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Deforestation in Australia: drivers, trends and policy responses

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Abstract. Australia's terrestrial environment has been dramatically modified since European colonisation. Deforestation – the clearing and modification of native forest for agricultural, urban and industrial development – remains a significant threat to Australia's biodiversity. Substantial policy reform over the last 40 years has delivered a range of policy instruments aimed to control deforestation across all Australian States and Territories. Despite these policy efforts – as well as strong governance and high institutional capacity – deforestation rates in Australia were nonetheless globally significant at the turn of this century. Legislation introduced in Queensland and New South Wales during the mid-2000s was at the time seen to have effectively ended broad-scale clearing; however, recent policy changes have raised concerns that Australia may again become a global hotspot for deforestation. Here, I describe the deforestation trends, drivers and policy responses in Australia over the last four decades. Using satellite imagery of forest cover and deforestation events across Australia between 1972 and 2014, I present a comprehensive analysis of deforestation rates at a fine resolution. I discuss trends in deforestation with reference to the institutional, macroeconomic and environmental conditions that are associated with human-induced forest loss in Australia. I provide a detailed history and critique of the native vegetation policies introduced across Australia over the last 40 years, including recent legislative amendments and reviews. Finally, I comment on future prospects for curbing deforestation in Australia, including the role of incentive-based policies such as carbon farming, private land conservation and biodiversity offsets. Despite being a highly active policy space, very little is known of the effectiveness of policy responses to deforestation in Australia, and whether the recent shift away from 'command and control' policies will necessarily lead to better outcomes. My analysis demonstrates the need for an effective policy mix to curb deforestation in Australia, including a greater focus on monitoring, evaluation and policy learning.

Additional keywords: biodiversity, biodiversity offsets, conservation, carbon farming, environmental policy, environmental regulation, native vegetation, remote sensing

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Introduction

Habitat loss is recognised as a major threat to biodiversity within the Oceania region (Kingsford *et al.* 2009). Globally and within Oceania, Australia is significant for both its megadiversity (Mittermeier and Mittermeier 1997), and the extent to which its terrestrial species and ecosystems have been impacted by human activities (Mittermeier *et al.* 1999; Myers *et al.* 2000; Evans *et al.* 2011; Williams *et al.* 2011). Prior to European colonisation, ~30% of Australia's terrestrial area was covered in 'forest' (Barson *et al.* 2000; Bradshaw 2012) – defined as forest and woodland dominated by trees at least 2 m high, with at least 20% canopy cover and a minimum area of 0.2 ha (Furby 2002). Since that time, ~40% of this original forest extent has been subject to deforestation: cleared or extensively modified for agricultural, urban or industrial development (Graetz *et al.* 1995; Barson *et al.* 2000; Lindenmayer 2005; Bradshaw 2012). Much of Australia's remaining forest, shrubland, grassland and open woodland ecosystems are now degraded or fragmented (Kirkpatrick 1994; Norton 1996; Tulloch *et al.* 2015).

As a developed nation, with strong governance arrangements, a high level of institutional capacity and a relatively small population, it might be expected that deforestation in Australia should be slowing towards a 'forest transition' – the cessation and eventual reversal of forest loss (Angelsen and Kaimowitz 1999; Rudel *et al.* 2005; Lambin and Meyfroidt 2011). Yet at the turn of the 21st century, Australia's deforestation rate was the sixth highest in the world (ACF 2001; FAO 2001), and the latest statistics suggest that Australia's deforestation may again become globally significant (Department of Science, Information Technology, Innovation and the Arts 2015; Bulinski *et al.* 2016).

The environmental impacts of deforestation cannot be disputed. Clearing, modification and fragmentation of native vegetation erodes soil, contributes to salinity, and are key

drivers in the decline of woodland birds, reptiles and mammals (Saunders 1989; Norton 1996; McAlpine *et al.* 2002). Land clearing, the local term for deforestation, has been repeatedly identified as the most significant threat to terrestrial biodiversity in Australia (State of the Environment 2011 Committee 2011). Deforestation is also a major contributor to human-induced climate change. In the base year of the Kyoto Protocol (1990), greenhouse gas emissions due to deforestation in Australia equated to 132 Mt CO2-e, or 25% of the country's total emissions (Macintosh 2012; Australian Government 2013). However, deforestation in Australia is also a deeply political issue, and has been a prominent topic of debate between environmentalists, farmers and foresters over the last four decades (Lindenmayer 2014). The drivers, trends and policy responses to deforestation cannot be fully understood without reference to its institutional[1] and macroeconomic dimensions, in addition to its ecological impacts and limits.

The history of deforestation in Australia was most recently examined by Bradshaw (2012), who draws upon the first systematic nation-wide study of land cover change over 1990–95 (Barson *et al.* 2000) and the National Carbon Accounting System (NCAS) (Australian Greenhouse Office 2003) to document the trends in forest loss and degradation across Australia from European settlement up until 2005. Bartel (2008, 2004) provides the most detailed reviews of Australia's native vegetation policies to date, and highlights the importance of the use of satellite imagery to monitor deforestation and to evaluate policy effectiveness. However, significant changes have occurred in the policy landscape since the publication of Bradshaw (2012) and Bartel (2004, 2008). Legislation introduced from 2005 in the historically high-deforestation States of Queensland and New South Wales had arguably marked the end of broad-scale land clearing in Australia (McGrath 2007; Taylor and Dickman 2014). Yet since 2010, a nationwide trend towards the relaxation of native vegetation regulations may be leading to increased deforestation (Bulinski *et al.* 2016), and so an up-to-date summary of deforestation trends, drivers and policy responses is needed.

Notwithstanding the extensive commentary that exists on Australia's protected areas (Taylor *et al.* 2011; Watson *et al.* 2011), natural resource management (Lockie and Higgins 2007; Hajkowicz 2009; Robins and Kanowski 2011), and forestry policy (Norton and Mitchell 1993; Kirkpatrick 1998; Lane 1999), there has been comparatively limited examination of the policy responses to deforestation (Bartel 2003, 2004, 2008; Macintosh 2012). Although the impacts on biodiversity from the loss and degradation of native forests through commercial forestry operations are well documented (Lindenmayer 2014), deforestation due to agricultural, urban and industrial development on private land, particularly since the 1970s, has had far more widespread impacts (Barson *et al.* 2000; Australian Government 2013).

Here, I provide a comprehensive review of policy instruments aimed to control deforestation in Australia over the last four decades. I focus specifically from 1970 onwards for three reasons. First, the early history of deforestation in Australia has been covered extensively elsewhere (Rolfe 2000; Bartel 2004, 2008; Seabrook *et al.* 2006; Bradshaw 2012; Bombell and Montoya 2014), but there has been comparatively limited focus on its policy dimensions (cf. Bartel 2004, 2008), and no analysis of contemporary policy trends from 2005 onwards. Second, in the context of Australia's history since European colonisation, government regulation of deforestation is only a fairly recent phenomenon. Deforestation for agricultural development has historically been incentivised by the Federal and State governments through low-cost finance, tax concessions, cheap land and lease conditions that required the removal and management of native vegetation (Australian Greenhouse Office 2000; Australian Bureau of Statistics 2002; Seabrook *et al.* 2006). Most of these incentives were removed by the 1980s, when public concern over the environmental effects of deforestation began to rise (Council of Australian Governments 1992). Finally, nationally consistent spatial data on deforestation events developed as part of the National Carbon Accounting System (NCAS) are now available from 1972 up to 2014 (Australian Department of the Environment 2015).

I first present a comprehensive analysis of deforestation rates at a fine resolution, by analysing satellite imagery of forest cover and deforestation events across Australia between 1972 and 2014. I discuss these statistics by State, land use and land tenure. Next, I provide a detailed history and critique of native vegetation policies across Australia, including recent legislative amendments and reviews. I conclude with an analysis of policy trends with reference to the broader macroeconomic trends over the last 40 years, and comment on future prospects for curbing deforestation in Australia, including the role of a more diverse range of policy instruments.

Deforestation trends and drivers

Data analysis and methodology

I draw upon the most recent national-scale spatial data to describe deforestation trends over time (Australian Department of the Environment 2015). The Australian Government compiles fine-resolution data of land cover change as part of the NCAS (Furby 2002; Lehmann *et al.* 2013). The NCAS uses over 7000 Landsat MSS, TM and ETM+ images to map forest extent and change at a 25-m resolution across the Australian continent, excluding the treeless inland desert areas and grasslands. Note that these spatial data exclude native vegetation types which do not meet the height, canopy cover and area thresholds of 'forest' as defined by Furby (2002), meaning that the loss of grassland, shrubland and open woodland is not captured by this analysis. While I discuss deforestation trends specifically with reference to data on forest extent and change, I refer to the policy responses to deforestation as 'native vegetation policies', which recognises that clearing of non-forest vegetation is often (but not always) regulated in addition to the clearing of forest.

