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Threatened fauna protections compromised by agricultural interests in Australia

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Abstract

Australia is a global leader in land clearing and biodiversity loss. The overwhelming majority of land clearing within Australia and, globally, is driven by agricultural conversion. The importance of agricultural lands also leads to the concentration of habitat protection in landscapes that do not support productive land uses, which might contribute to species conservation in marginal habitat. Using an integrated agricultural capability map and threatened vertebrate fauna range maps, we show that observed biases in protected area location have varied impacts at the species level. Specifically, threatened vertebrate fauna with habitat capable of supporting high-value productive lands received less protection and experienced greater habitat loss. Similarly, almost all species assessed received protection in the portions of their ranges less conducive to productive land uses. Finally, we identify regions of Australia at risk of future land clearing and the species likely to bear the brunt of the impacts. Our results demonstrate the importance of protecting land capable of supporting productive uses to conserve the most affected threatened species.

KEYWORDS

biodiversity conservation, conservation planning, habitat loss, land clearing, land use, productive land, protected-area management

1 | INTRODUCTION

Productive land uses, including agricultural and pastoral lands, are some of the most extensive causes of human modification to natural landscapes globally (Green et al., 2005; Evans, 2016). Consequently, land clearing for agriculture and pasture is one of the greatest drivers of habitat loss for the overwhelming majority of species (Maxwell et al., 2016; Ward et al., 2021). Similarly, the necessity of productive lands to support human populations pushes conservation actions into less productive landscapes (Pressey et al., 2000; Venter et al., 2018; Viera et al., 2019). With increasing global populations, the demand for productive lands will cause ever greater habitat loss around the globe (Green et al., 2005).

Australia is a global deforestation hotspot with substantial historical and ongoing land clearing and has experienced the largest documented decline in biodiversity of any continent over the last 200 years (Woinarksi et al., 2015; Evans, 2016; Ward et al., 2021). More than half of Australia's land area is utilized for primary production (ABARES, 2016), and intensive production landscapes that involve removal of native vegetation, such as cropping and modified pastures, account for around 15% of

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Australia's land area or some 1.15 million square kilometers. These land uses are largely confined to the eastern and southwestern agricultural and pastoral zones, overlapping Australia's hotspots of biodiversity, and threatened species richness (ABARES, 2016; Creswell & Murphy, 2017; Mittermeier et al., 2011).

While protected areas are one way of combating such pressures on biodiversity, Australia's protected area system is notably biased to the arid interior of the country where threatened species richness is lowest (ABARES, 2016; Creswell & Murphy, 2017) or to steep or infertile patches within productive landscapes (Pressey et al., 2000). This may undermine conservation goals in multiple ways, notably by (1) skewing protection in favor of species that inhabit these ecosystems (Venter et al., 2018; Pressey et al., 2017) and (2) protecting species in unproductive or marginal habitats that are unable to support adequate population sizes (Kawecki, 2008; Pironon et al., 2017; Kerley et al., 2020). Hence, the influence of productive land uses will have unequal impacts on species, depending on habitat preferences, among other things.

Both globally and locally within Australia, biases in protected area location have been documented and attributed to the effect of agricultural suitability on the location of conservation areas. However, these studies have focused on impacts on forest cover or vegetation types. To complement these studies, here we assess how agricultural capability affects individual faunal species. The aims of this paper are hence to (1) understand the influence of agricultural capability on habitat loss and habitat protection for threatened vertebrate fauna, (2) understand whether species protection is biased towards areas with low capability for agricultural uses, and (3) identify areas of Australia at risk of future land clearing due to agricultural capability and the threatened vertebrate fauna likely affected.

2 | METHODS

2.1 | Data

To determine the influence of agricultural capability on habitat loss and protection for threatened species, we obtained nationwide datasets on agricultural capability, cleared land, protected areas, and threatened vertebrate fauna ranges (Table 1). The Adams and Engert (2023) agricultural capability map ranks areas from 1 (highest) to 8 (lowest) based on various landscape and climate attributes and integrates capability of land for a wide range of agricultural practices (Figure 1). Agricultural capability has been demonstrated to be a strong predictor of land clearing (including for Australia; Adams & Engert, 2023) and is thus a good indicator of past loss driven by agricultural land uses as well as risk of future clearing in high capability areas.

