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Systems in peril: climate change, agriculture and biodiversity in Australia

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Abstract. This paper reflects on the interplay amongst three closely linked systems – climate, agriculture and biodiversity – in the Australian context. The advance of a European style of agriculture has imperilled Australian biodiversity. The loss and degradation of biodiversity has, in turn, had negative consequences for agriculture. Climate change is imposing new pressures on both agriculture and biodiversity. From a policy and management perspective, though, it is possible to envisage mitigation and adaptation responses that would alleviate pressures on all three systems (climate, agriculture, biodiversity). In this way, the paper seeks to make explicit the important connections between science and policy. The paper outlines the distinctive features of both biodiversity and agriculture in the Australian context. The discussion then addresses the impacts of agriculture on biodiversity, followed by an overview of how climate change is impacting on both of these systems. The final section of the paper offers some commentary on current policy and management strategies that are targeted at mitigating the loss of biodiversity and which may also have benefits in terms of climate change.

1. Introduction

Climate change poses a global threat to biodiversity and to human settlements. In the case of the island continent of Australia, the advance of a European style of agriculture over the past two centuries has already imperilled Australia's unique biodiversity, including many endemic species. The loss and degradation of biodiversity has, in turn, had negative consequences for agriculture and hence for Australia's economy, which is highly dependent on the export of commodities. While the Australian government has made commitments to protect and enhance biodiversity and to ecologically sustainable development, the reality is that environmental decline has continued and increasing numbers of indigenous species are threatened or have become extinct. Climate change is bringing new pressures to bear on both agriculture and biodiversity, with drought, floods and other extreme weather events imposing additional pressures on already stressed production and natural systems. Indeed, climate change threatens to administer the *coup de grace* to many unique and fragile ecosystems already damaged by human activity.

In this paper, we outline the characteristics of the environment and biodiversity of Australia; summarise the impacts of settlement of the continent on the natural landscape, particularly through land clearing and introduction of European agricultural practices; examine the various threats to

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biodiversity and agriculture, and the exacerbating effects of climate change; and finally consider policy and management responses to environmental and climate change. While both land and maritime environments are under threat, our focus in this paper is on terrestrial biodiversity and natural and agricultural ecosystems. We conclude that, while these are all imperilled by both past and current practices and climate change, it is possible to envisage mitigation and adaptation responses that would alleviate pressures on all three systems (climate, agriculture, biodiversity).

2. Biodiversity and settlement in Australia

2.1 International significance of Australia's biodiversity

The distinctive features of Australia's biodiversity have been attributed to "the country's size, isolation, naturally fragmented landscapes and long-term climate variability" (Beeton et al. 2006). Australia is included in a group of 17 countries identified as being 'megadiverse' (Mittermeier et al. 1997), because of the large number and high proportion of endemic species to be found within these countries. Although the group of megadiverse countries occupy less than 10% of the earth's surface, they are thought to support more than 70% of all known life forms. Of the megadiverse countries, only Australia and the United States are in the high income category, leading Williams et al. (2001) to suggest that a high level of biodiversity protection is a reasonable expectation of these countries. In practice, this has proved difficult to achieve.

Australia is home to an estimated 600-700,000 species, many of which are endemic. These include distinctively Australian species such as kangaroos and koalas, but - even more remarkably - "it is likely that about 90% of its native arthropods and plants are endemic to Australia, which is a level of endemism as high as that recorded for any part of the world, including small, remote islands" (Raven and Yeates 2007: 179). It has been estimated that 83% of mammals, 45% of birds, 89% of reptiles, 93% of amphibia and 90% of fishes are endemic to Australia (Cork et al., 2006), but many of the species native to Australia have not yet been described. This is particularly the case with organisms that are difficult to detect or of little direct interest to people (Chapman 2006: 2).

2.2 The impact of human settlement

When the Indigenous Australians arrived in the continent approximately 50,000 years ago, they used fire in many areas to transform the landscape from forests to open savannas in order to increase the availability of food (Dovers 1992), but their hunting and gathering activities were relatively gentle on the land. By contrast, European settlement from 1788 brought about a profound transformation, and one that was not for the better. As Raven and Yeates argue:

> *The antiquity and isolation of Australia, its ancient and often infertile soils, and its overall aridity, have given its environment a unique fragility that has not responded well to methods of cultivation and grazing developed in other better-watered and more fertile parts of the world. … [The] settlement of virtually all of the arable land during the 19th century without regard to the peculiar properties of the Australian environment led rapidly to many of the environmental problems faced today.*
> (Raven and Yeates 2007: 182)

In the course of 200 years (from 1788 to 1988), 17% of total land area was converted from forest, woodland or shrub cover to grassland or pasture. Mackey et al. (2008: 13) estimate that approximately 50% of woodland and forest ecosystems have been cleared, and in productive bioregions as much as 95% of all native vegetation has been modified or destroyed (see also ABS 2006; NLWRA 2001a). Clearing was undertaken to open up land for cropping, forestry, grazing and mining, as well as urban settlements. Today, about 60% of the land area is occupied by agricultural and pastoral enterprises (SOE, 1996). Grazing has resulted in environmental deterioration, exacerbated by recurrent droughts,

and the spread of introduced pests. Artificial pastures have replaced native grasses and more than 1700 species of weeds have become established (Raven and Yeates 2007: 183).

