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The second industrial transformation of Australian landscapes

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European colonization precipitated the first industrial transformation of Australian landscapes. We review the evolution of the environmental and societal setting of Australian landscapes since this first industrial transformation, the emergence of drivers precipitating a second industrial transformation, and what it will take to adapt. In concert with climate change and growing societal expectations of environmental stewardship, we identify six emerging economies for ecosystem services — carbon, water, food, energy, amenity and mining — which will exert transformational pressure on land use and management. The requirements for transformational adaptation — to thrive within environmental limits — include: fostering new partnerships between government, science, the private sector, and local communities to support local adaptation; identifying critical environmental limits and rationalizing environmental laws; establishing innovative social processes and adaptive governance; and developing innovative, well-supported market-based and community-based incentives.

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Introduction

Australian landscapes have experienced multiple transformations as a result of both environmental and human agency. European colonization, however, precipitated the first transformation that was industrial in scale and speed. We introduce these past transformations, providing the context for current environmental, societal and institutional settings in Australian landscapes. We argue that the drivers for a second industrial transformation of Australian landscapes are already evident and intensifying. These drivers are then reviewed with a focus on six emerging economies which are exerting transformational pressure on Australian landscapes. Finally, we recommend steps for creating a more enabling, science-informed institutional and governance structure within which communities can innovate, adapt and thrive through this transformation.

Past transformations, emerging drivers, current settings

Australian landscapes — with their unique landforms, waters, plants, animals and people — are an emergent property of the combined forces of humans and nature shaping a complex social-ecological system [1^{••},2]. For millions of years, cycles of global change combined more recently with the land management practices of indigenous Australians have combined to transform the land and its biota [3].

The first industrial transformation of Australian landscapes began with European colonization in 1788 [4]. Industrial in nature, this transformation was rapid. Driven by the demands of an increasing population and enabled by mechanisation [5], this involved an unprecedented change to vegetation, native animals, soils, waters and atmosphere through large scale species introductions, livestock grazing, land clearance, irrigation, cultivation, urbanization and other developments [6]. Adverse environmental and social outcomes including the dispossession of indigenous people, large scale ecological degradation and species extinction, pest invasion, soil erosion and salinization, over-extraction of water resources and water quality decline have been the inevitable result of such transformative processes [7[•]]. Many local environmental and resource limits have been pushed or exceeded [6,8], mirroring global trends [9^{••}]. Mounting awareness and intolerance of some of these outcomes has changed

Box 1 The shaping of Australian landscapes and societal attitudes

The key drivers, events, and values that have progressively shaped Australian land use and management since European settlement in 1788 are:

- A shift in community attitudes to the land, from that of pioneers taming a foreign land, towards sustainability and stewardship.
- An increasing focus by governments and communities on rectifying the adverse consequences of past actions (e.g. soil erosion and salinization, ecological disturbance, water resources management) [7*].
- A shift towards recognising and managing landscapes as integrated systems (e.g. catchments, bioregions), rather than individual, disconnected elements [6,48**].
- Greater awareness of the need to adapt to climate variability and extreme events [24].
- The increased use of innovative market-based instruments and property rights to manage environments [44*].
- A growing diversity in the sources of rural wealth, with traditional agricultural industries being complemented (or replaced) by minerals, energy, carbon, water, biodiversity, and amenity [35].
- A greater respect for aboriginal rights to land and their traditional knowledge in land management—although this has occurred alongside ongoing chronic disadvantage.

These evolving and interacting influences have changed social norms defining appropriate land use and management within both private and public realms. Figure 1 represents the cumulative influence of these norms in shaping Australian land use. It illustrates some issues and events affecting private land managers (predominantly farmers) in the lower half of the figure. Broader public policy and non-agricultural land use trends are in the upper half. Later events tend to build on rather than displace earlier ones. Together they have created an array of competing demands on land.

societal attitudes (and institutional responses) over time from *pioneering* to *sustainability* (Box 1). This social evolution has shaped Australian landscapes during the first industrial transformation, and set the context for the second.

