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Research article

Farm revegetation has substantial potential to improve biodiversity outcomes

Karel Mokany [a,*], Hugh M. Burley [a], Chris Ware [b], Katherine M. Giljohann [c], Anthony P. O'Grady [b], Karen M. Christie-Whitehead [d], Matthew T. Harrison [e]

[a] CSIRO, Canberra, ACT, 2601, Australia
[b] CSIRO, Sandy Bay, TAS, 7005, Australia
[c] CSIRO, Clayton, VIC, 3168, Australia
[d] Tasmanian Institute of Agriculture, University of Tasmania, Burnie, TAS, 7320, Australia
[e] Tasmanian Institute of Agriculture, University of Tasmania, Newnham, TAS, 7248, Australia

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ABSTRACT

Agricultural expansion and intensification has caused habitat loss, contributing to the current biodiversity crisis. Reliable, efficient and consistent information at the farm-scale is critical to understand the magnitude of recent changes in biodiversity and to inform future management actions aimed at reversing historical declines. We apply a habitat-based biodiversity assessment approach to examine the potential for grazing farms across Australia to improve outcomes for biodiversity by revegetating 10 % of the farm area. Fourteen case-study farms distributed across Australia with diverse attributes were assessed, including an analysis of likely benefits for biodiversity 30 years after commencing a hypothetical revegetation scenario, within the context of estimates of recent historical changes. From 2004 to 2020, the three biodiversity indicators considered decreased for the majority of farms. The scenario for revegetating 10 % of the farm area was estimated to substantially increase the biodiversity indicators, with half of the farms estimated to achieve recovery for all 3 indicators to greater than 2004 levels by 2050. Smaller farms with lower average ecosystem condition in 2020 were estimated to achieve the greatest gains in biodiversity from the revegetation scenario, relative to their indicator values in 2020. Farm revegetation actions have substantial potential to improve outcomes for biodiversity, though such gains may be difficult and time consuming to achieve, emphasising the importance of avoiding further habitat loss through removal or degradation of native vegetation.

1. Introduction

The world is in the midst of a biodiversity crisis. Current rates of biodiversity loss are similar to those experienced during mass extinction events of geological history (Ceballos et al., 2015), with up to a million species at risk over the coming decades (IPBES et al., 2019). Agricultural expansion and intensification has been one of the main drivers of biodiversity loss to date, particularly through removal and degradation of natural vegetation (Jaureguiberry et al., 2022). While agriculture provides food and fibre that is critical for human survival and wellbeing, ongoing demands for greater production and increased profitability have led to a loss of biodiversity within agricultural landscapes (Dudley and Alexander, 2017; Secretariat of the Convention on Biological Diversity, 2020).

Given that more than a third of the world's ice-free land area is used for agriculture (FAO, 2023), alternative approaches to vegetation management in agricultural landscapes have the potential to play a valuable role in halting and reversing biodiversity declines (Leclère et al., 2020). In intensively farmed regions around the world, restoration planting or seeding of mixed native plant species has been demonstrated to promote plant and animal diversity (Barral et al., 2015; Atkinson et al., 2022). In more extensive systems such as rangelands, removing livestock grazing can enable natural regeneration of the in-situ native vegetation, with observed biodiversity benefits (Haby and Brandle, 2018; Bardgett et al., 2021).

While individual farmers may be supportive in-principle of revegetation actions that promote biodiversity, financial instruments to compensate for the potential costs and reductions in profitability may be

* Corresponding author.
E-mail address: Karel.Mokany@csiro.au (K. Mokany).

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necessary to facilitate broad-scale uptake of such revegetation actions. Carbon markets and trading schemes may be one avenue for renumeration following revegetation actions, with biodiversity co-benefits often enhancing the value of carbon-focussed revegetation projects (Bond et al., 2024). Dedicated biodiversity markets or financial instruments may be an additional avenue, though successful broadscale implementation of such approaches are yet to be demonstrated (Luxton et al., 2024). Land management decisions under carbon and biodiversity markets would likely be considered against commodity markets (Pham-Kieu et al., 2024). More traditional government funding programs for farmers in compensation for specific vegetation management actions are likely to play an ongoing role (Pe'er et al., 2019).

One of the substantial barriers to financial recognition of on-farm revegetation actions is reliable quantification of the biodiversity benefits of past actions, and understanding the likely future benefits of actions that are planned or only recently implemented (Thomas et al., 2023). On-ground ecological monitoring is the most rigorous approach to quantifying changes in biodiversity across a farm. However, ecological surveys are expensive, not easily comparable between regions, cannot be implemented retrospectively and do not directly provide information on likely change into the future (Herzog and Franklin, 2016; Targetti et al., 2016). Habitat-based assessment approaches are well placed to complement on-ground surveys and meet the needs for efficient standardised farm-scale biodiversity assessment that is highly scalable over space and time (Boykin et al., 2013). Such habitat based approaches do not attempt to directly observe biodiversity change, but instead combine spatially-complete information from remote sensing with spatial biodiversity models to estimate change in the provision of habitat for key biodiversity features (Mokany et al., 2022b).