Data on forest extent and change are available for 23 epochs (instances in time) from 1972 to 2014 in the intensive-land-use

[1]Institutions incorporate formal (laws, property rights) and informal (traditions, cultural and social norms) rules (North 1991). In this paper I focus on formal institutions, though recognise that cultural factors are also important drivers of deforestation behaviour (Australian Greenhouse Office 2000; Bartel and Barclay 2011).

zone only (Graetz *et al.* 1995), where most landscape modification has occurred. Forest change events were attributed to human intervention, meaning that 'natural' forest change attributable to factors such as fire (and associated recovery), dieback, salinisation, drought and seasonal flushing were removed (Furby 2002). Prior to 2004, annual data on deforestation events are not available within the NCAS, and are instead captured within multiyear epochs. For example, the 1972 epoch contains deforestation events over a five-year period from 1972 to 1977. Following expert advice (Australian Department of the Environment 2015; S. Reddy, pers. comm.), I converted deforestation events contained within the 23 epochs into annual values over 43 years from 1972 to 2014. Further details are provided in the Supplementary Material, available online.

The amount of arable land available to clear has been highlighted previously as an important factor influencing deforestation behaviour (Australian Greenhouse Office 2000; Bartel 2004, 2008). In particular, Bartel (2004) suggests that native vegetation policies introduced in South Australia in the 1980s may have had little effect simply because there was scarce primary (remnant) forest remaining on land suitable for agricultural development. As such, an exploration of deforestation trends in the context of the amount of primary forest remaining intact is warranted. To derive an estimate of the amount of primary forest remaining over time, I assume that the forest extent in 1972 (the earliest epoch in the dataset) is all primary forest. I then deduct the primary deforestation events each year from the remaining primary forest extent from the previous year. This calculation resulted in an estimate of primary forest remaining from 1972 to 2014. I derive an estimate of deforestation occurring on reforested land (regrowth deforestation) by considering deforestation events that occurred on land classified as non-forest in 1972, as well as land that was deforested, and subsequently reforested and deforested again over the 1972–2014 period. In reality, much of the forest extent in 1972 would in fact be regrowth forest, so the results I present here should be considered in the context of this simplifying assumption. While the total amount of deforestation would be unaffected by this assumption, the primary deforestation statistics should be regarded as an overestimate, and the regrowth deforestation as an underestimate.

I use the most recent national datasets (Geoscience Australia 1993; ABARES 2010) to summarise deforestation trends by land use and tenure. Note that land use and tenure data are not available over the full time series, so these summaries should therefore be considered only as an estimate. I use the 'raster' package (Hijmans and van Etten 2014) in R Statistical software (R Development Core Team 2014) for all raster processing.

Trends in deforestation

From 1972 to 2014, over 7.2 million ha of primary forest was cleared across Australia. The total land forested in 1972 was 101 million ha, hence the primary deforestation that has occurred up to 2014 represents a 7% reduction in this extent. An additional 9.5 million ha of regrowth forest were cleared over this period (Fig. 1). Most of this deforestation has occurred in Queensland, where 9.7 million ha of forest has been cleared, of which 3.6 million was primary deforestation.

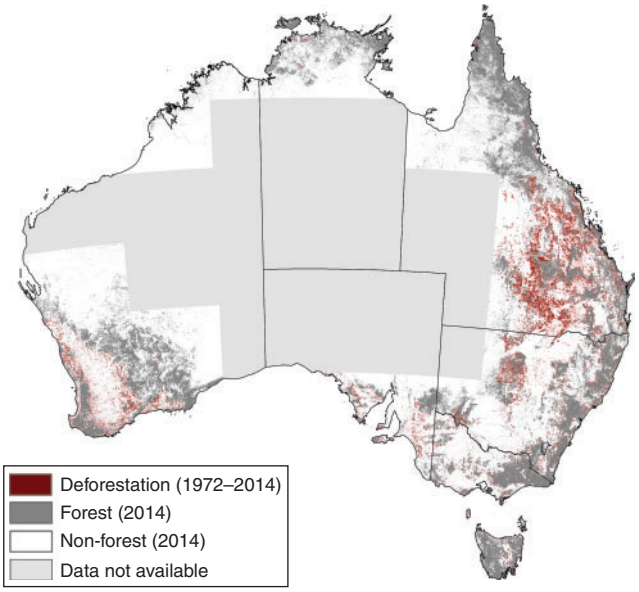

Fig. 1. Distribution of total deforestation events (including primary and regrowth deforestation) attributed to human intervention from 1972 to 2014. Forest change attributable to 'natural' factors such as fire, dieback, salinisation, drought and seasonal flushing is not shown. Data are sourced from the National Carbon Accounting System (NCAS) (Australian Department of the Environment 2015).

The greatest overall deforestation occurred in the decade of 1980–89, where close to 4.7 million ha of native vegetation (including 2.4 M ha of regrowth) was cleared across the country (Fig. 2). Total deforestation has declined in the following decades; however, regrowth deforestation increased again in the 2000s, during which time Queensland cleared 1.5 M ha of regrowth vegetation. The rate of primary deforestation has still substantially decreased since the 1970s, when extensive tracts of forest in south-western Western Australia and Queensland were cleared for agricultural development (Graetz *et al.* 1995; Barson *et al.* 2000).

As indicated by Fig. 3*a*, most deforestation has occurred for pasture, with much smaller percentages for cropping, forestry, urban development and mining. A surprisingly high percentage of clearing occurred in conservation areas and minimal-use areas; however, this may not be an accurate representation and should be regarded as an estimate only, given the use of the 2005–06 land-use layer (ABARES 2010). Only a small percentage of deforestation has occurred on public land (2%: Fig. 3*b*), with the remainder occurring on freehold (78% over 1972–2014) and leasehold (20%) land. Deforestation has occurred disproportionally on freehold land, relative to the percentage of total land mass held in this tenure (31%: Geoscience Australia 1993).

Relative to the amount of primary forest remaining, there has generally been a decline in primary deforestation in each State over time (Fig. 4), although an increase in the rate of deforestation can be seen in several states in the early 1990s and early–mid 2000s. At the national scale, there is an overall declining trend in deforestation, and a link to the amount of primary forest remaining to clear is also apparent (Figs 5*a*, *b*).

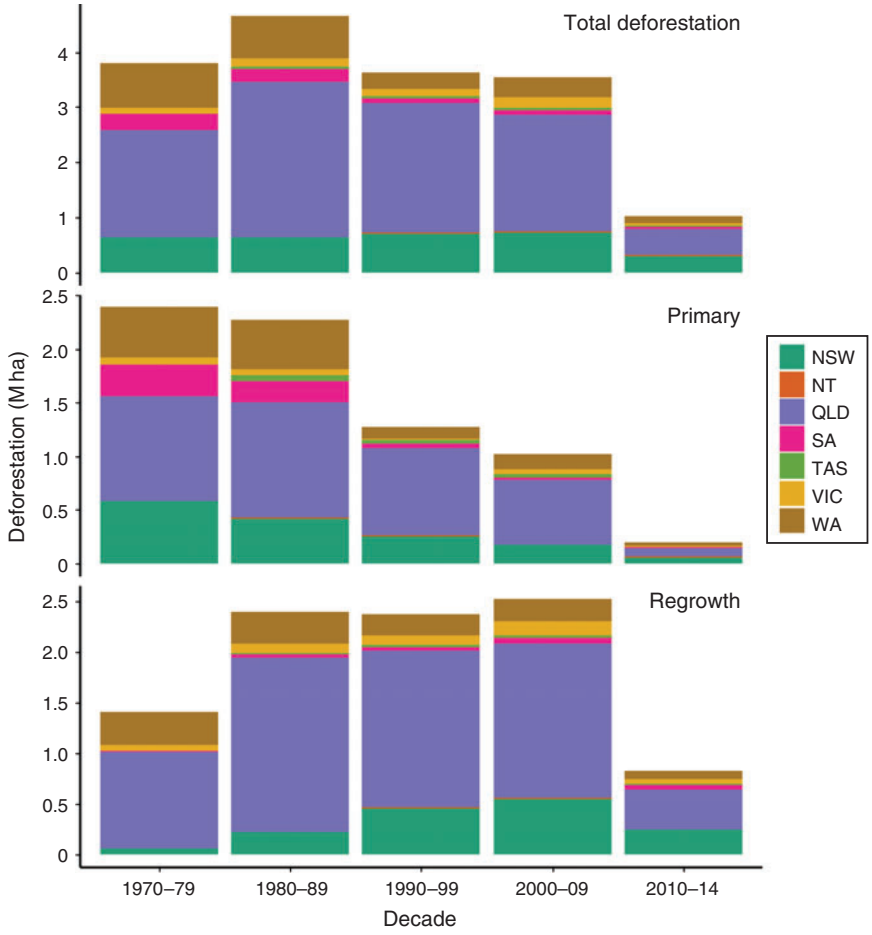

Fig. 2. Amount of deforestation (total, primary and regrowth) per decade, during 1972–2014, for all Australian states and territories (excluding Australian Capital Territory).

