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CLIMATE CHANGE AND ENVIRONMENTAL INFLUENCES ON AUSTRALIA'S POPULATION DISTRIBUTION

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Abstract

Australia has a distinctive population distribution characterised by a concentration in major metropolitan centres and coastal areas, with much of the continent being sparsely settled. This has been strongly shaped by historical, environmental and economic processes, but it is likely that climate change may have some influence in the future. The current generation of climate change models have limited spatial resolution, so it is difficult to be precise about the areas that will be most impacted by climate change. This paper investigates six major non-metropolitan regions that have been identified as areas likely to be most affected by climate change. While effects on coastal cities will be substantial, they are not considered in detail here. The six non-metropolitan 'hotspots', however, are each considered in turn and the potential health and population distribution effects discussed. It is argued that Australian discourse on climate change has not focused sufficiently on intranational variations in the potential effects of that change.

Introduction

Tony McMichael's contribution extended beyond epidemiology and public health disciplinary boundaries to influence the social sciences more broadly. His work linking the dynamics of change in people, place and health and the impacts of climate change was influential in geography and demography. He drew attention to the health implications of climate change and their potential effects on population distribution and redistribution, and provided insights into how particular types of climate change would have both direct and indirect impacts on health (McMichael, 2001; McMichael et al., 2006, 2010). In this context, the spatial dimensions of climate change, the location of 'hotspots' of significant changes in temperature, rainfall and extreme weather events are important. Yet this aspect of climate change remains neglected. Accordingly, this chapter seeks to identify these potential hotspots of severe climate change impact in Australia and relate them to present and potential future patterns of population distribution.

The current distribution of population in Australia is a function of the location of resources, environmental amenity, transport routes, historical forces, liveability, past and present government policy and global and national markets. Environment and climate have interacted to be influential in shaping this distribution. Accordingly, climate change can influence that distribution, such as by affecting the extent to which the inhabitants of an area can earn a local livelihood or by changing a location's liveability. Health dimensions are an important factor in the latter (McMichael et al., 2010).

This chapter begins by discussing briefly the current patterns of Australian population growth and distribution, and the forces that have shaped it. It then examines what is currently known about possible spatial differences in the impact of climate change across Australia. It is shown that there is at present a concentration of population in areas anticipated to experience significant detrimental climate change effects, especially rainfall decline. Moreover, many Australian hotspots of population growth are also hotspots of substantial anticipated impact by climate change.

Australia's Contemporary Population Distribution

Although the Aborigines' hunting and gathering economy meant larger numbers inhabited the well-watered eastern and south-western margins where food was more abundant, Table 10.1 shows that, compared with the contemporary population, the Aboriginal population had a more dispersed distribution. Contemporary Australia is one of the most spatially concentrated populations of all nations, with 89 per cent living in urban areas, 65 per cent in capital cities and 82 per cent living within 50 km of the coast. Few countries have a more uneven distribution of the population, with 0.34 per cent of the population living in 84.2 per cent of the land area of the continent, with a population density of less than 0.1 persons per km^2, and 90.5 per cent of the people living in the 0.22 per cent of the land area, with 100 persons or more per km^2. Moreover, there is a strong clustering on the east coast and south-east and south-west regions.

Table 10.1 Australia: Estimated distribution of Aboriginal population at the time of initial European settlement and total Australian population in 2011.

State	1776 Aboriginal population		2011 Total Australian population		Per cent of area
	Number	Per cent	Number	Per cent	
New South Wales (incl. ACT)	48,000	15.3	7,274,877	33.8	10.5
Victoria	15,000	4.8	5,354,040	24.9	3.0
Queensland	120,000	38.2	4,332,737	20.1	22.5
South Australia	15,000	4.8	1,596,570	7.4	12.8
Western Australia	62,000	19.7	2,239,170	10.4	32.9
Tasmania	41,500	1.5	495,350	2.3	0.9
Northern Territory	50,000	15.9	211,944	1.0	17.5
Total	314,500	100.0	21,504,688	100.0	100.0

Source: Smith, 1980, p. 69; Australian Bureau of Statistics (ABS), 2011 Census of Population and Housing.