Many of the changes introduced by European settlers have had adverse effects on biodiversity, which quickly became apparent. Mackey et al. (1998: 13) report that as early as the 1920s transformation of the landscape had led to many species becoming extinct or threatened. The abandonment of indigenous fire management practices altered fire regimes in ways which damaged fire-sensitive species and ecosystems (Bowman 2000). Furthermore, altered fire regimes and introduced pasture species have interacted with adverse ecological effects, particularly in northern regions (Soule et al., 2004: 268). Cork et al. (2006) report that there are now less than 2% of the original native grasslands in the temperate zone, which has severely reduced habitats for native fauna (see also Beeton et al. 2006: 37, 39). In many cases, the harmful practices of settlers in the early days were the result of "government policies that encouraged (and even forced) farmers to clear natural vegetation from their properties under terms of conditional purchase" (Tonts 2005: 197; Bolton 1981) and later were promoted through "financial support from government agencies and new land clearing technologies developed by CSIRO [the Commonwealth Scientific and Industrial Research Organisation]" (Beeton et al. 2006: 72). In interviews, farmers not infrequently raise the issue of government responsibility for instigating environmentally damaging practices in the past.

European farming practices have proved environmentally damaging in a number of ways. Destruction of native vegetation was initially encouraged by a desire to create a landscape that was more like 'home', with British crops and animals (Dovers 1992). Several of these introduced plants and animals subsequently became notorious pests. Settlers lacked the skills and knowledge of the environment to realise that the introduced European agricultural practices were often unsuited to the Australian environment (Gray and Lawrence 2001). The adoption of high-input 'productivist' farming techniques, from the 1950s, increased production by privileging economic returns over land stewardship (Cocklin, 2005). The emphasis on ever-increasing production has become even more pronounced since the 1970s/early 1980s due to a shift in government ideology. The adoption of a free-market policy stance by Australian governments has led to the expectation that farmers will become more competitive through stripping away the price supports, import restrictions and subsidies that had previously buffered them against the fluctuations of global commodity prices (Dibden and Cocklin, 2005, 2009; Tonts 2005). Falling prices for agricultural produce, together with rising prices for inputs (such as fertilisers, livestock feed, fuel), have pressured farmers to increase both the intensity and scale of production through farm expansion – in some areas through further land clearing – with predictable consequences for the environment:

> … *market liberalisation, the cost-prize squeeze, and the increasing influences of multinational agri-food companies have further underscored long-standing patterns of environmental degradation. … Significantly, it is not only the environment that suffers – literally millions of dollars of production are lost each year, impacting adversely on individual farmers and their communities* (Cocklin 2005: 174).

3. Biodiversity in decline

Ecosystems continue to be destroyed in many regions. The 2006 national *State of the Environment Report* reported that 17 million hectares have been cleared since 1973, with 1.5 million hectares of that deforestation occurring between 2001 and 2004 (Beeton et al. 2006). Because many of these changes in land use are quite recent, Australia stands out as being one of only a few developed countries "that remains a leading contributor to the current human-induced global mass extinction event" (Mackey et al., 2008: 11). Data collected in the Australian Bureau of Statistics *Measures of Australia's Progress* (ABS 2009a) showed that, between 2000 and 2008, "the number of terrestrial bird and mammal species assessed as extinct, endangered or vulnerable rose by 14% from 154 to 175 (of which 69 were

birds and 106 were mammals)", with 18% of these presumed extinct. Johnson (2006) found that nearly half of all mammal extinctions globally have occurred in Australia in the last 200 hundred years. Native species have also declined in range, with some experiencing serious but often unacknowledged regional declines – what Mackey et al. (2008: 11) describe as "secret extinctions".

Despite efforts to reverse this trend, declines in biodiversity are continuing because many of the threats that have caused past extinctions or declines are still present. These include the impact of invasive organisms – estimated to be increasing at the rate of 20 new pests or diseases each year; changed fire regimes; widespread drought conditions, now into the thirteenth year in south-eastern Australia; declining native vegetation, water quality and quantity (BDWG 2005; Cork et al. 2006; Mackey et al. 1998; O'Brien, 1990). Some regions are also affected by ongoing land clearing, pollution of waterways, soil salinity and modified waterways (Cork et al. 2006). The National Biodiversity Strategy Review Task Group (NBSRTG, 2009) identified several long-standing threats to Australia's biodiversity:

- invasive species
- loss, fragmentation and degradation of habitat
- unsustainable use of natural resources
- changes to the aquatic environment and water flows
- inappropriate fire regimes.

The Task Force also added a new but increasingly important threat: "climate change (resulting in conditions such as prolonged drought)".

4. Agriculture and the environment

Agriculture has been seen by conservationists and others "as contributing significantly to erosion of biodiversity (and possibly ecological function), through the clearance of natural vegetation … and the intensification of farming practices on land already highly modified" (House et al., 2008: 153). However, environmental degradation does not in general result from deliberate action but through the "tyranny of small decisions" - "decisions that were never consciously made" but may nonetheless have severe impacts (Odum, 1982: 728; see also Kahn, 1966). This description is well exemplified by agriculture, where "individual farmers rarely set out to diminish the quality of the environment, and generally the actions of each have a relatively minor impact in themselves, but cumulatively their 'decisions' impact in significant ways upon the environment" (Cocklin, 2005: 173; see also Cocklin, 1993; Spaling and Smit, 1995). Moreover, the decisions of farmers have not been made in isolation. They have been influenced by government policies, which have until recently been unsympathetic to environmental concerns, and more recently have been largely determined by what might be called the 'tyranny of the market'. As Tonts (2005: 197) points out: "In order to remain profitable, farmers are often forced to use large quantities of fertilisers and pesticides, and in some cases to overstock their paddocks or clear more native vegetation, despite an acute awareness that land degradation is a serious problem."

Numerous reports attest to the degraded state of the Australian environment, particularly its land and water resources (e.g., Australian State of the Environment Committee, 2001; Beeton et al. 2006; Conacher and Conacher, 2000; Yencken and Wilkinson, 2000). Land clearing remains a particularly significant threat to biodiversity, which "destroys and degrades the habitat on which native species rely", "allows weeds and invasive animals to spread, contributes to greenhouse gas emissions and can lead to soil degradation, such as erosion and salinity, which in turn can affect water quality" (ABS 2009a).