When quantifying threatened vertebrate fauna ranges, we used both "likely to occur" and "may occur" areas within the Species of National Environmental Significance (SNES) database. As many of Australia's threatened species have lost substantial areas of pre-European habitat (Ward et al., 2022), the "may occur" range may often be a more accurate representation of pre-European extent than the "likely to occur" range alone. We clipped the range maps to include only the Australian landmass (including Tasmania and large islands) and excluded all species with ranges not overlapping this area. We also excluded species that do not use terrestrial ecosystems as habitat, including marine species and seabirds that only spend time on small islands. We retained range maps for 319 federally listed terrestrial vertebrate fauna species, including 36 frog species, 46 reptiles, 90 mammals, and 147 birds (see Supplementary data file for details).

2.2 | Influence of agricultural capability on habitat loss and protection

We aimed to determine the influence of agricultural capability on habitat loss and protected area coverage for Australia's threatened terrestrial vertebrate fauna. For each species, we calculated the proportion of its range, regardless of protection status or current presence of intact vegetation, on high-value land. We also calculated the proportion of its range, regardless of current presence of intact vegetation, within protected areas, and the proportion of its range that had been cleared. As some species primarily have ranges on islands (e.g., seabirds), we accounted for the fact that our model only assessed small portions of their range by including a model term describing the proportion of each species range that was covered by the agricultural capability map.

We determined the influence of agricultural capability on (1) habitat clearing and (2) habitat protection using generalized linear models (GLMs) with beta error distribution using "proportion of habitat on high-value land," "taxonomic class," and "proportion of range mapped" as independent variables and "proportion range cleared" and "proportion range protected" as response variables. Beta error distribution with logit link function was used as both the response and predictor variables were proportions. We included a small bias to all values of 0 and 1 as Beta regression does not allow values of exactly 0 or 1. The taxonomic class was included as a model term as different groups may receive different levels of protection, for example, due

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TABLE 1 Key datasets utilized in this study.

Dataset	Description	Source
Agricultural capability	A nationwide map of current agricultural capability for Australia. This map was created by integrating various Australian state and federal government datasets on the capability of land to support multiple productive uses, including rainfed and irrigated agriculture, pastoral lands, and forestry. Agricultural capability is scored from 1 to 8 (with 9 representing unknown capability). The initial 0.0003 decimal degree map was resampled to 1 ha resolution using the majority function in Arcmap 10.7.	Adams and Engert (2023)
High-value agricultural land	Areas scoring 1–3 based on the agricultural capability data were defined as high-value lands that require minimal inputs for productive uses.	Adams and Engert (2023)
At-risk land	High-value agricultural land that had not been cleared and was not currently under protection was defined as “at-risk” land.	Adams and Engert (2023)
Cleared land	Cleared lands (where native vegetation has been removed or significantly modified) were extracted from the National Vegetation Information System theme maps (NVIS). Intact lands are areas where native vegetation has not been removed or significantly modified.	Australian Government (2021a)
Protected areas	All protected areas are registered within the Collaborative Australian Protected Area Database (CAPAD), regardless of protection level.	Commonwealth of Australia (2021)
Land tenure	Land tenure information, with a particular focus on differentiating freehold, leasehold, and crown (public) land in Australia for the period 2015–2016.	ABARES (2021)
Federal electorates	Federal electorate boundaries as defined by the Australian Electoral Commission.	AEC (2021)
Threatened species ranges	Range information for Australia’s federally listed threatened fauna species was accessed through the Species of National Environmental Significance database. Both “likely to occur” and “may occur” ranges were combined to quantify species range extents. The “likely to occur” ranges were areas of suitable or preferred habitat, within ecologically reasonable distances from “known to occur” locations, and the “may occur” ranges were areas within a broad environmental envelope or geographic region that encompassed all areas that could provide habitat for the species.	Australian Government (2021b)

to public perceptions of species importance (Walsh et al., 2013). All beta GLMs were carried out using the `betareg` package (Cribari-Neto & Zeileis, 2010).