A number of biophysical, economic and social drivers are exerting further transformational pressures on Australian landscapes. In the absence of immediate and deep cuts to global emissions, climate change [10] will have an increasingly significant impact on Australian landscapes and people [11–15]. Long term effects of changing climatic trends will impact on landscapes — threatening the sustainability of agricultural [16–20] and ecological systems [21,22]. More pertinently, the increased frequency of extreme events such as drought, fire, storms and floods [12**,23] will influence the landscapes we use and live in [24–27]. Economic and social drivers of transformation include new markets, international demand for land and water resources, rising energy costs, growing social expectations of environmental stewardship, looming limits to critical resources such as oil and phosphorus, the changing

needs of an ageing population and changing global dietary preferences [28,29,30*,31,32]. As a result, our land systems are increasingly being asked to satisfy multiple demands, values and functions [33,34*,35–37]. These pressures affecting Australia are typical of those felt globally [38**].

Resilience, and the capacity for innovation in meeting past environmental challenges is well demonstrated in Australia — at the individual, community, corporate and institutional levels. Faced with a highly variable and changing climate and nutrient-poor soils, Australian farmers have become some of the most adaptable and efficient in the world [39,40]. They have also become more attentive to social and environmental sustainability [41]. Community-engaged approaches, supported by non-government organisations, have become central to improving the sustainability of Australian landscapes. Innovative, local, community-based programs have been successfully implemented [42–46]. Commercial organisations are increasingly aware of the need to defend their social license to operate, triggering many to expand their corporate social responsibility activities [47]. Over recent decades, comprehensive institutional reform has been implemented to support a regional delivery model for investment of Commonwealth funds in natural resource management [48**,49]. Reviews of Australian publically funded environmental management programs over the last 20 years have not only pointed to the successes of these programs in raising awareness and building capacity, but have also identified failures in governance [48**], and in targeting, monitoring and evaluating investment [49–53]. Strengthened leadership, social and human capital and democratic institutions are central to Australia's capacity to cope with and shape rapid change [1**,54].

Emerging economies changing Australian landscapes

The last decade has seen the emergence of economies centred around a suite of ecosystem services that are broader than the traditional agricultural production and conservation functions of landscapes [55,56]. Here, we focus on six emerging economies driving change in Australian landscapes — carbon, water, food, energy, amenity and mining. We note that this list is not exhaustive and that there are other similar markets for ecosystem services that may also become influential (e.g. biodiversity conservation). Each of these will combine with other economic forces (e.g. rising input costs, changing global demand), social forces (e.g. changing demographics) and biophysical forces (e.g. climate change) in influencing land use [32,57,58]. Given high levels of technological advancement, when the likely impact of these markets is considered as an integrated whole, the rate of change in land use and management may be much faster even than the first industrial transformation of Australian landscapes.

Along with the obvious risks associated with trade-offs and unintended outcomes [59], there will be opportunities for beneficial adjustment and re-organisation [60,61*].

The first emerging economy is a carbon market. Following international trends, Australia introduced a fixed price carbon market in July 2012, transitioning to an emissions trading scheme in 2015. Under this scheme, landowners may be paid for emissions abatement. This creates an incentive for landholders to adopt new land uses (e.g. reforestation) and land management practices (e.g. perennial cropping, soil carbon management) [62,63]. The plan to re-invest carbon revenues in the land sector will accelerate the development of technologies that couple carbon sequestration with works that improve biodiversity outcomes at the landscape scale [64–66].

The second emerging economy is a water market. In southern Australia in particular, climate change may reduce the availability of water resources [67]. Policy-driven increases in the share of water for the environment, and the increased evapotranspiration from reforestation may further reduce water availability [68]. Where extractions are regulated and water resources are fully allocated, less water means higher prices, further encouraging water use efficiency [69]. Landholders who respond to the carbon price in ways that impact upon water resources (e.g. through reforestation) may have to offset the impact by buying water entitlements.