Australia's old, shallow soils are readily damaged by agricultural activities (ABS 2009b). In consequence, land degradation has afflicted Australian agriculture in many areas for more than a century, and has been recognised as a matter for state government attention since the 1930s (Vanclay and Lawrence 1995: xiii). Yet, despite increasing evidence of the severity of problems such as wind and water erosion, acidification and salinisation, it took a long time for the full gravity of the environmental damage to be recognised and for an awareness to dawn that some – perhaps most – of the land available for agriculture cannot safely be used for this purpose. As late as 1916, for example, land susceptible to salinisation at Nyah (in the mid-Murray region of northern Victoria) was distributed to returning soldiers as part of a soldier settlement program, with disastrous consequences both for the aspiring farmers and the environment (Barr and Cary 1992: 261).

Soil salinity (which is the result of both irrigation and tree clearing) is a major contributor to land degradation (ABS 2002; Beeton et al. 2006). The pervasiveness of salinisation resulting from irrigation has caused some researchers to question whether this land management strategy can be sustained (Haw et al. 2000: 156). Dryland salinity is a result of clearing native species whose adaptive root systems help to ensure salts in groundwater are not transported to the surface (Brennan 2004). It has gained great significance in Australia due its extent, economic cost and irreversibility (LWRRDC 1999). An assessment of dryland salinity indicated that approximately 5.7 million hectares were at risk or affected by dryland salinity and that within 50 years this might increase to more than 17 million hectares (NLWRA, 2001b). The non-farm effects of dryland salinity represent a significant cost for local and state governments: these effects include declining water quality, infrastructure damage to roads and buildings, habitat decline, increased flood potential, social costs and increased public expenditure on drainage schemes (LWRRDC 1999: 7-8). It is equally damaging for the natural environment, threatening biodiversity through the degradation of habitats and its effects on water quality (ABS 2009b). In 2001, it was estimated that up to 20,000 km of streams could be significantly salinity-affected by 2050 and that about 630,000 hectares of native vegetation and associated ecosystems were at risk; this could increase to 2 million hectares over the next 50 years (NLWRA 2001b).

Land clearing and intensive agriculture have resulted in both water and wind erosion in many areas (Beeton et al. 2006). For example, broadacre cropping regions, such as the Wimmera and Mallee in western Victoria, have experienced severe dust storms which stripped and carried away large quantities of topsoil over considerable distances. The remedy for this problem has been sought in 'no-till' or 'conservation' farming, a benign sounding practice which depends on application of herbicides to avoid the necessity of ploughing. A study of adoption of sustainable farming practices found that use of these potentially hazardous and expensive chemicals was "seen by farmers and others to place farmers on a technological as well as economic treadmill … which delivers certain long-term costs but doubtful long-term benefits" (Gray el al. 2000: 35).[4] The impacts on biodiversity have not, to our knowledge, been studied, perhaps reflecting a general tendency in Australia to under-value biodiversity on *farmed* (contrasted with *wild*) lands.

5. Impacts of climate change

5.1 Climate variability and change

Australia's climate has long been subject to extreme variations, both between climatic zones and over time. Indeed, variability and extremes are such established characteristics of the climate that a popular Australian poem ('My Country') celebrates Australia as a land of "droughts and flooding rains". Despite "severe climatic oscillations … over the last 500,000 years", Mackey et al. (2008: 12)

[4] This reluctance to adopt "zero tillage" appears to have been overcome, with no till practices used on "nearly two-thirds of land prepared for crops and pastures" in 2007-08 (ABS 2009b).

conclude that "all native species extant when Europeans first occupied the continent 220 years ago had persisted through all these long term trends and oscillations in temperature, CO2 concentration and wetness." Thus, Australian flora and fauna are to a large extent adapted to a highly variable climate (Soulé et al. 2004). What is different now is the scale of the problem and the fact that climate change is affecting a landscape which is already severely damaged and "in which the habitats have been fragmented, invaded by alien species, and otherwise disturbed, all of these factors increasing the impact of global warming greatly" (Raven and Yeates, 2007: 183; Mackey et al. 2008).

There is now scientific consensus that profound, human-induced climate changes can be anticipated in coming decades, and indeed have already have begun. Climate change projections for Australia (CSIRO and BOM 2007) indicate that significant increases in temperature can be anticipated: annual warming is predicted to increase on average by 1.0^{o}C by 2030 relative to 1990 levels, with an increase in the frequency of very hot days (over 35.0^{o}C). Rainfall projections are even more concerning, with declining rainfall predicted for all regions except the far north, and major changes in seasonal rainfall patterns in the east, south-east and south-west, i.e., in the major agricultural areas. Reduced rainfall will result in even larger decreases in stream flows (Garnaut 2008: 109). Drought may be expected to occur more frequently across Australia, particularly in south-western Australia, with up to 20 per cent more agricultural drought months[5] over most of Australia. Decreases in rainfall due to climate change are likely to be exacerbated by the influence of El Niño weather events, which reduce rainfall dramatically across southern Australia: the last El Niño in 2006 reduced rainfall to the lowest level every recorded in parts of southern Victoria and northern Tasmania. As a result of climate change, extreme events – heatwaves, bushfires, tropical cyclones and floods – will also become more common in some areas (CSIRO and BOM 2007; Garnaut 2008). Two new categories of fire weather have been defined – "very extreme" and "catastrophic" (Garnaut 2008: 120); an instance of catastrophic fire weather in south-eastern Australia recently resulted in the deaths of 173 people in one day.

