Social and public health effects of climate change in the '40 South'

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This work provides an overview of the literature on the current and projected social and health effects of climate change in countries affected by sub-Antarctic atmospheric circulation, including Argentina, Australia, Chile, New Zealand, and South Africa. These countries, which for convenience we gloss as '40 South', are already experiencing considerable impact. Climate change particularly impacts on water and food security, extreme weather events and migration. Projections indicate that the continuing impact of climate change may precipitate political and socioeconomic crises, including increased local, regional, and international migration. We highlight the similarity of the countries in terms of geography, current, and projected climate change impacts, adopted mitigation and adaptation strategies, and vulnerable population groups. While the health and social consequences of climate change draw attention to the differences in the social, political, and economic differences between the countries, we argue the strategic and scientific value of comparisons between them.

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INTRODUCTION

Climate change presents major socioeconomic, public health, and political challenges, which require multilateral efforts through international collaboration for their effective resolution.[1,2] The Climate Conference in Copenhagen at the end of 2009, the work of the United Nations Framework Convention on Climate Change, and more recent political and scientific meetings, all highlight the complex political considerations that shape government standpoints, policies, programs, and collaboration, often in the absence of an evidence-base. While there needs to be greater investment in research on which basis governmental and intergovernmental decisions can be made, projects such as EACH-FOR,[3] The RECOPOL project,[4] and Cape Farewell[5] highlight how collaborative research programs can support advocacy and develop practical solutions to address climate change.

In climate science as in other fields, research efforts have been concentrated in the geopolitical north, and have proceeded with limited social science involvement. In this article, we argue the value for 'south' co-operation, and in particular, for multidisciplinary research to explore the social impact of climate change and to identify strategies of resilience, adaptation, and mitigation of climate change. We start with the premise that there is strategic and intellectual value in collaboration among the countries affected by sub-Antarctic circulation, countries to which we refer collectively as '40 South'. These countries, including Argentina, Australia, Chile, New Zealand, and South Africa, have much in common for climatic, geographic, and broad historical reasons, distinct from North America and Northern Europe for which there is a much more substantial climate-related research base. These 40 South countries have significantly large extratropical populations and expanding urban centers (Figure 1); economically and politically, they are of global importance. Yet for cultural reasons—differences in colonization, language, political alignment, and academic association—there is a very weak tradition of collaborative scholarship and policy alliance among these countries.

The sub-Antarctic atmospheric circulation is a defining feature affecting climate in southern latitudes. The climatic conditions in 40 South are substantially influenced by the El Niño/La Niña Southern Oscillation (ENSO), and by the longitudinal movement of warm low-latitude surface waters and

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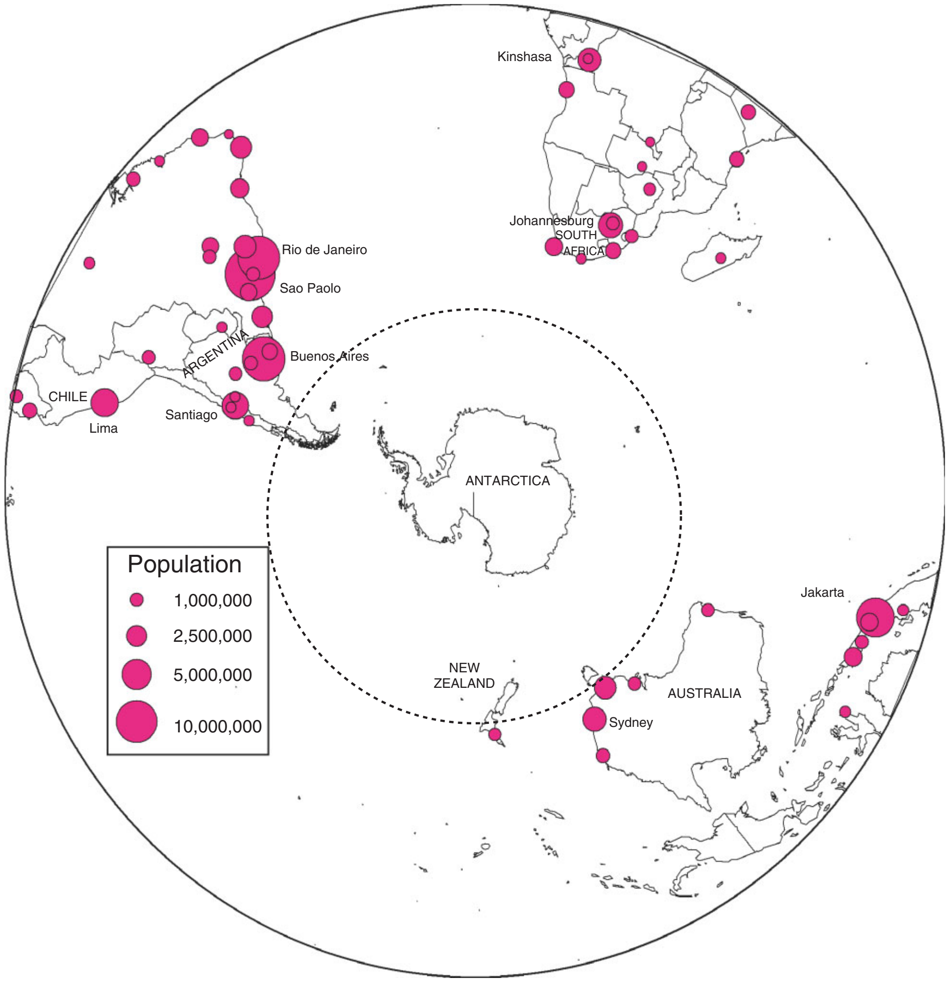

FIGURE 1 | Population densities of major settlements in the Southern Hemisphere. Dotted circle shows location of 40°S latitude.

accompanying moist air.[6–12] The observed poleward shift of large-scale atmospheric circulation systems in recent decades, such as jet streams and mid-latitude storm tracks, is associated with dryer conditions for semi-arid regions of southern Australia, southern Africa, and parts of South America, while bringing increased moisture to other areas.[13,14] The Pacific Decadal Oscillation (PDO) modulates ENSO-related climate variability in these countries,[15,16] but also influences weather patterns. When in the same phase, ENSO and PDO may enhance precipitation signals; when in opposite phases, the effects of ENSO variability are suppressed.[17] In addition, the Indian Ocean Dipole (IOD) is associated with surface air temperature anomalies in Australia, Africa, and South America.[18–23] The recent southern drift in the Southern Annular Mode is also affecting climatic patterns in the region.[24] These features of the sub-Antarctic system, in concert with responses to changing greenhouse gas concentration, are distinct from the Northern Hemisphere circulation, and consequently projected climate realizations are also distinct.

Social and health trajectories follow from these patterns, variations and projected changes. Below, we describe the regional and country-specific studies that have been undertaken in 40 South, primarily in the past decade. As social and public health researchers, our focus is on the associations between extreme weather and the social consequences of associated environmental events, including water and food insecurities, changes in disease epidemiology, and changes in population movement and migration.

The extant literature reflects research undertaken predominantly at country level, and draws attention to specific local vulnerabilities that distinguish these countries. As set out in Table 1, Australia and New Zealand are high income, highly urbanized nations, with strong democratic traditions and the political and scientific infrastructure to anticipate the mid- to long-term effects of climate change, and to some degree, to establish programs to address these. Other countries in the region for which some research has been undertaken on climate change and extreme weather events—Chile, Argentina, and South Africa, and the countries with which they share borders—are mainly middle income countries with weaker governance and more vulnerable economies; of the countries we include, South Africa is weakest on various development indices (again, Table 1) and faces unique governance problems. Countries that are near neighbors of 40 South—Namibia, Lesotho, Mozambique, and the Pacific Islands, for instance—are resource poor and particularly vulnerable to weather extremes and long-term climate change, and will depend on regional and international resources to respond to these. National and community resilience to climate-related crises consequently varies according to economic and political status and modes of governance. But in all 40 South countries, extreme weather events have increased over the past 100 years,[25] and these have already precipitated various economic, population, and settlement changes. As we illustrate, the weather can have profound and extensive social, economic, and political effects.

EXTREME WEATHER EVENTS

Floods

Increased atmospheric greenhouse gases very probably lead to changes in the incidence and severity of floods, affecting population health through disruptions to the supply of potable water, the destruction of housing, transport, sewerage and other infrastructure, and may increase the risk of water-borne diseases.[26–30] Coastal storm surges, rapid spring melt, extreme rainfall events, and the progressive thinning of mountain glaciers have caused floods in 40 South in the distant past and recently.[31,32] Coastal floods impact most severely on coastal and estuary communities, where population settlement is especially dense, but floods associated with unpredictable inundation or glacial melt pose significant hazards in mountain regions and downstream, as illustrated historically in the Chilean Patagonia[31] and in Australia in 2011.

