

# The hidden impact of policy changes on remnant vegetation in Queensland, Australia

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## ARTICLE INFO

### Keywords:

Vegetation management act  
Queensland  
Land clearing  
Comparative policy analysis  
Regional ecosystems  
Spatial policy analysis

## ABSTRACT

Habitat loss is a key driver of species extinction, demanding effective policies to regulate land clearing and mitigate this threat. This study examines the impact of policy changes on the availability of vegetation for clearing in Queensland, Australia, focusing on three policy variants from 2012, 2015, and 2019. Our analysis highlights significant shifts in remnant vegetation availability. In 2015, the introduction of permissions for clearing native vegetation for agricultural and pastoral production resulted in an additional 84 million ha of remnant vegetation becoming available for clearing. Furthermore, changes made in 2015 decreased riparian buffer zones, further expanding the extent of remnant vegetation on which clearing for specific purposes is permissible. Between 2015 and 2019, we identified five policy changes with substantial implications for vegetation management, including revoking permission for establishing broad acre cropping or grazing properties and removing thinning as a relevant clearing purpose. While the 2019 guidelines provide increased protection for remnant vegetation, it's crucial to note that all policy changes took place within a relatively brief period. Sudden policy changes can disrupt existing land management practices and strategies, potentially leading to confusion and challenges in adapting to new regulations and requirements. Our findings underscore the need to consider the ecological effects of rapid policy changes, as underestimating their overall impact on vegetation can have far-reaching implications for species preservation and ecosystem health.

## 1. Introduction

Habitat loss from land clearing poses a significant and ongoing threat to biodiversity. Land clearing is a complex phenomenon influenced by many factors, including human population dynamics, economic forces, scientific and technological advancements and policy decisions (Lambin et al., 2003; Lambin and Meyfroidt, 2011). Its environmental consequences are profound and encompass the reduction in species extent and abundance (Haddad et al., 2015), the fragmentation and isolation of habitats (Holland and Bennett, 2010) and the disruption of ecological processes (Cogger, 2003). Australia's commitment to the United Nations Convention on Biological Diversity in 1993 led to collaborative efforts across jurisdictions to reduce vegetation loss. Despite this, in just over a decade (2004–2017) 43 million hectares have been lost in global land-clearing hotspots (Pacheco et al., 2021). Of these, the east coast of Australia is one. The most recent evaluation of clearing rates in Queensland shows that clearing of remnant and non-remnant vegetation

was 418,400 ha in 2019 (Queensland Government, 2022). As Queensland's clearing rates increased to, and subsequently exceeded, historical highs between 2018 and 2019, some authors suggest that the eastern Australian coast (and Queensland, in particular) is at the front of global forest loss (Heagney et al., 2021) (Fig. 1).

Clearing in Queensland was over 1.05 million ha in the early 2000 s, representing 0.56% of the State's total land area (Kehoe, 2009). To address the significant threat that vegetation loss poses to both the natural environment and productive land uses, Queensland introduced the Vegetation Management Act (the Act) in 1999. The Act was designed to address concerns surrounding broad-scale clearing of native vegetation, promote ecologically sustainable land use and safeguard regional biodiversity. Broad-scale clearing refers to extensive vegetation removal over large areas. Under the Act, regulations and restrictions are established to manage and control such activities, focusing on preserving and sustaining the State's vegetation and ecosystems. The Act distinguishes between two categories of regulated vegetation: remnant vegetation

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(never previously cleared) and high-value regrowth (previously cleared but has since regrown). The Act largely dictates the stipulations under which land clearing can occur by regulating clearing in vegetation communities based on biophysical characteristics of the proposed clearing site (i.e., the slope of the land) or the percentage of the vegetation community remaining in the landscape. Such characteristics are documented in land clearing guidelines (also called clearing 'codes'). Clearing outside of the parameters outlined in guidelines may require further approvals or may not be deemed permissible.

The Act was widely accepted as an effective policy for managing land clearing but has been controversial in its attempts to reconcile the needs of rural landholders and biodiversity conservation (McAlpine et al., 2002; Neldner, 2018). Following a broad-scale clearing ban under the Act in 2006 (McGrath, 2007), clearing rates for remnant woody vegetation declined from 212,000 ha between 2005 and 2006 to 26,000 ha between 2010 and 2011. This marked a historic low for clearing rates in Queensland (Queensland Department of Environment and Science, 2015, 2017) (Fig. 1). However, between 2013 and 2018, the Act was amended twice, reflecting major shifts in political parties and overarching policy (Boer, 2023; Butler and Fensham, 2020; Maron et al., 2015). In 2012, there was a change in Government, and in 2013 the Act was amended, allowing for the resumption of broad-scale clearing for high-value dryland and irrigated agriculture as part of a government initiative to expand agricultural development (Crisafulli, 2013). In the following years, Queensland's land clearing rate increased to over 395,000 ha between 2015 and 2016 (Fig. 1) (Queensland Government (2017, 2015) saw another state election and change of Government, with the incoming Government making an election commitment to "reinstate a responsible vegetation management framework" (Queensland Government, 2018c). The amendments to the Act to return protections for high-value remnant vegetation were passed in 2018.