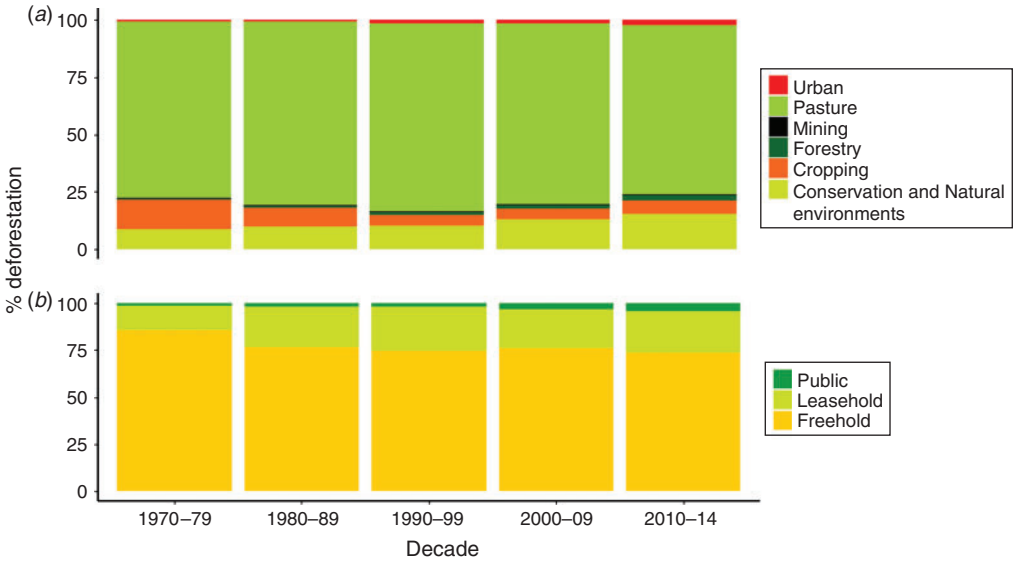

Fig. 3. Percentage of total deforestation in each decade, by (*a*) land use (as of 2005–06, above) and (*b*) land tenure (as of 1993, below). Data are sourced from ABARES (2010) and Geoscience Australia (1993), respectively.

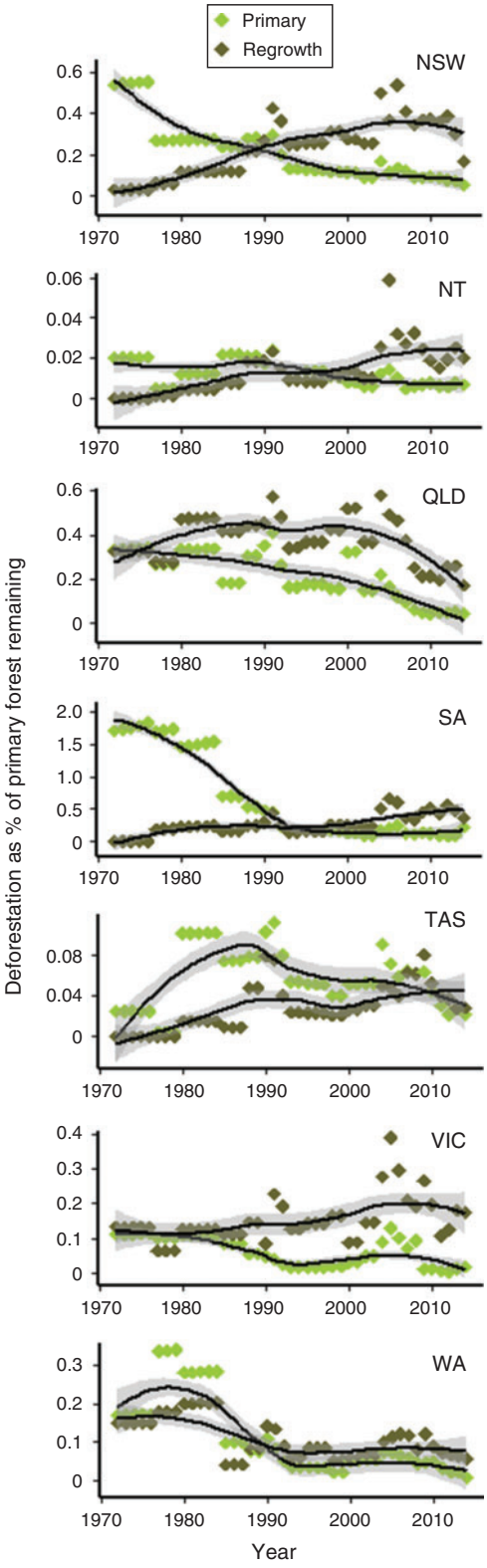

Fig. 4. Deforestation as a percentage of primary forest remaining, with separate Loess (local regression: Cleveland and Devlin 1988) curves for primary and regrowth deforestation, for all Australian States and Territories (excluding Australian Capital Territory). Grey shading indicates a 95% confidence interval around the Loess curve.

There appears to be some relationships between deforestation in Australia over time and key macroeconomic and climatic variables (Fig. 5), though this requires further analysis to confidently attribute any change in these variables to the rate of deforestation. Similarly, a rigorous quantitative evaluation is needed to reliably establish what effect the introduction of native vegetation policies over the past four decades has had on deforestation in Australia.

A history of native vegetation policy in Australia

Deforestation is mainly regulated at the State level in Australia (Bricknell 2010). Land clearing has been listed as a Key Threatening Process under the Federal Government's *Environmental Protection and Biodiversity Conservation Act (1999)* (EPBC Act) since 2001 (Department of the Environment 2001; Lindenmayer 2005). The Federal Government has limited jurisdiction over State environmental matters unless there are impacts on Matters of National Environmental Significance such as a threatened species or ecological communities, or activities on Commonwealth land (Peel and Godden 2005). This means that vegetation communities generally receive no federal protection until they have already been extensively cleared (Tulloch *et al.* 2015).

Nonetheless, several attempts have been made to deliver a coordinated, national approach to the management of native vegetation. Since 1997, various commitments to address the decline in native vegetation have been made through nationally funded programs and frameworks (Natural Resource Management Ministerial Council 2001). The Natural Heritage Trust funding package aimed to deliver no net loss of native vegetation within Australia by July 2001. This goal was not met (Beeton *et al.* 2006). The most current framework outlines a target for a net national increase in native vegetation extent and connectivity by 2020 (COAG Standing Council on Environment and Water 2012). This framework, like others before it, is not prescriptive or binding.

The current environmental offsets policy under the EPBC Act aims to compensate for significant impacts on Matters of National Environmental Significance relative to a 'business as usual' baseline (Australian Government 2012; Maron *et al.* 2013*b*), which as described by Maron *et al.* (2015) is one of ongoing biodiversity decline. Although not directly related to native vegetation policy and management in the State jurisdiction, the declining baseline assumed by the national environmental offsets policy suggests that the national target of a net increase in native vegetation is not expected to be met.

Protected areas can play a key role in reducing deforestation if genuine averted losses can be secured, and deforestation is not simply displaced elsewhere (Andam *et al.* 2008; Miteva *et al.* 2012; Pressey *et al.* 2015). Australia's National Reserve System is focussed primarily on meeting goals for the conservation of biodiversity (NRMMC 2009; Watson *et al.* 2011), and it is not known whether the system as a whole has had an impact on deforestation in Australia. However, Pressey *et al.* (2002) demonstrated that protected areas in New South Wales are biased towards steep and infertile public land, rather than on privately managed land where deforestation is generally higher. State-level policies designed to regulate deforestation on private