The third emerging economy is food-based agricultural commodity markets. Greater demand from an increased global population, coupled with growth in the per capita wealth of many developing countries and a change in social preferences to a more protein-rich diet, is likely to increase demand for food by about 60% by 2050 [28,70,71]. Conversely, increasing costs of water and energy-intensive inputs like fertilisers, diesel and pesticides will reduce agricultural profits. These opposing forces will continue to influence how agricultural land is used and managed. Increased agrifood demand could rejuvenate parts of the agricultural sector, particularly livestock industries, which have long struggled against declining terms of trade, counteracting the move away from agricultural production motivated by the carbon price and climate change adaptation [57]. It may also encourage pushes to develop new agricultural regions such as northern Australia [72].

The fourth emerging economy is energy. Despite increased energy efficiency in some sectors, society's total energy demand is projected to continue to increase [73]. Current sources of energy pose a dual risk for Australia — being either energy-insecure, carbon-intensive, or both. As the real cost of renewable energy drops and the cost of fossil fuel rises, Australia's energy mix is in transition. Large scale unconventional gas resources (e.g. coal seam

gas) have become economically viable, sometimes displacing agriculture and creating a focal point for land use tensions. The increasing use of renewables, and the decentralization of power generation creates opportunities for Australian landscapes to provide a diverse range of energy sources. These include biofuels, solar photovoltaic and solar thermal, biomass, wind, geothermal, wave and tidal sources. However, many of these energy sources also compete for land and present their own sustainability challenges [74–78].

The fifth emerging economy is amenity — rural living and nature tourism. There has been a rapid increase in people living in and enjoying Australian landscapes — some in retirement, and others in search of an alternative to urban lifestyles [58,79]. Urban hinterlands, which now extend a large distance from cities and include much of the southern and eastern coastlines of Australia, have become a focus for residential development, tourism and associated infrastructure [80] as people seek out opportunities to enjoy aesthetically pleasing, more natural landscapes [81]. The human and social capital within these *post-agricultural landscapes* will change as population density, education and income levels all increase [58]. The look and feel of these landscapes, once largely devoted to agricultural production, can be expected to change, not least through the adoption of conservation and reforestation on private land.

The sixth emerging economy is mining. Buoyed by global demand for energy and ore, Australia is developing its mineral resources rapidly. The result is a shift in working arrangements associated with the *fly-in, fly-out* lifestyle. In addition to the physical alteration of mining landscapes and the supporting infrastructure [82], and general sustainability questions [83], this economy is increasing the cost of employing people to manage natural resources and produce food and fibre. Some of the rents from exploitation of non-renewable resources could be used to encourage environmental improvement in Australian landscapes.

Collectively, these transformational drivers will bear heavily on rural landholders. We need to find ways to support landholders to adapt to these pressures and to capture the opportunities created by new economies for ecosystem services. At the same time we must minimize trade-offs and anticipate unintended consequences [59]. Incremental adjustment is unlikely to enable rapid adaptation [25**,26*]. Opportunities provided by these emerging economies must be harnessed to enable positive transformational adaptation in land use and management.

New partnerships, science, governance and institutional settings

Enabling positive transformational adaptation in Australian landscapes requires new partnerships between

government, science, the private sector and communities. These partnerships need to be supported by renegotiated institutional settings and governance. There is good evidence that cohesive communities can voluntarily achieve results that governments cannot force [45,84]. It is, however, necessary to remove impediments to local innovation and allow more *space* for communities to create local solutions to the challenges that they will face. Local, adaptive solutions are required because the challenges themselves are uncertain, they will impact differently on different communities, and they will change over time [14,85,86]. Innovation and change will require support for communities to make adaptive decisions within clearly defined, science-informed, democratically determined environmental limits [87,88]. These are the foundations of collaborative, community-based natural resource management [89].

