Building Resilient Human Settlements in a Climate of Change

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Introduction

The main purpose of this chapter is to 1) note the impacts of climate change on human settlements and vice versa, and 2) propose design and institutional strategies to improve the resilience of human settlements to withstand these impacts or at least reduce the vulnerability of human settlements to these impacts.

This chapter constructs a Human Settlement Resilience Framework and interventionist strategies. These strategies are based on the premise that resilience can be built into human settlement development.

Background and Context

Living conditions – economic, social, environmental, and institutional – are changing on Earth.

This is not new, nor is it unique. The economic, social, environmental and institutional world constitutes a dynamic system, always in transformation from one state to another, sometimes smoothly and sometimes turbulently. However there is sufficient scientific consensus that anthropogenic impacts are resulting in an alarming degree of climatic, environmental and social change beyond rates experienced over the last 650 000 years (IPCC2007).

Global temperatures cycle between geological intervals of warmer global average temperature known as Interglacial Periods, and periods of colder global average temperature, known as Glacial Periods. Long glacial periods are therefore separated by more temperate but shorter interglacials. During these past interglacials, where the climate more or less matched present day temperatures, the tundra (vast level treeless Arctic region where subsoil is frozen) receded towards the poles. As the tundra recedes it gets replaced by forests. This alternating cycle of floral and faunal expansion and retraction enables palaeontologists to study the climatic conditions prevalent at the time and the age of the particular interglacials (Kottak 2005).

Periods do occur within an interglacial where conditions are optimal, known as the climatic optimum of an interglacial, and this generally occurs during the middle part of the interglacial. The climatic optimum is preceded and followed by periods that are less favourable although it is still better than the conditions found in the preceding/succeeding glacial.

The current Holocene interglacial period, which commenced about 11 400 years ago (the end of the Pleistocene which lasted 2.5 million years) and in which we now find ourselves, experienced its climatic optimum roughly 3000 BC-500BC, resulting in an environmentally benign period highly supportive of human development. This period coincides with the transition out of the Stone Age to the Bronze Age and into the Iron Age. Our current climatic phase following this optimum is still within the same interglacial (the Holocene).

The history of ancient Mesopotamia, coinciding as it did with the Bronze Age, begins with emergence of urban societies during the Ubaid Period (ca. 5300 BC). It is also perhaps not coincidental that in historical archaeology the ancient literature of the Iron Age includes the earliest texts preserved in manuscript tradition, including the oldest parts of the Hebrew Bible.

What distinguish our current climate of change from previous periods of change are two factors – human consumption growth, and anthropogenic induced environmental impacts.

The global population breached 7.0 billion in November 2011. Over half of this population live in poverty, and over half live in cities (and there is a strong correlation between the two). There has therefore been a concentration of population within urban areas: there are now 21 megacities in the world (UNEP 2011). Urbanisation generally improves standard of living resulting in higher rates of resource consumption: it is not coincidental that global GDP has increased by 74 per cent over the past 20 years (UNEP 2011).

The natural environment goes through cycles of growth and decline in response to climate change: however what is different now is the coupling of anthropogenic and climate change impacts on the natural environment. The sheer 'weight' or footprint of the current human consumption on natural resources (resource depletion), the reduction in biodiversity (replaced by mono-agriculture), and the influence of climate change on ecosystem health and distribution, is projected to result in an extinction event (Woolridge 2008).

Resilience

In environmental terms ecosystem resilience can be defined as "the capacity of an ecosystem to tolerate disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes" (Holling 1973). An ecosystem demonstrates resilience by withstanding shocks and the ability to rebuild itself. Disturbance of sufficient magnitude or duration may profoundly affect an ecosystem and may force it to a threshold point beyond which a different set of processes and structures predominates (Folke et al 2004). One such disturbance is human activities including reduction of biodiversity, exploitation of natural resources, pollution, land-use, and anthropogenic climate change (Folke et al 2004).

Resilience can also be applied to social systems: resilience in psychology refers to an individual's ability to cope with stress and adversity, or what is commonly referred to as a person's ability to 'bounce back' (Masten 2009). Research indicates that resilience is the result of an individual's ability to interact with their environments and the processes that either promote well-being or protect them against the overwhelming influence of risk factors (Zautra et al 2010).

When applied to human settlements resilience has been defined as "the capacity and ability of a community to withstand stress, survive, adapt, bounce back from a crisis or disaster and rapidly move on. Resilience needs to be understood as the societal benefit of collective efforts to build collective capacity and the ability to withstand stress" (ICLEI 2011a), and "the ability of a system, community or a society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions" (ICLEI 2011b).

The ICLEI (2011) submits that urban resilience is therefore the ability of urban systems to withstand certain levels of stress by:

- Having flexible systems to absorb sudden shocks and slow onset of events;
- Distributing stress across systems and avoiding single pressure points;
- Restoring functionality in a timely manner to contain loss and avoid disruption;
- Having substitutable systems if a major loss in functionality occurs;
- Designing systems that safely fail to avoid catastrophic failure; and
- Developing the ability to identify problems and building capacity to deal with them, establish priorities and mobilise resources to respond, adapt, and rapidly move on.