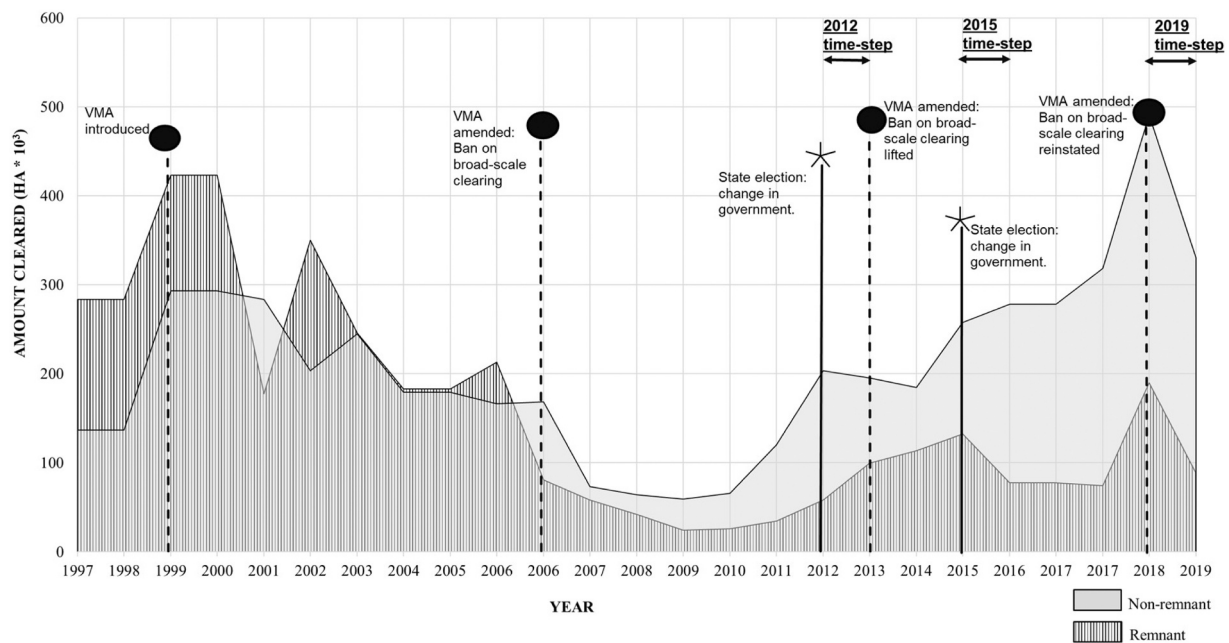
As a result of this extensive and ongoing clearing, many vegetation communities in Queensland are vulnerable to collapse (Tulloch et al., 2015). Such a marked change in clearing rates may be attributable to policy changes. Previous studies have commented on the substantial

effects of rapid policy change on vegetation management in Queensland. For example, Taylor (2013) estimated that 1.3 million ha of previously uncleared vegetation would be exposed to clearing following the 2013 changes to the Act. Furthermore, a 2017 study also found that the Act failed to protect the forest types experiencing the highest clearing rates (Rhodes et al., 2017). Another recent study found that the Act was largely ineffective at reducing land clearing (Simmons et al., 2018). Queensland, therefore, represents an ideal case study for understanding how policies affect land clearing.

We explore variations associated with the guidelines underpinning the Act, noting that guidelines express the Act's policy intent and allow landholders to interpret and apply rules to their land use practices. To understand the impact of the 2013 and 2018 amendments, we collected clearing guidelines corresponding to 2012, 2015, and 2019 time-steps. The 2012 clearing guidelines provide a reference for clearing assessment before amendments to the Act in 2013. The 2015 clearing guidelines reflect permissible clearing specified in the 2013 amendments. The 2019 clearing guidelines reflect the 2018 amendments. For each time-step, we described the fundamental policy changes. We calculated whether changes resulted in an increase or decrease in remnant vegetation that would require additional assessment under the Act before clearing. By analyzing and comparing these three time-steps, our research demonstrates the importance of conducting comparative policy analysis to inform future decision-making processes. This approach allows us to assess the full spectrum of potential outcomes, providing insights regarding the overall impact of policy changes.

## 2. Methods

A proposal for clearing under the Act may fall into one of three categories: accepted, prohibited or assessable (England, 2016). Accepted development is deemed low risk because it does not significantly impact the environment and, therefore, does not require an application or approval. Prohibited development is not permitted under any circumstances (Queensland Government, 2020). Assessable



**Fig. 1.** Hectares of remnant woody vegetation and non-remnant vegetation cleared in each biannual reporting period in Queensland. Data are derived from Queensland's State Wide Land and Trees Study (SLATS) using the latest reporting (Queensland Government, 2018b). State Elections, which resulted in a change of Government and subsequent amendment to the Vegetation Management Act, 1999 are noted with stars and solid black lines. The timing of important amendments to the Vegetation Management Act, 1999 are noted with black points and dashed vertical lines. The periods assessed (2012, 2015 and 2019) are also indicated (Taylor, 2013).

Graph adapted from (Taylor, 2013).

development requires a developer to demonstrate compliance with relevant regulations and codes. The Act has supporting guidelines that describe the characteristics of vegetation that will require assessment under the Act. For example, according to 2019 clearing guidelines, assessment and approval would be required if the proposed clearing is within 20 m of a major watercourse (Queensland Government, 2019). If the proposed development cannot demonstrate compliance with the thresholds outlined in clearing codes, then the non-compliant part of the application can be denied or approved with conditions. Approval with conditions is integrated into an Environmental Authority held by the proponent and subject to regular audits by state or local governments (England and McInerney, 2017).

Assessable development, as regulated under the Act, necessitates government assessment and approval for any associated clearing activities. Clearing guides are publicly accessible documents that delineate the biophysical and landscape criteria, triggering regulatory actions in accordance with the Act. Proponents of clearing activities are mandated to adhere to these guidelines. These guidelines offer valuable insights into potential clearing activities, particularly those related to the conservation of remnant vegetation classified as endangered ecosystems, as they outline an appraisal framework designed to achieve the biodiversity outcomes outlined in the Act.