Science has a pivotal role in informing and supporting effective transformational pathways. Great advances have been made in understanding the biophysical and economic processes operating in agro-ecosystems [90]. Identification of critical environmental limits — to resource use, development and environmental degradation — on the basis of clear principles and sound science is a necessary extension of this work [9**,91]. Science can also provide the necessary tools for measurement, monitoring, management and decision support for local innovation and adaptation [92–96]. However, the social processes underpinning transformational adaptation such as coordinating action, knowledge exchange, trust and relationship building, engagement and innovation adoption are less well understood [97]. A better understanding of these social processes is required, as are new tools and more effective techniques for supporting them [e.g. [98,99–102]]. **Box 2** provides an example of *envisioning* as one tool that can implement these principles for supporting and managing rapid change. Science and government need to work in partnership with communities, reflecting that knowledge and clear governance are fundamental to local innovation, co-learning and effective action [1**,48**,103,104]. With the support of sound science, it is essential to understand what the nation thinks is a desirable future, and then to engage all in pursuing it.

On behalf of the community, governments need to provide leadership by making tough decisions on environmental limits that are informed by science (but not dictated by science alone) and embed these limits into law. This would best occur alongside a rationalization of the literally hundreds of laws and institutions affecting natural resource management across the mix of private tenures, public lands and native title that make up the Australian landscape [105]. Existing arrangements are unnecessarily complex and are insufficient for enabling coordinated local innovation and action. Excessive

Box 2 Envisioning: catalysing positive change through co-creating a shared vision

Developing a shared vision — a values-rich story co-created by stakeholders describing the future they want — can play a powerful role in catalysing positive change [123]. This *envisioning* process is an example of a tool for managing change and can complement many other effective community-based natural resource management techniques.

Development of a vision has been widely used in planning for sustainability in Australian landscapes [124–126] and elsewhere [127]. However, in conventional planning, the vision typically takes the role of an end goal. This approach assumes stationarity, predictability, and linear, direct cause and effect [128]. It assumes that we can predict the outcome of specific actions, under complex and uncertain conditions, over long time frames. Such assumptions are at odds with the non-linear and non-stationary behaviour of complex adaptive social-ecological systems such as those operating in Australian landscapes [2,4,109,129].