Floods from heavy rainfall can have catastrophic effects locally and on communities downstream, resulting in loss of life, damage to private property, government and private infrastructure, basic supplies and resources, and productivity. Although flood plain management and other protection measures take account of these risks, policies need to identify more effective ways to solve or mitigate flood-related problems at source, during development, for example, to address development patterns in floodplains, rather than to rely on emergency management.[33–35] At the same time, substantial variation exists across and within 40 South countries in their preparedness and response strategies, in the administrative, communication, legal, jurisdictional, and political capacity to respond quickly and effectively, and in local capacity to support emergency responses and ensure timely and effective reconstruction.[29,36–38] Even in countries with well developed disaster management strategies at a national level, such as in Australia and New Zealand, community predisaster preparedness can be inadequate.[39] The floods, fires, and cyclones that occurred in Australia in the first 2 months of 2011 illustrates this well: the preparedness of local and state governments as Cyclone Yasi approached, aimed at preventing loss of life and minimizing property damage, contrasted sharply with the limited ability of state governments to anticipate and respond to floods and fires during this same period.

Extremely heavy rainfall and cyclones leading to local and downstream flooding are common in 40 South, and there is an increasing number of retrospective and projection studies now published for South America, Southern Africa, and Australia.[36,38,40–51] In contrast, there is a much smaller corpus of social research, particularly in relation to the uneven impact of such events on especially vulnerable populations.[52–55] In Argentina, for example, the geographic areas most under climate stress, including coastal zones, flood plains, and mountain slopes, are occupied by low income populations who live in poorly built houses and are least resilient to environmental and economic shocks.[56] In South Africa, the people worst affected by sudden floods live in makeshift housing and have few resources to retrieve possessions, escape, and resettle.[57] This is true everywhere; in Australia, the populations most severely affected by the 2011 floods resided in poor towns in cheap rental accommodation, in areas with limited services, and in caravan parks; wealthier residents who owned water-side property, as in Brisbane, were far better able to draw on social networks to help with evacuation and to begin reconstruction.

But extreme weather and sudden floods are only part of the picture. With land use changes, floods after prolonged droughts can contribute to dry land salinity, with consequent negative health effects,[58] as we elaborate below. We need longitudinal studies of such communities to document the toll and pervasiveness of such changes.

Droughts

In a hotter world, with more evaporation, overall precipitation will increase; however, its geographical

TABLE 1 | Sociodemographic and Economic Indicators of 40 South Countries

Country	Largest cities	Population	Percentage Living in Urban Areas	Percentage of Population Indigenous	Total Adult Literacy Rate	GDP (PPP) Total, 2010 Estimate	GDP (PPP) per Capita, 2010 Estimate for 2011	Agriculture Percentage of Share of GDP, 2010 Estimate	CO_2 Emissions, Metric Tons per Capita, 2007 Estimate	Energy Consumption kWh, 2007 Estimate
Argentina	Buenos Aires, Cordoba, Rosario	40,091,359 (2010)	91	1.6	98.0	632.223 US$ billion	16,289	8.5	4.6	99.21 billion
Australia	Sydney, Melbourne, Brisbane, Perth, Adelaide	22,598,000 (2011)	89	1.0%	99.0	882.344 US$ billion	41,089	4.0	19.0	222.00 billion
Chile	Santiago, Puente Alto, Concepción	17,206,500 (2011)	88	4.6	97	257.546 US$ billion	15,883	5.6	4.3	57.29 billion
New Zealand	Auckland	4,405,800 (2011)	87	14.6 Māori	99.0	119.791 US$ billion	28,344	4.5	8.4	39.24 billion
South Africa	Cape Town, Johannesburg	49,991,300 (2010)	61	79.4 Black (Indigenous populations not reported)	88	524.341 US$ billion	10,881	3.0	9.0	215.10 billion

Sources: International Monetary Fund Data and Statistics, The CIA World Factbook, and UNdata.

distribution and seasonality will change. Despite the increase in precipitation intensity, it is estimated that there will be longer periods between the rainfall events and a decrease in average rainfall;[11] and despite increased precipitation, greenhouse gas effects will contribute to an enhanced evaporation and evapotranspiration outweighing the increase in precipitation.[59] Drought-related stress affects agricultural, horticultural, and transient communities. There are declines in pasture for stock and water for agriculture, horticulture, and animals, so affecting productivity, leading to financial hardship and associated chronic social pressures. In South Africa, Chile, and Argentina, the increasing occurrence of drought has impacted on local agrarian and indigenous populations dependent to a significant extent on subsistence agriculture, herding, and seasonal labor.[60–62] In consequence, individual and community hardship can be significant, precipitating migration into townships in search of wage work or family support.[36,63] In Australia, there is virtually no subsistence farming, but increases in the incidence, duration, and severity of droughts, which are probably exacerbated by climatic change, have severely impacted on rural communities. The social and health impacts—increased indebtedness and unemployment, family disruption, increased illness, and mental health problems such as depression and suicide—have been dramatic.[64–71] In Argentina, there is also evidence of increased suicide, and fear of drought compounds other socioeconomic stressors as families move to farming areas with better climatic conditions, or abandon farms and relocate to urban areas.[72–77]

Fire

Bushfires are projected to increase in occurrence and intensity with protracted droughts and increased daytime temperatures.[78,79] Bushfires are characterized by high morbidity: burns, respiratory illnesses, psychological problems associated with fear, anxiety, grief, and loss among survivors and fire-fighters, and vicarious posttraumatic stress in the wider population.[29,80–86] As illustrated in Australia, the greatest risks and economic impact of bushfire is in rural and peri-urban settings, where habitat, livestock and farmland, and human health and wellbeing, are all vulnerable.[85,87,88]

WATER SECURITY

Climate change has direct impact on water supply, because of drought and as a result of fluctuations in water yield and quality following extreme rain events and floods. Surface water resources reduce with low precipitation; ground water shortages occur because of saltwater intrusion linked to rising sea levels.[89,90] The increased frequency of floods, droughts, and bushfires has the potential too to result in higher sediment loads, affecting potability.[28,82] During floods, waterways may be polluted with chemicals from industrial and agricultural sectors, and as reported in Australia in 2011, through breakdowns in waste and sewerage systems.[91,92] However, climate change does not affect water security in an even manner. Fowler,[93] for example, over a decade ago projected increased water yields with climate change in New Zealand. Even so, in continental areas in 40 South, reduced water supply remains a problem because of a combination of low precipitation, decreased average runoff, and increasing demand from farmers, householders, and industry; in South Africa and Australia, select towns already have had to rely on water purchased and shipped when local reserves ran dry.[94,95] Again, the impact of this on poor populations receives the least attention, but where populations rely on local rivers for domestic purposes and food production, water insecurity is an increasing public concern and politicized question.[28,89,96]

The need for changes in water management and conservation to increase water security is addressed in policy documents and the research literature.[36,50,93,97–101] In Australia, conservation strategies have been adopted by governments and consumers to reduce usage and recycle water, and water markets and other initiatives are recurrently debated and introduced.[36,95,102–113] At the same time, householders and farmers have often taken innovative steps—changing to crops requiring less water, for instance, and using gray water. But problems with governance have limited the number of public initiatives in the region, and large scale projects, such as waste water recycling and desalination systems, have generated considerable resistance by consumers and hostility in communities where the plants are to be located. In research and policy terms, there is a need to address the factors associated with community water management, and the mechanisms required to manage and sustain local waste disposal and water supply systems. Again, this is most urgent in poor (and often remote) populations where infrastructure and governance are especially weak.

FOOD SECURITY

Indigenous people and pastoralists are most vulnerable to food insecurity through the loss of local food resources.[37,114] But few hunter–gatherer communities in the 40 South still rely on or supplement their diet with wild foods, and for most populations in the region, and globally, food availability depends locally upon crop viability and yields, livestock, and fishing.[115,116] The projected impacts of climate change on agricultural yields are characterized by very large differences between geographic regions, and between cultivars. For example, because of climate-related increases in precipitation, in Pampas, Argentina, wheat, maize, sunflower, and soybean yields are projected to increase.[117] But decreases in maize production are projected in the tablelands of South Africa (the western Highveld),[118] and there has already been documented decreases in sugarcane production as a result of salinization of soil and higher temperatures.[119] In Chile, decreases in maize and wheat production are also projected,[120,121] and grape and wine production, major exports for all 40 South countries, is also vulnerable.[122,123] In general, the picture is of decreased crop yield, changes in varietals, and changes in the quality of produce, all affecting food supply. In agriculture, shifts of planting dates, the introduction of climatically-adapted varietals, and the use of irrigation and fertilizer, have all been proposed to enhance farm level and local community adaptations to drought. However, these interventions are not necessarily sustainable with increased climate change (dependence on irrigation is a case in point here), and long-term resolutions to support sustainable food production require political will as much as technological answers.