2.3 | Habitat protection in areas of low agricultural capability

We compared the location of protected areas for each species to understand if threatened vertebrate fauna received protection in the parts of their ranges less valuable for agriculture. We used chi-square tests to compare, for each species, the proportion of its protected and unprotected range area in each agricultural capability class (Figure 3a). Chi-square tests were used on the proportion of area, as this is insensitive to the number of observations, allowing us to make reasonable comparisons of value distributions with many observations (i.e., species’ range areas assessed a 1-ha cell resolution).

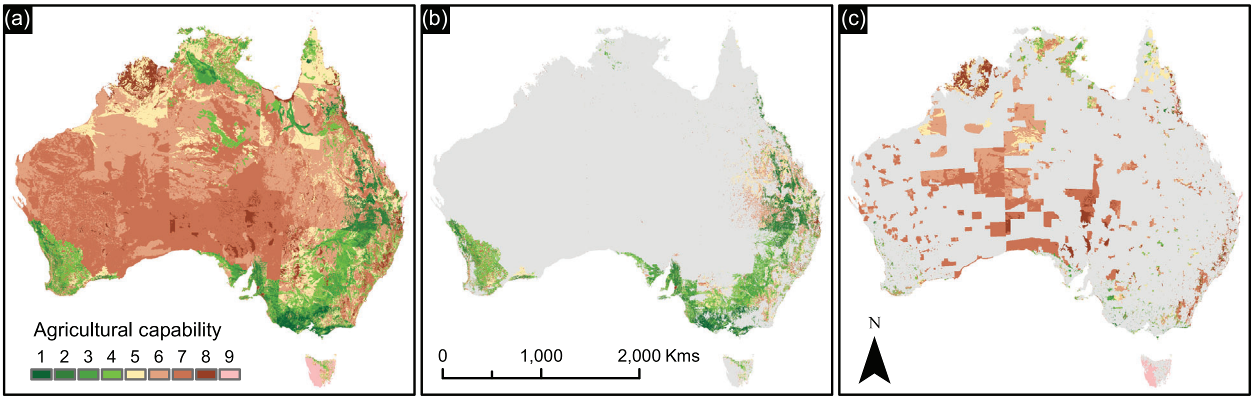

FIGURE 1 Agricultural capability of Australia. (a) The agricultural capability map for Australia (1 = highest, 8 = lowest, 9 = unknown). (b) The agricultural capability of land that had been cleared by 2020. (c) The agricultural capability for land within protected areas from CAPAD (2018).

2.4 | Areas at risk of future land clearing

To identify areas that might experience land clearing in the future, we identified land "at risk" of clearing or conversion due to agricultural capability. We defined "at-risk" areas as being land with high agricultural capability that had not been cleared and was not currently within a designated protected area (Table 1). We calculated the proportion of species ranges that were "at risk" and combined those with proportions of ranges cleared to determine potential impacts of future habitat loss. We additionally determined priority areas for monitoring of land-clearing legislation by quantifying the extent of "at-risk" land within individual states and federal electorates. These administrative units were selected as land clearing policy is largely regulated at the state level, and threats to Species of National Environmental Significance specifically (such as land clearing) are regulated at the federal level (e.g., through the Environmental Protection and Biodiversity Conservation Act; Ward et al., 2019). As land clearing in threatened species habitat is regulated at the federal level, voting patterns in federal electorates can influence the effectiveness of these legislations. To support these priority areas, we quantified the extent of "at-risk" land within each land tenure type.

3 | RESULTS

3.1 | Influence of agricultural capability on habitat loss and protection

We found that agricultural capability was an important predictor of threatened vertebrate fauna protection and habitat loss (Figure 2). Threatened vertebrate fauna with greater proportions of their ranges on high-value lands received less protection and experienced more habitat loss (Tables S1 and S2 in the Supporting Information). For example, species with 0% of their range in high-value land lost native vegetation across a predicted 16.19% of their range, while those with 95% high-value lost vegetation across 92.16%. Similarly, species with 0% of their range in high-value land were protected across a predicted 38.95% of their range, while those with 95% high-value were protected across 8.36%. This general trend was consistent for all taxonomic groups. However, the taxonomic group had a significant influence on both levels of protection and amounts of habitat loss. For example, birds experienced greater relative amounts of habitat loss than mammals (Figure S1 in the Supporting Information). Similarly, birds and reptiles received relatively less protection than frogs, and reptiles received less protection than mammals.

