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**Limits to adaptation or a second modernity? Responses to climate change risk in the context of failing socio-ecosystems**

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**Limits to Adaptation or a Second Modernity? Responses to climate change risk in the context of failing socio-ecosystems**

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**Abstract**

There is a concerning fallacy at the heart of the debate on climate change adaptation – that adaptation will involve re-adjustments primarily on the periphery of functioning socio-ecological systems. Yet, dominant modern systems are already in crisis. Case study examples from research across global, continental and regional scales are used to argue that gaps between sustainability goals and outcomes are already significant. Analyses of food security, human migration and natural resource management systems indicate that climate change forms only part of failing relationships between people and their environments. There is a need to transform socio-ecosystems so that they become resilient in the context of broader learning on environmental uncertainty, variability, change and risk. Such transformations will occur both *in situ*, to ensure that local environments are not further degraded or people entrenched in failing systems, and *ex situ*, as people, systems and infrastructure become increasingly mobile to deal with changing circumstances.

**Keywords**

Climate change adaptation, food security, migration, natural resource management, risk society, transformation, social learning.

## 1. Introduction

Much is being made of the barriers and limits to climate change adaptation, even before societies truly begin to grapple with the complex socio-ecological challenges ahead (see for examples Adger et al., 2009; Australian Government, 2011; Carlsson-Kanyama et al., 2013; de Bruin and Dellink, 2011; Jones and Boyd, 2011; Moser and Ekstrom, 2010; O'Brien and Wolf, 2010; Preston et al. 2013). While there is considerable value in drawing attention to the need to swiftly reduce greenhouse gas emissions to reduce the rates of global climate change, a focus on the limits of adaptation has the potential to hinder comprehensive and effective decision making. In their review on the topic, Biesbroek et al. (2013, page 1127) note that assessments of adaptation barriers "tend to itemise and reify barriers and treat them as static one-dimensional entities in a dynamic governance process." More than that, a focus on climate change adaptation barriers could simultaneously: inhibit attempts at adaptation; make irrelevant experiments in building resilience and flexibility into systems: and, undermine confidence in prosecuting the type of comprehensive environmental policy that will lead to transformations in failing socio-ecosystems.

A number of the studies that focus on adaptation barriers and limits are couching future challenges in their wider socio-ecological context (Barnett and O'Neill, 2010). For example, Jones and Boyd (2011), MacCallum et al. (2013) and Rothman et al. (2013) argue that any examination of climate change adaptation must incorporate wider issues of social vulnerability and marginalisation. Nevertheless, the highlighting of the problematic nature of adaptation before countries, industries, communities and individuals embark on a process of learning how to adapt, threatens to undermine responses. It needs to be strongly stated, that any limits to adaptation are going to be highly contextual to the place, system, goals or ambitions of different people. As Adger et al. (2009, page 349) note, "What may be a limit in one society may not be in another, depending on the ethical standpoint, the emphasis placed on scientific projections, the risk perceptions of the society, and the extent to which places and cultures are valued." In fact, there is a danger that a focus on barriers and limits to effective change could conceptualise adaptation within a scope that is bounded and specific to climate change, rather than a new way of understanding human-ecological relationships.

The response to climate change is beginning to alter the way that society responds to socio-ecological risk. Yet, there is now the potential for socio-ecological research and governance to respond to those specific risks in isolation, rather than acknowledging that many of the relationships between societies and ecosystems across scales are failing or in crisis. There is a particular concern that a focus on barriers or limits may infer that climate change adaptation can be conceptualised, modelled and carried out on the periphery of dominant societal activities – that once such limits and barriers are understood, the challenges can be dealt with directly and separately from other socio-ecological risk. Yet in reality, much climate change adaptation will be occurring within the context of core socio-ecosystems which are already failing to adapt to changing circumstances (for environmental hazard examples see Mercer, 2010; Schipper and Pelling, 2006).

This paper introduces the changing notions of socio-ecological risk through three socio-ecological case-studies undertaken by the author at three differing scales: global (agroecosystems and food security), continental (human migration in Asia) and regional (natural resource management in South Australia). That analytical review frames the argument that unless climate change adaptation is integrated into a broader re-analysis of and response to socio-ecological risk, sustainable responses to the challenges ahead will not evolve, and all societies will remain under-developed in relation to risk (World Commission on Environment and Development, 1987).

## 2. Changing notions of environmental management and risk

Throughout the modern era, democratic, wealthy states have appeared to govern environmental issues more effectively. Many important, local scale impacts of human activities on the environment, such as much pollution and resource degradation have been better managed (Ryding, 1994). Those successes have led to a pervading sense of modern societies having overcome immediately important environmental problems. However, it could be argued that modern environmental management has developed under a veneer of success, because the most difficult environmental concerns have never been fully dealt with: managing environmental risk; establishing sustainable rates of resource exploitation and consumption; and, extending effective management systems to the periphery and for the most vulnerable people (McGranahan et al., 2001; Okereke, 2006; Rothman, 1998). Environmentally degrading practices that were seen as detrimental in core areas of wealthy countries have been largely exported to the margins or to developing states (Dasgupta et al., 2002). The failure to fully implement ecologically sustainable practices has been isolated from the powerful political, economic, social and research interests within wealthy countries, and so their problematical nature was largely nullified in policy.

Climate change is a different and far more complex environmental problem, because it challenges even the successes of modern environmental management. Nevertheless, most adaptation responses to the impacts of climate change are being framed within dominant neo-liberal societal frameworks, rather than challenging those frameworks as themselves faulted (Birch and Mykhnenko, 2009; Peck, 2004). In other words, processes of ecological modernisation are seen to be largely sufficient; such that market-led change, regulatory reform and assessment, and the development and implementation of new plans and technologies that lead to safer places or cleaner production dominate environmental policy (Blowers, 1997; Hajkowicz, 2009; Mol and Spaargaren, 2000; York and Rosa, 2003). However, it is increasingly clear that there the new environmental risks emerging from climate change are closely associated with the ongoing inability to sustainably manage levels of resource exploitation and consumption. Moreover, the neo-liberal approach relies on continuing confidence in market forces and political-economic structures that could themselves be seen to be in crisis (Hoogvelt, 2010; Lofdahl, 1998).

Ulrich Beck has detailed the risks of not recognising and responding to the limitations and fallibility of modern systems for the emerging risk society (Beck, 1992; 2009). While some researchers make the distinction between “Weak” and “Strong” ecological modernisation (Christoff, 1996; Neumayer, 2003), the key to risk society theory is that rather than successful modernisation overcoming societal risk, the form that development is taking exacerbates future threats. Commentators such as Hulme (2008), Jasanoff (2010) and Urry (2011) are suggesting specific targeted responses to future risks in capitalist societal activities will be insufficient and, rather, a cultural transformation is required now to prepare for an increasingly uncertain future. In just one example of broader socio-ecological risk, globalisation has increased the interdependency of societies. Peck (2001, page 446) notes that “the embrace of neoliberalism leads states to denigrate their own capacities and potentialities, to restructure and cut themselves, to engineer their own ‘reform’ and downsizing.” States have withdrawn to various forms of minimalist intervention, and supra-national governance institutions, other than the dominant economic organisations of the World Bank, the World Trade Organisation (WTO), International Monetary Fund (IMF) and

Global Groupings such as the Group of 20, have been marginalised from important decision-making. The resulting outcome of the neoliberal framing of governance structures is to globalise the risk of systemic failure (Beck, 2000; 2009; Athanasiou, 1996). The question that is examined here in relation to case studies of global food security, regional human migration and local natural resource management: are our societies' socio-ecological institutions, systems and technologies so infallible that strong global interdependency will be sustainable in the long-term with a focus on climate change adaptation alone?

## 3. The example of climate change and global food security

The first case study example draws from the author's international research of the impact that modern agricultural development has had on agrobiodiversity, and the roles for local diversity to support risk adaptation across global agroecosystems (Bardsley, 2003; Bardsley and Thomas, 2006). The work draws from case studies of mountain agroecosystems in Thailand, Nepal, Turkey and Switzerland, to examine the roles of diversity in rice and wheat production systems to maintain socio-ecological resilience.

Humanity has been quite effective at feeding itself during the modern era. The increased productivity required by growing populations has been met for most people by expanding agricultural areas, exploiting natural resources and applying technological advances (Evenson and Gollin, 2003). The Green Revolution was particularly successful in increasing global agricultural productivity in resource rich areas, but recent rates of production growth are not keeping up with the rates of increased demand, and the costs of agricultural modernisation that neglected to respond to the complexity of local social and environmental conditions are still being deliberated (Ringler et al., 2010). While specific understanding of climate change impacts on food supply systems is vital, there is an insufficient accompanying ownership that the modern agricultural development has not been successful for many resource-constrained systems or poorer people (Evenson and Gollin, 2003; Perkins, 1997; Shiva, 1991). Key to the case study research findings was that locally diversity has comprehensively diminished across agroecosystems at different scales during the modern era, as cropping systems, farms, regions and countries utilise similar biological resources, technologies, methods and policies (Bardsley and Thomas, 2006; FAO, 1996). That loss of diversity has increased agroecological vulnerability, and has been implicated in the partial collapse of different crop production systems in association with climatic or crop disease impacts at different times in diverse such places such as the Middle East, Southeast Asia and the USA (Bardsley and Thomas, 2005; Thrupp 2000).