Reduced pasture, the changing incidence of vector-borne animal diseases, and extreme weather events reducing livestock productivity, are all anticipated to increase livestock mortality and impact the availability of meat and the nutritional quality of dairy products.[37,124,125] This has been reported and projected for Argentina[126] and South Africa,[127] with productivity expected to decrease with higher atmospheric temperatures. In New Zealand, pasture growth and milk production are likely to be promoted in the medium term, although this is not straightforward. Declining pasture quality because of the climate change, for example, may result in the increased dominance of C4 grasses, with flow on implications in relation to stock and fodder.[128–130] Similar impacts have been projected for Argentina.[131,132] Decreases in dairy cattle under some climate change scenarios have also been projected for Chile, primarily due to declining farmers' choices[132] and possible heat stress of cattle in some locations.[133]

Climate change will also impact marine and freshwater fisheries, affecting the distribution of fish species and catch rates.[134,135] While most coastal dwellers in Australia, New Zealand, and Argentina are not dependent on local marine foods, the nutritional status of impoverished coastal dwellers across South Africa especially could be at risk with projected declines in marine food availability.[136,137] In all 40 South countries, too, these factors especially affect indigenous coastal dwellers relying on marine resources for cultural and subsistence reasons. Concurrently, global parameters may influence food availability. Population growth and food demand affects the distribution and cost of food; changes in the price of oil, market systems, and purchasing power all also influence food supply and access.[98,138–140] Local food stability, and food production for national needs and for export, for example, will be affected by increased extreme weather events, depending upon country capacity to balance variations in yields.[30,141,142] Access to food supplies is often limited after a disaster, during economic downturn, and during conflict,[30,76,90,138] and so preparedness for disaster, including adequate food storages and changes in dependence on food imports, may also influence food stability.[30] Poor households everywhere are vulnerable to changes in food supply and associated fluctuations in price. Poor households everywhere are vulnerable to changes in food supply and associated fluctuations in price. Children, noted particularly in South Africa,[143] may suffer from even greater malnutrition than at present, increasing their susceptibility to infectious diseases.[144]

HEALTH RISKS AND DISEASE

Climate shapes the physical environment in which health is maintained and disease spread. The World Health Organization (WHO) estimates that around 150,000 lives are lost annually as a direct result of anthropogenic climate change, including cardiovascular mortality and respiratory illnesses, changes in the epidemiology of infectious disease, and malnutrition from drought and crop failure. However, while the countries that produce the most carbon emissions experience their share of extreme weather, and changes in the incidence and prevalence of disease, the irony—as the WHO observes—is that the poorest regions and poorest people in the world, least responsible for global warming, are experiencing the greatest increase in diseases because of global warming.[145,146] These include respiratory illness from wind-borne dust, the increased risks of diarrhoeal diseases—a major, climate change-related health and development issue for children, vector-borne diseases, such as arboviruses due to altered ecology, and mental health problems because of environmental degradation and changes in productive activity, employment, and income.[58,65,71,147]

Heat Waves and Heat Stress

The trend of increased frequency, intensity and duration of heat waves is consistent for all 40 South countries,[26–30] although the rate of change and the severity of heat waves are greater in continental settings, for example, South Africa and Australia, than in small islands like New Zealand. In general, heat waves are associated with increased morbidity from cardiovascular, respiratory, and mental illnesses, and increased hospital admissions for heat stress, heat stroke and dehydration.[148–151] Elderly people who have an existing chronic illness and frequently multiple comorbidities are especially vulnerable to heat waves.[151–154] Woodruff et al.[155] have argued that with population aging, heat-related mortality will increase substantially, particularly among the increasing numbers of extremely old people, in Australia and probably New Zealand. In Argentina, Chile, and South Africa, population aging, social, and economic inequality, relatively poor access to health services, poor quality and crowded housing, and lack of access to basic services including potable water, all combine to place older populations at even greater risk.

Heat waves in large cities are exacerbated by the urban heat island effect, as described for Buenos Aires (Argentina), Johannesburg and Cape Town (South Africa), Santiago (Chile), and Melbourne (Australia).[47,156–162] Increased population density, decreased vegetation cover, heat from various combustion processes related to vehicles, heating and air conditioning, all contribute to increased urban air temperatures.[47,157,162,163] Again, poor people in substandard crowded housing, rudimentary informal settlements and slums, and homeless people—affecting all populations in 40 South—are especially vulnerable.[164]

Vector-Borne Infectious Diseases

The impact on vector-borne infections of changing climatic conditions, including precipitation, air and water surface temperatures, is complex. Changes in ecology influence the breeding, life-cycle, and survival of vectors,[165] and the maturation and replication of the infectious agent,[166] such that as control activities are effective in one area, new areas, where a particular vector-borne infection has not been endemic, open up. Globally, ecological changes have hindered control program efforts and supported the continued prevalence of vector-borne infectious diseases, already endemic in southern Africa and the tropical regions of South America, such as schistosomiasis, malaria, and dengue (resulting, e.g., from deforestation and building large dams).[167–169] But in addition, mosquito-borne parasitic infections such as malaria and filariasis, which are not currently major problems for the 40 South countries, arboviruses such as dengue, Ross River fever, Barmah Forest virus and chikungunya, tick-borne diseases and typhus, have re-emerged in areas where they were once declared eradicated[170,171] and have moved into once naïve temperate zones. Both Australia and Pacific Island nations are vulnerable in this respect.[172]

Key climatic variables and extreme weather events provide the ecological preconditions for vectors and hosts of infectious disease, and hence the risk of transmission of infection. The observable changes in disease distribution, intensity, and seasonality are further complicated by the status of vector- and disease-control programs, by drug and insecticide resistance where control programs have been operating, and by local alterations in water storage and irrigation habits and land-use changes.[173,174] War and civil unrest, seasonal and permanent population movement for economic and political reasons, and the immune status of mobile populations, all further influence the transmission and control of disease,[175–178] often overshadowing the effects of climate change.[179] With increased migration, there is also an increased risk of infectious diseases introduced by immigrants, with increasing demands for medical care and health and other services, and pressure on services.[180–182] Increased international migration especially may increase imported cases of infection from countries with endemic vector-borne infections, to settings where the vector is present, as is the case for dengue fever in Australia.[178]

Change in land settlement, urbanization and industrialization also have implications on the endemicity and potential epidemics of vector-borne disease, and on air-borne infections—SARS, avian influenza, and so on[152,171,183,184]—through the combined effects of population density, poor infrastructure and lack of adequate dry and wet waste disposal, and changes in temperature and precipitation. In this respect, the countries at greatest risk are arguably those of the political 'south'—sub-Saharan Africa and the poorest countries of South and Southeast Asia especially—but vector-borne and other 'old' infectious diseases, and a growing number of 'new' diseases, are not confined by borders.

Water-Borne Infectious Diseases

The increased potential for water-borne infections has been projected for all countries in 40 South.[180] In warm climates, coastal and estuarine water warming and flood-related water pollution may lead to the increased potential for water-borne infections such as cholera.[176] But flood-related contamination of waterways and associated outbreaks of water-borne infections are already common. As early as 2000, heavy rainfall after prolonged drought in KwaZulu Natal, South Africa, resulted in a large cholera outbreak,[185] and cholera and other water-borne diseases are increasingly common in the aftermath of weather-related disaster. Leptospirosis was reported in Argentina after floods in 1998,[186] and Nagels and associates[43] reported rising *Escherichia coli* bacterial concentration after floods in Waikato, New Zealand, in 1999. While Australia and New Zealand have public health systems in place to minimize the effects of pollution, and the capacity to act quickly to mend broken infrastructure and monitor changes in pathogens, poorer monitoring and ineffective public health and water management systems in other countries mean that these infections can reach epidemic proportions.[92,176,180,187]

Food-Borne Diseases and Nutritional Compromises

Climate changes will potentially increase the incidence of food-borne infectious diseases, particularly affecting the young, elderly, and those with compromised immunity. This group of infectious diseases is broad, with various pathogens characterized by a complex ecology. Although food-borne disease is affected by various factors including seasonality, behavior, and public health control,[188,189] high mean temperature and humidity can affect the quality and safety of food, and pathogens such as campylobacter thrive in precooked food and commercial foods that are increasingly part of the dietary of urban dwellers throughout the region. Social and political events, such as civil disruption, population displacement, and prolonged residence in refugee camps where hygiene and sanitation are rudimentary, all alter the conditions for food safety and contribute to the recurrence of food-borne disease.[30]

Elderly people with an existing chronic condition, particularly those in institutional care, have an increased risk for enteric infections and a reduced physical resilience for recovery.[152] The compromised health status of people with either infectious or noninfectious disease further impacts on nutritional status, and affects their resilience. For example, the prevalence of diabetes among former subsistence populations—including Indigenous Australians, Maori in New Zealand, Khoi and San in South Africa, and indigenous populations in Latin America—increases their vulnerability to infection under conditions of economic constraint and environmental stress.[190–194] And most particularly, populations with a high incidence of HIV (notably in southern Africa) are vulnerable when there is inadequate and poor quality food.[195–199] The downturns in regional food yields triggered by climate change have the potential to increase rates of malnutrition in children,[144] particularly in South Africa, where malnutrition is considered as one of the major underlining causes of child mortality by increasing the risk of death because of infections.[200] In addition to increasing susceptibility to infections, micronutrient deficiencies may slow cognitive development of the child, contributing to poorer school performance, and increase the later risk of ill health.[201] The needs, vulnerabilities, and adaptive strategies of vulnerable populations require specific attention.[56,201,202]

ENVIRONMENTAL MIGRATION

Historically, people in disrupted environments, unable to maintain the rhythms of everyday life, have migrated. Although migration is still motivated by economic and political factors, there has long been evidence of environmental-related population movement.[203–206] With the exception of Australia and New Zealand, countries in 40 South do not have the infrastructure and governmental capacity to absorb even the current flow of legal and illegal immigrants, and increased rural to urban environmental migration will stretch services and infrastructure. The health consequences of substandard living arrangements, inadequate hygiene and sanitation, and food and water insecurity and lack of safety, are already compounded in South Africa by its weak health infrastructure and a fragile health system.