5.2 Environmental impacts of climate change

A number of studies have identified the serious threat which climate change poses to Australia's fragile environment and ecosystems. This threat is amplified by the extent of damage already brought about over two centuries of human-induced environmental changes. Thus, a *Climate Change Review,* commissioned by the Australian government, came to the view that:

> *… added stressors from climate change would exacerbate existing environmental problems, such as widespread loss of native vegetation, over-harvesting of water and reduction of water quality, isolation of habitats and ecosystems, and the influence of introduced plant and animal pests* (Garnaut 2008: 141; see also Mackey et al. 2008).

Similarly, Cork et al. (2006) argued that: "Climate change will further compound and intensify pressures on biodiversity, especially by affecting rainfall patterns, and hence fire frequency, affecting regeneration of vegetation, and changing where plants and animals can live." Raven and Yeates (2007: 183) went further, concluding that: 'Perhaps the most important problem of all affecting the survival of Australia's unique plants and animals is global warming".

Morton et al. (2009: 3) identified various direct and indirect effects of climate change including:

- Range shifts of species, range fragmentation or shrinkage, extinctions and changes in the structure of ecosystems
- Potentially greater vulnerability to biological invasions

[5] These are months when agricultural production is constrained by extremely low soil moisture as a result of seasonal temperatures and rainfall (CSIRO and BOM 2007).

- Additional alteration to fire regimes
- Changes in linkages between ecological and socio-economic systems.

Already there are some convincing examples that climate-change induced shifts have occurred in the Australian Alps since the 1960s, such as the encroachment of snow gums (*Eucalyptus pauciflora*) on sub-alpine grasslands and changes in the ranges of vertebrates (Cork et al. 2006; Hughes 2003). For some species occupying specialized ranges, changes to their habitat due to climate change are likely to be fatal. The future of the flora and fauna of the Australian Alps is particularly hard to resolve, given the lack of higher terrain anywhere in Australia for species to migrate or be relocated to (NBSRTG 2009: 65). Similar impacts on higher altitude species have been detected in the Australian tropical rainforests (Cork et al. 2006; Krockenberger et al., 2003; Williams and Hilbert 2006, Williams et al. 2008).

Also facing a very uncertain future are numerous wetlands, due to declining rainfall and, on the coast, the prospect of saltwater intrusion and inundation (Hughes 2003). The RAMSAR-listed Coorong wetlands and adjacent lakes at the mouth of the Murray River have already been damaged, possibly beyond repair, by salinisation and acidification resulting from a combination of drought and over-extraction of water preventing environmental flows in the river (Office for Water Security 2009). Without global mitigation of climate change, Garnaut (2008: 125) found that by mid-century another major natural icon, the Great Barrier Reef, would be effectively destroyed, together with other reef systems, with "serious ramifications for marine biodiversity", as well as associated activities, such as tourism (see also Johnson and Marshall, 2007).

Agricultural areas in much of the country will also be damaged by climate change. According to Gunasekera et al. (2007: 657), "Australia is projected to be one of the most adversely affected regions from future changes in climate in terms of reductions in agricultural production and exports." The Garnaut report found that, without effective global mitigation of climate change, agriculture would be adversely affected by changes in temperature and water availability with the result that:

> *By mid-century, there would be major declines in agricultural production across much of the country. Irrigated agriculture in the Murray-Darling Basin would be likely to lose half of its annual output. This would lead to changes in our capacity to export food and a growing reliance on food imports.* (Garnaut 2008: 125)

Indeed, drought in much of the Murray-Darling Basin (MDB) has already reduced availability of water for irrigation-dependent agriculture and resulted in severe stress for farmers. Given that this area has been the food bowl of Australia, producing more than 40% of the total gross value of agricultural production, this is a serious matter. Without mitigation, it is predicted that impacts will be profound by the close of the century with Garnaut forecasting that:

> *The increased frequency of drought, combined with decreased median rainfall and a nearly complete absence of runoff in the Murray-Darling Basin, is likely to have ended irrigated agriculture for this region. Depopulation will be under way.* (Garnaut 2008: 129)

Other impacts on agricultural productivity – crop yields and livestock carrying capacity – are likely to include increased average temperature, changed rainfall patterns and increased climate variability; reduced soil moisture and increased evaporation; more severe weather events, including bushfires and flooding; an increased risk of soil erosion as a result of reduced ground cover and increased frequency of extreme wind and rain events; and increased incidence and occurrence of pests and diseases (AGO 2007; DCC 2008; Garnaut 2008). Weeds are already a major problem for Australian farmers, but this problem is likely to escalate as a result of changes in temperature combined with financial pressures

on farmers which limit their ability to effectively manage them (DCC 2008). Some positive effects could occur, although generally only in the short run: in some regions, there could be a decrease in pests and diseases, while wheat production could increase in some parts of Western Australia because decreasing rainfall is likely to reduce soil salinity (Garnaut 2008: 132). Effects of climate change may include shifts in geographical location of production (Morton et al. 2009), with some farming groups and politicians expressing enthusiasm for the prospect of agriculture moving from the increasingly desiccated farming areas of southern Australia to the better watered north, ignoring the climatic extremes, and the pests and diseases, to which the northern region is prone. Some farming areas have become marginal, and many farmers have reduced production, due to drought. Perhaps because of this experience of drought, a substantial proportion of farmers appear to have accepted that the climate has already changed: a survey of all agricultural businesses in 2006-07 (when many regions experienced a severe drought) found that "65.6% reported that they considered the climate affecting their holding had changed" (ABS 2008: 4).

6. Environment and biodiversity protection policies

The imminent prospect of dangerous climate change is not only raising concerns about the probable environmental impacts but also about the adequacy and effectiveness of current and proposed strategies for biodiversity conservation and natural resource management. Before considering strategies specifically addressing impacts of climate change, we outline the development and characteristics of existing policies and programmes for biodiversity protection and sustainable land management.