What forces explain this stark contrast in population distribution? Clearly, the changing nature of the economy involving a contracting proportion of the population required to produce food and an increase in urban-based secondary, tertiary and quaternary activities is a major factor. Historical elements, such as the fact that each state was formerly a separate colony with its capital being an entrepot linkage point with Britain, have also played a role. In the contemporary context location of key resources, differences in the amenity of areas for retirees and tourists, strategic location in relation to transport and accessibility are important. A crucial element, however, is environment, as it was to Aboriginal Australia. The extent to which the environment affects the potential to earn a living is of basic importance. Moreover, 'prevailing climatic conditions, and in weather variability affect human well-being, safety, health and survival' (McMichael et al., 2010, p. 195).

The role of the environment and climate in shaping population settlement in Australia after European colonisation was recognised by geographers a century ago (Price, 1939). Arguably, however, the environmental role has been neglected with the decline in the proportion of the population working in primary industry, massive developments in transport and communication, medical advances and technological development such as air conditioning. Almost a century ago, Griffith Taylor argued that:

> the contemporary margins of settlement in Australia already closely approximated the limits which had been set by the very nature of the physical environment: whether people, plants or animals were considered, the appropriate environmental controls could be ignored only at a cost. (quoted in Powell, 1984, p. 87)

There is much to support Taylor's argument that the fundamental structure of Australian settlement was already established by the second half of the 19th century (Rowland, 1982).

A further aspect relates to spatial patterns of population growth. Not only is the Australian population distribution highly concentrated but also there is considerable spatial variation in the pattern of *population change* – growth and decline. This is evident in Table 10.2, which shows the pattern of recent population change by remoteness categories. In both numerical and relative terms, recent population growth is concentrated in the major cities (those with 100,000 or more inhabitants) that are, apart from Canberra, located in the south-east and south-west coastal areas. The impact of the mining boom on very remote areas since 2006 is also evident.

Table 10.2 Australia: Population change by remoteness area, 1996–2012.

Remoteness area category	Population change (thousands)		Growth rate (%) p.a.			
	1996–2006	2006–12	1996–2001	2001–06	2006–11	2011–12
Major cities of Australia	2069.2	1790.4	1.8	1.4	1.7	1.8
Inner regional Australia	330.2	66.1	0.3	1.4	1.2	1.2
Outer regional Australia	9.3	80.7	–0.7	0.8	0.6	1.0
Remote Australia	–12.2	5.0	–0.7	0.0	0.7	1.3
Very remote Australia	–5.7	39.8	–0.5	–0.2	2.6	1.3
Total	2390.8	1982.1	1.2	1.3	1.5	1.6

Source: Authors' work, calculated from ABS censuses.

In summary, in Australia there is strong spatial differentiation of population distribution, population density and population growth, which have been shaped by economic and historical forces along with environmental and climate elements.

Spatial Differences in the Impact of Climate Change in Australia

In this section, we consider how the spatial patterns described above interact with the predicted effects of climate change. Before that, however, it is instructive to consider some of these relationships over recent decades.

One major effect of climate change is anticipated to be a change in rainfall and water run-off. The recent 13-year drought in south-eastern Australia, together with the continuing droughts in south-western Australia, is consistent with long-term rainfall declines associated with climate change (State of the Environment, 2011). Figure 10.1 presents analysis by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Bureau of Meteorology (BOM) (2010) relating to national rainfall trends between 1960 and 2009. The long-term rainfall increase in north-western Australia is balanced by a significant decline in the closely settled south-eastern and south-western parts of the nation. Of interest is that, in 2011, the majority of Australians lived in areas experiencing a long-term decline in rainfall, although the population was growing faster in this area experiencing an increase in rainfall.