The extreme poverty of many immigrants, with the declining capacity of health and social institutions, contributes to their poor health, as noted above. Experiences of environmental crises, as has occurred periodically because of drought in South Africa, highlight the social and economic consequences of internal migration, and the environmental, social, and public health problems that follow.[207] Similarly, Buenos Aires and its surrounding cities have been affected by internal migration because of floods in Patagonia,[208,209] adding to existing problems of unemployment, environmental pollution, low wages, poverty, and the increased incidence of HIV infection.[183,210–212]

With climate change and disruptions to local economies, increased international/intercontinental migration—voluntary, forced and humanitarian—is probable.[203,204] People facing social and financial problems in environmentally degrading environments will seek to resettle, suggesting an urgent need for the reform of immigration and foreign emergency policies.[26] While climate change affecting the small island states of the Pacific extends our discussion beyond 40 South, Australia, New Zealand, and Chile are all on the Pacific Rim, and Australia particularly will receive increasing refugees from the Pacific.[37,114,205] Unplanned international migration can exacerbate political, economic, and environmental problems in the host country, and will place heavy demands on housing, education, and welfare services.

All countries located in 40 South are expected to experience increased population movement from areas that cease to be viable economically because of drought, floods, and other environmental stresses. The source countries and triggers of migration, and the upstream pressures, will clearly differ—environmental degradation and civil disorder in one case; threats to the viability of small islands in another. While distance precludes large scale continental migration, the general range of problems is not dissimilar, and again point to the value of both comparative research and common problem solving (Box 1).

BOX 1

THE POLITICS OF SCIENCE

International research has been driven from the political north, its empirical foci on matters that impact on the north politically and economically. In consequence, political alliances and research programs initiated by the political north with low and middle income countries (the political 'south') have been strategic. Alternative focuses—the Pacific Rim, South–South collaborations, MENA (Middle East and North Africa), and potentially 40 South—shift our thinking as scientists, requiring that we forge new scholarly collaborations to conduct research relevant to different geopolitical and policy settings.

CONCLUSION

A growing literature draws attention to the potential effects of climate change in and around 40 South. High ambient temperatures and greater climate variability have the potential to affect water and food availability and security, to increase the risk of infectious diseases, and associated mental and physical health problems, and to undermine social and economic structures and public health systems in all countries. Although the longer term social costs of climate change are conjectural, the broad picture is of comprehensive pressure on the environment and those who live in it.

Our attention to 40 South derives from the climatic distinctiveness of the Antarctic circulation and the geographic commonalities across the region. In other respects—importantly, in terms of language of communication, the organization of civil society, and political culture, they are very different. But drawing together the countries of this region, we argue, will strengthen our understanding of both social and meteorological commonalities, illustrating the implications of climate change and climate-related distress for population policy, infrastructure, and public services. In this article, we have concentrated on impacts of climate change, but there are commonalities across the countries on the response side also. For instance, the challenge of reducing carbon emissions from the agricultural sector is particularly acute for New Zealand,[213] but is shared to a large extent by Argentina and Chile.[214,215] New Zealand[216] and Chile[217] share a bounty of renewable energy sources, especially hydroenergy, while there are expanding opportunities for solar energy in Australia[218,219] and South Africa.[220] All five countries have interests in the sustainable design and operation of cities. For example, the development of the sustainable transport system in Perth, Australia,[221] and the use of innovative approaches to ecosystems and biodiversity conservation in Durban, South Africa,[222] provide opportunities for learning and improving. While the geographic, social, and economic contexts may vary widely, we suggest that unique collaborative opportunities exist to build our understanding of the social and health impacts of climate change, and so inform national and international decisions, policy, and action.

REFERENCES

1. Calvello A, ed. *Environmental Alpha: Institutional Investors and Climate Change*. Hoboken, NJ: John Wiley & Sons; 2009, 404.
2. Cooper RN. International approaches to global climate change. *WBRO* 2000, 15:145–172.
3. Renaud F, Bogardi JJ, Dun O, Warner K. *Control, Adapt or Flee. How to Face Environmental Migration? InterSecTions 'Interdisciplinary Security ConnecTions*. Publication series of UNU-EHS No. 5/2007. Bonn: United Nations University Institute for Environment and Human Security; 2007.
4. McCants CY, Spafford S, Stevens SH. Five-spot production pilot on tight spacing: rapid evaluation of a coalbed methane block in the Upper Silesian

Coal Basin, Poland. *International Coalbed Methane Symposium,* Tuscaloosa, Alabama; 2001, 193–204.

5. Buckland D, McEwan I, Gormley R, Whiteread A, Eastley M, Edwards N, Ehrlich G, eds. *Burning Ice: Art and Climate Change*. London: Cape Farewell; 2006, 176.
6. Grimm A, Tedeschi R. ENSO and extreme rainfall events in South America. *J Clim* 2009, 22:1589–1609.
7. Holmgren M, Stapp P, Dickman CR, Gracia C, Graham S, Gutiérrez JR, Hice C, Jaksic F, Kelt DA, Letnic M, et al. A synthesis of ENSO effects on drylands in Australia, North America and South America. *Adv Geosci* 2006, 6:69–72.
8. Isla FI. ENSO-dominated estuaries of Buenos Aires: the interannual transfer of water from Western to Eastern South America. *Global Planet Change* 2008, 64:69–75.
9. Reason CJC, Jagadheesha D. A model investigation of recent ENSO impacts over southern Africa. *Meteorol Atmos Phys* 2005, 89:181–205.
10. Poveda G, Waylen PR, Pulwarty RS. Annual and interannual variability of the present climate in northern South America and southern Mesoamerica. *Palaeogeog Palaeoclim Palaeoecol* 2006, 234:3–27.
11. Tebaldi C, Hayhoe K, Arblaster JM, Meehl GA. Going to the extremes. An intercomparison of model-simulated historical and future changes in extreme events. *Clim Change* 2006, 79:185–211.
12. Yin JH. A consistent poleward shift of the storm tracks in simulations of 21st century climate. *Geophys Res Lett* 2005, 32:L18701.
13. Bengtsson L, Hodges KI, Roeckner E. Storm tracks and climate change. *J Clim* 2006, 19:3518–3543.
14. Seidel DJ, Fu Q, Randel WJ, Reichler TJ. Widening of the tropical belt in a changing climate. *Nature Geosci* 2008, 1:21–24.
15. Folland CK, Renwick JA, Salinger MJ, Mullan AB. Relative influences of the interdecadal Pacific oscillation and ENSO on the South Pacific convergence zone. *Geophys Res Lett* 2002, 29:1643.
16. Salinger MJ, Renwick JA, Mullan AB. Interdecadal Pacific oscillation and South Pacific climate. *Int J Climatol* 2001, 21:1705–1721.
17. Andreoli RV, Kayano MT. ENSO-related rainfall anomalies in South America and associated circulation features during warm and cold Pacific decadal oscillation regimes. *Int J Climatol* 2005, 25:2017–2030.
18. Ashok K, Guan Z, Yamagata T. Influence of the Indian Ocean dipole on the Australian winter rainfall. *Geophys Res Lett* 2003, 30:1821–1824.
19. Pezza A, Durrant TH, Simmonds I, Smith I. Southern Hemisphere synoptic behaviour in extreme phases of SAM, ENSO, sea ice extent, and Southern Australia rainfall. *J Clim* 2008, 21:5566–5584.
20. Reason CJC. Sensitivity of the southern African circulation to dipole sea-surface temperature patterns in the south Indian Ocean. *Int J Climatol* 2002, 22:377–393.
21. Risbey JS, Pook MJ, McIntosh PC, Wheeler MC, Hendon HH. On the remote drivers of rainfall variability in Australia. *Mon Weather Rev* 2009, 137:3233–3253.
22. Schott FA, Xie S-P, McCreary JP, Jr. Indian Ocean circulation and climate variability. *Rev Geophys* 2009, 47:RG1002.
23. Ummenhofer CC, Sen Gupta A, Pook MJ, England MH. Anomalous rainfall over Southwest Western Australia forced by Indian ocean sea surface temperatures. *J Clim* 2008, 21:5113–5134.
24. Sen Gupta A, England MH. Coupled ocean–atmosphere–ice response to variations in the southern annular mode. *J Clim* 2006, 19:4457–4486.
25. World Meteorological Organization. *A Snapshot of Some Extreme Events (*) Over the Past Decade*. Geneva: World Meteorological Organization; 2010.
26. Barnett J, Adger WN. Climate dangers and atoll countries. *Clim Change* 2004, 61:321–337.
27. Easterling DR, Evans JL, Groisman PY, Karl TR, Kunkel KE, Ambenje P. Observed variability and trends in extreme climate events: a brief review. *Bull Am Meteorol Soc* 2000, 417–425.
28. Mirza MQM. Climate change and extreme weather events: can developing countries adapt? *Clim Policy* 2003, 3:233–248.
29. Pritchard F, Gow KM. Bushfires: preparation, resilience and recovery. In Gow K, Paton D, eds. *The Phoenix of Natural Disasters: Community Resilience*. New York: Nova Science Publishers; 2008, 209–233.
30. Schmidhuber J, Tubiello FN. Global food security under climate change. *Proc Natl Acad Sci* 2007, 104:19703–19708.
31. Harrison S, Glasser N, Winchester V, Haresign E, Warren C, Jansson KA. glacial lake outburst flood associated with recent mountain glacier retreat, Patagonian Andes. *Holocene* 2006, 16:611–620.
32. Rignot E, Rivera A, Casassa G. Contribution of the Patagonia icefields of South America to sea level rise. *Science* 2003, 302:434–437.
33. McInnes KL, Macadam I, Hubbert GD, O'Grady JG. A modelling approach for estimating the frequency of sea level extremes and the impact of climate change in southeast Australia. *Nat Hazards* 2009, 51:115–137.
34. Walsh KJE, Betts H, Church J, Pittock AB, McInnes KL, Jackett DR, McDougall TJ. Using sea level rise projections for urban planning in Australia. *J Coastal Res* 2004, 20:586–598.
35. Thomas M, King D, Keogh D, Apan AA, Mushtaq S. Resilience to climate change impacts: a review of flood mitigation policy in Queensland, Australia. Based on case studies of flood events in 2008. *AJEM* 2011, 26:8–17.