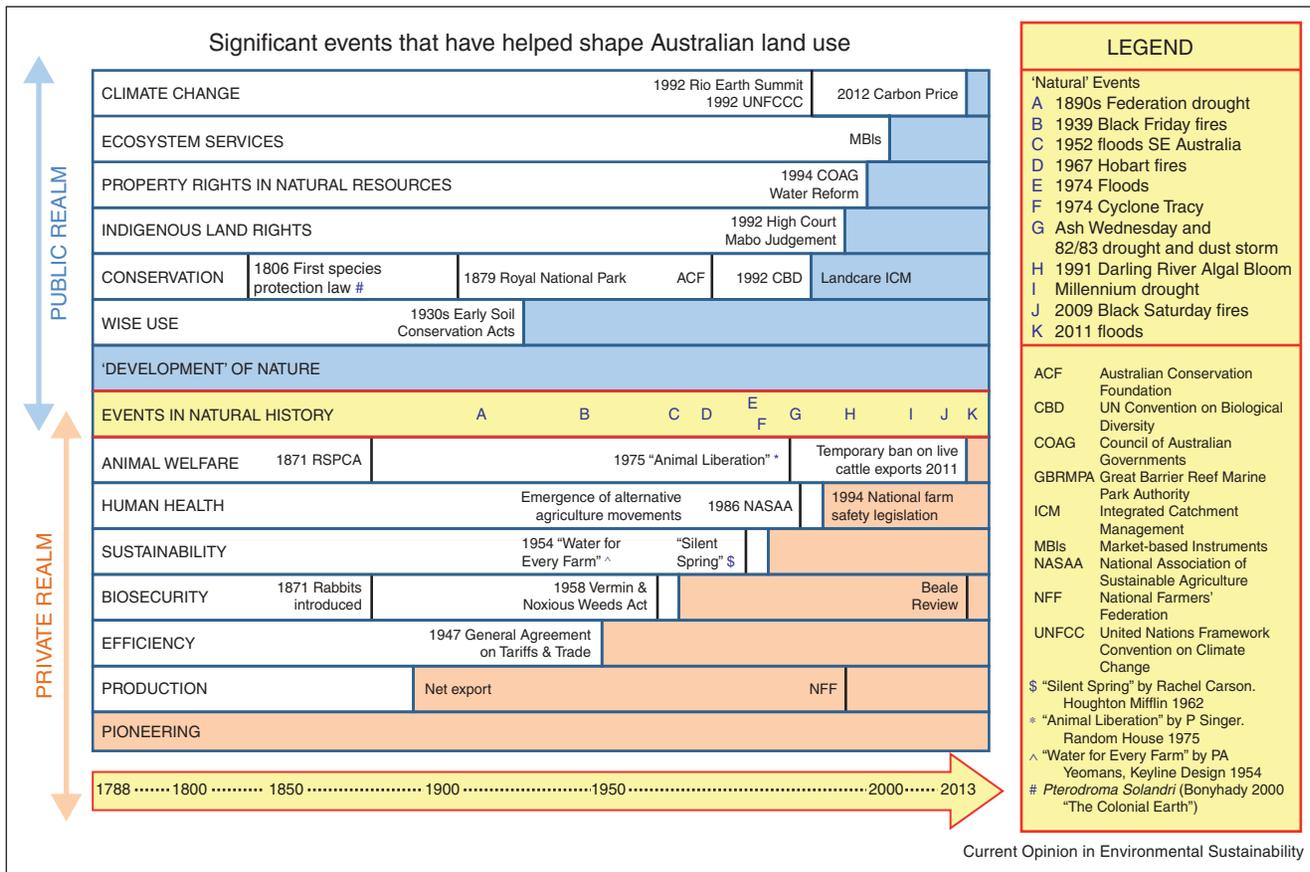
In circumstances of high complexity and uncertainty, it is not possible to predetermine the specific steps to a desired future. Rather, progress is achieved through a process of informed muddling through [130]. Co-creating a vision is an adaptive change process [131–133]. Envisioning requires conversations between people. The conversation, relatively unstructured except for a common focus on what people really want, is part of the change [134]. A vision can be used to orient action and inform the *next steps* for achieving the desired future [135]. The vision will evolve as people reprioritise their own values over time [131]. Developing a shared vision for local and regional landscapes can guide positive transformational change.

Envisioning can also help facilitate collaborative, community-based natural resource management and adaptation in other ways. It facilitates discussion of issues most important to people, and the sharing of desired futures at the level of values. Through the expression of shared values, long-term objectives, and aspirations, common ground can emerge between diverse stakeholders. A facilitated process of sharing values builds relationships. This provides a foundation for navigating uncertain futures in contested spaces where we may not always agree on the detail, but we must act nonetheless. The envisioning process, then, is much more than an end goal in a planning process to be implemented later — it is a collaborative and adaptive change and learning process. Without a shared vision, attempts at new partnerships, governance arrangements, and local adaptation will have little chance of success.

complexity provides scope for technical game-playing, thereby wasting resources and effort in non-productive transactions and creating confusion. In the interests of efficiency and fairness, Australia's system of environmental rules and their administration could be streamlined and simplified [106,107]. Governments also need to supervise the governance arrangements that will ensure the integrity of the rules, markets and administrative settings supporting natural resource management [44*].

Governance approaches are required that can cope with the complexity and uncertainty characteristic of social-ecological systems by enabling learning, adaptation, cooperation and innovation by communities [108,109]. Governance arrangements capable of coping with these conditions may need to be polycentric, multi-level and nested in structure [110*,111–115]. Effective governance

Figure 1



Representation of major defining events that have helped shape Australia’s land use since European colonization. Events reflect the evolution of societal values, attitudes, and movements.

may also need to be subsidiary—where decision-making responsibility is devolved to the lowest level that can effectively discharge it [48**] and responsibility for decision-making is only released to higher levels when the lowest level accepts that this is better [109]. This also allows for decision-making responsibility to be matched to the level and scale of the natural resource management issue. Governance institutions need to be accountable, legitimate, transparent, accountable, inclusive, fair, integrated, capable and adaptable [116**]. While Australia has adopted a devolved, regional delivery model for community-based natural resource management [49], critiques have pointed to issues such as difficulty engaging large regional constituent populations, free-riding, entrenched opposition and patchy results [48*, 117]. Regional agencies have been perceived in some cases as extensions of government [117] rather than as part of the community, reinforcing a top-down rather than bottom-up approach. There is room for substantial improvement in the natural resource governance of Australian landscapes.