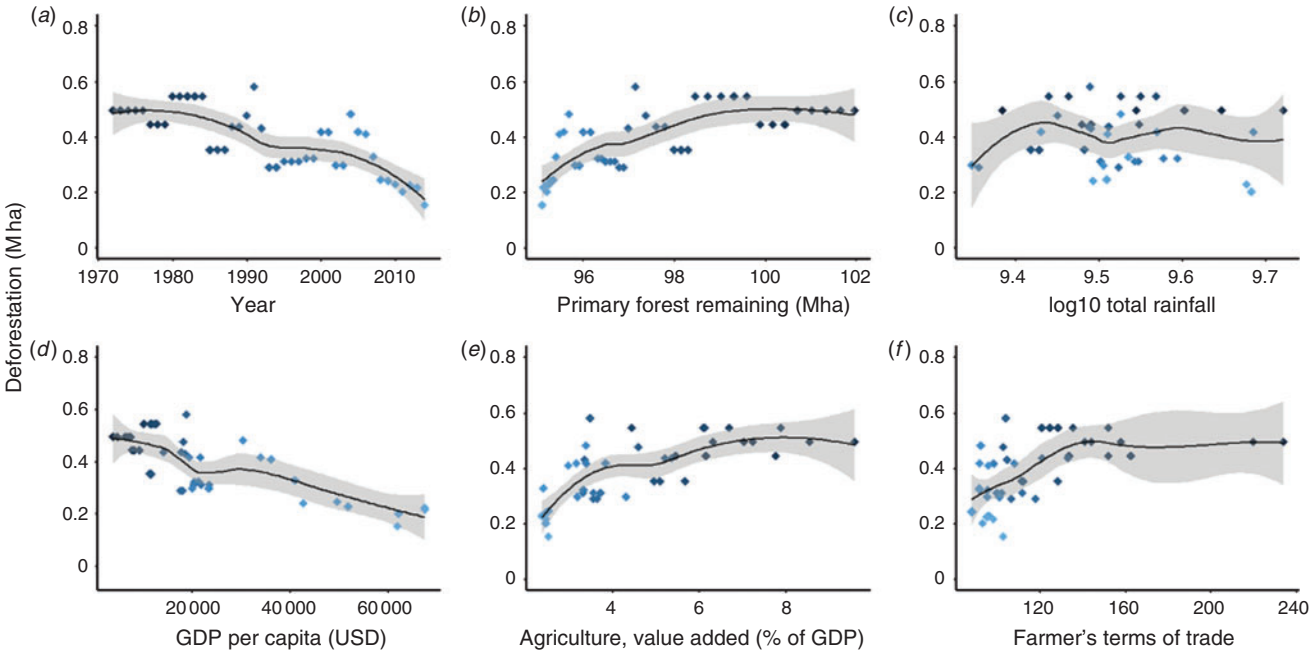

Fig. 5. Trends in national-scale deforestation and key macroeconomic variables. Data points area shaded by year (1972: dark blue, to 2014: light blue). A Loess curve is fitted to each plot and grey shading indicates a 95% confidence interval. Plots are total deforestation versus: (*a*) year; (*b*) extent of primary forest remaining; (*c*) log-transformed total rainfall (Evans 2014); (*d*) gross domestic product per capita (current USD) (The World Bank 2015); (*e*) agriculture, value added (% total GDP; value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs) (The World Bank 2015); (*f*) farmer's terms of trade (ABARES 2015).

(freehold and leasehold) land are therefore the main focus of this paper.

For the remainder of the paper, I focus primarily on policy reforms that have occurred in the historically high-deforestation states of Queensland, New South Wales, Western Australia, South Australia and Victoria. Most clearing for agriculture in Tasmania occurred during the 1970s and 1980s (Kirkpatrick 1991), and was not regulated until 2002 when the *Forest Practices Act 1985* was amended to prohibit non-commercial clearing of forest for agricultural purposes (Bricknell 2010). Limited deforestation has occurred in the Northern Territory, as its rangelands are generally suitable for grazing in their natural state (Australian Greenhouse Office 2000). Controls were introduced in 2002 under the *Planning Act 1999* and *Pastoral Land Act 1992*. With a total area of 2358 km^2, deforestation in the Australian Capital Territory is insignificant relative to other Australian jurisdictions, and policies dealing specifically with native vegetation have only recently been introduced (Bricknell 2010).

In the following section, I describe how policy responses to deforestation have evolved in all Australian jurisdictions over the last four decades. I also provide a comprehensive summary of major native vegetation policies implemented at the Federal, State and Territory levels from 1970 to 2016 in Tables 1–4.

The beginnings of reform: 1970–89

The beginnings of policy reform occurred in South Australia, which by 1975 had cleared 75% of the native vegetation within its agricultural zone (nearly 20% of the total State area: Australian Greenhouse Office 2000; Bartel 2004). The State's first policy effort in 1980 aimed to provide incentives for the retention of native vegetation on private property via legally binding agreements. Heritage Agreements were the first example of conservation covenants in Australia (Bartel 2004), and provided financial assistance to cover land, fencing and management costs, but did not compensate for the opportunity costs of agricultural production. Landholders who engaged with Heritage Agreements were those who held conservation-oriented values, whereas the policy did little to change the behaviour of landholders who were clearing extensively (Harris 2013). Once it became clear that Heritage Agreements had failed to reduce deforestation, the State's first clearing controls were attached to the *Planning Act 1982*, which also included an extensive compensation scheme. In 1983, the requirement under the *Crown Lands Act 1929* to clear vegetation as a condition of lease was removed (Australian Greenhouse Office 2000). With the introduction of the *Native Vegetation Management Act (NVMA) 1985*, South Australia became the first State in Australia to restrict the clearing of native vegetation on private property (Table 1) (Bartel 2004). The introduction of the *Native Vegetation Act (NVA) 1991* removed the compensation arrangements that were part of the NVMA 1985. Clearing permits are granted under the NVA 1991 on the condition of vegetation being compensated elsewhere, making South Australia arguably the first State to adopt environmental offsetting. Despite being an early adopter of native vegetation policies, South Australia may be an example of a State where

Table 1. Major native vegetation policies over 1970–89

Jurisdiction	Year	Policy name	Policy intent	Instrument type (Gunningham and Sinclair 1999*a*)	Details	Source
South Australia	1980	Heritage Agreements under the *South Australian Heritage Act 1978*	To maintain or improve native vegetation with high conservation value on private land	Voluntarism, economic	Legally binding agreements between the Crown and individual (current and future) landholders. Financial incentives provided to cover fencing costs, management assistance and advice; State and Local Government land charges are waived.	Harris 2013; Slee 1998
	1983	Development Control Regulations under the *Planning Act (PA) 1982*	To curb native vegetation clearance	Command and control	Prescribed vegetation clearance as a class of development that required consent of the South Australian Planning Commission. Applied to clearing for agricultural purposes and commercial harvesting.	Harris 2013;
	1985	*Native Vegetation Act (NVA) 1985*	To curb native vegetation clearance	Command and control, economic	Clearing controls removed from *PA 1982* and placed under *NVA 1985*. Compensation is paid to those refused clearing approval, and offered financial assistance to landholders prepared to enter a Heritage Agreement to protect remnant native vegetation.	AGO 2000; Harris 2013; Slee 1998
Western Australia	1978	*Country Areas Water Supply Act (CAWSA), Part IIA, 1976*	To protect quality of water supply from salinity	Command and control	Vegetation clearance controlled in six south-western catchments (~5% of rural parts of the State).	Slee 1998
	1986	*Soil and Land Conservation Act (SALCA)1945*	Conservation of soil and land resources, and mitigation of the effects of erosion, salinity and flooding	Command and control	In 1986, it became a requirement under the *SALCA 1945* to obtain a notice of intention to clear for areas of 1 ha or more.	Bennett 2002; Slee 1998
Victoria	1989	Amendment S16 to the *State Section of the Planning Scheme (SSPS)* under the *Planning and Environment Act 1989*	Nature conservation and land management (soil, watercourses, greenhouse carbon loads, groundwater, dryland salinity control) ***End of broad-scale clearing in Victoria***	Command and control	Planning permits are required to remove, destroy or lop native vegetation. Applied statewide to freehold, leasehold, Crown land (except Crown land used for forestry, and national parks). The Act specifically rules out the payment of compensation.	Slee 1998

Table 2. Major native vegetation policies over 1990–99

Jurisdiction	Year	Policy name	Policy intent	Instrument type (Gunningham and Sinclair 1999*a*)	Details	Source
Commonwealth	1999	*Environmental Protection and Biodiversity Conservation Act (1999)*	Protection of matters of national environmental significance	Command and control	Limited remit over vegetation clearance, only if 'significant impact'.	
South Australia	1991	*Native Vegetation Act (NVA) 1991*	To retain native vegetation. ***End of broad-scale clearing in South Australia***	Command and control	End of compensation payments under *NVA 1988*. Applies to freehold and leasehold land, with exception of certain urban areas.	Harris 2013; Slee 1998
New South Wales	1995	*State Environmental Planning Policy (SEPP) No. 46* under the *Environmental Planning and Assessment (EPandA) Act 1979*	To prevent inappropriate native vegetation clearance	Command and control	Clearing of native vegetation (>2 ha per annum) prohibited except with development consent of the Director-General of the Department of Land and Water Conservation (DLWC) and National Parks and Wildlife Service (NPWS)	Bombell and Montoya 2014; Slee 1998
	1998	*Native Vegetation Conservation Act (NVCA) 1997*	Conservation and management of native vegetation in in accordance with the principles of ecologically sustainable development	Command and control, economic	Brought all the clearing of all native vegetation in NSW under one regulatory regime (including leasehold land in Western Division). Regional vegetation management plan specified where clearing could occur. Provided some financial incentives for landholders to protect native vegetation.	Bombell and Montoya 2014; Smith 1999
Queensland	1995	*Land Act 1994*	Sustainable resource use and development	Command and control	Control of vegetation clearing on leasehold and State lands.	AGO 2000; Slee 1998
Victoria	1997	Victoria's Biodiversity Strategy 1997	Biodiversity conservation	Voluntarism, information	State-wide target of 'no net loss' of native vegetation by 2001 (baseline 1999). 'Net gain' target from 2002.	Department of Natural Resources and Environment 1997