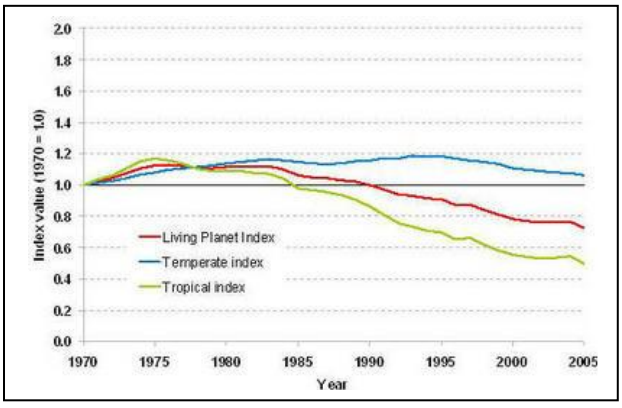
The current interdisciplinary discourse on resilience is now studying the interactions of humans and ecosystems via socio-ecological systems, and the need for shift from the maximum sustainable yield paradigm to environmental management which aims to build ecological resilience through resilience analysis, adaptive resource management, and adaptive governance (Walker et al, 2004).

It is thought that there have been five mass extinctions in the last 540 million years when over 50 per cent of animal species died (Sepkoski and Raup 1982). A mass extinction is characterised by a sharp drop in the diversity and abundance of macroscopic life (Nee 2004).

Notwithstanding these five events, the Earth has been able to recover, albeit over millions of years. And each recovery has demonstrated an outburst of new specie development and growth (Benton 2004; van Valkenburgh 1999).

Projections of ongoing specie loss point to the potential of a sixth mass extinction (Woolridge 2008; Jackson 2008). The *Living Planet Index (LPI)* is used as an indicator of the state of global biological diversity based on trends in vertebrate populations of species from around the world: between 1970 and 2007 the index fell by 28 per cent suggesting that anthropogenic influences are degrading natural ecosystems at an unprecedented rate (LPI 2010).

Figure 1: Living Planet Index



Source: http://www.maps.grida.no

While it is likely that the Earth would recover from such a sixth extinction (based on evidence from the previous five) the future of terrestrial specie, including *Homo Sapiens*, is not clear. Given that the greatest driver of this unprecedented global warming is anthropological in origin, logic would suggest that the risk of a sixth extinction could be reduced. The ability to survive this type of event requires human resilience and since the dominant location of the specie is in urban areas, by implication the ability that is sought could be called human settlement resilience.

The resilience of human settlements will be supported if the causes of mass extinctions can be identified. The relationship between mass extinctions and causes was summarised by MacLeod (2001) as follows:

Flood basalt events – involves the formation of large igneous provinces which produce dust and particulate aerosols which inhibit photosynthesis; emit sulphur oxides which are precipitated as acid rain causing specie poisoning; and emit carbon dioxide resulting in sustained global warming.

Sea-level falls – reduces the continental shelf area (the most productive part of the oceans) sufficiently to cause a marine mass extinction, and disrupt weather patterns sufficiently to cause extinctions on land.

Asteroid impacts – the impacts from large enough asteroids or comets cause food chains to collapse both on land and at sea by producing sufficient dust and particulate aerosols to inhibit photosynthesis.

Sustained global cooling – kills many polar and temperate species while forcing others to migrate reducing the area for tropical species, and makes the Earth more arid by locking up moisture in ice.

Sustained global warming – has the opposite effect of cooling i.e., tropical species migrate thereby reducing the area for polar species, makes the Earth wetter, and possibly causes anoxic events in the oceans. There is sufficient evidence to confirm sustained global warming as a cause of extinctions (Mayhew, Jenkins, and Benton, 2008).

Anoxic events – are events in which the middle and even upper layers of the ocean become deficient or totally lacking in oxygen.

Hydrogen sulphide emissions from the seas – in which warming disturbs the oceanic balance between photosynthesising plankton and deep-water sulphate-reducing bacteria resulting in massive emissions of hydrogen sulphide which poisons life on land and in the oceans (Kump, Pavlov and Arthur, 2005).

Oceanic overturn – is a disruption of thermo-haline circulation which lets surface water (which is more saline than deep water because of evaporation) sink down, bringing anoxic deep water to the surface resulting in the death of most oxygen breathing organisms inhabiting the surface and middle depths (Wilde and Berry, 1984). High levels of carbon dioxide have caused global warming in the past, and influenced ocean circulation and how that warmth was distributed around the globe. The Late Cretaceous Epoch is a perfect example of greenhouse climate on Earth and mimics the conditions currently manifesting: carbon dioxide levels are rapidly approaching levels most recently experienced during ancient greenhouse times (Macleod et al, 2011).