3.2 | Habitat protection in areas of low agricultural capability

Our results show that, in general, threatened vertebrate fauna received protection in the parts of their ranges that have lower agricultural capability (Figure 3). Of the 319 species included in our analysis, 253 species (79.3%) were protected in areas of habitat that had lower mean agricultural capability than the unprotected habitat within their ranges. Conversely, only 27 species (8.5%) were protected in parts of their range with higher agricultural capability than those unprotected, and 39 species (12.2%) were protected in areas of equal value. These differences were consistent across all taxonomic groups.

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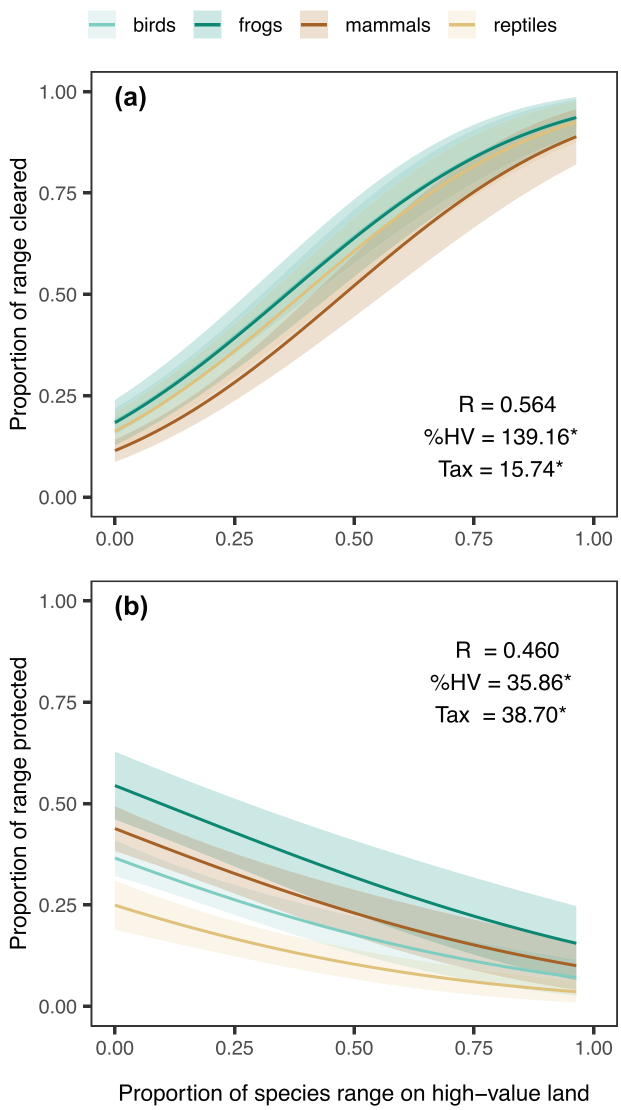

FIGURE 2 Habitat loss and protection for Australia's threatened fauna in relation to agricultural capability. Both (a) habitat loss (positive) and (b) habitat protection (negative) were strongly correlated with the proportion of high-value land in species ranges in all vertebrate groups. Figure panels show fitted response values from Beta GLMs. Shaded ribbons indicate model confidence intervals.

3.3 | Areas at risk of future land clearing

We identified large areas of Australia at risk of future land clearing due to agricultural capability (Figure 4). This potential future land clearing would significantly impact multiple threatened vertebrate fauna (Figure 4a). While most species (260 species or 81.5%) were at risk across less than 5% of their total ranges, these species had on average lost around 30% of the vegetation within their ranges already (mean = 29.1, SD = 26.0). However, we found 23 species at risk of losing more than 10% of their remaining ranges, and 10 species were at risk of losing more than 20%. Of the 10 species at risk across more than 20% of their ranges, four were endemic to Melville Island in the Northern Territory. Additionally, we found that 15 species with intact vegetation across more than half of their ranges might eventually exceed 50% loss when factoring in at-risk areas.