Table 3. Major native vegetation policies over 2000–09

Jurisdiction	Year	Policy name	Policy intent	Instrument type (Gunningham and Sinclair 1999*a*)	Details	Source
Commonwealth	2001	National Framework for the Management and Monitoring of Australia's Native Vegetation	To reverse the long-term decline in the quality and extent of Australia's native vegetation cover by June 2001	Voluntarism, information	Provided the framework for the implementation of the Natural Heritage Trust Partnership Agreement between the Commonwealth and the State and Territory Governments.	Natural Resource Management Ministerial Council 2001
South Australia	2002	*Native Vegetation Act (NVA) 1991*	Permitted clearing conditional on achieving 'significant environmental benefits'	Command and control, economic	Landholders could apply for financial assistance for delivering 'significant environmental benefits', enter into a Heritage Agreement or pay into a Native Vegetation Fund.	South Australian Government 2002; Bricknell 2010
New South Wales	2005	Native Vegetation Regulation 2005 under the *Native Vegetation Act (NVA)2003*	To end broad-scale clearing except where the clearing will improve or maintain environmental outcomes ***End of broad-scale clearing in New South Wales***	Command and control, economic	Permits required to clear vegetation, granted on condition of improving or maintaining environmental outcomes. Approval not required to clear regrowth vegetation or for routine agricultural activities.	Productivity Commission 2004
	2008	BioBanking under *Threatened Species Conservation (Biodiversity Banking) Regulation 2007*	To address the loss of biodiversity values from habitat degradation	Economic	Created a market where biodiversity credits could be bought and sold.	Department of Environment and Climate Change 2007; Gibbons *et al.* 2009
Queensland	2000	*Vegetation Management Act 1999*	To preserve endangered ecosystems, prevent land degradation, maintain biodiversity	Command and control	Regulates the clearing of vegetation on freehold land. Clearing of regrowth vegetation still allowed.	Kehoe 2009; McGrath 2007
	2003	*Vegetation (Applications for Clearing) Act 2003*	To restrict vegetation clearing	Command and control	Imposed a moratorium on applications to clear remnant vegetation on freehold and leasehold land.	McGrath 2007
	2004	*Vegetation Management and Other Legislation Bill 2004*		Command and control		Kehoe 2009; McGrath 2007
	2006	*Vegetation Management and Other Legislation Bill 2004*	To end broad-scale clearing of remnant vegetation. ***End of broad-scale clearing in Queensland***	Command and control	A ballot for clearing of 500 000 ha was held in September 2004. All clearing permits issued under the ballot expired on 31 December 2006. Development applications guided by *State Policy for Vegetation Management* (2006). Provided $150 million of financial assistance over five years.	Giskes 2004; McGrath 2007

	2008	Queensland Government Environmental Offsets Policy (QGEOP) incorporating the Policy for Vegetation Management Offsets (2007)	To counterbalance unavoidable, negative environmental impacts that result from a development.	Command and control, economic	A vegetation management offset may be secured to meet the performance requirements of a Regional Vegetation Management Code under the *Vegetation Management Act 1999*. Proponents may directly secure and manage an offset, engage a third party, or pay into an offset fund.	Environmental Protection Agency 2008
	2009	*Vegetation Management and Other Legislation Amendment Act 2009*	To regulate clearing of regrowth vegetation	Command and control	Amendments to the *VMA 1999* to protect 'high value regrowth'.	Taylor 2015
Victoria	2003	Victoria's Native Vegetation Management – A Framework for Action (2002)	To achieve a state-wide Net Gain in the extent and quality of native vegetation	Command and control, information	Given regulatory force in 2003 when changes were made to the Victoria Planning Provisions (VPP). Framework must be considered when assessing proposals to clear vegetation.	Department of Sustainability and Environment 2010
	2006	BushBroker	To facilitate achievement of state-wide Net Gain target	Economic	Created a market where native vegetation credits could be bought and sold.	Nemes *et al.* 2008; O'Connor 2009; Stoneham *et al.* 2003
Western Australia	2004	Environmental Protection (Clearing of Native Vegetation) Regulations 2004 under the *Environmental Protection Act 1986*	Conservation, preservation, protection, enhancement and management of the environment	Command and control	Amendments introduced provisions for regulating the clearing of native vegetation on all land in Western Australia via a permit system. Approval conditions may include establishing a vegetation offset or contribution to an offset fund.	Squelch 2007
	2006	Environmental Offsets Position Statement no. 9	To achieve a 'net environmental benefit' from new developments	Command and control, economic	Formalised offsetting provisions in Western Australia after being considered on an *ad hoc* basis since at least 2000.	Environmental Protection Authority 2006, 2008; Hayes and Morrison-Saunders 2007
Tasmania	2002	*Forest Practices Act 1985*	To regulate non-commercial clearing	Command and control	Amendments in 2002 prohibit non-commercial clearing of forest for agricultural purposes.	Bartel 2004; Bricknell 2010
Northern Territory	2002	Land clearing guidelines 2002 under the *Planning Act (PA) 1999* and *Pastoral Land Act (PLA) 1992*	To minimise the impact of land clearing on natural resources	Command and control	Clearing on freehold, Crown and indigenous land regulated by *PA 1999*, where landholders are required to obtain a permit to clear more than 1 ha of native vegetation. Consent required to clear on pastoral land under the *PLA 1992*.	Department of Natural Resources, Environment and the Arts 2005

Table 4. Major native vegetation policies over 2010–16

Jurisdiction	Year	Policy name	Policy intent	Instrument type (Gunningham and Sinclair 1999*a*)	Details	Source
Commonwealth	2012	Australia's Native Vegetation Framework	To deliver a net national increase in native vegetation extent and connectivity by 2020	Voluntarism, information	Framework to guide actions across government strategies, policies, legislation and programs related to native vegetation management.	COAG Standing Council on Environment and Water 2012
	2012	*EPBC Act Environmental Offsets Policy*	To maintain or improve viability of matters of national environmental significance	Command and control, economic	Limited remit over vegetation clearance, but relevant as assumed baseline trajectory of biodiversity decline runs counter to goal of 2012 Native Vegetation Framework.	Australian Government 2012
New South Wales	2013	Native Vegetation Regulation 2013 under the *NVA 2003*	To deliver a balanced regime of environmental protection and efficient agricultural management	Self-regulation, information	Self-assessable codes to be made for certain common clearing activities without the need for a permit.	Byron *et al.* 2014; Lane 2013; Stoner and Parker 2013
	2014	NSW biodiversity offsets policy for major projects	To achieving long-term conservation outcomes while enabling development	Command and control, economic	Currently applies only to State significant development and infrastructure, but recommended for expansion to all development activities by Byron *et al.* 2014.	Byron *et al.* 2014
Queensland	2011	Queensland Biodiversity Offset Policy (Version 1)	To ensure that there is no net loss of biodiversity	Command and control, economic	Offsets may be provided directly, through a third party, or as a payment to a trust fund.	Department of Environment and Resource Management 2011
	2012	Vegetation Management Regulation 2012 under the *Vegetation Management Framework Amendment Act 2013*	To reduce red tape and regulatory burden, simplify vegetation management framework, and maintain sustainable vegetation clearing practices to protect native vegetation	Self-regulation, information	Introduced a series of self-assessable codes for vegetation clearing, removed regulations on 'high value' regrowth clearing, introduced permitted clearing for necessary environmental clearing, high and irrigated high value agricultural clearing.	Taylor 2013, 2015
	2014	Queensland Environmental Offset Policy Version 1.0 and Version 1.1 under the Environmental Offsets Regulation 2014 and *Environmental Offsets Act 2014*	To counterbalance significant residual impacts on matters of National, State or local environmental significance	Command and control, economic	Offsets may be provided directly, through a third-party, or as a financial settlement.	Department of Environment and Heritage Protection 2014

	2016	*Vegetation Management (Reinstatement) and Other Legislation Amendment Bill 2016*	To reduce deforestation rates and consequential carbon emissions	Command and control	If passed, the Bill would reinstate the *Vegetation Management Act 1999* as per the 2009 amendments. The protection of high-value regrowth would be extended to three additional Great Barrier Reef catchments, and environmental offsetting would be required for all residual impacts on prescribed environmental matters rather than only significant residual impacts.	State of Queensland 2016
Victoria	2013	Permitted clearing of native vegetation – Biodiversity assessment guidelines (2013)	To improve and strengthen the regulatory system to deliver better outcomes for the environment and the community	Self-regulation, command and control, information	Replaces 'Victoria's Native Vegetation – A Framework for Action' as incorporated document in the Victoria Planning Provisions (VPP). Permit required to clear vegetation only where there is a 'high risk' to biodiversity.	Department of Environment and Primary Industries 2013*a*, 2013*b*
South Australia	2013	*Native Vegetation (Miscellaneous) Amendment Act 2013*	To deliver more flexible arrangements for managing native vegetation	Command and control, economic	Amendments to the NVA 2011 to introduce the Third Party Significant Environmental Benefit Offsets Scheme.	South Australian Government 2002
Western Australia	2011	WA Environmental Offsets Policy	To ensure that economic and social development may occur while supporting long-term environmental and conservation values	Command and control, economic	'Like for like' no longer required, offset must be 'proportionate' to the significance of the environmental value being impacted.	Western Australian Government 2011
	2013	Environmental Protection (Clearing of Native Vegetation) Regulations 2004 under the *Environmental Protection Act 1986*	To reduce unnecessary regulatory burden without compromising significant environmental values	Command and control	Amendment in 2013 allows landholders to clear up to 5 ha per year on individual properties, and maintain cleared areas for pasture for up to 20 years without requiring a permit.	Department of Environment Regulation 2014

deforestation rates have declined simply because there was little land left to clear (Bartel 2004; Fig. 4).