Plate tectonics – continental movement can cause or contribute to extinctions through initiating or ending ice ages; altering climate through changed ocean and wind currents; exposing seaways and land bridges, and creating super continents which reduces the continental shelf, the species-rich portion of the ocean.

Anthropogenic influences on disruption events

There are at least two major impacts of anthropogenic origin which impact negatively on ecosystem resilience namely agriculture and human settlements. Recent research suggests that in the US about 50 per cent of the warming that has occurred since 1950 is due to land use changes in the form of clearing forests for crops and cities rather than to the emission of greenhouse gases made up predominantly of carbon dioxide, methane, nitrous oxide, and halocarbons (Georgia Institute of Technology, 2009).

Agricultural activities displace indigenous biodiversity and replace it with monoculture crops, such as wheat, maize, and fruit. In addition, the use of pesticides and herbicides further undermines the resilience of the remaining ecosystem. Large-scale farming production is also dependent on an energy-intensive supply chain, a significant contributor to greenhouse emissions.

Human settlements also displace indigenous biodiversity, but replace it with concrete and tar and, where planting is done, generally with alien vegetation.

Figure 2: Reconstructed before and after view of Manhattan Island, New York

Source: http://www.strangecosmos.com/

Fossil fuel burning for energy in buildings and transportation account for 23 per cent and 31 per cent of total carbon emissions in South Africa (cidb 2009). However, fossil fuel is also consumed to pump water (along the whole supply chain) and sewerage (again along the whole supply chain). An appropriate mix of government regulation, energy savings technologies and behavioural change could substantially reduce carbon dioxide emissions from the built environment (UNEP 2007).

These two anthropogenic impacts increase with population growth and/or income, in terms of land use change, increasing food production, extracting raw materials, and providing shelter. Despite China's efforts to reduce their carbon emissions, emissions increased between 1992 and 2007 largely on the back of infrastructure investment and its energy intensive supply chain such as steel and cement production (UEA, 2011). With the world population expected to breach 7 billion on 1st November 2011, and 9 billion by 2050, the global extinction crisis for animals and plants imperilled by overpopulation's effect on habitat, water, air and other natural resources is expected to increase (Center for Biological Diversity, 2011).

Building resilient human settlements

This nexus between people and planet can therefore be described as a reciprocal relationship with disruption events impacting on both sides: major disruption events as a result of natural causes increases the vulnerability of both the planet and people, and so will anthropogenic contributions to typical causes of disruption events as listed earlier. This nexus is also the focus of research on building resilience in a climate of change.

From the above the following interventions need to be implemented if human settlements are to become resilient, i.e., less vulnerable to disturbance events.

1) Reduce the loss of biodiversity
2) Reduce the exploitation of natural resources
3) Reduce pollutants
4) Eco-management of land use
5) Reduce anthropogenic contributions to climate change
6) Building in flexibility and substitutable systems to reduce failure and promote recovery.

In the *Global Change Grand Challenge National Research Plan, South Africa*, four major cross-cutting knowledge challenges and 15 key research themes are identified (DST 2009). The four cross-cutting knowledge challenges are:

- Understanding a changing planet
- Reducing the human footprint
- Adapting the way we live
- Innovation for sustainability

This provides a useful framework to use to focus on building resilient human settlements. Using the research findings from above, the four major cross-cutting intervention areas and the corresponding key strategies can be described as indicated in Table 1 below.

Table 1: Framework for Building Resilient Human Settlements

Understanding socio-ecological systems	**Reducing human settlement footprint**	**Adapting the way we live**	**Innovating for resilience**
Observation and monitoring	Net-zero greenhouse gas emissions	Denser mixed-use urban development	Passive technologies (natural heating and cooling, lighting, ventilation)
Dynamics of ecosystem and human settlement interaction	Net-zero potable water consumption	Transit-oriented development (bike, bus, rail)	Active technologies (intelligent lighting and hvac, phase-change materials)
Linking land use change, climate change and disturbance events	Net-zero waste production	Re-establishing biodiversity in urban areas	Developing bio-based materials
Improving model predictions at different scales (urban, events)	Net-zero biodiversity loss	Reducing resource consumption	Solar technology
Food and water security	Net-zero toxic emissions (VOC, ODP)	Reducing vulnerability to disturbance events (sea-level rise, flooding, heat, drying, precipitation, wind)	Preparing for rapid change and disturbance events

Conclusion

Building human settlement resilience is wholly within our capability: all of the technology required and the enabling policies are do-able. There are areas, most notably in the science of earth systems, and the socio-ecological interactions where our knowledge is insufficient. Similarly, the modelling technology and the efficiency ratios of solar energy generators, requires further development. But principally the pathway to resilience is known.

The biggest hurdle to success is located in a willingness to adapt the way we live: will our species have the resolve to make the adjustments, and will it do so in time? Early signs emanating from civil society are that there is a groundswell of recognition that all is not as it should be. It may just signal a changing of the guard.

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