To examine the evolution of these guidelines, we collected them at three significant time points: 2012 (prior to 2013 amendments allowing broad-scale clearing), 2015 (following 2013 amendments that permitted broad-scale clearing), and 2019 (after 2018 amendments that removed broad-scale clearing provisions) using comparative evaluation.

## 2.1. Comparative evaluation

Comparative policy approaches examine the similarities and differences between policies across nations or sub-nations or through time (Ciccia and Javornik, 2019; Fischer and Miller, 2017). They are often used to inform future policy development. Our comparative approach identified features that constrain clearing under these guidelines and compared these constraints across time-steps. Ultimately, our

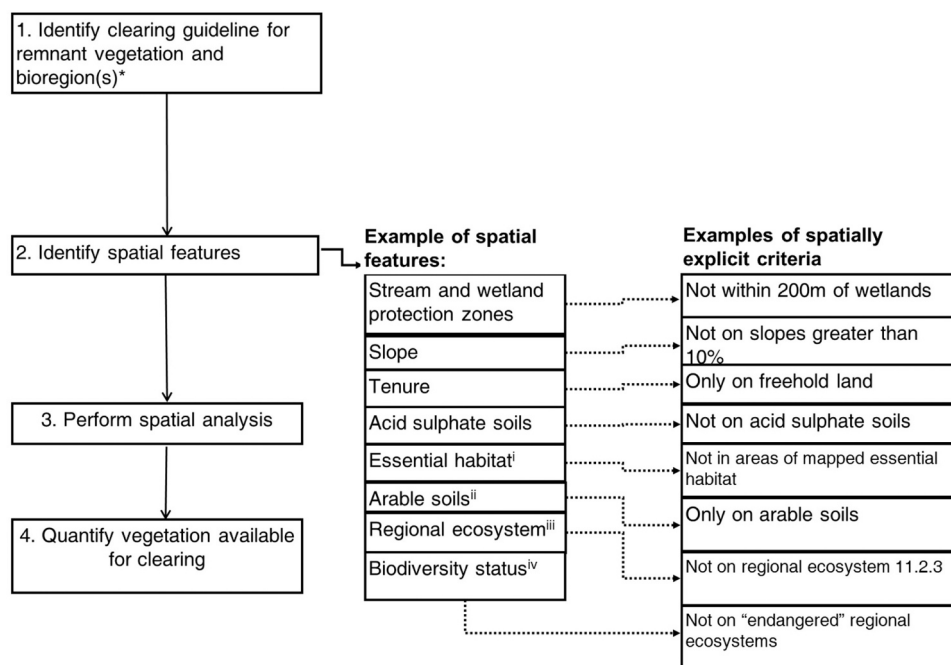
comparative analysis aimed to: 1. Identify fundamental policy changes regarding each constraint that resulted in increased or decreased exposure to possible clearing, 2. Provide a summary statement to interpret the overall impact of the change, and 3. Describe the extent of an increased or decreased amount of remnant vegetation exposed to clearing for each purpose (Fig. 2).

### 2.1.1. Step one: identify relevant clearing guidelines

Clearing guidelines corresponded to regions, vegetation categories, and clearing purposes (2012) or simply vegetation categories and clearing purposes (2015). To obtain guidelines for the 2012 and 2015 time-steps, we consulted with officers responsible for monitoring clearing compliance across the State. For the 2019 time-step, we obtained clearing guidelines directly from the Department's website (<https://www.dnrme.qld.gov.au>).

Clearing activities that do not align with these guidelines may be allowed, but only after obtaining development approval. Such approvals usually involve a comprehensive environmental impact assessment, where the regulatory authority can impose conditions to minimize adverse effects on biodiversity. This study does not predict potential development approvals; therefore, we assume a high level of compliance with the clearing guidelines in our analysis. Clearing activities that require offsets were considered unavailable for clearing, as predicting offset requirements was beyond the scope of this study. Additionally, our analysis does not encompass clearing exceptions listed in Schedule 21 of the Planning Act 2016 (formerly the Sustainable Planning Act 2009). These exceptions include vegetation removal for essential management purposes, post-bushfire management, and urban development in specific vegetation types or priority development areas. Our assumptions may result in an underestimation of potential clearing because we do not account for larger development projects or activities on assessable vegetation.

In the guidelines, clearing purposes are also called management or operational works and relate to why a proponent may want to clear vegetation. To maintain consistency, we use "clearing purposes" to refer to any clearing activity described by the clearing guidelines. We



**Fig. 2.** Interpretation of clearing guidelines to produce summaries of clearing guidelines for each purpose. <sup>i</sup>2012 time-step only. <sup>\*</sup> 2012 Time-step only <sup>i</sup>Vegetation in which a species that is Endangered or Vulnerable under the Nature Conservation Act (1992) occurs. <sup>ii</sup>Land classified as having potential for agricultural development (Queensland Government, 2014). <sup>iii</sup>Regional ecosystems are unique vegetation classes in Queensland, Australia (Neldner et al., 2019). <sup>iv</sup>Biodiversity status categories are endangered, of concern, or least concern (no concern at present). See Supplementary for definitions of Biodiversity Status.

comprehensively reviewed all guidelines and identified the clearing purposes therein. We refer to single, one-off clearing events (i.e., clearing to build a shed) or environmental clearing (i.e., removal of *Lantana camara* or other invasive exotic species) as general clearing purposes and focus our findings on five clearing purposes:

1. Agricultural and grazing: broad-scale clearing to establish new areas for high-value agriculture or irrigated high-value agriculture on fertile soils or broad-scale clearing to develop new areas of cattle production (limited to areas on grazing leases).
2. Extractive industry: the clearing of vegetation to establish mines;
3. Encroachment: the removal of native woody plants (i.e., gidgee, *Acacia* sp. Or false sandalwood (*Eremophila mitchellii*), from grasslands to allow for native grass regeneration for pasture;
4. Fodder harvesting: selective harvesting of tree species for stock feed;
5. Thinning: selective removal of trees to reduce them to a density specified for the ecosystem.