Early policies in Western Australia were focussed on soil conservation and the control of salinity (Table 1) (Australian Greenhouse Office 2000). Statewide controls on the rate and extent of clearing were introduced in 1986 under the *Soil and Land Conservation Act (SALCA) 1942*, which required landholders to obtain a permit to clear 1 ha or more of native vegetation (Slee 1998). In Queensland, deforestation was still strongly encouraged by Government. Concerns were raised by scientists in the early 1980s about the extent of vegetation loss in the Brigalow Belt regions and its impacts on biodiversity, but this had little effect on the rate of deforestation (Bailey 1984; Seabrook *et al.* 2006).

In 1989, the Victorian Native Vegetation Retention (NVR) controls under the *Planning and Environment Act 1987* introduced the requirement that landholders acquire a permit to remove, destroy or lop native vegetation. This arguably marked the end to broad-scale clearing in Victoria (Department of Natural Resources and Environment 2002).

High rates of loss: 1990–99

In response to rising public concern about environmental degradation and biodiversity loss (Council of Australian Governments 1992), several State governments initiated major policy reforms to control deforestation (Table 2). In 1995, the Queensland *Land Act 1994* was introduced to control vegetation clearing on leasehold and State land (Rolfe 2000). At this time, clearing on freehold land was still regulated by local governments under the *Local Government Act (LGA) 1993* and the *Planning and Environment Act 1990* (Slee 1998).

Controls were also implemented in 1995 in New South Wales, with the introduction of the *State Environmental Planning Policy no. 46* (SEPP 46). The SEPP 46 aimed to 'prevent inappropriate native vegetation clearance and to ensure that native vegetation is managed in the environmental, social and economic interests of the State' (Slee 1998; Bombell and Montoya 2014). SEPP 46 was soon replaced by the *Native Vegetation Conservation Act (NVCA) 1997*, which came into force in 1998. Under the NVCA, landholders were required to gain approval to clear native vegetation (Productivity Commission 2004). In 1997, the Victorian government announced a Statewide target of 'no net loss' of native vegetation by 2000 as part of the State's biodiversity strategy (Department of Natural Resources and Environment 1997).

Despite these reforms, deforestation rates remained high (Fig. 3). In 1999, the Queensland and New South Wales governments permitted the clearing of over 730 000 ha of native vegetation (Australian State of the Environment Committee 2001; Lindenmayer 2005).

A decade of reform: 2000–09

The high rates of deforestation seen in Queensland continued well into the 2000s. Regulations on vegetation clearing on freehold land came into force under the *Vegetation Management Act (VMA) 1999* in 2000. However, the deforestation rate increased after the introduction of the VMA to 528 000 ha $year^{-1}$ over 2001–03 (Department of Natural Resources and Mines 2005). It was not until 2006 that amendments to the VMA phased out broad-scale clearing of remnant vegetation. A moratorium on clearing applications in May 2003 signalled the Government's intention to end broad-scale clearing of vegetation by 2006 (McGrath 2007; Kehoe 2009). This policy change has been credited with the national drop in deforestation from 2007 onwards (ABARES 2014). An offsets policy was released in 2007 to assist proponents in meeting requirements under the amended VMA, which was incorporated into a broader environmental offsets policy in the following year (Environmental Protection Agency 2008). Further amendments to the VMA came into force in 2009, which created protection for 'high value' regrowth (vegetation not cleared since 31 December 1989) in 'priority' Great Barrier Reef catchments (Macintosh 2012) (Table 3), after a temporary moratorium earlier in that year.

In 2005, the New South Wales *Native Vegetation Act (NVA) 2003* came into force, which prohibited clearing vegetation unless it could be demonstrated that it would 'improve or maintain environmental outcomes' (Gibbons and Lindenmayer 2007). An offset policy was formalised in 2008 with the introduction of the BioBanking scheme, which aimed to create a market for vegetation offsets in New South Wales (Gibbons *et al.* 2009). The NVA 2003 has been credited with the dramatic decline in approved clearing in New South Wales after 2005 (Taylor and Dickman 2014). However, exempted and illegal clearing likely still occurred at a high rate (Bricknell 2010; Gibbons 2012) although these statistics are not publicly reported (Taylor and Dickman 2014). A statutory review of the NVA 2003 in 2009 concluded that the Act remained valid and that no fundamental changes were necessary, though some stakeholders expressed concerns about lack of flexibility in restrictions, policy overlap and complexity, and the level of Government enforcement (Department of Environment, Climate Change and Water NSW 2009; Bombell and Montoya 2014).

Victoria revised its Statewide 'no net loss' goal in 2003 with the introduction of the Victorian Native Vegetation Management Framework, which aimed to achieve a Statewide net gain in vegetation extent and quality (Department of Natural Resources and Environment 2002). However, the objective for 'permitted clearing' on private land was still to achieve a 'no net loss' (Department of Sustainability and Environment 2012). Subsequent evaluations have indicated that neither the Statewide nor permitted clearing goals have been met (Dart and Grossek 2007; Department of Sustainability and Environment 2008). Amendments in 2006 to the Victoria Planning Provisions (VPP) aimed to simplify the permitting process for local councils and to provide consistency across the State (Department of Sustainability and Environment 2010). The BushTender and BushBroker programs were initiated in 2007 to provide landholders opportunities to sell and purchase vegetation credits, respectively (Stoneham *et al.* 2003; Nemes *et al.* 2008; O'Connor 2009).

Reforms also occurred in Western Australia, with the amendment of the *Environmental Protection Act 1986* (WA) to provide stricter and more consistent controls for clearing native vegetation across the State (Squelch 2007). The Western Australian government also formalised an environmental offset policy in 2006 after releasing several guidance and position statements in the preceding years (Hayes and Morrison-Saunders 2007).

The decade of reform saw the introduction of significant controls on deforestation in Queensland and New South Wales, and ambitious commitments in Victoria. Primary deforestation was substantially reduced across the country (Fig. 2), and many heralded this time as the end of land clearing in Australia (McGrath 2007; Squelch 2007; The Wilderness Society 2007). However, landholders have generally been opposed to top-down regulation (Australian Greenhouse Office 2000; Bartel and Barclay 2011), and concerns about policy duplication, inconsistencies and inefficiencies became more prominent over time (Productivity Commission 2004).

Contemporary policy responses: 2010–16

While the previous decade was marked by increasingly tight restrictions on deforestation across Australia, policy responses from 2010 have followed a trend of relaxing these controls (Table 4).

In 2011, the newly elected government of New South Wales announced a statutory review into the Native Vegetation Regulation 2005 made under the *Native Vegetation Act 2003* (Parker 2011) in an effort to 'strike the right balance between sustainable agriculture and protecting the environment'. Following the release of the review's independent report in 2013 (Lane 2013), the NSW government introduced self-assessable codes that permitted landholders to undertake 'low impact clearing activities' such as clearing of paddock trees, removal of invasive native species and native vegetation thinning without requiring approval. Concerns about the relaxation of native vegetation policies were raised by the environmental sector (Taylor and Dickman 2014), while the changes were reported as generally welcomed by landholders (Condon and Bryant 2013). A comprehensive review of the *NVA 2003* and related biodiversity policies was announced in mid-2014, and the final report released December 2014 (Byron *et al.* 2014). In their report, Byron and colleagues recommended the repeal of the *NVA 2003*, and combining native vegetation regulations with other biodiversity policies under a single *Biodiversity Conservation Act*. They also argued that the 'improve or maintain' test under the *NVA 2003* is 'unnecessary and burdensome at the site scale', and that offsite, third-party biodiversity offsetting should be applied to all environmental impacts (rather than only to threatened species and communities), along with increased investment in conservation on private and public lands. At the time of writing, it appears that the reforms recommended by Byron and colleagues have yet to be drafted into legislation (Druce and Foley 2015).

The Victorian government initiated a review of the Native Vegetation Management Framework in 2012, in an effort to improve regulatory performance through the reduction of 'red tape' (Department of Sustainability and Environment 2012). The reforms introduced in 2013 provided a risk-based approach to the regulation of vegetation clearing, whereby only 'moderate' or 'high' risk clearing required on-site assessment, and offsetting of ecological impacts (Department of Environment and Primary Industries 2013). The Statewide goal for native vegetation was again revised, this time to 'No net loss in the contribution made by native vegetation to Victoria's biodiversity'.