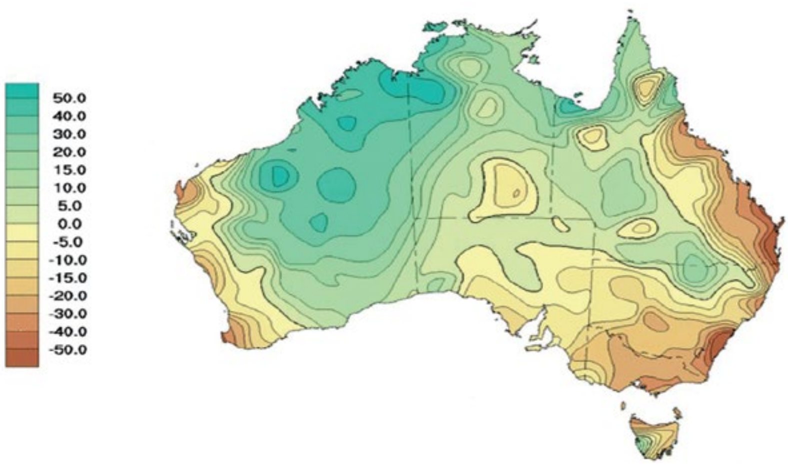

Figure 10.1 Trends in annual total rainfall, 1960–2009 (millimetres per decade).

Source: CSIRO and BOM, 2010, with permission from the Bureau of Meteorology.

Table 10.3 Australia: Population growth in long-term rainfall trend areas, 2006–11.

Long-term rainfall trend (mm)	2006 population	2011 population	Change 2006–11	Change 2006–11 (%)	Growth rate per annum (%)
Increase (+10 or greater)	462,629	545,947	83,318	18.01	3.37
Stable (between +10 and –10)	2,285,712	2,459,589	173,877	7.61	1.48
Decline (–10 or less)	16,923,224	18,439,950	1,516,726	8.96	1.73
No data	26,234	13,245	–12,989	–49.51	–12.78
Total	**19,697,799**	**21,458,731**	**1,760,932**	**8.94**	**1.73**

Source: Authors' work, from BOM, Trend in Annual Total Rainfall 1960–2009 (2011) and ABS Censuses (2006, 2011). Population data based on ABS Census 2006 CD centroid and 2011 SA1 centroid population counts (usual resident). Annual average growth rate has been calculated over a five-year period (2006–11).

It is difficult to identify precisely locations in Australia that will be impacted most severely by climate change. This section summarises current understanding of likely spatial variation in climate change in Australia over the next few decades. The climate change models used here are the widely used CSIRO–BOM regional climate change projections for 2030, 2050 and 2070, and the assumptions underlying them are detailed in CSIRO and BOM (2007). These models have a spatial resolution of around 250 km between grid squares, and provide only an average over those grid squares so that 'within square' heterogeneity is not captured.

With respect to rainfall, it is projected that by 2030 there will be little change in precipitation in the north and decreases of 2–5 per cent elsewhere. The decreases are highest in winter and spring, especially in the south-west, where they reach 10 per cent. In summer and autumn, decreases are smaller, with slight increases in the east. Daily precipitation intensity increases in the north and decreases in the south. The models show that droughts will increase in frequency over most of Australia, but especially in the south-west. It is also shown that there is a substantial increase in fire-weather risk, especially in south-eastern Australia. Regarding temperature, it is projected that by 2030 there will be an increase of around 1°C in average temperature – 0.7–0.9°C in coastal areas and 1–1.2°C inland. There is little variation in the results over the full range of climate change scenarios in the 2030 projections. However, there is greater variation in the projections to 2050 and 2070. The major regional variations are of less warming in the southern and north-east and more inland areas.

Turning to sea level rise, the CSIRO and BOM (2007, p. 92) point out that the Intergovernmental Panel on Climate Change (IPCC) projects an 18–59 cm rise in sea level by 2100, with the east coast of Australia anticipated to record a rise above the global mean (Climate Commission, 2011, p. 12).[1] The impact of sea level rise, however, can be exacerbated by storm surges that enable inundation and damaging waves to penetrate further inland (CSIRO and BOM, 2007, p. 94). On average, sea levels have risen globally by 3.2 mm/year since the early 1990s.