The genesis of environmental conservation in Australia was associated with the growing appreciation, mainly amongst urban residents, of the natural environment, and particularly of 'wilderness' areas: This led to the establishment of nature reserves, primarily for recreation (Mosley 1978). During the 1970s and 1980s, an increasingly well-supported nature conservation movement engaged in a series of often contentious campaigns to protect wilderness areas from development. Subsequently, a number of states enacted wilderness protection legislation (Mackey et al. 1998). In Australia, as in other 'settler societies', a far higher valuation has been placed on natural areas than on the farmed countryside (Figgis, 2003). By contrast, in Europe, people have tended to "value the managed landscape that has evolved over the centuries" (Dobbs and Pretty, 2004: 225). The notion of protecting 'multifunctional' farmed landscapes, appreciated for their beauty and heritage attributes, has played an important role in Europe but has little resonance in Australian environmental and rural policies (Bjørkhaug and Richards 2008; Dibden and Cocklin 2009). Nonetheless, it has become increasingly apparent that the environmental values and problems of agricultural areas can no longer be neglected, given that farmers manage around two-thirds of Australia's land area, including landscapes with important conservation values (Davidson et al. 2006: 6); for example, "50 per cent of Victoria's threatened vegetation types are found almost entirely on private land" (Beeton et al. 2006: 43)

From the late 1980s, a number of farmer-led environmental groups sprang up in the state of Victoria, partly with state government encouragement, to tackle issues connected with salinity (Salt Action groups) and tree clearing (Farm Trees and Landcare groups). A joint initiative of the Australian Conservation Foundation and the National Farmers Federation persuaded the Australian government to launch a national Landcare programme in 1989/90. Another potentially significant initiative related to the Murray-Darling Basin (MDB), which covers over one million km^2 of south-eastern Australia including 75% of the country's irrigated land (ABS 2007; Garnaut 2008: 129): the Murray-Darling Basin Agreement, signed in 1992, promised state collaboration in promoting the integrated management of the MDB (although the agreement has signally failed to deliver urgently needed environmental improvements).

Some important international initiatives in the late 1980s also propelled the Australian government in the direction of greater concern both for the natural environment and for broader issues of sustainability. Of particular importance was the report of the United Nation's World Commission on Environment and Development (1987), *Our Common Future*, popularly known as the Brundtland Report. According to Tonts:

> *This report had a particularly important legitimising role within government. With increasing global attention being given to environmental issues, governments could no longer continue to dismiss the problems facing natural environments. Furthermore, by emphasising the connections between ecosystems, economies and societies, the Brundtland Report forced governments to begin to think about the issues in a more integrated and systematic way.*
> (Tonts 2005: 198)

In 1992, the Australian government responded to the Brundtland Report by launching a *National Strategy for Ecologically Sustainable Development* (ESD), with ESD defined as "using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained" (Commonwealth of Australia, 1992: 6). This was accompanied by the signing of an agreement which committed all levels of government to the principles of sustainability. In the same remarkably busy year, Australia made a further international commitment, this time to biodiversity conservation, as a signatory of the 1992 International Convention on Biodiversity; it also committed to five-yearly independent state of the environment reporting (Cork et al. 2006; NBSRTG 2009), the most recent being undertaken in 2006 (Beeton et al. 2006).

Commitments to improved natural resource management were backed up by two major Australian government funding programmes. The National Heritage Trust was established in 1996 with the goal of stimulating "activities in the national interest to achieve the conservation, sustainable use and repair of Australia's natural environment" (http://www.nht.gov.au): A$3 billion was allocated for projects that addressed major natural resource management issues. In 2000, a further A$700 million was made available through the National Action Plan on Salinity and Water Quality (NAP) to address the problems of regions in the Murray-Darling Basin. Responsibility for planning and administering environmental programmes was assigned to 56 regional 'community'-based catchment management groups. This model, based on 'civic regionalism' (Lane 2006), has been criticized on the grounds that it devolves responsibility without power (Dibden and Cocklin 2005), and its effectiveness has been questioned. For example, Beeton et al. (2006: 98) have pointed to: "the ephemeral character of groups receiving financial assistance, the short-term benefits of their work, the lack of scientific information combined with local knowledge as it is replaced with citizens' views and experiences, and the lack of a wider strategic direction in their work." They confront the core issue in natural resource management in Australia, attempting to mediate "the tension between conservation and production in agricultural landscapes" (House et al. 2008: 153). Many of the regional boards (e.g. in Victoria) are dominated by farmers, which creates the risk that producer interests will be privileged over the natural environment. They now find themselves facing a new challenge, incorporating responses to climate change into their planning and management responses (Campbell 2008; DCC 2008).

7. Australian policies in relation to the agriculture and the environment

The capacity of the Australian government to respond to environmental issues has been constrained by the important of exports of primary products to the country's economy. This dependence on exports underlies both an interest in encouraging the production of high volumes of commodities as efficiently and cheaply as possible and a commitment to trade liberalisation, which has been promoted actively through the World Trade Organisation (Dibden and Cocklin 2009, Dibden et al. 2009; Pritchard 2005). In particular, Australia has strongly opposed subsidization of agriculture, since this is a battle it cannot

win against the giant economies of its competitors in Europe and North America. In support of this position, subsidies to farmers have been reduced to the second lowest amongst OECD countries (OECD 2006: 44), and European support for 'multifunctional' agriculture, including payment of agri-environmental incentives, has been strongly criticised in the WTO. Australian governments have also deregulated agricultural marketing arrangements which had to some extent provided a buffer against low and often wildly fluctuating global commodity prices. As Dibden and Cocklin (2009: 164) argue, this "unwillingness to provide more than token support for farming and for agriculture-dependent areas has created a disjuncture between entrenched political positions … and the reality of a growing environmental and social crisis in the countryside".