It is uncertain how much climate change will effect net global food production, because gains in production in the near term due to the warming of northern Asia, Europe and North America could be considerable (Beddington et al., 2012; Osborne et al., 2013; Parry et al., 2004). Nevertheless, projected climate change will have significant impacts on agriculture in many of the places where food insecurity and rates of resource depletion are already severe and the implications will range across environmental, social, technological and political-economic fields (Godfray et al., 2010; Solomon et al., 2007; Vermeulen et al., 2011). For example, many dryland agricultural systems are experiencing warming and increased evapotranspiration, as well as reduced or more variable rainfall (Spiertz, 2010). New water for agricultural irrigation is increasingly scarce or contested in many key catchments, and climate change will often worsen shortages in many places (Hanjra and Qureshi, 2010; Ringler et al., 2010). In fact, analyses suggest that there are not only limited opportunities for further expansion of agricultural production areas around the globe, but in many places climate change will significantly deplete resources and increase environmental hazards, especially in marginal dryland, highland and coastal regions where such socio-ecosystems are already failing many people (Gornall, 2010; Nelson et al., 2009).

While climate change will affect agricultural production, exchange and consumption systems, the changes will be multiplying or intensifying problems with systems that are already at or nearing crisis.  The concerns of providing an assured food supply are already very real with ongoing malnutrition for approximately one billion people around the globe (WFP and FAO, 2009).  For example, the global food price spikes of 2008-2009 that reduced food security for millions of people had little to do with changes to climate, but rather an inability to purchase food at cheap prices (Ringler et al., 2010; Rosegrant, 2008; von Braun, 2008).  Furthermore, as food prices rose in 2008, "Argentina, Cambodia, China, Egypt, India, Kazakhstan, Pakistan, Russia, Ukraine and Viet Nam restricted food exports in an attempt to shore up domestic supplies" (Demeke et al., 2009, page 11).  The liberalisation of food supply systems means that people with buying power are able to access more, higher quality food, while poor people continue to lack access to sufficient nutrition.  While global trade in agricultural goods can supplement for local production, more people in cities and landless labourers have become much more dependent on production system from distant places over which they have little direct influence.

As food demand increases, the Green Revolution process of more efficient exploitation of vast areas for their natural resources will not be repeated because there are few new major spaces or ecological niches for humanity to exploit (Pimental et al., 2010).  New calls are being made for strong response to the challenges to the global food system, and many states and dominant global institutions are pushing for greater liberalisation of agricultural production and trade systems to allow for price signals to reflect the growing demand.  "Over the last few decades, the WTO has been making coherent efforts, on the one hand, to liberalize agricultural trade on the grounds that it would contribute to the growth of the global economy via specialization and expanded production and trade, benefit consumers around the world, and stimulate farming sectors in developing countries by enabling them to access markets in developing countries" (Moon, 2011, page 14). Yet, we do not yet know whether the global, liberalising, technologically-driven modern agroecosystem on which humanity is reliant is a resilient system and can withstand substantial ecological and social shocks, or, in fact, whether the dominant technological and institutional production responses, such as fossil-fuel dependent precision agriculture or the application of genetically-modified organisms, could themselves be faulted in the long-term (Diamond, 2005). As Harlan (1995, page 115) states, 'famine and starvation are an integral part of agricultural systems and agricultural systems are fundamentally unstable.' As even marginal communities reliant on highly variable production systems lose local diversity and become more dependent on external inputs, these also lose the capacity to innovate locally without outside assistance. Thus, new climate challenges are going to be strongly exacerbated by mutual interdependency, rising energy costs and the loss of diversity throughout a global system increasingly reliant on a limited, dominant range of methods of production, storage, processing and exchange (Bardsley, 2006b; Bridge, 2010).

As climate change adaptation approaches are developed for agriculture, the broader global challenge of maintaining viable food production systems forever and for all will need to frame the response. Most researchers publishing in the field of global food security are still confident of some future success, but there is the real risk that humanity is losing its capacity to re-arrange systems to overcome material, socio-cultural and financial food insecurity (Bardsley, 2003; Bardsley, In Press; Hertel and Rosch, 2010). Inherent in an analysis of food security adaptation issues are both consumption failures, as the wealthy consume too much of the world's food or resources that would be otherwise used to produce food, and issues of environmental justice, because food is already insufficiently financially, materially or socio-culturally accessible for one-seventh of humanity. As Godfray et al. (2010, page 812) state, "A threefold challenge now faces the world. Match the rapidly changing demand for food from a larger and more affluent population to its supply; do so in ways that are environmentally and socially sustainable; and ensure that the world's poorest people are no longer hungry." Analysis of specific climate change impacts in a failing global food system without discussion of, or responses to, the broader context of food insecurity, appear almost as an arrogance, particularly for those people who are already failing to access sufficient, nutritious food. The research on the erosion of global agricultural diversity, and the associated loss of opportunities to sustain and exploit difference across agroecosystems, suggests that the dominant process of food production needs to be reconceptualised more broadly, especially for marginal regions and communities that are unable to maintain or develop sustainable local production systems (Bardsley, 2003, UNCTAD, 2013).

## 4. The example of climate change and human migration in Asia

The second systemic example draws from a review undertaken of human migration and climate change in Asia (Hugo et al., 2009; Hugo and Bardsley 2014). Climate change is projected to have a significant impact on the environments and societies of Asia, but how large populations will prepare for and react to the impacts is highly uncertain (Cruz et al., 2007; Preston et al., 2006). Across Asia, average night and day temperatures are projected to increase in the order of 1-3$^{o}$C by 2050, with associated increases in more extreme heat waves (Solomon et al., 2007). Monsoonal activity is projected to increase in intensity, leading to increased average precipitation across much of South, East and Southeast Asia. Increasing variability in the Asian monsoon will have significant implications for food production and flood risk. Water stress in relation to access to non-polluted fresh water is already a significant problem across large parts of the region, and these risks could be increased with more variable winter rainfall (Nohara et al., 2006; Vörösmarty et al., 2000). The challenge of greater rainfall variability could be particularly important for Central Asia, where there is a projected drying trend for many semi-arid areas (Arnell et al., 2004), and the number of intense typhoons have increased across Asia (Vecchi and Soden, 2007; Webster et al., 2005). As storm surge results from an association of high wind speeds and wave action, and low air pressure, often in association with high tides, more intensive summer monsoons are likely to impact on many low-lying areas in the form of more regular, flooding and greater salt-water intrusion (Levy et al., 2008; Nicholls et al., 1999; von Storch and Woth, 2008). Of particular concern could be major delta regions including those of the Indus, Ganges-Brahmaputra, Chao Phraya, Mekong, Red, Yangtze and Yellow rivers (Cruz et al., 2007; Ericson et al., 2006; Yusuf and Francisco, 2009). These same areas are major population centres so climate change impacts will present fundamental challenges to many millions of people within Asian societies (Hugo et al., 2009). Furthermore, many more people are moving into harm's way as Asian urban development concentrates in river valley, coastal and delta areas (Hugo, 2011).

The intensity and scope of projected climate change impacts suggest that adaptation cannot be a static process. People will learn to adapt to the impacts as they are better understood and experienced, or more information becomes available about successful and failed responses to changing environmental conditions. Nevertheless, the level of impacts projected for many Asian societies already struggling to manage environmental hazards and depleted resources could often require adaptation responses exceeding local capacities (Dilley et al., 2005). As large, poor populations, experience significant environmental change that exceeds thresholds of adaptive capacity more often, policy responses will increasingly need to look beyond *in situ* adaptation: the climate change adaptation that is undertaken within or for a place rather than involving the movement of people away from that place, and recognise that there must be an increasing focus on *ex situ* adaptation: that adaptation to climate change impacts which will involve the movement of people, systems and/or assets from a place of vulnerability (Bardsley and Hugo, 2010).