The 2012 guidelines corresponded to bioregions or groups of bioregions. Bioregions are geographically distinct areas characterized by unique climates, geology, and ecological processes. They represent a relatively large-scale ecological unit within which the flora, fauna, and ecological communities share similar environmental conditions and interact similarly (Thackway and Cresswell, 1997). We applied Steps 2–4 within the boundaries of the relevant bioregions.

The Act regulates the extent and type of vegetation that can be cleared by classifying vegetation into vegetation categories (Queensland Government, 2018a). Four other vegetation categories are classified under the Act (A,B,C,R and X). The most strictly protected vegetation category is Category A, where clearing is prohibited. Category X does not have enforceable guidelines around clearing. The remaining two categories are Category B (remnant vegetation) and C/R (respectively, high-value regrowth vegetation and high-value regrowth vegetation within a watercourse or drainage boundary). To understand the implications for previously uncleared vegetation where biodiversity values are expected to be greater than non-remnant vegetation (Lindenmayer et al., 2012; Maron et al., 2018), we constrain our analysis to clearing guidelines for remnant vegetation (Category B).

#### 2.1.2. Step 2: identify spatial features that constrain clearing

The guidelines describe biophysical and landscape characteristics where clearing may occur without requiring assessment under the Act, although there may be further restrictions under interacting policies and legislation. These characteristics relate to slope, watercourses and wetlands, tenure, soil type or areas deemed essential habitat.

In addition to the criteria detailed in the clearing guidelines, we accounted for key federal legislation (the Environment Protection and Biodiversity Conservation Act, 1999; EPBC Act), which states that clearing of vegetation cannot occur in areas occupied by a National Heritage place or World Heritage place; the catchment of a declared Ramsar wetland or habitat for species listed under the EPBC Act. Furthermore, clearing in State Forests, National Parks, and other protected areas as defined by the Forestry Act 1959 or the Nature Conservation Act 1992 is not permissible. Such areas were removed from all spatial layers included in this analysis. Data were available for World Heritage Areas, Ramsar Wetlands, National Heritage Places, State Forests and other protected areas, but not for threatened species distributions.

#### 2.1.3. Step three: perform spatial analyses for 2012 and 2015 time-steps

Using the results of the comparison above, we quantified the spatial impact of guideline changes on the area of vegetation available for clearing in the 2012 and 2015 time-steps (Fig. 2). We focused our spatial analysis on the 2012 and 2015 time-steps, representing the most variable range of clearing guidelines because the 2012 and 2015 guidelines provided a strict (2012) and relaxed (2015) time-steps for rules

regarding the clearing. The changes to guidelines in 2019 effectively reversed the fundamental changes introduced in 2015.

Above, we identified all features constraining the clearing of remnant vegetation. We then used this spatial data relating to each of these features to apply these constraints to mapped remnant vegetation to summarise the extent of permissible clearing. Further details and a list of datasets used are provided in [Supplementary Table S2](#).

We determined the remaining area of remnant vegetation for each clearing purpose through a series of spatial analyses in ArcMap 10.7 (Environmental Systems Research Institute, 2011). We systematically applied the restrictions outlined in the clearing guidelines to spatial features. For instance, if a clearing guideline stipulated a minimum distance of 200 m from a watercourse, we buffered the watercourse by 200 m and then removed it from consideration. To ensure consistency across both time-steps, we utilized the extent of remnant vegetation as mapped in 2015. Once we determined the total extent for each clearing purpose, we merged the extent for each purpose to determine the total remnant vegetation outside of spatial constraints. We then compared the total extents for 2012 and 2015 by mapping the intersections (where clearing could occur in both time-steps) and symmetrical differences (where clearing could occur not occur in either time-steps).

All spatial analyses, including typology checks (e.g., sliver polygons, polygon overlap and polygon gaps), were carried out in ArcMap using the Australian Albers Equal Area projection (EPSG:9473), as recommended by the Queensland Department of Environment and Science (Queensland Government, 2015).

#### 2.2. 4 Quantify the total area of remnant vegetation available for clearing

Following the spatial analysis, we summarized the total available clearing area for the 2012 and 2015 time-steps by calculating the remaining area. Most clearing purposes explicitly prohibit clearing within regional ecosystems with an endangered or of concern biodiversity status (Supplementary Material, Table S1). However, given that regional ecosystems are mapped as nested polygons, we calculated the proportion of not of concern at present regional ecosystems within each polygon, excluding portions of polygons that were endangered or of concern. We calculated the total area for each clearing purpose using the *tidyr* (Wickham and Wickham, 2017) and *dplyr* (Wickham et al., 2019) packages in R (R Core Development Team, 2013).

