero Lankao, P. with Bao, M., Berkhout, F., Cairncross, S., Ceron, J-P., Kapshe, M., Muir-Wood , R. and Zapata-Marti, R. (2007), “Chapter 7: Industry, Settlement and Society”, in Parry, M., Canziani, O., Palutikof, J., Van der Linden, P. and Hanson, C. (eds) *Climate Change 2007: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the IPCC, , Cambridge University Press, Cambridge & New York, pp. 357-390.

Among extreme events, the most well-known hazards and risks include increasingly frequent and severe storm surges, flooding (from rainfall run-off, overflowing rivers and/or storm surges) and droughts, while the more permanent slow-onset events include sea level rise, increasing ambient temperatures and falling groundwater tables or river levels, thus affecting drinking water supplies. Less well known but no less potentially damaging is the effect of salinisation of groundwater aquifers through saltwater penetration of coastal dunes as a result of increasingly severe and frequent storm surges, rising sea levels and/or reduced fresh water tables. Certain physical and socio-economic attributes of place, such as terrain and topography, geology, proportion of wetlands and other flood-prone areas, sub-standard urban planning and infrastructure, elaborate but ineffective management plans, and population characteristics, combine with these risks to create particular vulnerabilities (De

Sherbinin *et al*. 2007; Parnell, Simon and Vogel 2007; IHDP Update 2007; Satterthwaite *et al*. 2007).

Moreover, scale effects remain important. A focus on entire cities may detract from considering the impacts upon particular areas and groups of people, especially the most vulnerable. A cross-cutting intra-urban analysis that highlights differential vulnerabilities to GEC of particular places (localities) and people within cities is therefore essential. Commonly, these two categories overlap, as when poor people occupy marginal land that is particularly vulnerable to extreme events and GEC, e.g. low-lying wetland margins, river or estuary banks, steep slopes, the perimeter of petrochemical complexes and fuel depots. Satterthwaite *et al*. (2007) summarise the case study literature, containing many such examples from poorer countries around the world; Simon (2008) focuses on Africa in a global context, which includes numerous continental and global learning networks of leading cities.

Furthermore, as the livelihoods and disasters literatures demonstrate conclusively, young children, lactating mothers and the elderly constitute particularly vulnerable groups in most contexts – a point recently highlighted for urban children in the context of GEC by Bartlett (2008).

Concluding Prospects

The evidence assembled in the IPCC AR4 points with increasing confidence at even more profound GEC impacts, especially on urban areas around the world, than previously thought. The growing literature on individual cities is also demonstrating with growing regularity, the range and nature of such impacts. These comprise both the increasing frequency and severity of extreme events and the slower, longer-term changes to prevailing conditions. It is the combination of the two, with hurricanes and storm surges on top of a rising sea level, for instance, that makes GEC so potentially damaging. Complementing this analysis, the Stern Review Report (2006, 2007) provides a convincing economic argument in favour of taking resolute measures to mitigate and adapt to the effects of GECs, namely that this course of action will be substantially cheaper than doing nothing.

By way, of conclusion, and in anticipating the contributions of the case study presentations that follow, a few brief thoughts on the potential contribution of cities to mitigating GHG emissions and integrating GEC into urban planning and managements are in order.

As the relatively easy, straightforward and cheap mitigation measures (e.g. the fitting of low-energy bulbs in street lighting) are addressed, attention must shift to the more structural, long-term and costly adaptation measures that involve hard decisions and a change to current unsustainable and vulnerable lifestyles. Urban densification (i.e. a movement towards more compact urban form), permitting and encouraging in appropriate ways the (re)creation of multifunctional land-use zones (particularly combining residential with non-polluting and disturbance-causing economic activities), and providing effective, affordable and accessible public transport to shift the balance away from private vehicles are likely to be among the key adaptive measures to reduce urban per capita contributions to GEC.

In terms of the urban impact of GECs, the issues outlined so far suggest the potential of an integrated approach to vulnerability, adaptation and resilience (VAR) – one of four crosscutting themes of the IHDP's programme.[3] Adaptation is the process of structural change in response to external circumstances.[4] As properties of socio-ecological systems (SESs), the concepts of *resilience*, *robustness*, and *vulnerability* are heavily interlinked (Young *et al*. 2006). Robustness is a set of system properties favouring the endurance of the system to disturbances without changes in system structure; robustness depends crucially on past adaptation activity. Resilience is "the capacity of a system to absorb and utilize or even benefit from perturbations and changes that attain it, and so to persist without a qualitative change in the system's

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[3] IHDP's core research projects are linked by four crosscutting themes, which crystallize key aspects of human dimensions research: "*Vulnerability/Resilience/Adaptation*: What factors determine the capacity of coupled human-environment systems to endure and produce sustainable outcomes in the face of social and biophysical change? *Thresholds/Transitions*: How can we recognize long-term trends in forcing functions and ensure orderly transitions when thresholds are passed? *Governance*: How can we steer tightly coupled systems towards desired goals or away from undesired outcomes? *Social Learning/Knowledge*: How can we stimulate social learning in the interest of managing the dynamics of tightly coupled systems?" The definitions of vulnerability, resilience and adaptation that are provided are found in Young *et al*. (2006).

[4] A related term such as *adaptedness* refers to the effectiveness of a dynamic structure in dealing with its environment; *adaptability* refers to the capacity to adapt to future changes in the environment of the system concerned (Young *et al*. 2006).

structure" (Holling 1973, cited in Young *et al*. 2006: 305).

Robustness and resilience differ in that the concept of resilience allows for temporary changes in functioning and dynamics, as long as the system remains within the same stability domain but the concept of robustness does not. Vulnerability is a state where neither robustness or resilience help the system survive without structural change (Young *et al*. 2006). Disturbances affecting a vulnerable state will lead to a structural system adaptation or collapse. All three terms express a temporary condition of the interaction between a system and its context (Young *et al*. 2006).

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