With future climate change, many more people may become trapped in intractable situations of environmental degradation and poverty with limited agency to respond to risk (Black et al., 2011; Geddes et al., 2012). However, many others will have the capacity to move either temporarily or permanently as they experience environmental change, or perceive of new risks. For these reasons, future climate change will increase the likelihood that there will be both linear and non-linear increases in the numbers of people who will need to move temporarily or permanently within or from Asia at different times (Bardsley and Hugo 2010; Hugo et al. 2009). While human migration will form an increasingly important component of effective societal adaptation to environmental risk across Asia in the future, in many cases migration policy is already being challenged (Black et al., 2008; Castles, 2006; Hugo, 2006; IOM, 2010; van Naerssen et al., 2008). Most of the stresses being applied to policy are not directly linked to environmental drivers, even though thresholds of environmental change and associated socio-ecological risk are already being met in some areas, such as the Ganges-Brahmaputra delta (Hugo et al., 2009; Karim and Mimura, 2008; Mikhailov and Dotsenko, 2006; Shamim, 2008). Studies from Bangladesh for example, suggest that many people have already made decisions to migrate internally or internationally as a result of environmental change in the delta region, and environmental change has become one ultimate cause of their decisions to migrate (Begum, 1999; Hossain, 2005; Reuveny, 2007).

While economic migration is improving opportunities for millions of people within source and destination countries in Asia, many other people are not able to exploit opportunities from greater mobility (Munck, 2009). For example, there is often insufficient resourcing and political will to provide effective emergency shelter and permanent housing for people affected by environmental hazards (Kelman et al., 2011). The United Nations High Commission for Refugees (UNHCR, 2011) is already supporting over 25 million displaced people globally, mostly from and within poorer countries and over 10 million of whom are refugees, with "Some 7.2 million refugees were stuck in protracted situations at the end of 2010" (page 2). Asia already accounts for about one quarter of current refugees, and many of those people originate from areas of South and Central Asia that are projected to experience considerable environmental change (IOM, 2010; Solomon et al., 2007). Again there is a sense of social planetary enclosure, because abundant opportunities for the international resettlement of forced migrants are seen as increasingly limited (for an Australian example see Louis et al., 2010). So while it is possible to argue that it will be necessary to develop new policy to respond to potential non-linear changes in migration due to changing environmental circumstances (Bardsley and Hugo, 2010), many displaced people, in Asia and other areas of the globe, are already in desperate need of more effective global and regional political support and resourcing (IOM, 2010; Warner et al., 2009).

Future migration policy developments must begin to take thresholds of social mobility into account to ensure that migration can become an increasingly effective component of societal adaptation to climate change. As Hugo (2011, page 12) states "it is possible to not only cope with these changes but also to harness that population mobility to reduce poverty and enhance economic and social development." However, to achieve such a goal, the policy development and resourcing of human mobility in Asia, and elsewhere, cannot be framed simply by the emerging challenge of climate change, but within the increased need to move as a necessary part of the human condition during the global era (Warner 2012).

There are failures of both consumption and distribution of the new mobility. As the expectation of humanity to be able to move to make a better life has risen dramatically during the last twenty years, many millions are benefitting hugely from the liberalisation of movement (Munck, 2009). However, another large group of people who are mobile or would wish to cross international borders to seek a better life are either extremely limited in their opportunities for resettlement or must confront persecution and alienation to achieve their goal. With projected climate change, more people in vulnerable areas will learn that staying in place and trying to adapt *in situ* will fail, or that life will become more difficult and less rewarding than exploiting *ex situ* adaptation opportunities. As a result, and as with food security issues discussed above, the requirement for effective socio-ecological risk management extends beyond a response to climate change, and rather presents broad transformational challenges to the organisation of states, and their internal and international policies for governing socio-ecological change.

## 5. The example of climate change and natural resource management

The third case study draws from research undertaken in South Australia (SA) to examine the vulnerability of regional Natural Resource Management (NRM) to projected climate change to the year 2030. Integrated vulnerability analyses were undertaken in two regions: one the core urban/peri-urban region of the Adelaide-Mt Lofty Ranges (AMLR); the other the peripheral, sparsely populated Alinytjara Wiluṟara (AW) region (Figure 1). These are two of eight NRM regions in SA that were defined under the Natural Resources Management Act (SA) 2004

(AMLR NRM Board, 2008; AW NRM Board, 2010; SA Government, 2004). An integrated approach to assess climate change vulnerability was developed to facilitate discussion on, and to support action for, climate change adaptation (Adger 2006; Bardsley, 2006a; Bardsley and Rogers, 2011; Bardsley and Wiseman, 2012 The Allen Consulting Group, 2005). In both cases, the research was undertaken in strong partnerships with the regional NRM Boards, which govern regional planning and investment, and support local NRM activities.

The AMLR region covers a land area of about 535,000 hectares and a similar area of marine and estuarine environments (AMLR NRM Board, 2008). It contains the State capital, Adelaide, a city of approximately 1.2 million people, with significant capacity to undertake research, planning and action to manage natural resource systems (Bardsley and Sweeney, 2010; Robins and Dovers 2007; SA Government, 2006). The region's natural resources contribute significantly to liveability of Adelaide, and the associated primary industries are important for the South Australian economy and local food supplies (AMLR NRM Board, 2008; Davidson, 2010). In contrast, the AW NRM region is remote and covers the semi-arid north-west of SA (AW NRM Board, 2010, page 2). The AW region has a land area of over 250,000 $km^2$, or about 26% of the State. There are only just over 2000 people living in the region, mostly of Pitjantjatjara, Yankunytjatjara and Ngaanyatjaara descent (AW NRM Board, 2010). More than half of the region is held as dedicated Aboriginal Lands, administered under the SA Government Lands Administration Trust Act 1966, with important local autonomy of decision-making through local council bodies (SA Government, 2010).

**Figure 1 Location of the Adelaide-Mt Lofty Ranges and Alinytjara Wilurara Natural Resource Management Regions**

The AMLR experiences a relatively humid Mediterranean climate, and both past trends and future projections suggest that such climate types are likely to experience future drying trends (Dünkeloh and Jacobeit, 2003; Fu et al., 2006). If projections of warming, as well as reductions in average annual rainfall of up to 15% by 2030 are realised, the consequences for the AMLR region are likely to be: less reliable rainfall; shorter growing seasons; more extreme weather events; and, hotter and longer hot spells (McInnes et al., 2003; Suppiah et al., 2006). The climate change vulnerability analysis for the AMLR (Bardsley, 2006a) and subsequent detailed analyses of adaptation opportunities for systems across the AMLR region (Bardsley and Sweeney, 2010) suggest that many individuals, businesses and organisations will struggle to effectively implement adaptation options for effective long-term sustainable management. Important systems are highly vulnerable with particularly challenges for biodiversity conservation, bushfire management and flood risk management along coasts and rivers.

Climate change projections suggest that a drying trend can be expected for the area where Adelaide sources much of its water (Chiew et al., 2008; Suppiah et al., 2006). Already, Adelaide's water supply has come under substantial strain during the decadal drought of the 2000's in southeastern Australia, which has only been managed with a combination of strong policies, including: restrictions on use within both rural and urban settings; prioritisation of water for the city over rural areas and uses; greater use of recycled water; and more recently, the establishment of a desalination plant (AMLR NRM Board, 2011; SA Government, 2005). Those processes have led to significant deprivation for farmers reliant on irrigated systems (Staniford et al., 2009). Moreover, there continue to be important NRM challenges for the region, particularly where they overlap with the spatial expansion of the city. For example, vital agricultural production areas, such as the Virginia market garden region, where an effective water recycling irrigation system has been established, are facing considerable pressures from urbanisation (Laurenson et al., 2010). Climate change will make it considerably more difficult for agricultural producers to simultaneously manage current pressures from urbanisation, industrial deregulation and international competition (Bardsley and Pech, 2012); or biodiversity managers to conserve species that are already experiencing an “extinction debt” from impacts of urbanisation, clearing and invasive species (Szabo et al. 2011); or for landholders to work with government to manage bushfire risk (Hennessy et al., 2005). In just one example, viticulture across the region is coming under increasing pressure from international competition, while also facing increasing water restrictions and pressures from urbanisation, but climate change could also reduce the quality of the local product (Lereboullet et al., 2013).

To deal with the levels of future risk, Adelaide peri-urban landscape and planning will need to explicitly value, define and protect the unique multifunctional space. Such changes are being forced on governments (see SA Government, 2009), but further, strong planning responses need to re-conceptualise the planning approach from one that continues to focus on opportunities for economic growth from the exploitation of natural resources, to one that works to consolidate sustainable processes of local management. Even then, the AMLR is a wealthy, core region with unique adaptive capacities for the State of SA (Robins and Dovers, 2007). In contrast, the AW region does not suffer from over-development associated with inappropriate urbanisation and resource exploitation, but a lack of capacity to respond to management and planning needs (Davies et al., 2008).