Projection of future climate change is improving, but the inherent uncertainty is exacerbated when it is spatially disaggregated. It is not yet possible to anticipate precisely the climate change impacts at local and community levels in Australia, but some generalisations can be made:

- Rainfall is likely to be reduced in the southern areas of Australia, especially in winter, and in southern and eastern areas in spring, due to a southerly contraction in the rainfall belt. Intense rainfall events in most areas will become more extreme and frequent, although future changes in summer tropical rainfall in northern Australia remain uncertain.
- As temperatures and dryness increase, so too does the frequency of extremely hot days, especially in inland Australia, with consequent increased bushfire risk.

The Climate Action Network (2006) has identified six major hotspots of potential high impact of climate change in Australia, shown in Figure 10.2. This classification focuses predominantly on non-metropolitan areas and hence misses the effects of climate change on large metropolitan centres, such as:

1. Potential inundation and storm surge impacts along coasts.
2. Constraints on urban water supplies created by the reduced rainfall and run-off in the watersheds of large mainland metropolitan centres and in the Murray–Darling Basin, which supplies a significant part of the water supply of Adelaide and Melbourne. Decreased run-off, especially in inland catchments, will be exacerbated by increased evaporation due to higher temperatures. For example, for Sydney, it is projected that there will be a 22 per cent increase in pan evaporation in inland catchments and a 9 per cent increase in coastal catchments by 2070 (Department of Climate Change and Energy Efficiency (DCCEE), 2011a, p. 1).
3. There will be increased risk of extreme bushfires near several capitals. For Sydney, for example, fire seasons will start earlier and end later and the number of extreme fire danger days will rise from 9 at present to 15 by 2020 (DCCEE, 2011a).

1 It should be noted that the IPCC put substantial qualifications on these numbers – for example, they do not include the full ice melt factors.

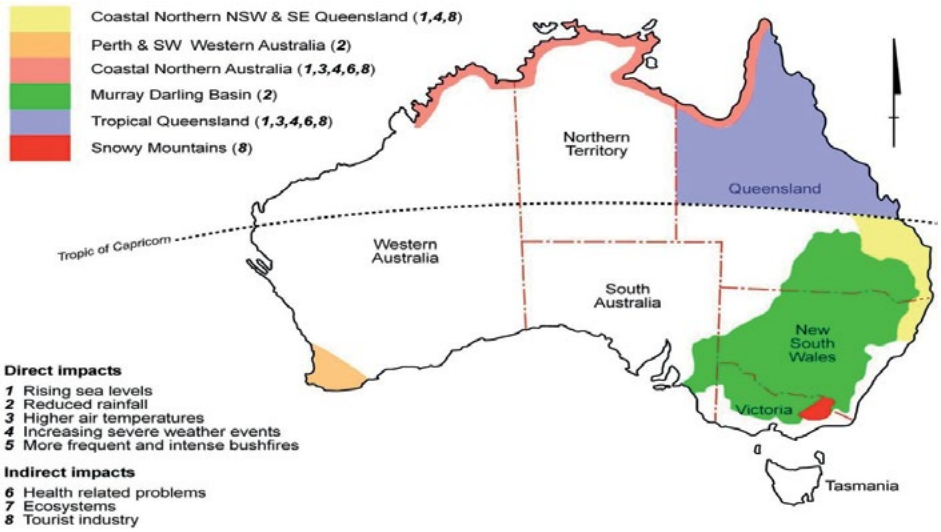

Figure 10.2 Broadly defined non-metropolitan climate change impact hotspots in Australia.

Source: Chris Crothers, Faculty of Arts, University of Adelaide, using information from Climate Action Network, 2006.

In this context, it is important to note that several potential negative health outcomes from climate change are especially important in large cities. Gamble et al. (2008) have identified climate-sensitive health outcomes in US cities that provide insights into the likely health effects of climate change in Australian metropolitan areas. These include thermal extremes involving both heatwaves and coldwaves. In Sydney, for example, extreme heat days are projected to increase from 3.5 per annum currently to 12 by 2070 (DCCEE, 2011a).

