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Spatial and temporal patterns of land clearing during policy change

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ABSTRACT

Environmental policies and regulations have been instrumental in influencing deforestation rates around the world. Understanding how these policies change stakeholder behaviours is critical for determining policy impact. In Queensland, Australia, changes in native vegetation management policy seem to have influenced land clearing behaviour of landholders. Periods of peak clearing rates have been associated with periods preceding the introduction of stricter legislation. However, the characteristics of clearing patterns during the last two decades are poorly understood. This study investigates the underlying spatiotemporal patterns in land clearing using a range of biophysical, climatic, and property characteristics of clearing events. Principal component and hierarchical cluster analyses were applied to identify dissimilarities between years along the political timeline. Overall, aggregate landholders' clearing characteristics remain generally consistent over time, though noticeable deviations are observed at smaller regional and temporal scales. While clearing patterns in some regions have shifted to reflect the policy's goals, others have experienced minimal or contradictory changes following regulation. Potential 'panic' or 'pre-emptive' effects are evident in the analysis, such as spikes in clearing for pasture expansions, but differ across regions. Because different regions are driven by different pressures, such as land availability and regulatory opportunity, it is imperative that the varying spatial and temporal behavioural responses of landholders are monitored to understand the influence of policy and its evolution. Future policy amendments would benefit from monitoring these regional responses from landholders to better assess the effectiveness of policy and the potential perversities of policy uncertainty.

1. Introduction

Deforestation, with its consequential effects of habitat loss, fragmentation, and degradation, is a well-recognized threat to biodiversity and ecosystem function (McAlpine et al., 2002; Lindenmayer et al., 2005; Bradshaw, 2012). Environmental regulations and other policy instruments greatly influence deforestation rates around the world, whether directly or indirectly (Meyfroidt and Lambin, 2011). A number of countries have directly reduced deforestation rates using conservation policies incorporating logging bans (Southworth and Tucker, 2001; Mather, 2007), mandated reforestation or afforestation (Klock, 1995; Wang et al., 2007), and land use restrictions (Fox et al., 2009; Assunção et al., 2012). Other countries such as Costa Rica and India have experienced a decline in deforestation indirectly, due to economic and ideological pressures (Kull et al., 2007; Daniels, 2009) and forest management decentralisation (Agrawal, 2007; DeFries and Pandey, 2010), respectively. Angelsen and Kaimowitz (1999) argue that policy instruments and macroeconomic variables represent the underlying causes of deforestation, and these factors will directly influence more immediate causes of deforestation, such as institutions, infrastructure, markets, and technology.

Policy instruments can thus modify the dynamics of the human-environment system, but by doing so, may not always work as intended. Policies can even lead to the potential for perverse, or unintentional, outcomes to emerge (Miteva et al., 2012). Some conservation policy instruments have resulted in leakage effects, whereby deforestation is displaced from the regulated region into unregulated areas (Wear and Murray, 2004; Oliveira et al., 2007; Gaveau et al., 2009). Other policies meant to indirectly curb deforestation, like those reducing agricultural rents or removing clear-to-own property laws, may also result in

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accelerated clearing rates when they are poorly implemented, lack public support, or introduce high levels of legislative uncertainty (Kaimowitz et al., 1998; Angelsen, 2009).

Vegetation management policies directly affect the livelihoods of agricultural landholders, placing constraints on economic growth, property rights, and potentially tenure security (Alston et al., 2000; Sant'Anna and Young, 2010; Aldrich, 2012). The link between deforestation and issues of property rights and tenure security has been most obvious in developing nations, where landholders clear forest to lay their claim on the land, prevent squatters from infiltrating, and receive financial incentives (as well as property legitimacy) from the government (Alston et al., 2000; Aldrich et al., 2012; Brown et al., 2016). When this sense of security and autonomy is threatened by incoming policies dictating how landholders are permitted to manage their land, some may react by pre-emptively clearing vegetation. If controversial policies are complemented by high political instability, regime changes, or legislative ambiguity, the reactions from landholders to this uncertainty can significantly increase deforestation rates over time (Deacon, 1994; Barbier and Burgess, 2001).

Deforestation patterns in Australia are broadly reflective of the rapid rate of modern deforestation globally (Lindenmayer et al., 2005). In its relatively brief colonial history, Australia has seen agricultural expansion reduce forest cover by nearly 15%, with 7.2 million ha (7%) of primary forests cleared in the last 40 years alone (Bradshaw, 2012; Evans, 2016). Since the 1970s, the State of Queensland has lost 9.7 million ha of total forest from land clearing, accounting for more than 60% of clearing in the entire country over this period (Evans, 2016), with native vegetation cover reduced by at least 50% over the last 200 years (Australian Bureau of Rural Sciences, 2010). Like many developing countries, the first century of development in Queensland was marked by heavy governmental encouragement for landholders to clear as much vegetation as possible in an effort to raise economic prosperity (Braithwaite, 1996; Bradshaw, 2012). It was not until the end of the 20th century that public opinion began to change regarding the value of native vegetation, and the Queensland Government entered into a period of land clearing policy reform, which brought about the first strict regulations on vegetation management practices with the *Vegetation Management Act (VMA) 1999*. Landholders in Queensland have since experienced considerable evolutions in state vegetation management policy.