### 3. Results

The 2015 guidelines introduced several significant changes compared to 2012 (Table 1). Perhaps the most notable change was the re-introduction of broad-scale clearing for agricultural and grazing purposes. However, it is important to note that proponents seeking to clear land for agriculture or grazing were limited to a maximum clearing area of 5 ha per property without requiring approval under the Act, potentially acting as a moderating factor on the overall volume of clearing for these purposes (Queensland Government, 2013a).

The second policy change involved reducing buffer zones around wetlands and watercourses. For instance, in 2012, clearing was prohibited within 200 m of a stream order 5 in the Brigalow Belt Bioregion. In 2015, this buffer zone was reduced to 100 m. Crucially this change applied across all clearing purposes, including agriculture and grazing, extractive industry, encroachment, fodder harvesting, and thinning.

The third change removed at-risk and dense regional ecosystems from the 2015 clearing guidelines. In the 2012 guidelines, regional ecosystems were classified based on whether they were dense or at-risk (see Table 1). To be considered dense, regional ecosystems had a foliage cover ranging from 100% to 70% (Neldner et al., 2019). To be considered at-risk, regional ecosystems were those likely to be cleared to less than 30% of their estimated pre-European extent (Queensland Government, 2012). Notably, these restrictions for clearing at-risk and dense regional ecosystems applied to specific purposes such as fodder



**Table 1**

Summary of the policy changes identified in a comparative analysis for the 2012 and 2015 time-steps. See [Supplementary Table S1](#) for definitions of 'no concern at present,' 'of concern,' and 'endangered' regional ecosystems.

Guideline change	Clearing purpose effected	Key spatial impacts	Interpretation
Re-introduction of broad-scale clearing	Agriculture and grazing	Remnant vegetation can be cleared for broad-acre cropping and grazing	More vegetation classified as least concern (also called 'no-concern at present') is exposed. In some circumstances, permits to clear 'of concern' or 'endangered' vegetation could be requested.
Changes to wetland and stream protection zones	Agriculture and grazing, fodder harvesting, extractive industry, thinning and encroachment.	Overall reduction of buffer zones in a riparian area	More vegetation is available for clearing in riparian areas
Removal of restriction for regional ecosystems that were classified as at-risk <sup>a</sup> and for regional ecosystems that were classified as dense <sup>*</sup>	Agriculture and grazing, extractive industry, thinning	Increase in non-assessable vegetation.	Vegetation in these categories is no longer considered assessable under the Act/
Removal of the requirements for vegetation clearing permits	Agriculture and grazing, fodder harvesting, extractive industry, thinning and encroachment	No specific spatial impacts	Reduced potential for regulation.
Removing the requirement to demonstrate thickening	Thinning	No specific spatial impacts	Increased vegetation available to clear for thinning, but an overall reduction in the extent compared to 2012. Vegetation clearing can potentially occur in areas without thickening or encroachment.

<sup>a</sup>At-risk regional ecosystems were considered at risk of having their total extent reduced to below 30% of their pre-European extent ([Queensland Government, 2012](#)).

<sup>\*</sup>Dense regional ecosystems are allocated based on having a percentage foliage cover of 100–70% ([Queensland Government, 2012](#)).

harvesting, extractive industry, and general clearing. However, it is worth mentioning that most at-risk vegetation communities were predominantly found in the Brigalow Belt and Mulga Lands regions, where recent clearing activities have been concentrated ([Queensland Government, 2015](#)) (See [Supplementary Material Fig. S6](#) for the mapped extent of at-risk and dense regional ecosystems).

The fourth policy change introduced the concept of "self-assessable" clearing. This means that proponents of clearing are not required to provide evidence of clearing compliance or request permission to clear if specific conditions are met.

The fifth change in the guidelines eliminated the need for proponents to demonstrate vegetation thickening. Previously, proponents were obligated to submit satellite imagery demonstrating thickening or encroachment as part of their application. This imagery was assessed during the application process, and if thickening was not observed, the

application was not approved ([Table 1](#)).

The 2019 guidelines marked a significant shift in vegetation management policy, effectively reversing several fundamental changes introduced in 2015. These alterations aimed to achieve their objectives through five primary mechanisms ([Table 2](#)). The most pivotal of these changes was the removal of broad-scale clearing for agricultural and grazing purposes. The second significant policy modification entailed reducing buffer zones, particularly those encircling wetlands and watercourses. Notably, these buffer zones were decreased from 200 to 100 m for stream order 5, allowing for greater riparian vegetation clearance under the 2019 guidelines.