Climate Change Hotspots, Population and Health

We will now turn to each of the six hotspot areas, examining the potential health and population impacts of climate change more closely, using a framework developed by McMichael et al. (2010, p. 196). Table 10.4 summarises these impacts.

Table 10.4 Potential health risks in Australian climate change hotspot areas.

Categories of health risk (after McMichael et al., 2010, p. 196)	Coastal NSW S.E. Qld	Perth and S.W. WA	Coastal northern Australia	Murray–Darling Basin	Tropical Qld	Snowy Mountains
Direct acting risks						
Injury and death from extreme events – floods, storms, fires	X	X	X	X	X	X
Illness and death from more frequent and intense heatwaves	X	X	X	X	X	
Increased risk of respiratory illnesses from high air pollution		X	X	X	X	X
Exacerbation of respiratory allergic condition from pollen		X	X	X	X	X
Indirect acting risks						
Impoverishment by impaired/failed agriculture or other livelihood	X	X	X	X	X	X
Increased risk of gastroenteritis			X		X	
Change in seasonal outbreak of mosquito-borne infection			X		X	
Health risk associated with displacement	X	X	X	X	X	
Increased mental health risks	X	X	X	X	X	X

Source: Authors' work.

Coastal northern New South Wales and south-east Queensland

This region has one of the most rapidly growing populations of any region in Australia in recent decades, with metropolitan peri-urban and coastal development associated with the Brisbane–Gold Coast and Sunshine Coast complex. Two major elements of climate change – increased sea levels and increased severe weather events – are likely to affect the area. The rapid recent growth of population in this region has been associated with increased tourism and lifestyle-related in-migration including young families and retirees (Burnley and Murphy, 2004). The imminent retirement of baby boomers is likely to see a substantial future influx of people in their 60s, and of a working-age population to service them. The pattern of coastal areas with rapid population growth and in-migration being at substantial risk of significant impact of climate change is one that is replicated in many parts of the world (McGranahan et al., 2007).

It has been estimated that between 43,900 and 65,300 residential buildings with a current value of between A$14 and 20 billion are at risk of inundation in coastal New South Wales if sea levels were to rise by 1.1 m. While this rise is substantially higher than current IPCC projections for 2100, it is potentially possible if there are no mitigation interventions. Such a rise would put at risk up to 4800 km of roads, 320 km of railways and up to 1200 commercial buildings (DCCEE, 2011b). Queensland shows similar patterns for a similar sea level rise. From a health perspective, Table 10.4 indicates that this devastation would result in increased injury and death. Moreover, the region will also be influenced by greater frequency and intensity of heatwaves, with likely pronounced health effects, especially for the large numbers of older people in the area. Indirect effects include the loss of livelihood in agriculture and tourism, increased exposure to mental health problems and displacement from coastal areas. In the face of such trends, it would be difficult in the longer term to sustain the current rapid rates of population growth.

Perth and south-west Western Australia

One of the most consistent findings in climate change modelling in Australia (CSIRO and BOM, 2007) is a reduced rainfall in the south-western corner of the Australian continent. This has clear implications for the wheat–sheep as well as viticulture and other intensive agriculture in that region. In addition, Perth is currently Australia's most rapidly growing capital city, but the reduction in rainfall anticipated in its hinterland has dire implications for the water supply of the capital and has already seen the increasing use of desalination technology.

Rainfall has already fallen by around 15 per cent in south-western Western Australia since the 1970s. The annual average stream flow into Perth dams has fallen from 338 gigalitres over 1911–74 to 177 in 1975–2000 to 75 in 2000–10. Modelling suggests that there could be a 7 per cent decrease in rainfall and a 14 per cent decrease in run-off over the 2021–50 period, and that the region could experience 80 per cent more drought months by 2070 (DCCEE, 2011c). Furthermore, the number of very hot days per year in Perth over 35°C will increase from 28 currently to 67 in 2070.