In attempting to improve environmental management *without subsidising* landholders, Australian governments at both federal and state levels have relied on a limited range of instruments, primarily information provision, voluntary action and regulation. The federal government's preferred model for promoting better natural resource management practices has been "the participatory, self-help approach epitomized by the National Landcare Programme (Dibden and Cocklin 2005: 138). This programme has sought to develop a national network of voluntary, community-based groups to address local environmental problems with limited financial support and advice from government agencies (Higgins and Lockie 2002; Lockie and Higgins 2007). While Landcare groups have been established in all states (Hodges and Goesch 2006; Nelson et al. 2004), they have never been able to attract more than a minority of landholders and the outcomes have been patchy. Not surprisingly, farmers tend to prefer to undertake environmental work which will improve production, such as planting trees on farm for shade and shelter for livestock or eradicating pest plants and animals. As a result, there is doubt that real ecological benefits have been achieved, particularly when a wider landscape perspective is taken.

In moving to a system of regional governance from 1996, more emphasis was placed on planning, setting targets and monitoring, at least partly as a response to criticisms that the Landcare Programme had failed to evaluate environmental outcomes to ensure that funds were well spent. Although improvements in environmental performance were in the main "to be accomplished through persuasion, education, information and incentives, some coercive power is provided by state-level legislation regulating water use and protecting native vegetation" (Dibden and Cocklin 2005: 140). In practice, much of the effort to conserve biodiversity has focused on preventing further clearing of native vegetation through regulation. Most states introduced legislation to regulate clearing of native vegetation, but "the legacies of past vegetation clearing—including changed hydrology, habitat loss and fragmentation, and impacts on seed supplies and regeneration of native vegetation—remain strong drivers of biodiversity decline" (Cork et al. 2006). Moreover, enforcement of restrictions on clearing has often been ineffective. As Brennan (2004: 127) points out, over the past decade the rate of vegetation clearing has increased, in spite of regulation and policy prescriptions. Only Brazil, Indonesia, the Democratic Republic of the Congo, and Bolivia have cleared more forest than Australia. Efforts to reverse this decline have often been counter-productive: for example, the *State of the Environment 2006* report pointed to "a recent increase in some states in advance of stronger clearing legislation" (Beeton et al. 2006: 70). In states where uncompensated restrictions on clearing both extant vegetation and 'regrowth' have occasioned much bitterness, farmers' groups have pointed to the unfairness of the Australian government claiming credit, and a reduction in emissions targets, in its response to the Kyoto Protocol, on the basis of decreased clearing and hence at the expense of farmers (e.g., Skuthorp 2008). Studies of the effects of clearing restrictions on farmers have revealed that significant costs were borne by landholders while the benefits are experienced by the wider society (Davidson et al. 2006), a finding which prompted the Productivity Commission (2004) to recommend the development of native vegetation policies that provide landholders with positive incentives to retain and manage native vegetation.

This shift in position by the Productivity Commission forms part of a wider recognition that previous approaches have not worked. It has become apparent that voluntary programmes, such as Landcare, do not have the capacity or breadth of vision to overcome environmental problems at a wider 'landscape' scale. Moreover, it has also been recognised that farmers – trapped between the requirements to produce more and yet somehow protect the environment at their own expense – are not able to undertake the work required, particularly at a time when many are struggling as a result of low prices for agricultural produce and drought conditions. This has resulted in a new willingness to consider strategies, supported by government funding, which recognize the public benefits of farmers' environmental 'stewardship' activities (Dibden and Cockin 2009).

Federal government policies on environmental issues have in recent years tried to resolve the conflict between promoting agricultural production and the need to tackle environmental (and social) issues through a shift from reliance on voluntary activities to promotion and funding of market strategies (Dibden and Cocklin 2009). These include providing federal funding to encourage adoption of:

- environmental management systems (EMS), which aim to gain market advantages for landholders practising 'environmental-friendly' farming;
- market-based initiatives, such as 'auction' schemes in which landholders tender to provide ecosystem services. These auction systems have been directed to specific purposes, such as biodiversity conservation or salinity mitigation.

These programmes have been linked to Australia's commitment to ecologically sustainable development (ESD). Thus the National Framework for EMS asserts that:

> … *the principles for ESD developed for Australia apply to EMS. In return, implementation of this Framework and voluntary adoption of EMS will help Australia to deliver on these ESD principles.* (NRMMC 2002: 5)

Similarly, the Victorian state government has identified EMS as a tool for incorporating ESD principles, such as maintenance of biodiversity, into "performance standards" for agriculture (Anderson et al. 2001: 1). Victoria has been particularly active in establishing auction schemes, which primarily serve environmental purposes – such as biodiversity conservation or salinity mitigation (achieved through reafforestation), while one project aims to preserve an endangered species with great symbolic importance, the Red-tailed Black Cockatoo, which was the mascot for the 2006 Commonwealth Games in Melbourne.

8. Climate change policies

The natural environment and agriculture in Australia are both likely to be threatened by climate change and its associated impacts. The agricultural sector in Australia has been judged by the IPCC as "particularly vulnerable to climate changes" (Stokes et al. 2008: 1). The vulnerability of the agricultural sector to climate change has already been demonstrated in the past by the impact of drought – not only on farmers and rural areas but on the Australian economy: for example, as a result of a severe drought in 2002-03, the gross value of agricultural production for that year fell by 19% (to around A$32 billion) which reduced GDP by approximately 1% (ABS 2004; DCC 2008). Agriculture faces an additional challenge if the Australian government introduces a proposed emissions trading scheme, since the sector accounts for a substantial proportion of Australia's greenhouse gas emissions – indeed, it is the second largest source (after energy) with 16.3% of the total in 2007 (DCC 2009: 4). However, as we argue below, agriculture's losses and difficulties could represent a gain for biodiversity.