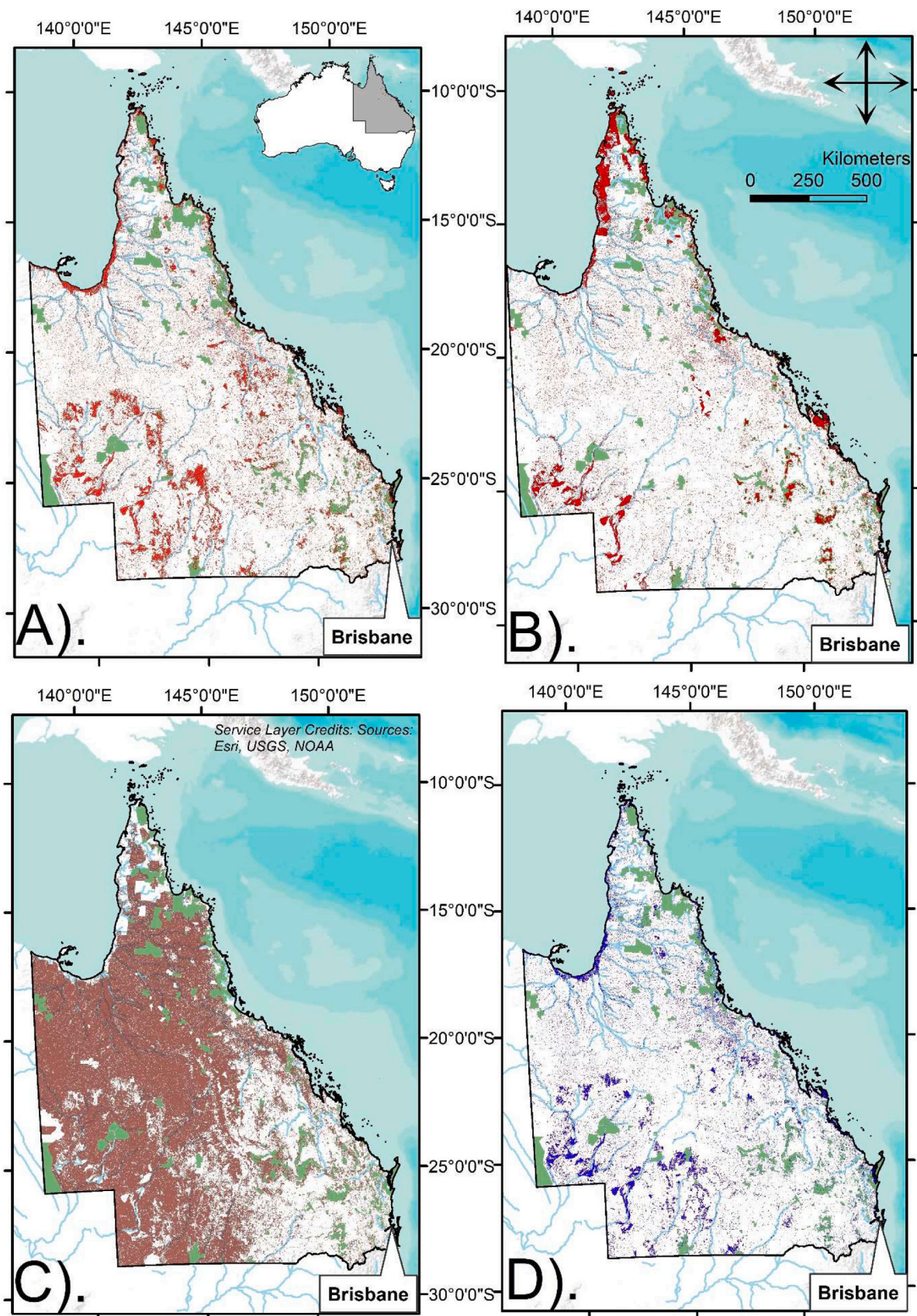
The remaining policy adjustments reversed many of the 2015 changes but also introduced further restrictions on clearing. One such change within the 2019 guidelines was the removal of thinning as a recognized clearing purpose. Consequently, if landowners wished to clear their property to manage dense vegetation, they were required to seek assessment under the provisions of the Planning Act 2016.

In the 2012 time-step, vegetation that could not be cleared without a development application under the Act, covered extensive areas of at-risk remnant vegetation, particularly in the coastal areas in the mid-northern half of the State. However, this condition was removed in the 2015 guidelines ([Fig. 3A](#)). Moreover, while large areas of non-assessable vegetation existed in the southwestern part of the State in both time-steps, the 2015 time-step allowed for even more non-assessable vegetation to be cleared without a development application, including significant coastal areas approximately 800 km north of Brisbane ([Fig. 3B](#)). Notably, the 2015 time-step introduced provisions for protecting remnant vegetation in the Cape York bioregion (the

**Table 2**

Summary of the fundamental policy changes identified in a comparative analysis for the 2015 and 2019 time-steps. See [Supplementary Table S1](#) for definitions of 'no concern at present,' 'of concern,' and 'endangered' regional ecosystems.

Guideline change	Key spatial impacts	Interpretation	Clearing purpose effected
Removal of broad-scale clearing for agriculture and grazing	Increase in remnant vegetation that is not exposed to potential clearing for this purpose	Less vegetation available for clearing	Agricultural and grazing
Changes to wetland and stream protection zones	Overall reduction of buffer zones in riparian areas, varying across Queensland	More vegetation is available for clearing in riparian areas	Agriculture and grazing, fodder harvesting, extractive industry, and encroachment
Introduction of riparian protection permits	No mappable spatial impacts	Greater scrutiny of clearing. This will likely result in higher compliance with the guidelines and a decreased amount of vegetation cleared overall.	Agriculture and grazing, fodder harvesting, extractive industry, and encroachment
Removal of thinning as a relevant clearing purpose	No mappable spatial impacts	Less vegetation available for clearing	Thinning
Reinstating the need to demonstrate encroachment is occurring	No mappable spatial impacts	Greater scrutiny of clearing. This will likely result in higher compliance with the guidelines and a decreased amount of vegetation cleared overall.	Encroachment



**Fig. 3.** Extent of remnant vegetation (shown in red) outside of clearing constraints for the A) 2012 time-step and B) 2015 time-step. C.) Extent of remnant vegetation (shown in dark red) that can be cleared without development application under the Act's guidelines for both 2012 and 2015 time-steps. D) Areas in blue show remnant vegetation that will require approval under the Act both the 2012 and 2015 time-steps. Areas in green are public, protected areas and State Forests. Protected area spatial data were sourced from the Collaborative Australian Protected Areas Database ([Australian Government, 2014](#)).



northernmost bioregion of the State), which were absent in the 2012 guidelines (Fig. 3B). In the 2012 and 2015 time-steps, significant portions of remnant vegetation did not have characteristics that restrict clearing according to the guidelines (Fig. 3C).