The potential health impacts shown in Table 10.4, with the impacts from loss of livelihood, heatwaves and displacement of significant coastal populations, are likely to be significant. Again, this is a very rapidly growing population in this region and it will be difficult to sustain these high population growth rates in the longer term without reduced per capita water consumption. Moreover, the sustainability of primary industry will depend on the development of new methods and new mixes of agricultural activation.

Coastal northern Australia

The entire north coast of the continent is designated a climate change hotspot in Figure 10.2. All climate change models suggest that this region is likely to experience little change in precipitation, or even a small increase. This has led to some calls for encouraging population growth in the region, based partly on transferring some primary industry into these areas. There is a long history of such calls, and mostly ill-fated attempts, to establish intensive agriculture in the north (Davidson, 1965). However, the region is at risk to a number of other negative climate change impacts – rising sea levels, higher temperatures and increased severe weather events. These will impinge on the liveability of these areas, as well as the potential to expand their primary production, especially food production. The outlook for increasing demand for the types of foods produced in Australia among the rapidly growing middle classes of Asia is positive, but climate change will present challenges for the expansion of extensive and intensive agriculture and animal production in the region. The location of the region in close proximity to Asian markets is clearly a potential advantage to economic development in the area. Implications of these changes for health include a possible extension of the area receptive to *Ae. aegypti* mosquitoes, and hence the risk of more dengue fever and perhaps other vector-borne diseases (McMichael et al., 2006). This view is supported by others, including Newth and Gunasekara (2010). There have been calls to capitalise on the anticipated increase in the rainfall in northern Australia to increase the region's population significantly and alter Australia's population distribution significantly. Any such planning needs to consider fully, however, the liveability impacts of that climate change.

Murray–Darling Basin

The release of the Murray–Darling Basin report in November 2011 has underscored its significance to the national economy and the threats to the integrity of the system posed by excessive withdrawal of water from it for agricultural and urban uses (Murray–Darling Basin Authority, 2011). The 13-year drought that broke in 2010 showed the necessity to reduce water withdrawal from the basin significantly if it was to survive as a healthy system. Projected climate change exacerbates this situation. All models suggest that there is likely to be a reduction in rainfall in the watershed. Moreover, run-off reductions will exceed that of rainfall decrease, with important implications for irrigated agriculture along the system and for the cities that draw water from it. One study by Cullen and Eckard (2011) has suggested that these changes may see a significant relocation in Australia's dairying industry over the next few decades, perhaps to Tasmania.

As mentioned, these changes in rainfall and run-off in this region will affect the water supply to major cities in the south-east of Australia. Cities affected include Canberra (DCCEE, 2011d). In addition, the increased temperatures could increase bushfire risk in the ACT.

The Garnaut Climate Change Review (Garnaut, 2008) summarised the effects of climate change on Australian states in the absence of any mitigation. It found that climate change would potentially have a major effect on primary industry activity in each state. For example, it is suggested that, by mid-century, irrigated agriculture output in the Murray–Darling Basin could be reduced by half. It would seem, therefore, that the population supported by agricultural activity in the Murray–Darling Basin will be reduced, and in the absence of alternative economic activity, there will be population declines.

Tropical Queensland

Tropical Queensland contains some of the fastest growing communities in the country. In coastal areas, tourism, at least until recently, has been expanding exponentially, while mining activity has also been growing apace. Again, several significant impacts of climate change are anticipated in the region. These include rising sea levels, increased temperatures and increased incidence and severity of extreme weather events. The effects will vary between the coast and inland, but will be severe in both cases. Table 10.4 indicates that the area as a whole will be susceptible to both direct and indirect risk factors, including a southward extension of the area at risk of dengue fever (McMichael et al., 2006). As in northern coastal areas, liveability impacts of climate change need to be considered when assessing future regional development, but population growth in the region is likely to continue.