Within the AW NRM region, the provision of local services such as accommodation, water or sanitation can be difficult and expensive (AW NRM, 2010; Guerin and Guerin, 2010). Local indigenous people must already confront socio-ecological risk such as extreme heat, poor quality water supplies, limited nutrition, a lack of financial resources and a range of other socio-ecological risks, irrespective of future climate change (Anangu Pitjantjatjara Yankunytjatjara, 2009; Hill and Williams, 2009; Stafford-Smith et al., 2008). Modern scientific information for the AW NRM region is limited, while local traditional knowledge is comprehensive, but coming under threat due to intergenerational change. Moreover, when impacts from invasive species or from mining exploration do encroach on remote areas, it is very difficult to monitor issues closely or manage them effectively (Smyth et al., 2009; Zeng and Edwards, 2010). Simultaneously, however, the remoteness and isolation, vast size, and low density of population within the AW region provide advantages for adaptation, including effective local community structures and large areas of relatively undisturbed native ecosystems.

Significant climate change is projected for the AW region, especially increasing rainfall variability (McInnes et al., 2003; Quigley et al., 2010; Suppiah et al., 2006). To the year 2030, changes to climate and associated environmental systems may be difficult to detect, because of the extreme intra- and inter-annual variability in the local climate, especially with respect to rainfall (Box et al., 2008; Verstraete et al., 2009). Some key assets such as surface and groundwater dependent ecosystems; ecosystems impacted by invasive mammals; places at risk of flood and fire; and land sensitive to cattle over-grazing, could all be highly sensitive to climate change (Holmgren et al., 2006). However, in most cases, impacts of climate change in the AW region are likely to weaken already degraded ecosystems further, rather than lead to fundamental change (Bardsley and Wiseman, 2012). In part, that is because vital ecosystems have already passed through thresholds of change due to anthropogenic impacts since European colonisation (Robinson et al., 2003). Many other systems will not be highly exposed to climate change over the next 20 years and there are also significant opportunities to implement adaptation options: to protect vulnerable biodiversity; to control invasive species; to move assets out of the way of floods and fires; and monitor and manage grazing pressures more comprehensively. Of greater risk to NRM over the next generation, could be factors only indirectly related to climate change, such as demographic change and a lack of local management training and resources.

Future opportunities for autonomous, individual and community adaptation to risk are already constrained by challenging social circumstances (HORSCATSIA, 2004; Guerin and Guerin, 2010; Moran and Elvin, 2009). Climate change impacts will exacerbate the effects of weakening local management and create a greater demand on resources. Flooding over the 2011-2012 summer saw communities isolated and some people voicing concerns of flood damage and food security during regional workshops - issues that were also raised in the media (see Harper, 2011; Martin, 2011). Prior to the heavy rains, there had been a long dry period during which communities came under pressure from a lack of access to either external or local bushfood sources; insufficient feed and water for livestock; and, camels marauding through towns to find water. Yet, food security for remote indigenous communities have been ongoing in association with increasing dependence on relatively low quality and/or expensive food from local stores (Butler et al., 2011). New extremes of heat, dry or wet periods would more regularly challenge local communities to maintain food security, sustain local natural resources, and live from the land. It is this interaction between climate change, declining resource condition and a lack of capacity to undertake some difficult management activities, which forms the greatest risk to 2030, so development opportunities must work to support local people to manage all future risks to country and community (Wiseman and Bardsley, 2013).

## 6. Imagining Comprehensive and Effective Socio-Ecological Governance

There is a vast socio-ecological challenge ahead, and climate change adaptation research and policy development will need to acknowledge the breadth and depth of future risk. Analyses that consider climate change as a distinct issue may be useful for strongly anthropogenic socio-ecosystems such as engineered coastal and river flood defences, or some agricultural production systems, but such systems are mostly exceptional, and when considered in their broader context may also require further systemic modification. Case study research of global food security, Asian migration and regional NRM outline a broader failure to acknowledge the new challenges of risk across all spatial scales. It is a growing recognition of the current endogenous vulnerability of socio-ecosystems, as much as any increase in any particular exogenous drivers of environmental hazards or natural resource depletion resulting from climate change, which will need to guide societal adaptation responses (Beck, 2000: 2009).

The case studies of socio-ecosystems at different scales suggest that vitally important systems are not sustainable on a long-term basis irrespective of future climate change. However, that does not mean that constant and significant improvements cannot be achieved through creative approaches to the management of environmental resources, consumption, hazards, injustice and risk. On the contrary, humanity continues to be adept at creating and recreating better ways of doing and there should be a confidence that any perceived structural barriers or material limits, will only ever be the defining pre-conditions for constant critical analysis and socio-ecological experimentation. For that reason, the innovation that forms the basis of human adaptation to environmental risk must be framed within a dialectic that allows for constantly renewed relationships between humanity and the environment (Harvey, 1974).

Governing a reorganisation of environmental management will require numerous important and bold steps that would begin with supporting people and institutions to move into the conceptual space of constant learning and revision of risk adaptation practices (Berkhout et al., 2006; Folke et al., 2005; Tschakert and Dietrich, 2010). Rather than attempt to focus on limits and barriers of climatic risk alone, policy goals to manage risk will need to move people into a position where constant reform is possible and practical (Table 1).

**Table 1. Conceptual Differences Between a Narrow Focus on Climate Change and a Broader Acknowledgement of Socio-ecological Risk**

Comprehensive and sustainable adaptation policy and practices will require time and space to evolve in association with local complexities. For example, within the AMLR, issues of consumption are most strongly evident in relation to the ongoing expansion of the city of Adelaide into a unique, relatively humid space surrounded by a considerably drier region. Adjacent to the city, it may be necessary to identify areas or systems of key vulnerability, and pre-emptively support policy to reduce environmental risk via planning ongoing improvements in adaptation (Bardsley and Pech, 2012; Bardsley and Sweeney, 2010; Gordon et al., 2009). In comparison, issues of social justice are particularly evident within the AW region, such that the most important responses to climate change will be to strengthen local capacities to monitor and manage natural resources in the margins. There is an enormous wealth of local traditional knowledge extant in the AW NRM region, but that is threatened by intergenerational change, as people become less dependent on local resources to provide for their livelihoods. By integrating local, traditional and scientific knowledge, the traditional owners and managers of the lands, waters and biodiversity of the AW region could become a more comprehensive part of the solution to current management difficulties and future opportunities (Berry et al., 2010; Hill and Williams, 2009; May, 2010; Mercer et al., 2010). Clearly, in both core and peripheral regions, there are opportunities to build resilience with NRM systems, create options for adaptation, and exploit ecological change for socio-economic benefit if effective actions can be undertaken.

At global and continental scales the challenge remains for governance to meet the scale and scope of the risk. As human activities enclose the planet, food or livelihood insecurity for a billion people can no longer be considered a default position for food production and supply systems and mobility will need to remain a core element of adaptation within the biosphere. A new form of global cosmopolitanisation will need to emerge to define a second modernity that understands and responds to resource constraints, changing hazards and the necessity for social justice (Beck 2010). In other words, the second modernity will need to reconceptualise human adaptation as a great global experiment (Adger et al., 2005; Fankhauser et al., 1999; Gross and Krohn, 2005; Wals, 2007). As Löf (2010, page 530) notes, "Learning and governance are inherent components of adaptability: without learning we can neither adapt nor transform, and without governance we neither act on nor institutionally embed learning experiences." A focus on learning to adapt socio-ecosystems, rather than adapting to climate change impacts, moves away from a conception of risk that will be understandable, manageable or containable within limits definable within current dominant governance, technical and regulatory frameworks, to an acknowledgment that a new modern society will need to constantly evolve in responses to the recurring crises in human relations with the planet. Such transformations in relationships between people and their environments will only come with comprehensive critiques of current societal practice (Bennett, 2005).

To ensure that people who lack the financial, material or socio-cultural assets to effectively manage risk are not neglected, governments will need to make decisions that go beyond the limited actions of regulating the market (Table 1). 'Strong' adaptation would involve an increasing role for state and multi-state institutions to ensure that the care for all people and environments occurs across both current- and inter-generational timeframes (Daly and Lewis, 2000). Increasingly an alternative paradigm of socio-ecology could dominate in marginalised places and for disadvantaged groups, which more strongly considers issues of social justice, simultaneously as it considers the management of environmental risk (Prabhakar et al., 2009; Walker and Bulkeley, 2006). Without such a change, issues of long-term sustainability or justice will continue to be discounted as societies respond to increasing pressures of socio-ecological risk.

Policies to establish broadly sustainable human-environment relations will not be easily applied, because they will confront vested interest in less holistic approaches to environmental management. There is an ongoing responsibility for people educating, researching and acting in the socio-ecological fields to look beyond vested interest and make it plain that the environmental challenges of the future will not be manageable at the margins of societal activity. Governments and corporate elites will need to be consistently challenged and supported to own risk; to generate the public consent to transform failing systems; and, to develop and apply approaches to integrate responses to risk into all policy and practice (Chomsky and Herman 1988). To achieve such a goal, stronger integration of research and policy will be required to engage decision-makers and draw together often fragmented management and governance processes (Holmes and Clarke 2008; Morrison et al. 2004). Integrated governance systems would help to manage the potential for compounding systemic failures. For as we have seen with the case study examples, there is strong overlap between socio-ecological issues: with climate change and natural resource degradation effecting food insecurity, that in turn impacts on human mobility, social marginalisation and further environmental change.