Rural communities will need enough people with the freedom, skills, capacity and leadership to develop their local vision, and to implement science-informed action towards achieving it [41,118,119]. However, the cumulative burden of interacting societal expectations, economic forces and environmental change has already placed unprecedented pressure on many rural landholders and communities [58]. A greater need for effective sustainability action by communities is arising at the same time as the requirement for economic and technological innovation and transformational adaptation. In many agricultural landscapes, those expected to adapt and carry the responsibilities of production and sustainability are ageing — and there are relatively few of them to do the work [79,103] — considering the magnitude of the challenges. Effective responses to the challenges and opportunities we have outlined will require more emphasis upon decision-support and implementation resources for rural communities who are in need of assistance [e.g. [89,92,94**]].

Australia has pioneered many community, market and regulatory innovations in managing its natural resources [105]. Finding alternatives to government for funding solutions to environmental problems is urgent, given global financial uncertainty and competing demands upon the public purse. Private landholders carry a substantial burden of sustainability investment but there is a limit to that capacity, and the power of government to require investment or cooperation is also limited compared with some other countries [120]. There are many ways to achieve this including: taxation reform (e.g. taxation of resource exploitation); greater use of market, industry or voluntary instruments that rely less upon the public purse, and; user-pays models [121]. However, there are few (if any) perfect solutions. All instruments carry costs, implementation challenges and the risk of unintended outcomes. Strategies will have to become even more innovative, and engage a greater percentage of the community in effective action [89]. Australia will have to create a new fiscal model, capable of deploying significant investment, particularly from the private sector, with less reliance on government [44*]. Innovative regulatory arrangements are needed to support the integrity of markets and to build trust amongst the broader community — without which voluntary action will be impeded. Mistakes will be made [e.g. [122]], and will need to be learned from [38**].

Above we list a number of new partnerships, science, governance and institutional settings necessary for supporting adaptation and positive transformation of Australian landscapes. The reforms described have no priority or sequencing — they are all necessary and all need to occur now and in parallel. The list is not comprehensive and it is very unlikely to be sufficient to achieve transformational adaptation. Rather, these reforms are the first, most obvious steps towards creating social-ecological systems in Australian landscapes that are adaptive and resilient to the transformational drivers we have discussed, and beyond them those we cannot foresee.

Conclusion

Biophysical and economic drivers are converging that may induce a second industrial transformation of Australian landscapes. The combination of increased societal expectations of environmental stewardship and the specter of climate change require transformational adaptation. We need to adapt to our environment as it changes, and as we change, and we need to do it fast. The six emerging economies for ecosystem services — carbon, water, food, energy, amenity and mining — provide opportunities for the kind of transformation and adaptation that we need and want. These will shape how we use and conserve our unique natural capital but we need to manage the risks of trade-offs and unintended consequences. To achieve positive transformational adaptation of Australian landscapes and to provide an opportunity to thrive within environmental limits, new partnerships between

government, science, the private sector and communities are required. This is up to all Australians. Science needs to inform critical environmental limits and develop new ways of understanding the social processes underpinning transformational adaptation. Governments need to regulate environmental limits, streamline existing laws, institutions and governance, and establish and support innovative local adaptation. The private sector needs to better engage with communities, participate in new markets for ecosystem services, and reduce the reliance on government for funding environmental management. Despite being subject to unprecedented pressure already, individual landholders and communities have the responsibility of innovating and implementing evidence-based, collaborative change. These are the first steps needed on an adaptive path to sustainability in the second industrial transformation of Australian landscapes.

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