Finally, we used extent of at-risk land across federal electorates and land tenure types to identify priority regions for land-clearing governance. Tenure of at-risk land varied between states and territories (Figure 5a). In the governmental regions holding the majority of at-risk land—New South Wales, the Northern Territory, and Queensland—this land was predominantly in pastoral lease and freehold, tenures with high historical clearing rates. Alternatively, in Victoria and Western Australia, at-risk land was largely confined to freehold land and multiple-use forests.

Queensland and the Northern Territory alone hold more than half of the land at risk of future clearing (Figure 5b). New South Wales also hosts a substantial area of at-risk land, and, along with Queensland, it has had some of the highest historical rates of land clearing. Additionally, we found that just four of the 145 federal electorates we considered held 68.4% of at-risk land. Two of these electorates, Parkes and Maranoa, also had some of the highest rates of historical and ongoing land clearing (Figure 5c). A further 23 electorates each held more than 1000 km^2 of at-risk land. Multiple electorates had low amounts of at-risk land due to substantial historical land clearing rather than low areas of productive lands (Figure 5c).

4 | DISCUSSION

The capability of land for productive uses has important impacts on threatened species conservation in Australia and globally. We found that species with ranges intersecting productive lands endured more habitat loss and received less protection than those in unproductive regions. Similarly, almost all of Australia's threatened vertebrate fauna are protected in the portions of their ranges that are less conducive to productive land uses. Understanding and rectifying these biases is important for future expansion of protected area networks under global commitments, as many species will likely only receive the bare minimum protection, or protection in marginal habitat due to productive land biases. Increasing human populations and demand for agricultural products will likely aggravate these biases and amplify the impacts on threatened species. Identifying land at risk of future conversion

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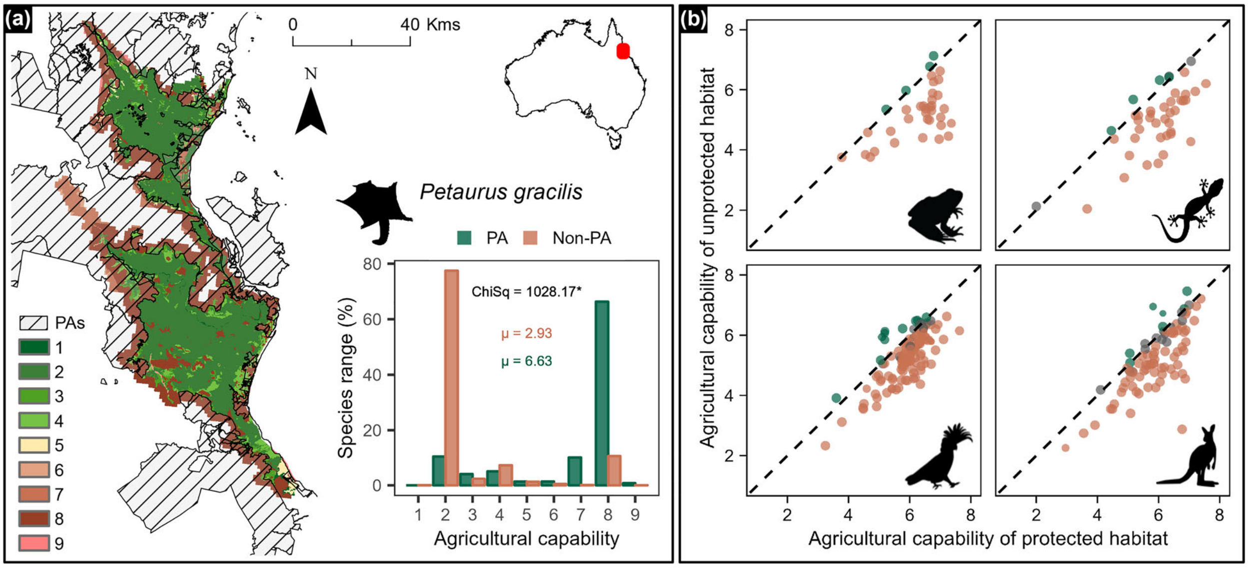