Following a series of reviews from 2009 to 2011, Western Australia's native vegetation regulations were amended in late 2013 (Department of Environment Regulation 2014). Landholders are now permitted to clear up to 5 ha per year on individual properties, and maintain cleared areas for pasture for up to 20 years without requiring a permit. The report from a recent senate inquiry into the gazetting of environmentally sensitive areas (ESAs) in Western Australia argues that the State's native vegetation regulations are 'confusing' and 'complex', and financially disadvantage landowners (Standing Committee on the Environment and Public Affairs 2015).

Perhaps the most environmentally significant policy change since 2010 has occurred in Queensland, where the latest data indicate that 266 191 ha of forest was cleared in 2013–14[2]. This is the highest deforestation rate recorded in Queensland since the end of broad-scale clearing permits in 2006 (Department of Science, Information Technology and Innovation 2015; Bulinski *et al.* 2016). Amendments to the *Vegetation Management Act 1999* in 2013 permitted landholders to clear remnant native vegetation to establish for 'high value agriculture', removed restrictions on clearing 'high value' regrowth, and removed the requirement to obtain a permit under the *Water Act 2000* to clear native vegetation in watercourses. Existing investigations into alleged non-compliance with the VMA were put on hold (Cripps 2012). In response, prominent Queensland ecologists issued a public statement that argued against the removal of clearing restrictions (Maron *et al.* 2013*a*), and the World Wildlife Fund has warned that Australia may again become a global hotspot for deforestation (Taylor 2013, 2015; WWF International 2015). In 2015, the newly elected Queensland Government promised to reinstate the provisions of the *Vegetation Management Act 1999* that were removed as part of the 2013 amendments by the previous government led by Premier Campbell Newman. At the time of writing, the *Vegetation Management (Reinstatement) and Other Legislation Amendment Bill 2016* (State of Queensland 2016) has not yet been passed by the Queensland Parliament, but is due to be reintroduced later in the year. In an effort to prevent a surge in deforestation before the passage of the tightened regulation (so-called 'panic clearing'), clearing restrictions would be applied retrospectively to 17 March 2016 – when the Bill was first introduced to Parliament (Chambers 2016).

Policy trends

From the preceding discussion of native vegetation policy reform over the last 40 years, some trends emerge. Up until the late 1980s, policies aimed to restrict deforestation were primarily framed around soil conservation and salinity prevention, rather than the protection of native vegetation itself (Table 1) (Slee 1998). However, increasing public concern for the environment in the 1990s saw a shift in focus to regulating native vegetation primarily to reduce environmental degradation and

[2]Note that this estimate is provided by Queensland's SLATS program (Department of Science, Information Technology and Innovation 2015), which considers a broader definition of 'forest' and has historically reported higher estimates of deforestation than the NCAS (Macintosh 2012; Bulinski *et al.* 2016)

biodiversity loss (Table 2). From 2000, regulation in most States became increasingly 'command and control', and the use of satellite imagery for monitoring and compliance more widespread (Bartel 2005, 2008). Offsetting arrangements, either as complementary policies or as conditions of approved clearance, were in place within most States and Territories by the mid-2010s (Table 3) (Maron *et al.* 2015).

Over the decade of reform, there was a sense of optimism that Australia's globally significant rates of deforestation had come to an end. However, within 10 years of what was celebrated as the end of broad-scale land clearing, major legislative changes have been made that relax clearing regulations. This new wave of policy reform is being mirrored in all of the high-deforestation States except South Australia, where only minor amendments have been made (Table 4). Although not clearly reflected in the NCAS data presented in this paper, the most recent data from the SLATS (Statewide landcover and trees study) program in Queensland suggest that there has been a sharp rise in deforestation since the government first signalled legislative changes (Department of Science, Information Technology and Innovation 2015; Queensland Audit Office 2015). In the absence of a robust quantitative evaluation, it is not yet clear whether deforestation rates have significantly changed following other recent policy changes in New South Wales, Victoria and Western Australia.

The relaxation of State-level native vegetation policies from 2010 has marked a shift in emphasis from 'command and control', to voluntary compliance and self-regulation. This change has occurred in parallel with Federal-level efforts to reduce 'red tape' in environmental approvals under the EPBC Act (Australian Government 2014*a*; Standing Committee on the Environment 2014), the 'opening up' (and subsequent reclosing) of National Parks to cattle grazing (Beilharz and Taylor 2015; Tlozek 2015), as well as possible amendments to the EPBC Act to redress what is perceived by some as an imbalance between environmental protection and economic opportunity (Senate Legislation Committee Environment and Communications 2015). The most recent announcement by the Queensland Government to revert back to 'command and control' regulation may suggest that the days of voluntary compliance and self-regulation are numbered (State of Queensland 2016). However, no other State Government has so far indicated any intention to reinstate strict regulatory controls on deforestation. In no other State has such a significant increase in deforestation occurred over 2012–14 as it has in Queensland, which has resulted in the release of carbon emissions almost equivalent to the amount secured through the Australian Government's Emissions Reduction Fund (Bulinski *et al.* 2016). The scale of deforestation and its contribution to climate change has provided the Queensland Government a policy platform to reinstate the *Vegetation Management Act 1999* in its previous form, with the intent to reduce greenhouse gas emissions and agricultural runoff into the Great Barrier Reef (State of Queensland 2016).

It is important to consider the broader macroeconomic environment when discussing trends in deforestation and policy responses over time (Fig. 5). The drivers of deforestation are highly context specific, and cannot be easily generalised (Geist and Lambin 2002). Many of the factors described by the international literature on deforestation, such as population growth, access to roads and shifting cultivation, are not relevant in Australia (Australian Greenhouse Office 2000; Lindenmayer 2005). Angelsen and Kaimowitz (1999) emphasises macroeconomic variables and policy instruments as key ultimate drivers of deforestation. Importantly, and rarely discussed in the literature, is the availability of suitable land, which ultimately limits the amount of primary forest that can be cleared (Australian Greenhouse Office 2000; Bartel 2004).

Rainfall, commodity prices and terms of trade are widely known to influence landholder clearing decisions (Rolfe 2002; Macintosh 2012; Australian Government 2013). The effects of rainfall are complex, however (Fig. 5*c*), as deforestation may be driven by high rainfall as well as drought conditions – the latter due to the increased production required to be profitable (Australian Greenhouse Office 2000). The relationship between deforestation rates and farmer's terms of trade has been used to estimate historical clearing from 1940 to 1970 (Commonwealth of Australia 2014), as well as to predict deforestation rates up to 2030 (Australian Government 2013).The Australian economy has undergone a restructure over the last several decades, leading to an increased contribution of the mining sector to economic growth, and unfavourable economic conditions for the agricultural sector (Gregory 1976; Connolly and Lewis 2010; Corden 2012).

When considered in the context of these broader policy trends and the decline of the agricultural sector (Fig. 5), the recent relaxation of native vegetation policies is not altogether surprising. 'Command and control' regulation is deeply unpopular amongst many rural landholders (Australian Greenhouse Office 2000; Bartel and Barclay 2011), who had historically held the right to clear vegetation without restriction, and indeed had been encouraged by Government to do so. Perceived and real impacts on farm productivity, inequitable impacts on landholders, and a large distance between the values and norms held by landholders and that of the Government and its policies mean that, at least at the present time, strict regulations on deforestation are politically unpalatable (Productivity Commission 2004; Bricknell 2010; Chambers 2016).

Future prospects for native vegetation policy in Australia

It is not yet apparent whether the current trend in deregulation will continue, or if it is simply a temporary pushback in the context of a long-term trend of clearing decline, worsening economic conditions, and the increasing scarcity of primary forest available to clear (Fig. 5). As highlighted by the previous section, relying too heavily on regulation can be politically costly, and may ultimately lead to policy failure (Bartel and Barclay 2011). Acceptance and compliance with native vegetation policies has proven to be extremely difficult to achieve in Australia (Bartel 2003; Bricknell 2010).

A key recommendation made within recent reviews of State-level native vegetation policy is the need to consider incentive-based and educational policies in addition to regulatory enforcement, in order to achieve positive environmental, social and economic outcomes (DSE 2012; Byron *et al.* 2014). Arguments in favour of using a diversity of instruments to meet environmental policy goals are not new (Bartel 2008; Commonwealth of Australia 2009; Bricknell 2010; Dovers and Hussey

2013), but the strengths and weaknesses of all policy options must be clearly considered (Gunningham and Sinclair 1999*b*). The recent increased emphasis on policies such as biodiversity offsetting, private conservation agreements and carbon farming is analysed below.