36. Bereciartua PJ. Vulnerability to global environmental changes in Argentina: opportunities for upgrading regional water resources management strategies. *Water Sci Technol* 2005, 51:97–103.
37. Preston BL, Jones RN. Climate change impacts on Australia and the benefits of early action to reduce global greenhouse gas emissions. February, 2006. A consultancy report for the Australian Business Roundtable on Climate Change. CSIRO, Aspendale, Victoria, 2006.
38. Vermaak J, van Niekerk D. Disaster risk reduction initiatives in South Africa. *Dev Southern Africa* 2004, 21:555–574.
39. Nicolopoulos N, Hansen E. How well prepared are Australian communities for natural disasters and fire emergencies? *AJEM* 2009, 24:60–66.
40. Barros V. Adaptation to climate trends: lessons from the Argentine experience, AIACC Working Paper No. 38. September 2006 Washington, DC: AIACC Assessments of Impacts and Adaptations to Climate Change; 2006.
41. Mason SJ, Waylen PR, Mimmack GM, Rajaratnam B, Harrison MJ. Changes in extreme rainfall events in South Africa. *Clim Change* 1999, 41:249–257.
42. Munckhof WJ, Mayo MJ, Scott I, Currie BJ. Fatal human melioidosis acquired in a subtropical Australian city. *Am J Trop Med Hyg* 2001, 65:325–328.
43. Nagels JW, Davies-Colley RJ, Donnison AM, Muirhead RW. Faecal contamination over flood events in a pastoral agricultural stream in New Zealand. *Water Sci Technol* 2002, 45:45–52.
44. Paskoff R, Manriquez H. Ecosystem and legal framework for coastal management in Central Chile. *Ocean Coast Manage* 1999, 42:105–117.
45. Pezza AB, Ambrizzi T. Variability of Southern Hemisphere cyclone and anticyclone behavior: further analysis. *J Clim* 2003, 16:1075–1083.
46. Seiler RA, Hayes M, Bressan L. Using the standardized precipitation index for flood risk monitoring. *Int J Climatol* 2002, 22:1365–1376.
47. Morris CJG, Simmonds I. Associations between varying magnitudes of the urban heat island and the synoptic climatology in Melbourne, Australia. *Int J Climatol* 2000, 20:1931–1954.
48. Kjeldsen TR, Smithers JC, Schulzeb RE. Regional flood frequency analysis in the KwaZulu-Natal province, South Africa: using the index-flood method. *J Hydrol* 2002, 255:194–211.
49. Shaban R. Australia's natural disasters: the 2009 fires and floods. *Austral Emerg Nurs J* 2009, 12:29.
50. Querner EP, Morabito JA, Rebori G. Cooperation on Water management issues, Argentina. Project in the framework of bilateral cooperation between Argentina and the Netherlands. Case studies on water management issues in Argentina, Alterra Wageningen, 2007.
51. Rosenzweig C, Iglesias A, Yang XB, Epstein PR, Chivian E. Climate change and extreme weather events; implications for food production, plant diseases, and pests. *Global Change Hum Health* 2001, 2:90–104.
52. Oliver-Smith A, Hoffman SM, eds. *The Angry Earth: Disaster in Anthropological Perspective*. New York and London: Routledge; 1999, 256.
53. Douglas I, Alam K, Maghenda M, McDonnell Y, McLean L, Campbell J. Unjust waters: climate change, flooding and the urban poor in Africa. *Environ Urban* 2008, 20:187–205.
54. Finch C, Emrich CT, Cutter SL. Disaster disparities and differential recovery in New Orleans. *Popul Environ* 31:179–202.
55. Fjord L, Manderson L. Anthropological perspectives on disasters and disability: an introduction. *Hum Organ* 2009, 68:64–72.
56. Hardoy J, Pandiella G. Urban poverty and vulnerability to climate change in Latin America. *Environ Urban* 2009, 21:203–224.
57. Bouchard B, Goncalo A, Susienka M, Wilson K. *Improving Flood Risk Management in the Informal Settlements of Cape Town*. Worcester, MA: Worcester Polytechnic Institute; 2007.
58. Jardine A, Speldewinde P, Carver S, Weinstein P. Dryland salinity and ecosystem distress syndrome: human health implications. *EcoHealth* 2007, 4:10–17.
59. Nicholls N. The changing nature of Australian droughts. *Clim Change* 2004, 63:323–336.
60. O'Farrell PJ, Anderson PML, Milton SJ, Dean WRJ. Human response and adaptation to drought in the arid zone: Lessons from southern Africa. *S Afr J Sci* 2009, 105:34–39.
61. Young G, Zavala H, Wandel J, Smit B, Salas S, Jimenez E, Fiebig M, Espinoza R, Diaz H, Cepeda J. Vulnerability and adaptation in a dryland community of the Elqui Valley, Chile. *Clim Change* 2010. 98:245–276.
62. Zycherman A. To beef or not to beef: defining food security and insecurity in Tucumán Argentina. *EEA* 2008, 4:28–37.
63. Tanco R, Kruse E. Prediction of seasonal water-table fluctuations in La Pampa and Buenos Aires, Argentina. *Hydrogeol J* 2001, 9:339–347.
64. Berry HL, Hogan A, Owen J, Rickwood D, Fragar L. Climate change and farmers' mental health: risks and responses. *Asia-Pac J Public Health* 2011, 23:119S–132S.
65. Nicholls N, Butler CD, Hanigan I. Inter-annual rainfall variations and suicide in New South Wales, Australia, 1964–2001. *Int J Biometeorol* 2006, 50:139–143.
66. Page AN, Fragar LJ. Suicide in Australian farming, 1988–1997. *Aust NZ J Psychiatry* 2002, 36:81–85.