The many threats to agriculture outlined above (section 5) will require farmers to make a variety of adjustments. A number of studies have discussed two types of responses to climate change (and to any potential emissions trading scheme for agriculture) – adaptation and mitigation (Gunasekera et al. 2007a; Jiang et al., 2009). Adaptation will be required whether an emissions trading scheme is applied to agriculture or not, since there will be no escaping the need to adjust to a changing climate. Mitigation refers to efforts to reduce greenhouse gas emissions, which is most likely to occur in conjunction with an emissions trading scheme. In practice, the two approaches are bound to overlap, with mitigation strategies underpinning adaptation (especially where a carbon price is applied), and many adaptation initiatives simultaneously contributing to mitigation efforts.

8.1 Adaptation strategies

Campbell (2008: 16) considers that it is helpful to conceptualise adaptation – at least for farm sectors and at regional or catchment scales – as "reducing vulnerability and/or increasing resilience." Change will be inevitable in many areas, as rising temperatures and decreases in rainfall make current farming practices untenable. Regions which will be particularly hard hit are those dependent on irrigation, such as the Murray-Darling Basin, and marginal farming areas, where farmers may already be operating beyond the desirable climatic limits for their productive activity. Garnaut (2008: 532) predicts optimistically that "land managers will respond to these dual challenges by pursuing new opportunities in carbon removal (or sequestration), energy production from biomass and low-emissions livestock production." Other forms of adjustment may require farmers to adapt current farming practices, adopt new technologies, switch to other forms of commodity production, combine on- and off-farm income earning activities or seek alternative sources of income outside of agriculture (FFRPG 2009; Gunasekera et al. 2007a).

The extent to which a majority of farmers will be willing to make 'adjustments' is at present uncertain. Stokes et al. (2008: 2) caution that adoption depends both on "confidence that the climate really is changing" and on "the motivation to change to avoid risks or use opportunities". A recent paper by Gray et al. (forthcoming) questions "the capacity of those currently managing Australia's farming and grazing lands to make the appropriate 'adjustments' that will, at one and the same time, deliver increased output (a key goal in terms of export income, and the key to continued economic viability) while protecting the environment – and all in the context of predicted climate changes." They point to a case study by Richards of the grazing industry in Central Queensland during a period of drought and falling prices. Graziers responded to this crisis situation by using more inputs, maintaining stocking rates, and clearing native vegetation, "despite the view of many observers (including some graziers) that this approach was unsustainable, and would lead to considerable environmental degradation" (Gray et al. forthcoming: 14-15; see also Bjørkhaug and Richards 2008). The lack of alternative options may have been equally important for graziers in this remote area.

Studies of farmers in the more closely settled state of Victoria indicate that in some areas adaptations are already occurring. For example, in our research in the Wimmera region of western Victoria, we found that, as the climate became drier, cropping was shifting southwards into former sheep country, which had previously been too subject to water-logging to be suitable for crops. A large, corporate farmer was already following another suggested strategy – spreading risk by growing crops in "multiple holdings in different climatic regions" (Gunasekera et al. 2007a: 500). Some grain growers are hoping to improve their future prospects by experimenting with genetically modified canola, although varieties which are drought tolerant – the most desirable trait for Australia – are not yet available (Glover et al. 2008). In more marginal country, an auction scheme (Catchment Tender), which paid farmers to plant trees for salinity mitigation, was quickly over-subscribed – a result which appears to have been partly a response to drought conditions (Dibden and Cocklin 2009).

8.2 Mitigation strategies

Agriculture has not at present been included in the Australian government's proposed emissions trading scheme (the 'Climate Pollution Reduction Scheme' or CPRS), largely because of the difficulty in measuring or estimating net emissions cost-effectively (Garnaut 2008: 558). However, the inclusion of agriculture is considered highly desirable, since agriculture currently accounts for about 16% of national greenhouse gas emissions (Jiang et al. 2009). Livestock production is particularly damaging, with methane from sheep and cattle comprising 12% of total greenhouse gas emissions – "the third highest single emissions source" (AGO 2005: 6). As a result, agriculture – particularly the livestock sector – would be "the hardest hit industry" if included in the CPRS (Jiang et al., 2009: xiv). Even without being included, farming would incur increased costs for inputs, such as fuel, electricity, farm chemicals and fertilisers. This would cause considerable hardship. As Jiang et al. (2009: xiv) point out: "Because most Australian agricultural products are exported and Australia is a small player in the world market, it is extremely difficult for Australian farmers to pass on the additional costs to their customers and end users."

The exclusion of agriculture form the CPRS is hence a mixed blessing – it means that farmers do not as yet incur charges for emissions from farming operations, yet at the same time does not relieve them of all costs resulting from the scheme and prevents them from taking advantage of potential opportunities. These opportunities include earning credits by reducing emissions from farming activities or for carbon sequestration in trees or – less certainly – in soil (Garnaut 2008; Gunasekera et al. 2007b). Some farmers are already taking action to guard against the risks and make the most of the opportunities which a future emissions trading scheme will bring. For example, the 'Resource Management Group' in the Northern Gulf region of far north Queensland is interested in opportunities to participate in environmental incentive schemes "related to carbon storage and sequestration"; potentially beneficial actions might include reducing carbon emissions through improved fire management in savanna landscapes (Greiner et al. 2009: 57; see also TS-CRC 2009). A similar scheme is already under way in northern Australia, using traditional Indigenous fire management skills (Garnaut Climate Change Review 2008).