Improving multidisciplinary research and education will be fundamental to support a comprehensive learning approach within societies. Social learning would occur both formally and informally to: understand the importance of risk (Bardsley, 2007): understand the processes and impacts of climate change (Burroughs, 2007); ensure that environmental scientists can work with demographers to better understand the drivers of human mobility (Bardsley and Hugo, 2010); and, develop NRM approaches that provide benefits for people living on the margins, just as improvements are made in the way water, land and biodiversity is managed (Hillman et al., 2005). Sustainable approaches to food security would see physical and social scientists collaborating to work across different scales: from examining farmers' and community decision-making at local scales; through regional planning and food systems analyses at regional scales; through to macro-economic, technical, demographic and policy change at national and international levels (Howden et al., 2007). For example, more emphasis could be placed on recognising and valuing systemic diversity, and supporting development to meet the needs of particular local socio-cultural and ecological conditions for food production, storage, exchange and marketing. Holistic studies of the way human processes effect and are affected by the environment will need to break down boundaries in research and policy practice to guide compound responses to complex risks. Cross-disciplinarily has been strongly argued for some time, but still most research is strongly embedded in either the physical or social sciences, rather than a being constructed and applied in a middle ground of socio-ecology, or what Castree (2005, page 102) refers to as "environmental geography." To achieve that goal, funding bodies and research institutions could more explicitly acknowledge the necessary roles of learning about human adaptation that crosses traditional conceptual boundaries.

## 7. Conclusion

The analysis of limits to climate change adaptation will provide important insights for research and policy, but it could also raise the expectation that a new era of risk will be manageable on the periphery of core societal activities. It is important to stop pretending that current human-environmental relations are effective and sustainable. Many core socio-ecosystems are not in conditions of equilibrium and climate change will impact upon them to exacerbate the scales and scopes of change. For example, global food security, human migration and NRM systems are already failing in many places and especially for the most vulnerable people. Adaptation will be taking place within a global context where the easy gains to resource and provide habitat for modern society have been made, and most current systems of exploitation are likely to become less resilient in the future. Unless climate change adaptation policy and practices are embedded within a broader transformation to a new type of modernity, sustainable systems will not be established and maintained in the long term and for all people and places, even if the negative impacts of climate change are reduced in the short-term or for particular, local situations.

To begin to achieve the level of response to emerging socio-ecological risks, of which climate change is a vital example, there needs to be an acknowledgement that society is not going to manage all risks well. Global society, and particularly the most vulnerable people within that society, cannot afford widespread systemic failures. Transformations to socio-ecosystems will need to occur *in situ*, to ensure that local environments are not further degraded or people entrenched in places where systems are failing, and *ex situ*, as people, systems and infrastructure becomes more mobile to deal with changing circumstances. On one hand that conclusion supports the call for more effective greenhouse gas mitigation policy to lessen future impacts of climate change, and on the other, suggests arguments for the holistic integration of adaptation approaches. All adaptation approaches will need to include assessments and responses to specific climatic risks, but must also recognise that to be effective such responses will accommodate all socio-ecological risk. More inclusive and holistic forms of social learning and experimentation could help guide such comprehensive adaptation approaches to socio-ecological risk.

## References


Adger W N, 2006, "Vulnerability", *Global Environmental Change* **16** 268-281.

Adger W N, Arnell N W, Tompkins E, 2005, "Successful adaptation to climate change across scales", *Global Environmental Change* **15** 77-86.

Adger W N, Dessai S, Goulden M, Hulme M, Lorenzoni I, Nelson D, Naess L, Wolf J, Wreford A, 2009, "Are there limits to social adaptation to climate change?" *Climate Change* **93** 335-354.

AMLR NRM (Adelaide and Mt Lofty Ranges Natural Resource Management) Board, 2008, "Creating a Sustainable Future: A Natural Resources Management Plan for the Adelaide and Mount Lofty Ranges Region", Volume A – State of the Region Report, Government of South Australia, Adelaide

AMLR NRM (Adelaide and Mt Lofty Ranges Natural Resource Management) Board, 2011, "Water Allocation Plans Overview", http://www.amlrnrm.sa.gov.au/Plans/Waterallocationplans/Waterallocationplansoverview.aspx

Anangu Pitjantjatjara Yankunytjatjara, 2009, "Anangu Pitjantjatjara Yankunytjatjara Annual Report 2008-2009" Anangu Pitjantjatjara Yankunytjatjara, Umuwa, South Australia

Arnell N W, 2004, "Climate change and global water resources: SRES emissions and socio-economic scenarios" *Global Environmental Change* **14** 31–52.

Athanasiou T, 1996, *Slow Reckoning: The Ecology of a Divided Planet* (Secker and Warburg, London)

Australian Government, 2011, "Barriers to Effective Climate Change Adaptation: Public inquiry", http://www.pc.gov.au/projects/inquiry/climate-change-adaptation

AW NRM Board (Alinytjara Wilurara Natural Resources Management Board), 2010, “Alinytjara Wilurara Regional NRM Plan”, Government of South Australia, Adelaide

Bardsley D, 2003, “Risk alleviation via in situ agrobiodiversity conservation: drawing from experiences in Switzerland, Turkey and Nepal”. *Agriculture, Ecosystems and Environment* **99** 149–157.

Bardsley D, 2006a. “There's a Change on the Way: An Initial Integrated Assessment of Projected Climate Change Impacts and Adaptation Options for Natural Resource Management in the Adelaide and Mt Lofty Ranges Region”, DWLBC Report 2006/06, Government of South Australia, Adelaide

Bardsley D K, 2006b, “Valuing diversity for sustainable futures: a response to Wood and Lenné”, *Land Use Policy* **23** 643-644

Bardsley D K, 2007, “Education for all in a global era? The social justice of Australian secondary school education in a risk society” *Journal of Education Policy* **22** 493-508

Bardsley D K, (in press), “Recreating diversity for resilient and adaptive agricultural systems”, in *The Globalisation of Agriculture* Eds G Robinson, D Schmallegger, J Cleary (Edward Elgar, Cheltenham UK)

Bardsley D K, Hugo G J, 2010, “Migration and climate change: examining thresholds of change to guide effective adaptation decision-making”, *Population and Environment* **32** 238-262.

Bardsley D K, Pech P, 2012, “Defining spaces of resilience within the neoliberal paradigm: Could French land use classifications guide support for risk management within an Australian regional context?” *Human Ecology* **40** 129–143

Bardsley D K, Rogers G, 2011, “Prioritising engagement for sustainable adaptation to climate change: an example from natural resource management in South Australia”, *Society and Natural Resources* **24** 1-17

Bardsley D K, Sweeney S M, 2010, "Guiding climate change adaptation within vulnerable natural resource management systems", *Environmental Management* **45** 1127-1141

Bardsley D K, Thomas I, 2005, "Valuing local wheat landraces for agrobiodiversity conservation in Northeast Turkey", *Agriculture, Ecosystems and Environment* **106** 407-412.

Bardsley D K, Thomas I, 2006, "In situ agrobiodiversity conservation: examples from Nepal, Turkey and Switzerland in the first decade of the Convention on Biological Diversity", *Journal of Environmental Planning and Management* **49** 653-674

Bardsley D K, Wiseman N D, 2012, "Climate change vulnerability and social development for remote indigenous communities of South Australia" *Global Environmental Change* **22** 713–723

Barnett J, O'Neill S, 2010, "Maladaptation", *Global Environmental Change* **20** 211–213

Beck U, 1992, *Risk Society* (Polity Press, Cambridge)

Beck U, 2000, *What is Globalization?* Translated by P. Camiller (Polity Press, Cambridge)

Beck U, 2009, *World at Risk* (Polity Press, Cambridge)

Beck U, 2010, "Climate for change, or how to create a green modernity?" *Theory, Culture and Society* **27** 254-266

Beddington J, Asaduzzaman M, Clark M, Fernandez A, Guillou M, Jahn M, Erda L, Mamo T, Van Bo N, Nobre C A, Scholes R, Sharma R, Wakhungu J, 2012, "Achieving food security in the face of climate change: Final report from the Commission on Sustainable Agriculture and Climate Change" CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), Copenhagen, Denmark.