67. Staniford AK, Dollard MF, Guerin B. Stress and help-seeking for drought-stricken citrus growers in the Riverland of South Australia. *Aust J Rural Health* 2009, 17:147–154.
68. Alston M. Globalisation, rural restructuring and health service delivery in Australia: policy failure and the role of social work? *Health Soc Care Comm* 2007, 15:195–202.
69. Alston M. I'd like to just walk out of here: Australian women's experience of drought. *Soc Rural* 2006, 46:154–170.
70. Hoogland S, Pieterse R. *Suicide in Australia, A Dying Shame*. Sydney: Wesley Mission; 2000.
71. Hu W, Nicholls N, Lindsay M, Dale P, McMichael T, Mackenzie J, Tong S. Development of a predictive model for Ross River virus disease using environmental data. *Am J Trop Med Hyg* 2004, 71:129–137.
72. Barros V. Adaptation to climate trends: lessons from the argentine experience. In: Leary N, Adejuwon J, Barros V, Burdon I, Kulkarni J, Lasco R, eds. *Climate Change and Adaptation*. London; Sterling, VA: Earthscan; 2007, 296–316.
73. Steiner HJ, Alston P, Goodman R. *International Human Rights in Context: Law, Politics, Morals*. Oxford; New York: Oxford University Press; 2008, 1497.
74. Wehbe M, Eakin H, Seiler R, Vinocur M, Ávila C, Maurutto C, Torres GS. Local perspectives on adaptation to climate change: lessons from Mexico and Argentina. In: Leary N, Adejuwon J, Barros V, Burdon I, Kulkarni J, Lasco R, eds. *Climate Change and Adaptation*. Earthscan: London; Sterling, VA; 2007, 315–331.
75. Judd F, Jackson H, Fraser C, Murray G, Robins G, Komiti A. Understanding suicide in Australian farmers. *Soc Psychiatr Psychiatr Epidemiol* 2006, 41:1–10.
76. Jury MR. Economic Impacts of climate variability in South Africa and development of resource prediction models. *J Appl Meteorol* 2002, 41:46–55.
77. Equity in response to climate change roundtable: an Australian snapshot. Available at: http://www.bsl.org.au/pdfs/Cambiar_climate__justice_Australian_snapshot_mar07.pdf. (Accessed July 20, 2011).
78. Flannigan MD, Krawchuk MA, de Groot WJ, Wotton BM, Gowman LM. Implications of changing climate for global wildland fire. *Int J Wildland Fire* 2009, 18:483–507.
79. Hasson AEA, Mills GA, Timbal B, Walsh K. Assessing the impact of climate change on extreme fire weather events over southeastern Australia. *Clim Res* 2009, 39:159–172.
80. Cameron PA, Mitra B, Fitzgerald M, Scheinkestel CD, Stripp A, Batey C, Niggemeyer L, Truesdale M, Holman P, Mehra R, et al. Black Saturday: the immediate impact of the February 2009 bushfires in Victoria, Australia. *Med J Aust* 2009, 191:11–16.
81. Macdonald E. Mental health needs post-disaster: supporting recovery of children and families. *Aust Occup Ther J* 2009, 56:79–80.
82. Sim M. Bushfires: are we doing enough to reduce the human impact? *Occup Environ Med* 2002, 59:215–216.
83. Tham R, Erbas B, Akram M, Dennekamp M, Abramson MJ. The impact of smoke on respiratory hospital outcomes during the 2002–2003 bushfire season, Victoria, Australia. *Respirology* 2009, 14:69–75.
84. Byrne MK, Lerias D, Sullivan NL. Predicting vicarious traumatization in those indirectly exposed to bushfires. *Stress Health* 2006, 22:167–177.
85. Reisen F, Brown SK. Implications for community health from exposure to bushfire air toxics. *Environ Chem* 2006, 3:235–243.
86. Yelland C, Robinson P, Lock C, La Greca AM, Kokegei B, Ridgway V, Lai B. Bushfire impact on youth. *J Traum Stress* 2010, 23:274–277.
87. Gillen M. Urban governance and vulnerability: exploring the tensions and contradictions in Sydney's response to bushfire threat. *Cities* 2005, 22:55–64.
88. Paton D. Living on the ring of fire: perspectives on managing natural hazard risk in Pacific rim countries. *J Pacific Rim Psychol* 2009, 3:1–3.
89. Jones JAA. Climate change and sustainable water resources: placing the threat of global warming in perspective. *Hydrol Sci J* 1999, 44:541–557.
90. Parry M, Rosenzweig C, Livermore L. Climate change, global food supply and risk of hunger. *Philos Trans R Soc Lond B* 2005, 360:2125–2138.
91. Euripidou E, Murray V. Public health impacts of floods and chemical contamination. *J Public Health* 2004, 26:376–383.
92. Nichols A, Maynard V, Goodman B, Richardson J. Health, climate change and sustainability: a systematic review and thematic analysis of the literature. *Environ Health Insights* 2009, 3:63–88.
93. Fowler A. Potential climate change impacts on water resources in the Auckland Region (New Zealand). *Clim Res* 1999, 11:221–245.
94. Jones R, Whetton P, Walsh K, Page C. *Future Impact of Climate Variability, Climate Change and Land Use Change on Water Resources in the Murray–Darling Basin. Overview and Draft Program of Research*. Aspendale, Victoria: CSIRO Atmospheric Research; 2001.
95. Quiggin J. Urban water supply in Australia: the option of diverting water from irrigation. *Public Policy* 2006, 1:14–22.
96. De Wit M, Stankiewicz J. Changes in surface water supply across Africa with predicted climate change. *Science* 2006, 311:1917–1921.
97. Australian Government. Department of Climate Change: Climate change adaptation actions for local

government, Report by SMEC Australia. Department of Climate Change; 2009.

98. Kamara A, Sally H. Water for food, livelihoods and nature: simulations for policy dialogue in South Africa. *Phys Chem Earth A/B/C* 2003, 28:1085–1094.

99. Chanan A, Kandasamy J, Vigneswaran S, Sharma DA. gradualist approach to address Australia's urban water challenge. *Desalination* 2009, 249:1012–1016.

100. Gunther P, Mey W, van Niekerk AM. A sustainable mine water treatment initiative to provide potable water for a South African city—a public-private partnership. *Water in Mining 2006, Proceedings—Multiple Values of Water*, Australasian Institute of Mining and Metallurgy; 2006, 189–198.

101. Velez OR, Fasciolo GE, Bertranou AV. Domestic wastewater treatment in waste stabilization ponds for irrigation in Mendoza, Argentina: policies and challenges. *Water Sci Technol* 2002, 45:127–132.

102. Anderson JM. Current water recycling initiatives in Australia: scenarios for the 21st century. *Water Sci Technol* 1996, 33:37–43.

103. Bauer CJ. In the image of the market: the Chilean model of water resources management. *Int J Water* 2005, 3:146–165.

104. Cáceres LV, Gruttner ED, Contreras RN. Water recycling in arid regions: Chilean case. *Ambio* 1992, 21:138–144.

105. Gibson HE, Apostolidis N. Demonstration, the solution to successful community acceptance of water recycling. *Wastewater Reclam Recycl Reuse* 2001, 43:259–266.

106. Hearne RR, Easter KW. *Water Allocation and Water Markets: An Analysis of Gains-from-Trade in Chile*. Washington, DC: World Bank; 1995, 100.

107. Hensher DA, Shore N, Train KE. Water supply security and willingness to pay to avoid drought restrictions. *Econ Rec* 2006, 82:56–66.

108. Marks J, Martin B, Zadoroznyj M. How Australians order acceptance of recycled water. National baseline data. *J Sociol* 2008, 44:83–99.

109. Olivier J, Rautenbach CJ. The implementation of fog water collection systems in South Africa. *Atmos Res* 2002, 64:227–238.

110. Sibly H. Urban water pricing. *Agenda* 2006, 13: 17–30.

111. Stenekes N, Colebatch HK, Waite DT, Ashbolt NJ. Risk and governance in water recycling. Public acceptance revisited. *Sci Technol Hum Values* 2006, 31:107–134.

112. Thevendiraraj S, Klemes J, Paz D, Aso G, Cardenas GJ. Water and wastewater minimisation study of a citrus plant. *Resour Conserv Recy* 2003, 37:227–250.

113. Ragab R, Prudhomme C. Climate change and water resources management in arid and semi-arid regions: prospective and challenges for the 21st century. *Biosyst Eng* 2002, 81:3–34.

114. McMichael A, Woodruff R, Whetton P, Hennessy K, Nicholls N, Hales S, Woodward A, Kjellstrom T. *Human Health and Climate Change in Oceania: A Risk Assessment 2002*. Canberra: Commonwealth Department of Health and Ageing; 2003.

115. McMichael A, Powles J, Butler C, Uauy R. Food, livestock production, energy, climate change, and health. *Lancet* 2007, 370:1253–1263.

116. Richardson RB. Ecosystem services and food security: economic perspectives on environmental sustainability. *Sustainability* 2010, 2:3520–3548.

117. Magrin G, Travasso M, Rodríguez G. Changes in climate and crop production during the 20th century in Argentina. *Clim Change* 2005, 72:229–249.

118. Walker NJ, Schulzea RE. Climate change impacts on agro-ecosystem sustainability across three climate regions in the maize belt of South Africa. *Agric Ecosys Environ* 2008, 124:114–124.

119. Deressa T, Hassan R, Poonyth D. Measuring the economic impact of climate change on South Africa's sugarcane growing regions. *Agrekon* 2005, 44:524–542.

120. Meza FJ, Silva D, Vigil H. Climate change impacts on irrigated maize in Mediterranean climates: Evaluation of double cropping as an emerging adaptation alternative. *Agric Syst* 2008, 98:21–30.

121. Meza FJ, Silva D. Dynamic adaptation of maize and wheat production to climate change. *Clim Change* 2009, 94:143–156.

122. Mira de Orduña R. Climate change associated effects on grape and wine quality and production. *Food Res Int* 2010, 43:1844–1855.

123. Webb L, Whetton P, Barlow EWR. Modelled impact of future climate change on phenology of wine grapes in Australia. *Aust J Grape Wine Res* 2007, 13:165–175.

124. Nienaber JA, Hahn GL. Livestock production system management responses to thermal challenges. *Int J Biometeorol* 2007, 52:149–157.

125. Valtorta SE. Animal production in a changing climate: impacts and mitigation. A Santa Fe National Council for Scientific and Technical Research, National Institute of Agricultural Technology, Rafaela Experimental Station; 2002.