Snowy Mountains

Climate change is likely to have a disproportionate effect on temperatures in mountain areas compared with sea level (CSIRO and BOM, 2007). Rising mountain temperatures will reduce snow in Australia's alpine areas, with consequences for run-off to irrigation and water reserves, as well as for tourism. Under an extreme emissions scenario with increased temperatures and decreased rainfall, the duration of the snow season in the Australian Alps could fall by 96 per cent by 2050, with disastrous consequences for vulnerable alpine flora and fauna (DCCEE, 2011a).

While those six areas are quite large and heterogeneous, it is useful to examine some of their population characteristics, including their vulnerability, which is relevant to health (Few, 2007). The Intergovernmental Panel on Climate Change (2008, p. 883) defines vulnerability to climate change as 'the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes'.

There is strong evidence that vulnerability and constraints on adaptation increase as the economic situation of individuals and communities declines (Brooks et al., 2005; Sevoyan and Hugo, 2014), though non-socio-economic factors also play a role. This is relevant to negative health risks. It is thus valid to consider the socio-economic situation of populations in hotspot areas, although analysis here is limited to averages across the entire hotspot area. In fact, within each area, there is considerable variation. The measures used are the Socio-economic Indexes for Areas (SEIFA) (Australian Bureau of Statistics (ABS), 2008), derived from 2006 census data. The averaged measure was obtained as a mean from all Census Collection Districts included in each of the hotspot areas. Only two hotspot areas have a SEIFA score average above that of the non-hotspot areas (see Table 10.5). These are coastal New South Wales and south-east Queensland, and the very large Murray–Darling Basin. In most areas, however, there is below average socio-economic status. This raises questions of the capacity of the communities in those areas to adapt to the impacts of climate change, including those related to health. There are especially low SEIFA scores in coastal Northern Australia.

Table 10.5 Australia: Climate change hotspot areas by SEIFA index,[a] 2006.

Climate change hotspot regions	Mean SEIFA score 2006
Non-hotspot areas	972.59
Coastal northern Australia	690.81
Coastal northern NSW and S.E. Qld	981.55
Murray–Darling Basin	978.96
Perth and S.W. Western Australia	938.51
Snowy Mountains	795.72
Tropical Queensland	932.55

[a] There are four different SEIFA indexes developed by the ABS. The one used here is the Index of Relative Socio-Economic Disadvantage.

Source: ABS, 2008.

Ethnicity is also of relevance to vulnerability. Cultural and language factors can limit social inclusion, increasing vulnerability to the risk of harm from deteriorating economic, social or environmental situation. Table 10.6 shows the proportion of the population in the hotspot areas born overseas at the 2006 census. This is below the national average in all but one, and due to the exclusion of metropolitan areas other than Perth. Most migrants to Australia, especially from mainly non-English speaking (NES) countries, concentrate in major metropolitan areas (Hugo, 2011). The one hotspot area with a high proportion of the population overseas-born is Perth and south-western Australia. Although the NES origin population are under-represented in hotspot areas, they are highly vulnerable to the effects of climate change, because of social exclusion and cultural isolation. Recent patterns of settlement of refugee-humanitarian migrants in non-metropolitan areas in Australia are relevant (Hugo, 2014). Recent displacement of Sudanese men living in caravans by floods in Queensland in 2012–13 points to the potential of being 'twice displaced' – ousted by war in their homeland and by the environment in their destination. One-fifth of new refugee (rather than total migrant) arrivals in Australia settle in non-metropolitan areas. Many carry a high risk of physical and mental health problems. This can be exacerbated by their isolated location and may be worsened by climate change.

Table 10.6 Australia: Birthplace composition of hotspot areas of climate change impact, 2006.

Climate change hotspot regions	Per cent Australia-born	Per cent mainly English-speaking countries	Per cent mainly non-English-speaking countries	Per cent of Aboriginal/ Torres Strait Islander descendant
Coastal northern Australia	77.1	5.6	8.4	23.0
Coastal northern NSW and S.E. Qld	74.4	10.7	8.1	2.1
Murray–Darling Basin	82.7	4.8	6.6	2.9
Perth and S.W. Western Australia	64.0	15.3	13.3	1.6
Snowy Mountains	77.1	5.6	4.7	0.5
Tropical Queensland	79.7	6.4	5.3	7.3
Non-hotspot areas	67.4	7.7	17.7	1.8
Total	70.9	8.4	13.7	2.3

Source: ABS (2011) Census of Population and Housing.