The most infamous period of land clearing in Queensland in recent history involved the rapid increase in clearing rates during 1999–2000 and 2002–2003, likely in response to the initial enactment of the VMA 1999 and subsequent stricter implementation in 2003—periods commonly referred to as *panic clearing* (Productivity Commission, 2004; Lindenmayer et al., 2005; Taylor, 2015). The definition of panic clearing, however, is unclear; it has been used to describe rushed clearing activities (i.e. future plans that were expedited) or unplanned clearing activities (i.e. activities that the landholder had no future intentions of executing), though evidence of both types of panic clearing have been reported anecdotally in this case (Senate Inquiry, 2010). Further, it is unclear whether panic clearing constitutes increased business-as-usual clearing (i.e. clearing locations similar to locations cleared in the past), increased atypical clearing (i.e. clearing locations dissimilar to those cleared in the past), or a combination of both. Identifying how these different characterisations of panic clearing contributed to the increased volume of clearing across regions is imperative to our understanding of how landholders make reactive, short-term land clearing decisions. One attribute of panic clearing remains consistent, however, which is that panic clearing is pre-emptive, due to expected clearing limitations imposed by future regulations (McIntyre et al., 2002; Productivity Commission, 2004; McGrath, 2007). Such perverse pre-emptive responses from landholders and stakeholders can also be found elsewhere in the conservation realm, following listings on the U.S. Endangered Species Act (Lueck and Michael, 2003) and trade bans under the Convention on International Trade of Endangered Species (CITES; Rivalan et al., 2007).

The convoluted introduction of strict vegetation management regulations in Queensland led to landholder uncertainty regarding future property rights and tenure security (Productivity Commission, 2004; Senate Inquiry, 2010), which has also been observed in developing countries undergoing substantial policy evolution (Alston et al., 2000; Aldrich et al., 2012). Queensland thus serves as an important and relevant global case study to highlight how these clearing behaviours may change over time amidst continual (and sometimes contradictory) changes to a single vegetation management policy. Further, the availability of quality data on the characteristics of clearing in Queensland allows for more thorough investigations that may not be present in other cases.

To date, the *extent* of state-wide vegetation clearing in Queensland has been widely publicised in the literature (e.g. Evans, 2016; Queensland Department of Science, Information Technology and Innovation, 2016), yet minimal attention has been placed on the *characteristics* of clearing over time in this case. This provides associative evidence of how vegetation management policy has affected aggregate landholder *actions* (i.e. the 'what'), rather than using the characteristics of clearing to investigate the dynamic and differential *behaviours* of landholders (i.e. the 'how'). Such temporal analyses have recently been used to assess global patterns of deforestation to identify drivers of clearing behaviour and forest transition (Hosonuma et al., 2012; Sandker et al., 2017), but these same concepts can be applied at finer scales. Previous investigations into the trends of land clearing in Queensland have also relied upon state- or national-level drivers of deforestation (e.g. Evans, 2016; Marcos-Martinez et al., 2018), despite the global recognition of regionally dependent deforestation drivers and landholder responses (Geist and Lambin, 2002). Thus these studies may produce generalised patterns and policy recommendations that may not adequately capture or identify regional landholders' behaviours and potential motivations.

This study investigates the underlying spatial and temporal characteristics and patterns of land clearing within the context of evolving vegetation management policies, using Queensland as a case study. Using a range of biophysical, climatic, and property characteristics to identify underlying patterns in clearing events across the political timeline, we analyse (1) how the observable biophysical, socioeconomic, and property characteristics of clearing events change over time, (2) what principle components can be derived from the spatial characteristics of clearing events, and (3) how these components differ between key policy periods. Further, we focus on periods described as panic clearing and assess how their clearing characteristics differ from previous years. To compare the potentially different spatial patterns, our analysis is undertaken at multiple scales: (1) an aggregate state-level analysis, (2) contrasting bioregion analyses, within a historical clearing hotspot (Brigalow Belt South), a relatively intact frontier for clearing (Cape York Peninsula), and an area of dense urban sprawl (South Eastern Queensland), and (3) a composite region of particular current environmental concern (Great Barrier Reef catchment).

2. Methods

2.1. Study areas

Queensland (QLD, 2.04 M km^2) is the most climatically diverse state in Australia, with 50–3000 mm mean annual precipitation depending on the region, including equatorial, tropical, subtropical, temperate, grassland, and desert bioregions. We examined clearing patterns across the entire State of Queensland, Australia, with a focus on four subregions of interest (Fig. 1): the Brigalow Belt South bioregion (BBS), Cape York Peninsula bioregion (CYP), South East Queensland bioregion (SEQ), and the Great Barrier Reef catchment (GBRC) as defined by the former Department of Environment and Resource Management (Rollason and Howell, 2012). The BBS bioregion (267,000 km^2), in