Bennett J W, 2005, *The Ecological Transition: Cultural Anthropology and Human Adaptation* (Aldine Transaction, New Brunswick)

Berkhout F, Hertin J, Gann D M, 2006, “Learning to adapt: organisational adaptation to climate change impacts” *Climatic Change* **78** 135-156

Begum A, 1999, *Destination Dhaka: Urban Migration: Expectations and Reality* (The University Press, Dhaka)

Berry H L, Butler J R A, Burgess C P, King U G, Tsey K, Cadet-James Y L, Rigby CW, Raphael B, 2010, “Mind, body, spirit: co-benefits for mental health from climate change adaptation and caring for country in remote Aboriginal Australian communities” *NSW Public Health Bulletin* **21** 139-145

Biesbroek G R, Klostermann J E M, Termeer C J A M, Kabat P, 2013, “On the nature of barriers to climate change adaptation”, *Regional Environmental Change* **13** 1119-1129.

Birch K, Mykhnenko V, 2009, “Varieties of neoliberalism? Restructuring in large industrially dependent regions across Western and Europe Europe”, *Journal of Economic Geography* **9** 355-380

Black R, Bennett S R G, Thomas S M, Beddington J R, 2011, “Migration as adaptation”, *Nature* **478** 447-449

Black R, Kniveton D, Skeldon R, Coppard D, Murata A, Schmidt-Verkerk K, 2008, “Demographics and climate change: future trends and their policy implications for migration”, Working Paper T-27 Development Research Centre on Migration, Globalisation and Poverty. University of Sussex, Brighton

Blowers A, 1997, “Environmental policy: ecological modernisation or the risk society?”, *Urban Studies* **34** 845-871

Box J B, Duguid A, Read R E, Kimber R G, Knapton A, Davis J, Bowland A E, 2008, “Central Australian waterbodies: the importance of permanence in a desert landscape. Journal of Arid Environments” **72** 1395-1413

Bridge G, 2010, “Geographies of peak oil: the other carbon problem”, *Geoforum* **41** 523-530

Burroughs W J, 2007, *Climate Change: A Multidisciplinary Approach*, (Cambridge University Press, Cambridge)

Butler R, Tapsell L, Lyons-Wall P, 2011, “Trends in purchasing patterns of sugar-sweetened water-based beverages in a remote Aboriginal community store following the implementation of a community-developed store nutrition policy”, *Nutrition and Dietetics* **68** 115–119

Carlsson-Kanyama A, Carlsen H, Dreborg K-H, 2013, "Barriers in municipal climate change adaptation: Results from case studies using backcasting", *Futures* **49** 9-21

Castles S, 2006, “Global perspectives on forced migration”, *Asian and Pacific Migration Journal* **15** 7-28.

Castree N, 2005, *Nature* (Routledge, London)

Chomsky N, Herman E, 1988, *Manufacturing Consent* (Pantheon, New York)

Christoff P, 1996, “Ecological modernisation, ecological modernities”, *Environmental Politics* **5** 476–500

Chiew F H S, Teng J, Kirono D, Frost A J, Bathols J M, Vaze J, Viney N R, Young W J, Hennessy K J, Cai W J, 2008, *Climate Data for Hydrologic Scenario Modelling across the Murray-Darling Basin* (CSIRO, Australia)

Cruz R V, Harasawa H, Lal M, Wu S, Anokhin Y, Punsalmaa B, Honda Y, Jafari M, Li, C, Huu Ninh N, 2007, “Asia” in *Climate Change 2007: Impacts, Adaptation and Vulnerability* Eds M L Parry, O F Canziani, J P Palutikof, P J van der Linden, C E Hanson, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. (Cambridge University Press, Cambridge) pp 469-506

Daly M, Lewis J, 2000, “The concept of social care and the analysis of contemporary welfare states” *British Journal of Sociology* **51** 281–298

Dasgupta S, Laplante B, Wang H, Wheeler D, 2002, “Confronting the environmental kuznets curve”, *The Journal of Economic Perspectives* **16** 147-168

Davidson M, 2010, “Social sustainability and the city”, *Geography Compass* **4** 872-880

Davies J, White J, Wright A, Maru Y, LaFlamme M, 2008, “Applying the sustainable livelihoods approach in Australian desert Aboriginal development”, *The Rangeland Journal* **30** 55-65.

De Bruin K C, Dellink R B, 2011, “How harmful are restrictions on adapting to climate change?” *Global Environmental Change* **21** 34-45

Demeke M, Pangrazio G, Maetz M, 2009, “Initiative on soaring food prices: Country responses to the food security crisis: Nature and preliminary implications of the policies pursued” http://www.fao.org/fileadmin/user_upload/ISFP/pdf_for_site_Country_Response_to_the_Food_Security.pdf

Diamond J, 2005, *Collapse: How Societies Choose to Fail or Survive* (Penguin, London)

Dilley M, Chen R S, Deichmann U, Lerner-Lam A L, Arnold M, 2005, *Natural Disaster Hotspots: A Global Risk Analysis* (The World Bank, Washington DC)

Dünkeloh A, Jacobeit J, 2003, “Circulation dynamics of Mediterranean precipitation variability 1948–1998” *International Journal of Climatology* **23** 1843–1866

Ericson J P, Vörösmarty C J, Dingman S L, Ward L G, Meybeck M, 2006, “Effective sea-level rise and deltas: causes of change and human dimension implications”, *Global and Planetary Change* **50** 63–82

Evenson R E, Gollin D, 2003, “Assessing the impact of the Green Revolution, 1960 to 2000”, *Science* **300** 758-762

Fankhauser S, Smith J B, Tol R S J, 1999 “Weathering climate change: some simple rules to guide adaptation decisions”, *Ecological Economics* **30** 67-78

FAO (Food and Agricultural Organisation of the United Nations), 1996, "Report on the State of the World's Plant Genetic Resources for Food and Agriculture prepared for the International Technical Conference on Plant Genetic Resources Leipzig, Germany 17-23 June 1996" FAO, Rome

Folke C, Hahn T, Olsson P, Norberg J, 2005, "Adaptive governance of social-ecological systems", *Annual Review of Environment and Resources* **30** 441-473

Fu Q, Johanson C M, Wallace J M, Reichler T, 2006, „Enhanced mid-latitude tropospheric warming in satellite measurements" *Science* **312** 1179

Geddes A, Adger W N, Arnell N W, Black R, Thomas D S, 2012, "Migration, environmental change, and the 'challenges of governance'" *Environment and Planning C: Government and Policy* **30** 951-967

Godfray H C J, Beddington J R, Crute I R, Haddad L, Lawrence D, Muir J F, Pretty J, Robinson S, Thomas S M, Toulmin C, 2010, "Food security: the challenge of feeding 9 billion people", *Science* **327** 812-818

Gordon A, Simondson D, White M, Moilanen A, Bekessy S A, 2009, "Integrating conservation planning and landuse planning in urban landscapes", *Landscape and Urban Planning* **91** 183–194

Gornall J, Betts R, Burke E, Clark R, Camp J, Willett K, Wiltshire A, 2010, "Implications of climate change for agricultural productivity in the early twenty-first century", *Philosophical Transactions of the Royal Society B* **365** 2973-2989

Gross M, Krohn W, 2005, "Society as experiment: sociological foundations for a self-experimental society" *History of the Human Sciences* **18** 63-86

Guerin B, Guerin P, 2010, "Sustainability of remote communities: population size and youth dynamics", *Journal of Economic and Social Policy* 13(2), Article 3 http://epubs.scu.edu.au/jesp/vol13/iss2/3

Hajkowicz S, 2009, “The evolution of Australia’s natural resource management programs: towards improved targeting and evaluation of investments”, *Land Use Policy* **26** 471-478

Hanjra M A, Qureshi M E, 2010, “Global water crisis and future food security in an era of climate change”, *Food Policy* **35** 365-377

Harlan J R, 1995, *The Living Fields: Our Agricultural Heritage* (Cambridge University Press, Cambridge)

Harper A, 2011, “There’s A Food Crisis Happening Now, but it’s not in Africa”, The Age October 28 2011. http://www.theage.com.au/opinion/politics/theres-a-food-crisis-happening-now-but-its-not-in-africa-20111028-1mnof.html

Harvey D, 1974, “Population, resources and the ideology of science”, Economic Geography **50** 256-77

Hennessy K, Lucas C, Nicholls N, Bathols J, Suppiah R Ricketts J, 2005, *Climate Change Impacts on Fire-weather in South-east Australia* (CSIRO, Aspendale, Australia)

Hertel T W, Rosch S D, 2010, “Climate change, agriculture, and poverty”, *Applied Economic Perspectives and Policy* **32** 355-385

Hill R, Williams L, 2009, “Indigenous natural resource management: overcoming marginalisation produced in Australia’s current NRM model”, in *Contested Country: Local and Regional Natural Resources Management in Australia* Eds M Lane, C Robinson, B Taylor (CSIRO, Collingwood, Victoria) pp 161-178.