Similarly, Fig. 3D illustrates the extent of vegetation that contains landscape and vegetation characteristics that, for both time-steps, will require assessment under the Act. However, we note that this does not include extent-based thresholds for clearing. These thresholds apply to each property and generally constrain clearing to less than 5 ha without further assessment.

In 2015, significant changes led to an overall expansion of potentially clearable remnant vegetation, as described in Table 3. In 2012, 79,561,000 ha of 'no concern at present' regional ecosystems that could be cleared for general purposes, accounting for 65% of the total area of Category B vegetation (122,804,000 ha). By 2015, this area had increased to 99,559,870 ha, representing 81% of the total Category B vegetation area. This increased by 19,998,870 ha, marking a substantial 25% expansion. In 2012, the available area for 'Extractive Industry' purposes was 16,000 ha. However, by 2015, clearing in Key Resource Areas was no longer included in clearing guidelines, effectively reducing the extent of remnant vegetation available for this purpose to 0 ha. For encroachment, in 2012, 3495,000 ha of remnant vegetation were designated for clearing. In 2015, this area had expanded to 4912,200 ha, representing an additional 1417,200 ha or 41% increase. Agriculture and grazing had no allocated area in 2012. However, by 2015, 84,843,000 ha of remnant vegetation were designated for this purpose. Within this, 9357,000 ha of regional ecosystems were located on highly arable soils. In 2012, 6205,000 ha were available for fodder production. By 2015, this area had increased to 10,437,000 ha, a substantial 68% increase. Thinning activities were permissible on 74,843,000 ha in 2012, but this was reduced to 11,485,000 ha in 2015, signifying a significant decrease of 63,358,000 ha or an 85% reduction. In 2012, the combined area of all regional ecosystems (including of-concern and endangered categories) not otherwise restricted by guideline constraints was 89,920,000 ha. By 2015, this extent had expanded to 111,186,000 ha, resulting in a net increase of 21,266,000 ha, representing a 24% growth.

#### 4. Discussion

Most recent clearing in Queensland has primarily involved the removal of woody vegetation for intensive land use practices, including grazing pasture, agriculture and forestry (Queensland Department of Environment and Science, 2015; Seabrook et al., 2006). Land clearing has well-documented, severe impacts on biodiversity due to habitat loss and fragmentation (Mantyka-pringle et al., 2012; Neldner et al., 2017). Indeed, the consequences of land clearing extend beyond immediate loss, including the long-term impacts of invasive species invasion (Apan et al., 2002; Lebbink et al., 2022). The re-introduction of broad-scale clearing in the 2015 time-step was driven by the policy objective of doubling Queensland's agricultural production by 2040 in response to

increasing global demands for food and biofuel products (Department of Agriculture, 2014; Miyake et al., 2012; Queensland Government, 2013b). However, these changes raised concerns about the weakening of management legislation for effectively conserving Queensland's biodiversity (Maron et al., 2015). We concluded that there was a net increase of 19 million ha of 'no concern at present' remnant vegetation available for various clearing purposes in the 2015 time-step. This increase primarily stemmed from vegetation made available for grazing and agricultural development clearing, notably with 84 million ha of remnant vegetation allowed to be cleared, 9.3 million ha of which occur on soils most suitable for agricultural or pastoral production. In response, the 2019 time-step eliminated broad-scale clearing for agriculture and grazing as relevant clearing purpose under the Act.

Nevertheless, in both the 2015 and 2012 time-steps, a significant portion (65–81%) of remnant vegetation lies outside the boundaries of landscape or biophysical features that restrict clearing, highlighting the potential extent of vegetation that can be cleared. While the Act governs the regulation of all remnant vegetation, our analysis reveals that significant amounts can be cleared under certain circumstances. Consequently, variations in the clearing guidelines, which form the foundation of the Act, play a crucial role in determining the extent of land clearing. For example, the 2015 time-step identified several policy changes that increased the amount of remnant vegetation available for possible clearing: 1) re-introduction of broad-acre cropping as an eligible clearing purpose; 2) reduction in buffer zones around wetlands and watercourses; 3) removal of considerations for at-risk and dense regional ecosystems; 4) introduction of 'self-assessable clearing'; 5) removal of the requirement to demonstrate vegetation thickening or encroachment. However, it is essential to note that the total clearing in a single event must remain below a specified threshold outlined in the guidelines, typically ranging from 2 to 5 ha. Consequently, clearing extent is restricted and may be carried out gradually over multiple events.

A net increase in permissible clearing of remnant vegetation may also encompass vegetation previously within riparian buffer zones. Clearing was permitted within specific distances of watercourses and wetlands based on factors such as stream size and the region of the proposed clearing. However, there was an overall reduction in these buffer zones in the 2015 time-step. Riparian corridors have long been acknowledged as having high biodiversity values (Gibbons et al., 2009; Jones et al., 2022) and significance in social values (Arsénio et al., 2020). Following the changes to clearing guidelines, the Queensland Government reported an increase in riparian vegetation clearing, particularly in Great Barrier Reef Catchments (Queensland Department of Environment and Science, 2015). Clearing in these areas increases sediment and nutrient run-off, negatively impacting marine biodiversity (De'ath et al., 2012). Responding to these concerns, the Queensland Government introduced riparian protection permits in 2019, which involve heightened scrutiny of clearing activities in these areas and may lead to reduced clearing within riparian zones.