FIGURE 3 Protected and unprotected portions of Australia's threatened species ranges in relation to agricultural capability. Agricultural capability was scored from 1 to 8, with lower values, indicating higher capability. (a) Mean agricultural capability was calculated for protected (PA) and unprotected areas (non-PA) of each species' range and value distributions compared using the chi-square test of independence. An example here is presented for the Mahogany glider, where the entire range of which is shown. (b) Agricultural capability of protected and unprotected areas of species ranges for all terrestrial vertebrate fauna for which range maps were retained across Australia. Brown circles show species in each taxonomic group that were protected in portions of their ranges with lower agricultural capability, while green circles are species protected in areas with higher agricultural capability. Gray circles showed no significant difference in values between protected and unprotected areas.

and with high biodiversity value can ensure conservation actions have a high impact (Pressey et al., 2007, 2021).

Protection of species in the less productive areas of their ranges may translate to protection in marginal habitat that supports lower population densities or even acts as sink habitat for many species (Hansen et al., 2000; Watson, 2011). This is concerning, as species that are managed in marginal habitat have been observed to be experiencing population declines even in the presence of conservation actions (Kerley et al., 2020; Lea et al., 2016). Our analysis identifies numerous species that might be significantly impacted by this bias, including the Mahogany glider (*Petaurus gracilis*), an endangered species which predominantly receives habitat protection in low-value marginal habitat while the majority of its range has been converted to agricultural lands. The continued decline of this species within its remaining habitat has been recognized, although there are currently no plans to protect or restore high-value habitat (NESP TSRH, 2019). With habitat protection globally biased to less productive lands, area-based conservation targets might not be adequate to protect landscapes capable of supporting viable populations. Hence, protected area planning should also consider ecological suitability and aim for sustained population sizes rather than just meeting area targets (Adams et al., 2021; Burgman et al., 2001).

Our results highlight the importance of agricultural capability as a predictor of habitat loss and threats to species persistence. Expansion of road and rail networks, irrigation, and other agricultural infrastructure is promoting development of agricultural landscapes independent of population centers and other socioeconomic drivers of land-cover change (e.g., Camkin, 2011; McCarthy & Obidzinsky, 2017). Examples of this phenomenon are already emerging across the globe, including agricultural development in the Ord River region of northern Australia (Camkin, 2011) and food estates in Indonesian Borneo and New Guinea (McCarthy & Obidzinsky, 2017). Increasing global urbanization will further contribute to the shift to industrial-scale agriculture (Satterthwaite et al., 2010). Hence, we can use information on agricultural capability to identify species and ecosystems threatened by future developments and establish proactive conservation measures where possible.

We identified vast areas of Australia at risk of future land clearing, and a number of species highly susceptible to habitat loss as a result. Not only have many threatened vertebrate fauna lost significant portions of their historical ranges, but our analysis identified those that have substantial areas of remaining vegetation within their range at risk of future land clearing. Given these are species that are already threatened, further loss of habitat has significant