Biodiversity offsetting

Biodiversity offsetting has been increasingly emphasised as an approach that can deliver environmental outcomes in a more flexible and efficient manner (Commonwealth of Australia 2009; Byron *et al.* 2014), and policies are now in place at the Federal and State level. While offsetting can provide efficiencies over regulatory approaches, generally it can only maintain existing trajectories of deforestation and biodiversity loss, rather than slow or reverse the decline (Maron *et al.* 2015). As highlighted by Maron and colleagues, all Australian offset policies aim to achieve a 'no net loss' of biodiversity relative to a business-as-usual scenario. In fact, most policies assume a background rate of loss that is far higher than the existing rate of deforestation, meaning that offset policies have the potential to exacerbate biodiversity loss. This issue is one of a range of perverse outcomes that can occur as a result of widespread adoption of biodiversity offsetting (Gordon *et al.* 2015), hence regulation will still be necessary if deforestation is to be reduced or reversed. Indeed, regulation effectively sets the 'cap' on permitted environmental impacts, and thus is required to create the demand for a functioning environmental market (Salzman and Ruhl 2000).

Private conservation agreements

The importance of providing incentives to protect native vegetation, wildlife and associated ecosystem services on private land is also regularly highlighted by commentators (Commonwealth of Australia 2009; Byron *et al.* 2014; Fitzsimons 2015; Hardy *et al.* 2016). Private land stewardship is a critical component of Australia's biodiversity conservation efforts, given that the majority (74%) of the continent is freehold, leasehold or under Indigenous management (Geoscience Australia 1993). It should be made clear, however, that increasing the area of land privately (or, indeed, publicly) managed for conservation does little to reduce the overall deforestation rate if they do not prevent the loss of forest (McDonald-Madden *et al.* 2009; Maron *et al.* 2013*b*). As was the case in the early South Australian Heritage Agreements, landholders who enter into voluntary conservation agreements are generally already sympathetic to nature conservation, and the incentives provided are not enough to change land-use decisions at a large scale. Landholders whose values do not align with conservation are not likely to change land practices unless it is economically profitable to do so – and even then, social and cultural norms can provide an additional barrier to participation (Bartel and Barclay 2011). As with other incentive-based programs, private conservation agreements are usually small-scale, prone to adverse selection (Ferraro 2008), and subject to short-term funding cycles (Senate Environment and Communications References Committee 2015). The efficacy of private conservation areas can also be compromised where land-use conflicts are not resolved (Adams and Moon 2013).

Carbon farming

Carbon farming also offers potential benefits for native vegetation protection and restoration, assuming there is a market price on carbon emissions (Crossman *et al.* 2011; Lin *et al.* 2013; Evans *et al.* 2015) and perverse impacts on biodiversity are avoided (Lindenmayer *et al.* 2012). Similar to private conservation agreements, factors such as high transaction costs, policy complexity and cultural norms can act as barriers to landholder participation in carbon farming projects (Macintosh 2013). A key difference is that carbon farming can be more profitable than existing agricultural land uses, particularly in marginal areas where significant economies of scale exist (Evans *et al.* 2015). While unlikely to be influenced by reforestation and afforestation projects, the rate of deforestation can be reduced where genuine avoided loss can be secured. As with other incentive-based schemes, carbon farming can only genuinely prevent or reverse forest loss if regulatory controls on deforestation exist. At present, the Australian Government's carbon farming policy (Australian Government 2014*b*) provides incentives for landholders to undertake avoided deforestation and reforestation, while State-level native vegetation policies have all recently been relaxed. This inconsistency in policy approach means that the environmental benefits generated by the Federal policy have largely been negated by recent increased deforestation (Department of Science, Information Technology and Innovation 2015; Bulinski *et al.* 2016) and creates significant policy uncertainty for landholders (Elks 2016).

The need for an effective policy mix

Incentive-based policies such as those outlined above are attractive as they can afford flexibility and efficiencies that traditional regulation cannot provide. Although it is sensible to consider the potential benefits offered by a range of policy instruments, there can be a temptation to recommend them as alternatives, rather than complements to regulation, or without a clear assessment of their likely efficacy (Gunningham and Sinclair 1999*a*). A combination of 'command and control' regulation, self-regulation, incentive-based and educational instruments will generally perform better than any single instrument in meeting a policy objective (Gunningham and Sinclair 1999*b*; Dovers and Hussey 2013). On the basis of the most recent deforestation trends and the history of native vegetation policy in Australia, it appears that a coordinated and mutually supportive policy mix has yet to be achieved with respect to effectiveness, equity and social and political feasibility.

Very little is actually known of the effectiveness of the various policy responses to deforestation over the last 40 years. Few Government-sponsored evaluations are available (but see Dart and Grossek 2007; Department of Sustainability and Environment 2008), and available data are often inadequate to conduct a rigorous evaluation (Byron *et al.* 2014). Environmental policies are notoriously difficult to evaluate, as environmental problems are generally complex, involve considerable uncertainties, and require detailed measurements and specialist methods to attribute a policy intervention to an observed response (Mickwitz 2003; Ferraro 2009; Keene and Pullin 2011). The efficacy of policy responses to deforestation can

only be reliably evaluated by considering observed deforestation rates (including regulated, exempted and illegal clearing), in addition to the other drivers of land management behaviour (Bartel 2004).

While it is recognised that macroeconomic, environmental and institutional arrangements all have an effect on deforestation rates (Angelsen and Kaimowitz 1999; Geist and Lambin 2002), how these variables interact and ultimately drive deforestation in Australia is poorly understood. Nonetheless, the reduction in deforestation since the 1990s has been attributed to government intervention in several instances (Garnaut 2008; Department of Environment and Resource Management 2010; Australian Government 2013). Macintosh (2012) argues that such suggestions are misleading, or at least incomplete, without explicitly considering the effects of commodity prices, terms of trade and rainfall on deforestation rates. A comprehensive evaluation of the impact of native vegetation policies on deforestation in Australia over time is needed, but this would require adequate data, appropriate methods and a willingness by relevant stakeholders to conduct such an analysis.

The lack of clear evidence for the historical effectiveness of Australia's native vegetation policies is extremely problematic, given the time and effort devoted to their design, implementation and review. Despite the introduction of a raft of policies aimed to reduce deforestation over the last 40 years, monitoring, evaluation and enforcement have been hampered by a lack of resources and information (Bartel 2003; Bricknell 2010; Nicol *et al.* 2014). The advent of satellite imagery was at one stage heralded as a new beginning that would enable greater monitoring and evaluation, and encourage compliance with clearing regulations (Bartel 2005; Purdy 2010). We have, however, yet to see a revolution in our understanding of native vegetation policy effectiveness in Australia. A key step required to deliver a more effective policy mix for addressing deforestation is therefore to invest a greater proportion of resources into monitoring, evaluation and compliance.

Conclusions

Native vegetation policy has been an extraordinarily active policy space in Australia over the last 40 years. Initially motivated by concerns around soil conservation and salinity, a growing interest around biodiversity conservation and ecologically sustainable development drove a wave of policy reforms over the 1990s and 2000s, which placed strict regulations on deforestation. An interest in providing landholders with flexibility and economic incentives to retain and restore vegetation saw the proliferation of offset policies from 2000 onwards. Since 2010, several Australian States have amended their native vegetation policies to place greater emphasis on self-regulation and voluntary compliance, in an effort to restore 'balance' between meeting environmental, social and economic objectives. The most recent increase in deforestation in Queensland has triggered a potential shift back to 'command and control', but at present it does not appear that the other States will soon follow suit.

Other than in Queensland, it is not yet clear whether this shift to self-regulation has preceded an increase in deforestation. Deforestation results as a combination of institutional, macroeconomic and environmental factors; hence a change in the rate of deforestation cannot be attributed to any particular event without a rigorous evaluation. The long-term trend in Australia over 1972–2014 is of a gradual decline in the rate of deforestation relative to the amount of primary forest available to clear on suitable land. Faced with worsening economic conditions and the expansion of agriculture into increasingly marginal areas, deforestation for agricultural, urban and industrial development will likely cease being economically viable before all of the remaining primary forest is cleared. However, the raft of policies implemented over the last 40 years illustrates that there is a desire in the Australian community to limit deforestation for a range of environmental objectives. To be effective, native vegetation policies therefore need to induce a 'forest transition' before deforestation meets its economic and environmental limits (Angelsen and Kaimowitz 1999; Rudel *et al.* 2005; Lambin and Meyfroidt 2011). Ultimately, Australia has the means to achieve this goal – it is a question of whether it is socially and politically feasible.

Environmental policy is made in the context of broader socio-political and economic trends. The recent shift towards self-regulation, flexibility and economic instruments reflects these broader societal trends – but this shift in focus on policy instrument *type* does not necessarily mean there will be a change in policy *effectiveness.* All environmental policy instruments, regardless of whether they are 'command and control', self-regulation, economic or informational, require monitoring, evaluation and enforcement if they are to be effective (Gunningham and Sinclair 1999*b*). Historically, these crucial steps in the policy process have been poorly executed with respect to Australia's native vegetation and biodiversity (Bartel 2003; Bricknell 2010). Ensuring that there is far greater capacity to monitor and evaluate the impacts of native vegetation policies will assist in delivering more effective, efficient and equitable outcomes.

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