Another very important dimension of ethnicity is the representation of Indigenous Australians in the hotspot areas. Table 10.6 shows that there is a striking pattern in evidence. In the coastal northern Australian hotspot area, almost one-quarter of the resident population are Aboriginal and Torres Strait

Islanders. This has significant implications for any adaptation strategies to be culturally sensitive and has important interactions with health impacts. It is also noticeable that the Indigenous population is also over-represented in the small population in the Snowy Mountains and in the Murray–Darling Basin.

In addition, demographic age structures can affect community capacity to adjust to climate change and have health implications. Some older populations experience impacts of particular climate change more intensely than other groups. For example, the heatwave in Adelaide and Melbourne in 2010 resulted in amplified death rates among older residents.

Table 10.7 shows that there is significant variation between hotspot areas in the proportion of the resident population aged 65 years and over. Older populations are under-represented in coastal northern Australia. Elsewhere, there is little variation in the proportion of the population in the older age groups, but they are a substantial fraction in each hotspot area.

Table 10.7 Australia: Climate change hotspot areas – percentage of the population 65 years and over, 2006.

Climate change hotspot regions	Number	Per cent
Coastal northern Australia	7,103	4.81
Coastal northern NSW and S.E. QLD	454,372	13.45
Murray–Darling Basin	352,672	13.21
Perth and S.W. Western Australia	204,733	12.82
Snowy Mountains	1,645	16.05
Tropical Queensland	71,833	10.64
Non-hotspot areas	1,548,199	13.66
Total	2,640,557	13.33

Source: ABS (2011) Census of Population and Housing.

In addition to looking at the characteristics of the population in each of the hotspot areas, the effects of climate change on families and households and the housing they occupy is important. Table 10.8 shows that average household sizes are bigger in coastal northern Australia and tropical Queensland than in non-hotspot areas. While the proportion of residents in single person households is only above the national average in Perth–south-west Australia and the Murray–Darling Basin, it is more than one-fifth of the population living in hotspot areas. Such households are more vulnerable on average (Sevoyan and Hugo, 2014), many are older and frail people, especially women. The proportion of the population renting their housing is also higher in hotspot areas than elsewhere; this is another factor associated with vulnerability.

Table 10.8 Australia: Climate change hotspot areas – household characteristics, 2006.

Climate change hotspot regions	Average household size	Per cent lone person households	Per cent who own or are purchasing their own home
Coastal northern Australia		19.5	51.9
Coastal northern NSW and S.E. Queensland		22.0	67.6
Murray–Darling Basin		23.5	73.5
Perth and S.W. Western Australia		24.6	71.5
Snowy Mountains		23.2	65.0
Tropical Queensland		20.9	63.8
Non-hotspot areas		23.7	70.0
Total		23.3	69.8

Source: ABS 2006 Census and Climate Action Network 2006 (manually digitised for GIS analysis).

Conclusion

Tony McMichael's work alerted many to the health implications of climate change and that these impacts required consideration not only of the nature of that change but its complex interactions with place, society and economy. The complexity is deepened by spatial variation, not only in the effects of climate change but also in the nature of environments and affected populations. Our understanding of this complexity is extremely limited, and this is a major barrier to developing effective policy responses. This chapter has sought to assemble current knowledge of domestic climate change effects in Australia and how these relate to population distribution dynamics and characteristics. It is imperative that our empirical understanding of climate change is expanded so that there can be greater certainty in locating the hotspots of greatest impact and thus taking steps to alleviate their impacts. Without this, impacts will fall disproportionately on the most vulnerable; social exclusion will worsen. It is important that Tony McMichael's work in linking health, place and people in the context of climate change in Australia be built on, not only by epidemiologists but also by population scientists and geographers.

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