Hillman T, Crase L, Furze B, Ananda J, Maybery D, 2005, “Multidisciplinary approaches to natural resource management”, *Hydrobiologia* **552** 99-108

Holmes J, Clarke R, 2008, “Enhancing the use of science in environmental policy-making and regulation”, *Environmental Science and Policy* **11** 702-711

Holmgren M, Stapp P, Dickman C R, Gracia C, Graham S, Gutiérrez J R, Hice C, Jaksic F, Kelt D A, Letnic M, Lima M, López B C, Meserve P L, Milstead W B, Polis G A, Previtali M A, Richter M, Sabaté S, Squeo F A, 2006, “Extreme climatic events shape arid and semiarid ecosystems”, *Frontiers in Ecology and the Environment* **4** 87-95

Hoogvelt A, 2010, “Globalisation, crisis and the political economy of the international monetary (dis)order”, *Globalizations* **7** 51-66

HORSCATSIA (House of Representatives Standing Committee on Aboriginal and Torres Strait Islander Affairs), 2004, “Many Ways Forward: Report of the Inquiry into Capacity Building and Service Delivery in Indigenous Communities” Parliament of the Commonwealth of Australia, Canberra

Hossain S, 2005, “Poverty, household strategies and coping with urban life: examining 'livelihood framework' in Dhaka city, Bangladesh”, *Bangladesh e-Journal of Sociology* **2** 45-52

Howden S M, Soussana J-F, Tubiello F N, Chhetri N, Dunlop M, Meinke H, 2007, “Adapting agriculture to climate change”, *Proceedings of the National Academy of Sciences of the United States of America* **104** 19691–19696

Hugo G, 2006, “Immigration responses to global change in Asia: a review”, *Geographical Research* **44** 155–172

Hugo G, 2011, “Future demographic change and its interactions with migration and climate change”, *Global Environmental Change* **21(Suppl 1)** S21-S33

Hugo G J, Bardsley D K, 2014, “Migration and environmental change in Asia”, in *People on the Move in a Changing Climate: The Regional Impact of Environmental Change on Migration* Eds E Piguet, F Laczko, Migration Issues Volume 2 (International Organization for Migration, Geneva) pp 21-48

Hugo G, Bardsley D K, Tan Y, Sharma V, Williams M, Bedford R, 2009, “Climate Change and Migration in the Asia-Pacific Region”, Final Report to the Asian Development Bank, Manila

Hulme M, 2008, “The conquering of climate: discourses of fear and their dissolution”, *The Geographical Journal* **174** 5-16

IOM (International Organization for Migration), 2010, “World Migration Report 2010, The Future of Migration: Building Capacities for Change” IOM, Geneva

Jasanoff S, 2010, “A new climate for society”, *Theory, Culture and Society* **27** 233-253

Jones L, Boyd E, 2011, “Exploring social barriers to adaptation: insights from western Nepal”, *Global Environmental Change* **21** 1262-1274

Karim M F, Mimura N, 2008, “Impacts of climate change and sea-level rise on cyclonic storm surge floods in Bangladesh” *Global Environmental Change* **18** 490-500

Kelman I, Ashmore J, Leon E, D'urzo S, 2011, “From research to practice (and vice versa) for post-disaster settlement and shelter”, *Environmental Hazards* **10** 262-278

Laurenson S, Kunhikrishnan A, Bolan N S, Naidu R, McKay J, Keremane G, 2010, “Management of recycled water for sustainable production and environmental protection: a case study with Northern Adelaide Plains recycling scheme”, *International Journal of Environmental Science and Development* **1** 176–180

Lereboullet A-L, Beltrando G, Bardsley D K, 2013, “Socio-ecological adaptation to climate change: A comparative case study from the Mediterranean wine industry in France and Australia”, *Agriculture, Ecosystems and Environment* **164** 273-285

Levy M A, Anderson B, Brickman M, Cromer C, Falk B, Fekete B, Green P, Jaiteh M, Lammers R, Mara V, MacManus K, Metzle S, Muñiz M, Parris T, Pullen R, Thorkelson C, Vorosmarty C, Wollheim W, Xing X, Yetman G, 2008, “Assessment of Select Climate Change Impacts On U.S. National Security”, Columbia University Working paper July 1 2008, CIESIN, New York

Lofdahl C L, 1998, “On the environmental externalities of global trade”, *International Political Science Revue* **19** 339-355

Löf A, 2010, Exploring adaptability through learning layers and learning loops. *Environmental Education Research* **16** 529-543

Louis W R, Duck J M, Terry D J, Lalonde R N, 2010, "Speaking out on immigration policy in Australia: identity threat and the interplay of own opinion and public opinion", *Journal of Social Issues* **66** 653–672

Martin S, 2011, "Bush garden turns into a wasteland" The Advertiser September 12, 2011. http://www.adelaidenow.com.au/bush-garden-into-a-wasteland/story-e6frea6u-1226134347519.

MacCallum D, Byrne J, Steele W, 2013, "Whither justice? An analysis of local climate change responses from South East Queensland, Australia" *Environment and Planning C: Government and Policy* doi:10.1068/c11295

May K, 2010, "Government support for indigenous cultural and natural resource management in Australia: the role of the Working on Country program", *Australian Journal of Social Issues* **45** 395-416

McGranahan G, Jacobi P, Songsore J, Surjadi C, Kjellen M, 2001, *The Citizens at Risk: From Urban Sanitation to Sustainable Cities* (Earthscan, London)

McInnes K L, Suppiah R, Whetton P H, Hennessy K J, Jones R N, 2003, "Climate Change in South Australia" CSIRO Atmospheric Research, Melbourne

Mercer J, 2010, "Disaster risk reduction or climate change adaptation: are we reinventing the wheel?" *Journal of International Development* **22** 247-264

Mercer J, Kelman I, Taranis L, Suchet-Pearson S, 2010, "Framework for integrating indigenous and scientific knowledge for disaster risk reduction", *Disasters* **34** 214−239

Mikhailov V N, Dotsenko M A, 2006, "Peculiarities of the Hydrological Regime of the Ganges and Brahmaputra River Mouth Area", *Water Resources* **33** 353–373

Mol A P J, Sonnenfeld D A, 2000, “Ecological modernisation theory in debate: a review”, *Environmental Politics* **9** 17-49

Moon W, 2011, “Is agriculture compatible with free trade?” *Ecological Economics* **71** 13-24

Moran M, Elvin R, 2009, “Coping with complexity: adaptive governance in desert Australia”, *GeoJournal* **74** 415-428

Morrison T H, McDonald G T, Lane M B, 2004, “Integrating natural resource management for better environmental outcomes” *Australian Geographer* **35** 243-258

Moser S C, Ekstrom J A, 2010, "A framework to diagnose barriers to climate change adaptation." *Proceedings of the National Academy of Sciences* **107** 22026-22031

Munck R, 2009, “Globalisation, governance and migration: an introduction” in R Munck Ed. *Globalisation and Migration: New Issues, New Politics* (Routledge, London) pp 1-20

Nelson G C, Rosegrant M W, Koo J, Robertson R, Sulser T, Zhu T, Ringler C, Msangi S, Palazzo A, Batka M, Magalhaes M, Valmonte-Santos R, Ewing M, Lee D, 2009, “Climate Change: Impact on Agriculture and Costs of Adaptation”, International Food Policy Research Institute, Washington, DC

Neumayer E, 2003, *Weak Versus Strong Sustainability: Exploring the Limits of Two Opposing Paradigms* (Edward Elgar, Cheltenham, UK)

Nicholls R J, Hoozemans F M J, Marchand M, 1999, “Increasing flood risk and wetland losses due to global sea-level rise: regional and global analyses”, *Global Environmental Change* **9(Suppl. 1)** S69-S87

Nohara D, Kitoh A, Hosaka M, Oki T, 2006, “Impact of climate change on river discharge projected by multimodel ensemble”, *Journal of Hydrometeorology* **7** 1076-1089

O’Brien K L, Wolf J, 2010, „A values-based approach to vulnerability and adaptation to climate change”, *Wiley Interdisciplinary Reviews: Climate Change* **1** 232-242

Okereke C, 2006, “Global environmental sustainability: intragenerational equity and conceptions of justice in multilateral environmental regimes”, *Geoforum* **37** 725-738

Osborne T, Rose G, Wheeler T, 2013, “Variation in the global-scale impacts of climate change on crop productivity due to climate model uncertainty and adaptation”, *Agricultural and Forest Meteorology* **170** 183–194

Parry M L, Rosenzweig C, Iglesias A, Livermore M, Fischer G, 2004, “Effects of climate change on global food production under SRES emissions and socio-economic scenarios”, *Global Environmental Change* **14** 53-67

Peck J, 2001, “Neoliberalizing states: thin policies/hard outcomes”, *Progress in Human Geography* **25** 445-455

Peck J, 2004, “Geography and public policy: constructions of neoliberalism”, *Progress in Human Geography* **28** 392–405

Perkins J H, 1997, *Geopolitics and the Green Revolution: Wheat, Genes, and the Cold War* (Oxford University Press, New York)