Some major problems stand in the way of enabling farmers to participate in emissions trading, relating to difficulties in measuring or estimating net emissions from agriculture, particularly in view of the large number of agricultural establishments (around 130,000) in Australia, with a wide diversity of emission profiles (Gunasekera et al. 2007a: 505). Garnaut (2008:559) has proposed "a large role for collective action among farmers, or private broking functions, to reduce the costs of individual farmers' interaction with an emissions trading scheme." This possibility is already being explored by some potential participants. For example, in Victoria, a review suggested a number of possible options for regional catchment management bodies in relation to emissions trading, including taking on responsibility for measurement and quality assurance or, more ambitiously, "becoming a direct player in the market by 'bulking up' revegetation projects and managing and marketing a carbon pool" (Campbell 2008: 29; see also Campbell 2007). Another proposal has been put forward by Australia's largest dairy co-operative, which recently obtained federal government funding to assist farmers to implement best management practices to reduce and mitigate emissions while maintaining productivity. The outcomes will be measured through the co-operative's existing intranet information management system for farmers, which currently integrates milk production and financial information but will be modified to incorporate tools to measure nutrient loss, nitrogen utilisation, energy use and the effects of greenhouse gas abatement strategies. The accounting tools will be set up in such a way that farmers can feed in information relating to emissions, including bills for energy, fertilisers etc. from third party vendors, and transmit these data to the co-operative. This scheme not only gives the co-op a means of mitigating the substantial emissions from dairy farming but may also, in future, enable it to act as a broker gaining credits for farmer members for their actions in reducing emissions.

8.3 Alternative futures

The future for both farmers and ecosystems will be very different but not necessarily worse than the past. The need for farmers to adjust simultaneously to the biophysical outcomes of climate change, the impacts of an emissions trading scheme and/or the threat of penalties for greenhouse intensive activities could produce positive changes for the environment, for example by requiring shifts in land use and farming practices. Climate mitigation strategies have been proposed which serve a dual purpose, both rewarding or compensating farmers and helping the environment, including biodiversity. Examples include:

- the proposed use of drought assistance to promote improved environmental management (exit of marginal farmers, less intensive land use, areas retired from production) rather than simply propping up farmers who are struggling to survive prolonged drought (Botterill and Fisher 2003; FFRPG 2009);
- carbon credits for tree planting on farmland ('carbon farming') – which could also enhance biodiversity;
- carbon offsets for vegetation management on farms – this "could provide several other private and social benefits, including shelter for livestock and crops, reducing the incidence of salinity and waterlogging and conserving biodiversity" (Gunasekera et al. 2007a: 507);
- especially in marginal areas, new crops (such as oil mallees or other eucalypts) could be grown with multiple benefits – generating income for landholders, sequestering carbon, producing a range of products (essential oils, charcoal, biofuels), and providing ecosystem services (AGO 2005).

Many studies of future outcomes from climate change envisage a dual or multi-track pattern of land use, with land allocated to *either* productivist agriculture *or* multifunctional land uses *or* complete withdrawal from farming uses. A Victorian government group considering the future of farming in the state (FFRPG 2009: 22) came to the view that: "With the majority of the state subject to some form of landscape stress, it is increasingly difficult to keep land in production and, in some cases, alternative futures or interim support may need to be considered if productive uses are no longer viable." The future thus looks grim for farmers in areas no longer considered suitable for intensive farming or indeed for any farming. There may be limited prospects for them to sell ecosystem services, but government schemes have thus far been limited in scope. Agri-environmental schemes similar to those found in Europe have been proposed as a means of combining support for farmers with conservation objectives (e.g., Attwood et al. 2009), but this would depend on a willingness by governments to make substantial financial commitments, and run counter to Australia's present free-trade policy position (Dibden and Cocklin 2009; Dibden et al. 2009). Probably the best prospect of adequately compensating farmers for contributions to the natural environment lies in creation of an active carbon market, with prices far higher than those currently contemplated (Campbell 2008). If the price for carbon was sufficient, this would make land under trees, shrubs, even grasslands, potentially more valuable – and allow carbon storage to be combined with conserving land for biodiversity (Lindenmayer 2007; Mackey et al. 2008).

9. Conclusion

From an environmental perspective, the Australian continent is an ancient land. For most of the last 50,000 years, the native flora and fauna have been able to evolve gradually in the presence of the Indigenous Australians. This is not to suggest that the first humans did not transform the landscape – their use of fire in particular had quite significant environmental consequences. However, it was Australian settler society and especially the introduction of a European style of agriculture over the past 200 years that has really imperilled Australian biodiversity. Agriculture has impacted heavily on Australian biodiversity, driven historically by a 'frontier' ethic and more recently by free-market

policies that emphasise production over stewardship. The losses have been massive, made all the more significant by the fact that so many of the Australian species are endemic.

At the same time, the loss and degradation of biodiversity has, in turn, had negative consequences for agriculture; there is a negative feedback loop, in that the destruction of biodiversity is affecting agricultural productivity. Dryland salinity is one of the most graphic examples. Vast tracts of the Australian landscape that have been cleared for agriculture have become useless as a result of soil salinity levels increasing to levels that are toxic to all but the most hardy of plants. Not only has the original fauna and flora been lost from these areas, but they are no longer suitable for production either.

Climate change is imposing new pressures on both agriculture and biodiversity and these impacts will intensify significantly. A majority of farmers now acknowledge that their farm enterprises have been impacted by climate change, a belief underpinned no doubt by the drought that has affected much of the southern agricultural landscapes for more than a decade. At the same time, there are discernible impacts on biodiversity particularly amongst 'indicator species' – e.g., vulnerable higher altitude species in both the temperate and tropical zones. Every indication is that Australian biodiversity will suffer even more, including iconic natural assets such as the Great Barrier Reef.

It is possible to envisage mitigation and adaptation responses that would alleviate pressures on all three systems (climate, agriculture, biodiversity). For example, innovation in public policy tools gives some hope for biodiversity management and climate change mitigation, but the reality is that a much more decisive and aggressive policy platform is required. Despite the rhetoric, it is as yet unclear as to whether Australian governments – federal and state – really have the political will to do what is required to protect the nation's unique flora and fauna from the combined threats of both agriculture and climate change.

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