Clearing thickened vegetation in 2012 required landholders to provide evidence, typically in the form of satellite imagery, demonstrating

**Table 3**

Area (in hectares) of 'no concern at present' remnant vegetation available for clearing in the two time steps, rounded to the nearest hundred. Percent remnant<sup>^</sup> was calculated based on the 2015 extent of remnant vegetation (Category B = 122,804,000 ha) for consistency across time-steps. Highly arable soils were determined using the Queensland Agricultural Land Audit (Department of Agriculture and Fisheries, 2014). PctChange refers to the percent increase or decrease between 2012 and 2015. \*The term 'Total general' is the total extent of regional ecosystems classified as Category B (i.e., includes endangered and of-concern regional ecosystems).

Purpose	Total (ha) (2012)	PctRem <sup>^</sup>	Total (ha) (2015)	PctRem <sup>^</sup>	Area change (2012 to 2015)	PctChange
General (least concern regional ecosystems)	79,561,000	65	99,559,900	81	19,998,900	25
Extractive industry (Key Resource Areas)	16,000	0	0	0	-16,000	-100
Encroachment	3495,000	3	4912,200	4	1417,200	41
Agriculture and grazing	0	0	84,843,000	69	84,843,000	NA
Agriculture (on highly arable soils)	0	0	9357,000	8	9357,000	NA
Fodder	6205,000	5	10,437,000	8	4232,000	68
Thinning	74,843,000	61	11,485,000.00	9	-63,358,000	-85
Total general*	89,920,000	73	111,186,000	91	21,266,000	24

vegetation thickening or encroachment. However, in the 2015 time-step, this requirement was removed, resulting in a overall reduction of 63million hectares of remnant vegetation that could be cleared for this purpose. It is important to note that vegetation thickening plays a vital role in Australian ecosystems' natural, long-term dynamics, as it allows young trees and shrubs to establish and regenerate, driven by the dynamic climate conditions (Butler et al., 2018; Cardno, 2015). Whether removing woody vegetation for establishing or maintaining open savannas and productive pastures is appropriate depends on species traits and the timing of vegetation removal (Daryanto and Eldridge, 2010). Additionally, thickening is not necessarily an indicator of poor ecosystem health (Daryanto and Eldridge, 2010; Eldridge and Soliveres, 2015). Recognizing these complexities, the Queensland Government undertook extensive consultations while developing the 2019 clearing guidelines. The outcome was that clearing for thinning was removed from the relevant clearing purposes in the 2019 guidelines, aligning with the Act's objectives, prioritizing addressing ecological threats and preserving biodiversity in local ecosystems (Butler et al., 2018).

The 2012 and 2015 time-steps show extensive increases and decreases in the amount of remnant vegetation eligible for clearing under variants of the Act. These findings demonstrate the impact of changes within the Act's framework. Significant policy changes, especially when perceived as extreme or uncertain, can create an atmosphere of instability and provoke landholders to engage in pre-emptive clearing, termed 'panic-clearing' (Simmons et al., 2018; Whelan and Lyons, 2005). Panic clearing is a well-known and unintended consequence of policy changes, which is an increase in vegetation clearing in the lead-up to the changes (Lawes et al., 2015; Reside et al., 2017). Consequently, landholders clear their properties to avoid the regulatory barriers of incoming policy changes (Australian Government, 2012; Marcos-Martinez et al., 2018). Notably, panic clearing was observed in Queensland before the initial ban on broad-scale clearing in 2004, underscoring the need for cautious and strategic planning when introducing and implementing policy changes. To prevent panic clearing ahead of policy reform, it may be helpful for governments to develop clear and consistent transitional pathways and effective communication strategies. Implementing these measures can help minimize perverse consequences, including panic clearing, and ensure smoother policy transitions.

The findings of this study underscore the critical importance of conducting thorough spatial impact assessments when implementing policy changes. Our analysis reveals significant shifts in land clearing purposes, with far-reaching consequences for Queensland's remnant vegetation. For instance, in 2015, there were substantial increases in areas allocated for extractive industry, encroachment, agriculture, and fodder, coupled with a significant reduction in areas available for thinning. These findings highlight the state-wide impact of the absence of landscape or biophysical features that may expose remnant vegetation to heightened vulnerability. While regulations are in place to restrict the extent of land clearing in a single event, the lack of formal security introduces an element of uncertainty regarding the preservation of remnant vegetation, particularly in the context of dynamic nature of land management policies. Throughout periods of policy reform presented here, notable and substantial fluctuations in allowable clearing areas were observed. These shifts emphasize the ongoing challenge faced by policymakers in striking a delicate equilibrium between accommodating the clearing needs of private landholders and fulfilling essential requirements for biodiversity management. Our findings emphasize the imperative of maintaining a balanced and stable approach to policymaking in land management because extreme swings in policy can have far-reaching consequences.

#### CRedit authorship contribution statement

**Stephanie Hernandez:** Writing – original draft, Visualization, Methodology, Formal analysis, Data curation, Conceptualization.

**Vanessa M. Adams:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Stephanie Duce:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

#### Declaration of Competing Interest

All authors have no conflict of interest to declare.

#### Data availability

Data will be made available on request.

#### Acknowledgments

The authors gratefully acknowledge Dr Martin Taylor, Dr Mirjam Maughan and Bruce Wilson for their insights into clearing guidelines and assessment of our interpretation. We also thank our anonymous reviewer for their instructive and insightful comments on this manuscript.

#### Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.landusepol.2024.107064.

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