Pimental D, Whitecraft M, Scott Z R, Zhao L, Satkiewicz P, Scott T J, Philips J, Szimak D, Singh G, Gonzalez D O, Moe T L, 2010, “Will limited land, water, and energy control human population numbers in the future?”, *Human Ecology* **38** 599-611

Prabhakar S V R K, Srinivasan A, Shaw R, 2009, “Climate change and local level disaster risk reduction planning: need, opportunities and challenges”, *Mitigation and Adaptation Strategies for Global Change* **14** 7-33

Preston B L, Suppiah R, Macadam I, Bathols J, 2006, “Climate Change in the Asia/Pacific Region”, A Consultancy Report Prepared for the Climate Change and Development Roundtable, CSIRO, Australia

Preston B L, Dow K, Berkhout F, 2013, “The climate adaptation frontier”, *Sustainability* **5** 1011-1035

Quigley M C, Horton T, Hellstrom J C, Cupper M L, Sandiford M, 2010, "Holocene climate change in arid Australia from speleothem and alluvial records", *The Holocene* **20** 1093-1104

Reuveny R, 2007, "Climate change-induced migration and violent conflict", *Political Geography* **26** 656-673

Ringler C, Bryan E, Biswas A K, Cline S A, 2010, "Water and food security under global change", in *Global Change: Impacts on Water and Food Security* Eds C Ringler, A K Biswas, S A Cline (Springer-Verlag, Berlin) pp 3-15

Robins L, Dovers S, 2007, "NRM regions in Australia: the 'haves' and the 'have nots'", *Geographical Research* **45** 273-290

Robinson A C, Copley P B, Canty P D, Baker L M, Nesbitt B J, 2003, "A Biological Survey of the Anangu Pitjantjatjara Lands, South Australia, 1991-2001", Department for Environment and Heritage, Government of South Australia, Adelaide

Rosegrant M, 2008, "Biofuels and grain prices: impacts and policy responses", Testimony for the US Senate Committee on Homeland Security and Governmental Affairs, International Food Policy Research Institute, Washington, DC

Rothman D S, 1998, "Environmental Kuznets curves-real progress or passing the buck? A case for consumption-based approaches", *Ecological Economics* **25** 177-194

Rothman D S, Romero-Lankao P, Schweizer V J, Bee B A, 2013, "Challenges to adaptation: a fundamental concept for the shared socio-economic pathways and beyond", *Climatic Change* 1-13

Ryding S-O, 1994, *Environmental Management Handbook* (IOS Press, Amsterdam)

SA (South Australian) Government, 2004, "South Australia Natural Resources Management Act 2004", Government of South Australia, Adelaide

SA (South Australian) Government, 2005, “Water Proofing Adelaide: A Thirst for Change 2005-2025”, Government of South Australia, Adelaide

SA (South Australian) Government, 2006, “Planning Strategy for Metropolitan Adelaide”, Government of South Australia, Adelaide

SA (South Australian) Government, 2009, “Planning the Adelaide we all want: Progressing the 30-year Plan for Greater Adelaide”, Government of South Australia, Adelaide

SA (South Australian) Government, 2010, “South Australia Lands Administration Trust Act 1966: Version 1.2.2010”, Government of South Australia, Adelaide

Shamim C, 2008, “Alternative views of environmental security in a less developed country: the case of Bangladesh”, *Journal of Third World Studies* **25** 253-272

Schipper L, Pelling M, 2006, “Disaster risk, climate change and international development: scope for, and challenges to, integration”, *Disasters* **30** 19-38

Shiva V, 1991, *The Violence of the Green Revolution* (Zed Books, London)

Smyth A, Friedel M, O’Malley C, 2009, “The influence of buffel grass (Cenchrus ciliaris) on biodiversity in an arid Australian landscape”, *The Rangeland Journal* **31** 307–320

Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt K B, Tignor M, Miller H L, 2007, *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press, Cambridge)

Spiertz H, 2010, “Food production, crops and sustainability: restoring confidence in science and technology”, *Current Opinion in Environmental Sustainability* **2** 439–443

Stafford Smith M, Moran M, Seeman K, 2008, “The ‘viability’ and resilience of communities and settlements in desert Australia”, *The Rangeland Journal* **30** 123-135

Staniford A K, Dollard M F, Guerin B, 2009, "Stress and help-seeking for drought-stricken citrus growers in the Riverland of South Australia", *Australian Journal of Rural Health* **17** 147–54

Suppiah R, Preston B, Whetton P H, McInnes K L, Jones R N, Macadam I, Bathols J, Kirono D, 2006, "Climate Change Under Enhanced Greenhouse Conditions in South Australia", CSIRO, Aspendale, Victoria

Szabo J K, Vesk P A, Baxter P W J, Possingham H P, 2011, "Paying the extinction debt: woodland birds in the Mount Lofty Ranges, South Australia" *Emu* **111** 59-70

The Allen Consulting Group, 2005, "Climate Change Risk and Vulnerability: Promoting an Efficient Adaptation Response in Australia", Commonwealth of Australia, Canberra

Thrupp L A, 2000, "Linking agricultural biodiversity and food security: the valuable role of agrobiodiversity for sustainable agriculture", *International Affairs* **72** 265 – 281

Tschakert P, Dietrich K A, 2010, „Anticipatory learning for climate change adaptation and resilience", *Ecology and Society* **15(2)** 11. http://www.ecologyandsociety.org/vol15/iss2/art11/.

UNCTAD (United Nations Conference on Trade and Development), 2013, "Wake up Before it is too Late: Make Agriculture Truly Sustainable now for Food Security in a Changing Climate", UNCTAD Trade and Environment Review, Geneva

UNHCR (United Nations High Commission for Refugees), 2010, "Global trends: 60 Years and Still Counting", UNHCR, Geneva

Urry J, 2011, *Climate change and society* (Polity Press: Cambridge)

van Naerssen T, Spaan E, Zoomers A, 2008, *Global Migration and Development* (Routledge, New York)

Vecchi G A, Soden B J, 2007, "Effect of remote sea surface temperature change on tropical cyclone potential intensity", *Nature* **450** 1066-1070

Vermeulen S J, Aggarwal P K, Ainslie A, Angelone C, Campbell B M, Challinor A J, Hansen J W, Ingram J S I, Jarvis A, Kristjanson P, Lau C, Nelson G C, Thornton P K, Wollenberg E, 2011, "Options for support to agriculture and food security under climate change", *Environmental Science and Policy* **15** 136-144

Verstraete M M, Scholes R J, Stafford-Smith M, 2009, "Climate and desertification: looking at an old problem through new lenses", *Frontiers in Ecology and the Environment* **7** 421-428

Von Braun J, 2008, "The food crisis isn't over", *Nature* **456** 701

von Storch H, Woth K, 2008, "Storm surges: perspectives and options", *Sustainability Science* **3** 33-43

Vörösmarty C J, Green P, Salisbury J, Lammers R B, 2000, "Global water resources: Vulnerability from climate change and population growth", *Science* **289** 284-288

Walker G, Bulkeley H, 2006, "Geographies of environmental justice", *Geoforum* **37** 655-659

Wals A E J, 2007, *Social Learning: Towards a Sustainable World: Principles, Perspectives, and Praxis* (Wageningen Academic Publishers, Wageningen)

Warner K, 2012, "Human migration and displacement in the context of adaptation to climate change: the Cancun Adaptation Framework and potential for future action", Environment and Planning C: Government and Policy **30** 1061-1077.

Warner K, Afifi T, Dun O, Stal M, 2009, "Climate change and migration: reflections on policy need", MEA Bulletin, Guest Article No. 64, February 27, 2009

Webster P J, Holland G J, Curry J A, Chang H-R, 2005, "Changes in tropical cyclone number, duration, and intensity in a warming environment", *Science* **309** 1844-1846

WFP (World Food Programme), FAO (Food and Agriculture Organisation), 2009, "The State of Food Insecurity in the World Economic Crises – Impacts and Lessons Learned" FAO, Rome

Wiseman N D, Bardsley DK, 2013, "Climate change and indigenous natural resource management: A review of socio-ecological interactions in the Alinytjara Wilurara NRM region", *Local Environment: The International Journal of Justice and Sustainability* **18** 1024-1045

World Commission on Environment and Development, 1987, *Our Common Future* (Oxford University Press, Oxford)

York R, Rosa E A, 2003, "Key challenges to ecological modernization theory", *Organization and Environment* **16** 273-288

Yusuf A A, Francisco H A, 2009, "Climate Change Vulnerability Mapping for Southeast Asia", Economy and Environment Program for Southeast Asia, Singapore

Zeng B, Edwards G P, 2010, "Perceptions of pastoralists and conservation reserve managers on managing feral camels and their impacts", *The Rangeland Journal* **32** 63-72