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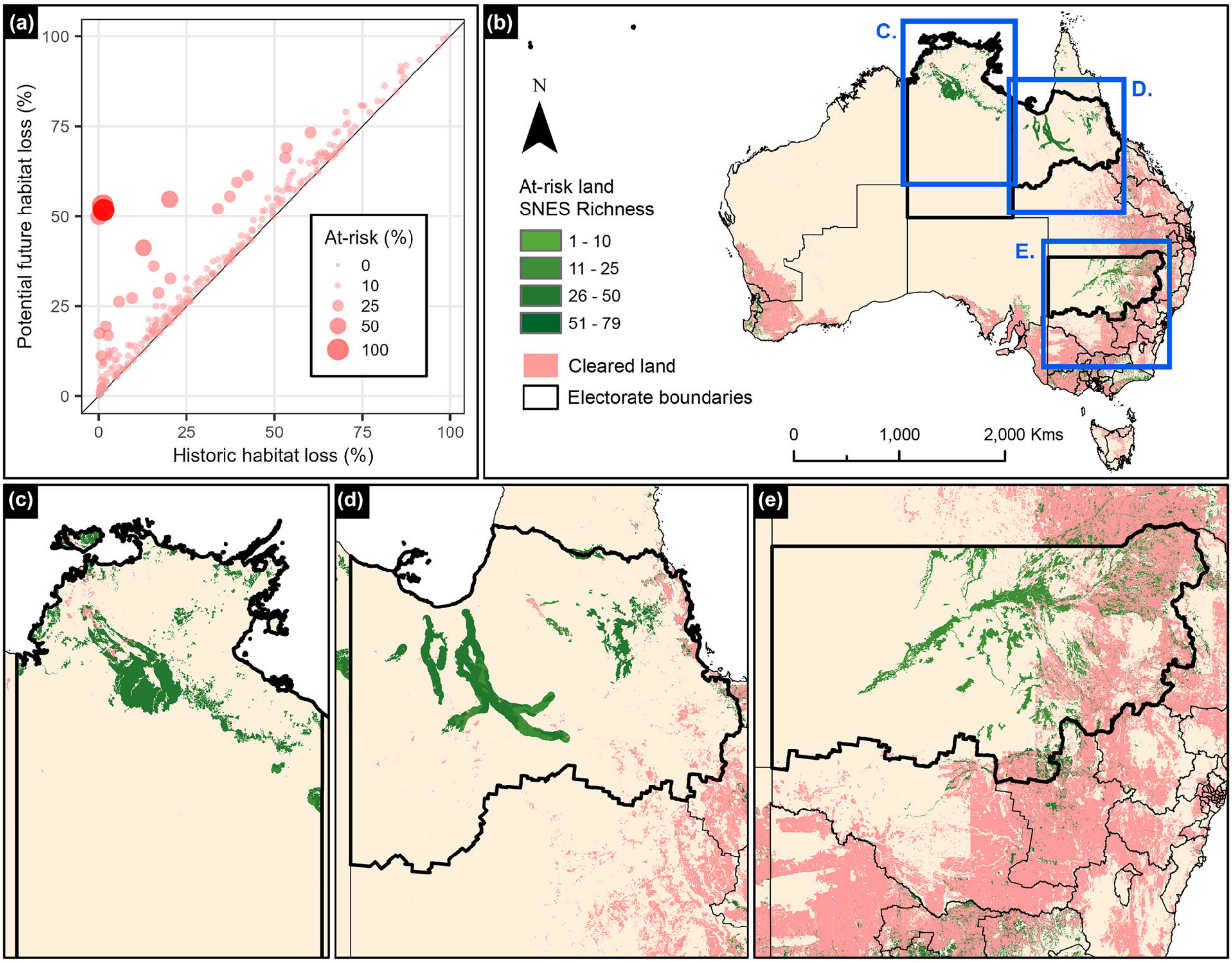

FIGURE 4 Parts of threatened species range at risk of future clearing. (a) Potential future habitat loss for threatened species (historical habitat loss plus at-risk habitat) against historical habitat loss. Dots are larger for species with more habitat at-risk of future clearing. (b) Nation-wide extent of land at risk of future clearing due to land capability. (C)–(E) Federal electorates with high proportions of national at-risk land (thick borders), respectively Lingiari, Kennedy, and Parkes. SNES richness refers to threatened vertebrate fauna richness.