126. De la Casa AC, Ravelo AC. Assessing temperature and humidity conditions for dairy cattle in Córdoba, Argentina. *Int J Biometeorol* 2003, 48:6–9.

127. Kurukulasuriya P, Mendelsohn R, Hassan R, Benhin J, Deressa T, Diop M, Eid HM, Fosu KY, Gbetibouo G, Jain S, et al. Will African agriculture survive climate change? *World Bank Econ Rev* 2006, 20:367–388.

128. Crush JR, Rowarth JS. The role of C-4 grasses in New Zealand pastoral systems. *N Z J Agric Res* 2007, 50:125–137.

129. Dynes R, Payn T, Brown H, Bryant J, Newtown P, Snow V, Lieffering M, Wilson D, Beets P. New Zealand's land-based primary industries & climate change: assessing adaptation through scenario-based modelling. In: Nottage RAC, Wratt DS, Bornman JF, Jones K, eds. *Climate Change Adaptation in New Zealand: Future Scenarios and Some Sectoral Perspectives*. Wellington: New Zealand Climate Change Centre; 2010, 44–55.

130. Johnson IR, Chapman DF, Snow VO, Eckard RJ, Parsons AJ, Lambert MG, Cullen BR. DairyMod and EcoMod: biophysical pasture-simulation models for Australia and New Zealand. *Aust J Exp Agr* 2008, 48:621–631.

131. Cabido M, Pons E, Cantero JJ, Lewis JP, Anton A. Photosynthetic pathway variation among C-4 grasses along a precipitation gradient in Argentina. *J Biogeogr* 2008, 35:131–140.

132. Seo SN, McCarl BA, Mendelsohn R. From beef cattle to sheep under global warming? An analysis of adaptation by livestock species choice in South America. *Ecol Econ* 2010, 69:2486–2494.

133. Arias RA, Mader TL. Determination of potential risk of heat stress of cattle in four locations of Central and Southern Chile. *Arch Med Vet* 2010, 42:33–39.

134. Meynecke J-O, Lee SY, Duke NC, Warnken J. Effect of rainfall as a component of climate change on estuarine fish production in Queensland, Australia. *Estuar Coast Shelf Sci* 2006, 69:491–504.

135. Munday PL, Jones GP, Pratchett MS, Williams AJ. Climate change and the future for coral reef fishes. *Fish Fisheries* 2008, 9:261–285.

136. Clark BM. Climate change: a looming challenge for fisheries management in southern Africa. *Mar Policy* 2006, 30:84–95.

137. Glavovic BC, Boonzaier S. Confronting coastal poverty: building sustainable coastal livelihoods in South Africa. *Ocean Coast Manage* 2007, 50:1–23.

138. Houghton J. Global warming. *Rep Prog Phys* 2005, 68:1343–1403.

139. Luo Q, Bellotti W, Williams M, Wang E. Adaptation to climate change of wheat growing in South Australia: analysis of management and breeding strategies. *Agric Ecosyst Environ* 2009, 129:261–267.

140. Meadows ME, Hoffman TM. Land degradation and climate change in South Africa. *Geogr J* 2003, 169:168–177.

141. Podestá GP, Messina CD, Grondona MO, Magrin GO. Associations between grain crop yields in Central-Eastern Argentina and El Niño–Southern Oscillation. *J Appl Meteorol* 1999, 38:1488–1498.

142. Ramankutty N, Foley JA, Norman J, McSweeney K. The global distribution of cultivable lands: current patterns and sensitivity to possible climate change. *Global Ecol Biogeogr* 2002, 11:377–392.

143. Tomlinson M, Chopra M, Sanders D, Bradshaw D, Hendricks M, Greenfield D, Black RE, El Arifeen S, Rudan I. Setting priorities in child health research investments for South Africa. *PLoS Med* 2007, 4:e259.

144. Bunyavanich S, Landrigan CP, McMichael AJ, Epstein PR. The impact of climate change on child health. *Ambul Pediatr* 2003, 3:44–52.

145. Baer H. Global warming as a by-product of the capitalist treadmill of production and consumption—the need for an alternative global system. *Aust J Anthropol* 2008, 19:58–62.

146. Baer HA. Toward a critical anthropology on the impact of global warming on health and human societies. *Med Anthropol* 2008, 27:2–8.

147. Tong S, Hu W, Nicholls N, Dale P, Mackenzie JS, Patz J, McMichael AJ. Climatic, high tide and vector variables and the transmission of Ross River virus. *Intern Med J* 2005, 35:677–680.

148. Guest CS, Willson K, Woodward AJ, Hennessy K, Skinner C, McMichael AJ. Climate and mortality in Australia: retrospective study, 1979–1990, and predicted impacts in five major cities in 2030. *Clim Res* 1999, 13:1–15.

149. Hansen A, Bi P, Nitschke M, Ryan P, Pisaniello D, Tucker G. The effect of heat waves on mental health in a temperate Australian city. *Environ Health Perspect* 2008, 116:1369–1375.

150. Semenza JC, McCullough JE, Dana Flanders W, McGeehin MA, Lumpkin JR. Excess hospital admissions during the July 1995 heat wave in Chicago. *Am J Prev Med* 1999, 16:269–277.

151. Bi P, Williams S, Loughnan M, Lloyd G, Hansen A, Kjellstrom T, Dear K, Saniotis A. The effects of extreme heat on human mortality and morbidity in Australia: implications for public health. *Asia-Pac J Public Health* 2011, 23:27S–36S.

152. Bambrick HJ, Capon AG, Barnett GB, Beaty RM, Burton AJ. Climate change and health in the urban environment: adaptation opportunities in Australian cities. *Asia-Pac J Public Health* 2011, 23:67S–79S.

153. Haines A, Kovats RS, Campbell-Lendrum D, Corvalan C. Climate change and human health: impacts, vulnerability, and mitigation. *Lancet* 2006, 367:2101–2109.

154. Vaneckova P, Hart MA, Beggs PJ, De Dear RJ. Synoptic analysis of heat-related mortality in Sydney, Australia, 1993–2001. *Int J Biometeorol* 2008, 52:439–451.

155. Woodruff RE, McMichael T, Butler C, Hales S. Action on climate change: the health risks of procrastinating. *Aust NZ J Public Health* 2006, 30:567–571.

156. Bejarán RA, Camilloni IA. Objective method for classifying air masses: an application to the analysis of Buenos Aires' (Argentina) urban heat island intensity. *Theor Appl Climatol* 2003, 74:93–103.

157. Coutts AM, Beringer J, Tapper NJ. Impact of increasing urban density on local climate: spatial and temporal variations in the surface energy balance in Melbourne. *J Appl Meteorol* 2007, 46:477–493.

158. Goldreich Y. Ground and top of canopy layer urban heat island partitioning on an airborne image. *Remote Sens Environ* 2006, 104:247–255.

159. Kruger AC, Shongwe S. Temperature trends in South Africa: 1960–2003. *Int J Climatol* 2004, 24:1929–1945.

160. Morris CJG, Simmonds I, Plummer N. Quantification of the influences of wind and cloud on the nocturnal urban heat island of a large city. *J Appl Meteorol* 2001, 40:169–182.

161. Pena MA. Examination of the land surface temperature response for Santiago. *Chile Photogramm Eng Rem S* 2009, 74:1191–1200.

162. Torok SJ, Morris CJG, Skinner C, Plummer N. Urban heat island features of southeast Australian towns. *Aust Meteorol Mag* 1 March 2001, 50:1–13.

163. Campbell-Lendrum D, Corvalan C. Climate change and developing-country cities: implications for environmental health and equity. *J Urban Health* 2007, 84.

164. Ramin B, Svoboda T. Health of the homeless and climate change. *J Urban Health* 2009, 86:654–664.

165. Carbajo A, Vera C, Gonzalez P. Hantavirus reservoir *Oligoryzomys longicaudatus* spatial distribution sensitivity to climate change scenarios in Argentine Patagonia. *Int J Health Geogr* 2009, 8:44.

166. McMichael AJ. Global climate change: will it affect vector-borne infectious diseases? *Intern Med J* 2003, 33:554–555.

167. Moodley I, Kleinschmidt I, Sharp B, Craig M, Appleton C. Temperature-suitability maps for schistosomiasis in South Africa. *Ann Trop Med Parasitol* 2003, 97:617–627.

168. Tanser FC, Sharp B, le Sueur D. Potential effect of climate change on malaria transmission in Africa. *Lancet* 2003, 362:1792–1798.

169. Vezzani D, Carbajo AE. Aedes aegypti, Aedes albopictus, and dengue in Argentina: current knowledge and future directions. *Mem I Oswaldo Cruz* 2008, 103:66–74.

170. Bhattacharya S, Sharma C, Dhiman R, Mitra A. Climate change and malaria in India. *Curr Sci* 2006, 90:369–375.

171. Baer H, Singer M. *Global Warming and the Political Ecology of Health: Emerging Crises and Systemic Solutions*. Walnut Creek, CA: Left Coast Press; 2009, 240.

172. Tong S. Ross River virus disease in Australia: epidemiology, socioecology and public health response. *Intern Med J* 2004, 34:58–60.

173. Kovats RS, Campbell-Lendrum DH, McMichael AJ, Woodward A, Cox JS. Early effects of climate change: do they include changes in vector-borne disease? *Philos Trans R Soc Lond B Biol Sci* 2001, 356:1057–1068.

174. Manderson L, Aagaard-Hansen J, Allotey P, Gyapong M, Sommerfeld J. Social research on neglected diseases of poverty: continuing and emerging fields. *PLoS Negl Trop Dis* 2009, 3:e332.

175. Harrus S, Baneth G. Drivers for the emergence and re-emergence of vector-borne protozoal and bacterial diseases. *Int J Parasitol* 2005, 35:1309–1318.

176. McMichael AJ. Ecological and social influences on emergence and resurgence of infectious diseases. In: Sleigh AC, Leng CH, Yeoh BSA, eds. *Population Dynamics and Infectious Diseases in Asia*. Singapore: World Scientific Publishing Company; 2006, 23–37.

177. Patz JA, Campbell-Lendrum D, Holloway T, Foley JA. Impact of regional climate change on human health. *Nature* 2005, 438:310–317.

178. Russell RC, Currie BJ, Lindsay MD, Mackenzie JS, Ritchie SA, Whelan PI. Dengue and climate change in Australia: predictions for the future should incorporate knowledge from the past. *Med J Aust* 2009, 190:265–268.

179. Lafferty KD. The ecology of climate change and infectious diseases. *Ecology* 2009, 90:888–900.

180. Khasnis AA, Nettleman MD. Global warming and infectious disease. *Arc Med Res* 2005, 36:689–696.

181. Moore M, Gould P, Keary BS. Global urbanization and impact on health. *Int J Hyg Environ Health* 2003, 206:269–278.

182. Prothero R. Migration and malaria risk. *Health Risk Soc* 2001, 3:19–38.

183. Granados J. On social progress and sustainability: Will Buenos Aires exist when the young of today are old? *Salud Colect* 2007, 3:63–70.

184. Harley D, Bi P, Hall G, Swaminathan A, Tong S, Williams C. Climate change and infectious diseases in Australia: future prospects, adaptation options, and research priorities. *Asia-Pac J Public Health* 2011, 23:54S–66S.

185. Griffith DC, Kelly-Hope LA, Miller MA. Review of reported cholera outbreaks worldwide, 1995–2005. *Am J Trop Med Hyg* 2006, 75:973–977.

186. Vanasco NB, Fusco S, Zanuttini JC, Manattini S, Dalla Fontana ML, Prez J, Cerrano D, Sequeira MD. Outbreak of human leptospirosis after a flood in Reconquista, Santa Fe, 1998. *Rev Argent Microbiol* 2002, 34:124–131.

187. Hunter PR. Climate change and waterborne and vector-borne disease. *J Appl Microbiol* 2003, 94: 37S–46S.

188. Kovats RS, Edwards SJ, Charron D, Cowden J, D'Souza RM, Ebi KL, Gauci C, Gerner-Smidt P, Hajat S, Hales S, et al. Climate variability and

campylobacter infection: an international study. *Int J Biometeorol* 2005, 49:207–214.

189. Hearnden M, Skelly C, Eyles R, Weinstein P. The regionality of campylobacteriosis seasonality in New Zealand. *Int J Environ Health Res* 2003, 13:337–348.
190. Green D. Climate change and health: impacts on remote indigenous communities in Northern Australia. Climate change impacts and risk. CSIRO Marine and Atmospheric Research Paper 012, November 2006, CSIRO Marine and Atmospheric Research; Aspendale, Victoria, 2006.
191. Albala C, Vio F, Kain J, Uauy R. Nutrition transition in Chile: determinants and consequences. *Public Health Nutr* 2002, 5:123–128.
192. Damman S, Eide WB, Kuhnein HV. Indigenous peoples' nutrition transition in a right to food perspective. *Food Policy* 2008, 33:135–155.
193. Kenealy T, Elley CR, Robinson E, Bramley D, Drury PL, Kerse NM, Moyes SA, Arroll B. An association between ethnicity and cardiovascular outcomes for people with Type 2 diabetes in New Zealand. *Diabet Med* 2008, 25:1302–1308.
194. Uauy R, Albala C, Kain J. Obesity trends in Latin America: transiting from under- to overweight. *J Nutr* 2001, 131:893S–899S.
195. de Waal A, Whiteside A. New variant famine: AIDS and food crisis in southern Africa. *Lancet* 2003, 362:1234–1237.
196. Drimie S. HIV/Aids and land: case studies from Kenya, Lesotho and South Africa. *Dev South Afr* 2003, 20:647–658.
197. Gwatirisa P, Manderson L. Food insecurity and HIV/AIDS in low-income households in urban Zimbabwe. *Hum Organ* 2009, 68:103–112.
198. Hendriks SL. The challenges facing empirical estimation of household food (in)security in South Africa. *Dev South Afr* 2005, 22:103–123.
199. Misselhorn AA. Is a focus on social capital useful in considering food security interventions? Insights from KwaZulu-Natal. *Dev South Afr* 2009, 26:189–208.
200. Chopra M, Daviaud E, Pattinson R, Fonn S, Lawn JE. Saving the lives of South Africa's mothers, babies, and children: can the health system deliver? *Lancet* 2009, 374:835–846.
201. Brinkman H-J, de Pee S, Sanogo I, Subran L, Bloem MW. High food prices and the global financial crisis have reduced access to nutritious food and worsened nutritional status and health. *J Nutr* 2010, 140:153S–161S.
202. Desanker PV, Justice CO. Africa and global climate change: critical issues and suggestions for further research and integrated assessment modeling. *Clim Res* 2001, 17:93–103.
203. Hugo G. Environmental concerns and international migration. *Int Mig Rev* 1996, 30:105–131.
204. Myers N. Environmental refugees: a growing phenomenon of the 21st century. *Philos Trans R Soc Lond B* 2002, 357:609–613.
205. Locke JT. Climate change-induced migration in the Pacific Region: sudden crisis and long-term developments. *Geogr J* 2009, 175:171–180.
206. Stephenson J, Newman K, Mayhew S. Population dynamics and climate change: what are the links? *J Public Health* 2010, 32:150–156.
207. Percival V, Homer-Dixon T. Environmental scarcity and violent conflict: the case of South Africa. *J Peace Res* 1998, 35:279–298.
208. The EACH-FOR Project Consortium: Preliminary findings from the EACH-FOR project on environmentally induced migration. Prepared by the EACH-FOR Project Consortium. Available at: www.each-for.eu. (Accessed September 1, 2008).
209. Environmental migrants: conference aims to build consensus on their definition, support and protection. Available at: http://www.eurekalert.org/pub_releases/2008-10/unu-emu100608.php. (Accessed June 10, 2010).
210. de los Angeles Pando M, Maulen S, Weissenbacher M, Marone R, Duranti R, Martínez Peralta L, Salomón H, Russell K, Negrete M, Sosa Estani S, et al. High human immunodeficiency virus type 1 seroprevalence in men who have sex with men in Buenos Aires, Argentina: risk factors for infection. *Int J Epidemiol* 2003, 32:735–740.
211. Sana M. Migrants, unemployment and earnings in the Buenos Aires metropolitan area. *Int Mig Rev* 1999, 33:621–639.
212. Auyero J, Swistun D. *Flammable: Environmental Suffering in an Argentine Shantytown*. Oxford: Oxford University Press; 2009, 208.
213. Leslie M, Aspin M, Clark H. Greenhouse gas emissions from New Zealand agriculture: issues, perspectives and industry response. *Aust J Exp Agr* 2008, 48:1–5.
214. Barros V, Grand MC. Implications of a dynamic target of greenhouse gases emission reduction: the case of Argentina. *Environ Devel Econ* 2002, 7:547–569.
215. Muñoz C, Paulino L, Monreal C, Zagal E. Greenhouse gas (CO_2 and N_2O) emissions from soils: a review. *Chil J Agr Res* 2010, 70:485–497.
216. Kelly G. Renewable energy strategies in England, Australia and New Zealand. *Geoforum* 2007, 38:326–338.
217. Mocarquer S, Rudnick H. The insertion of renewables into the Chilean electricity market. *IEEE PES General Meeting, Minneapolis*, July 25–29: 2010.
218. Kent A, Mercer D. Australia's mandatory renewable energy target (MRET): an assessment. *Energy Policy* 2006, 34:1046–1062.

219. Saddler H, Diesendorf M, Denniss R. Clean energy scenarios for Australia. *Energy Policy* 2007, 35:1245–1256.

220. Pegels A. Renewable energy in South Africa: potentials, barriers and options for support. *Energy Policy* 2010, 38:4945–4954.

221. Curtis C. Planning for sustainable accessibility: the implementation challenge. *Transp Policy* 2008, 15:104–112.

222. Aylett A. Participatory planning, justice, and climate change in Durban, South Africa. *Environ Plan A* 2010, 42:99–115.