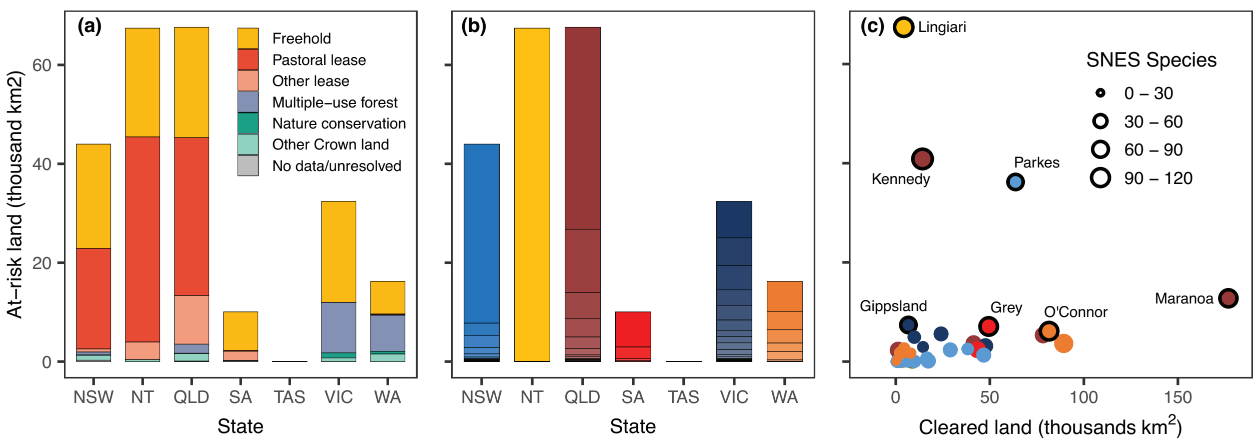

FIGURE 5 Distribution of land at-risk of clearing for agriculture across Australia's federal electorates and land tenure classes. (a) Distribution of at-risk land within land tenure classes by state or territory (NSW = New South Wales, NT = Northern Territory, QLD = Queensland, SA = South Australia, TAS = Tasmania, VIC = Victoria, and WA = Western Australia). (b) Distribution of at-risk land within electorates by state or territory. (c) Federal electorates by historic land clearing and land at risk of future clearing. Black borders indicate named electorates, which have the largest areas of at-risk land.

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repercussions for their viability. Of the electorates identified as hosting substantial tracts of at-risk land, Kennedy and Lingiari are vulnerable to future land clearing under various plans to develop northern Australia (Adams et al., 2016; Humphries et al., 2017; Meadows et al., 2020), and multiple other electorates host important agricultural and pastoral production regions with ongoing land clearing. As most agricultural land clearing in Australia is not referred to the Federal Government for assessment (Ward et al., 2019), and most at-risk land is in freehold or pastoral lease tenures, improved land clearing policies at the state level may play an important role in these at-risk regions (Bartel, 2003; Reside et al., 2017). While the effectiveness of such policies at the state level has been weakened over time, improved enforcement complemented by improved regulation of matters of national environmental significance could curb habitat loss (Evans, 2016; Heagney et al., 2021; Reside et al., 2017; Simmons et al., 2018; Ward et al., 2019). Similarly, the amount of at-risk land in freehold tenures suggests that private-land conservation measures may be important for maintaining populations of many threatened species (Kearney et al., 2022).

While the agricultural capability map utilized here is a strong predictor of land clearing (Adams & Engert, 2023), impacts to threatened species will also occur outside of areas predicted. For example, recent proposals to expand agricultural development in the Ord River and Cape York regions in Northern Australia are largely in areas identified as moderate capability, which are also subjected to significant land clearing (Adams & Engert, 2023; Adams et al., 2023). Additionally, some land uses, such as native timber forestry or mining, have resulted in clearing in areas not considered to be high value (Lindenmayer & Taylor, 2021). While the extent of these land uses is significantly smaller than agricultural and pastoral uses, they may have significant impacts on threatened and range-restricted species. Additionally, while our study focused on the complete removal of native vegetation, land degradation through actions such as grazing is also a significant threatening process for many species (Preece & Fitzsimons, 2022).

The effect of agricultural capability on the location of protected areas has been extensively documented (Pressey et al., 2000 Venter et al., 2018; Viera et al., 2019); however, unlike previous studies, we identified how these biases affected individual species. We confirmed that biases in the location of protected areas have varying impacts at the species level in terms of habitat loss and protection. Additionally, almost all species were protected in the portions of their ranges less conducive to productive uses. By highlighting the influence of agricultural capability on species persistence, we were able to identify substantial areas of land at risk of future clearing, and numerous species likely to be significantly impacted. These results can be used to prioritize conservation actions to maximize conservation impact.

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CONFLICT OF INTEREST STATEMENT

The authors declare no competing interests

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the relevant references.

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Additional supporting information can be found online in the Supporting Information section at the end of this article.

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