Here we assess the potential biodiversity benefits of revegetation actions for a diverse set of 14 case-study livestock grazing farms distributed across Australia. Using a habitat-based biodiversity assessment approach, we first quantify recent historical change (2004—2020) in three biodiversity indicators. We then project likely future change in the same indicators (2020—2050) under a scenario where 10 % of the area of each farm is revegetated. By exploring how the projected biodiversity outcomes vary with farm area and starting ecosystem condition, we examine where the greatest gains are likely to result from on-farm revegetation actions.

2. Methods

2.1. General approach

The biodiversity assessments for the 14 case-study farms were undertaken using a habitat-based assessment approach considering three complementary biodiversity indicators. For past-to-present monitoring, this involved using remote sensing data to estimate changes in ecosystem condition at fine spatial resolution (≈1 ha) and at regular reporting periods (annual from 2004 to 2020). Ecosystem condition information was then combined with spatial biodiversity layers to determine the consequences of change in ecosystem condition for threatened species habitat and native plant species persistence. Projections of potential benefits of the proposed revegetation actions on each farm for each biodiversity indicator were made using a consistent approach, based on estimated changes in ecosystem condition following revegetation.

2.2. Case-study farms

Fourteen case-study farms were selected from across Australia, based on expressions of interest from farmers, the willingness of the farmers to contribute their time to the study and ad-hoc stratification across agroecological regions, farm size, and agricultural operations (Fig. S1 – Supporting Information). All case-study farms were primarily livestock grazing enterprises for wool or meat (farm code 'Ca' = cattle, 'Sh' = sheep), with a median farm size of 3820 ha (range: 254 — 522,638 ha). Farm boundaries specified as spatial polygons were derived from existing data sources in consultation with each farmer. Five farms were comprised of multiple spatially discontinuous polygons (CaC1, CaC3, ShC2, ShC3 and ShR3) (Fig. S1). For the future projections of hypothetical revegetation actions, farmer interviews were used to identify area/s equivalent to approximately 10 % of the farm where such actions would most likely be implemented, specified as spatial polygons (Fig. S1). The proportion of total farm area on which to apply the revegetation scenario (10 %) was selected as a nominal maximum area that farmers suggested they would revegetate and to provide a standardised value for comparing revegetation actions across farms of different size.

2.3. Biodiversity indicators

For each farm, the values of three biodiversity indicators were quantified: (1) effective habitat area, (2) threatened species habitat, and, (3) benefit for species persistence.

Effective habitat area (EHA) is an estimate of the total area of habitat available for biodiversity, in units of hectares. It is calculated by summing the ecosystem condition value (c_i; 0−1 scale) of each grid cell i within the farm boundary, weighted by the grid cell area (a_i) in hectares (i.e. $EHA = \sum c_i a_i$). Ecosystem condition represents the capacity of each grid cell to support the suite of species originally occurring there in a pre-intensification reference state (for Australia equivalent to pre-1750). For example, an ecosystem condition value of 0.5 (or 50 %) is equivalent to half of the grid cell being completely degraded, supporting none of the originally occurring native species, and the other half of the grid cell being in an unmodified intact reference state. Ecosystem condition was estimated for each year based on remotely sensed data, in an approach that incorporated the environmental context of each location (Appendix S1 – Supporting Information). Given that there is no consistent on-ground measurement of ecosystem condition across Australia, the spatial time series of estimated ecosystem condition was validated using >180,000 on-ground vegetation surveys (Mokany et al., 2022a). The proportion of the observed species that were native was used as a surrogate measure of ecosystem condition, assuming that the proportion of species that are native increases as ecosystem condition increases. (Appendix S1 – Supporting Information).

The threatened species habitat (TSH) indicator represents an estimate of the amount of habitat being provided to nationally listed threatened species. The amount of threatened species habitat for grid cell i is calculated by multiplying the ecosystem condition of that grid cell (c_i; 0−1 scale) by the number of threatened species with potential distributions that overlap that grid cell (n_i) (Giljohann et al., 2022), taking into account the area of the grid cell (a_i) in hectares (i.e. $TSH_i = c_i n_i a_i$). For a farm, the threatened species habitat is simply summed across the grid cells covered (i.e. $TSH = \sum c_i n_i a_i$). In calculating threatened species habitat, all ecosystem condition values < 0.5 are set to 0, under the assumption that areas of low ecosystem condition provide no meaningful habitat for threatened species (Giljohann et al., 2025). For both the grid cell and farm scale, the units of the threatened species habitat indicator are 'species hectares' (species.ha), where for example a value of '10' could indicate that 10 ha of habitat are provided for one threatened species, or that 1 ha of habitat is being provided for 10 threatened species (or many other alternatives).

The benefit for species persistence indicator is an estimate of how all the areas of habitat across the farm in combination contribute to the long-term persistence of Australian native plant species across all of Australia. The units of this indicator are 'species', being the number of additional native plant species that are expected to persist in the long term in Australia due to the habitat provided on the farm, compared to a counterfactual case where there is no habitat on the farm (minimum indicator value = 0). Higher values indicate a greater contribution of the farm to the maintenance of native plant diversity. In contrast to the

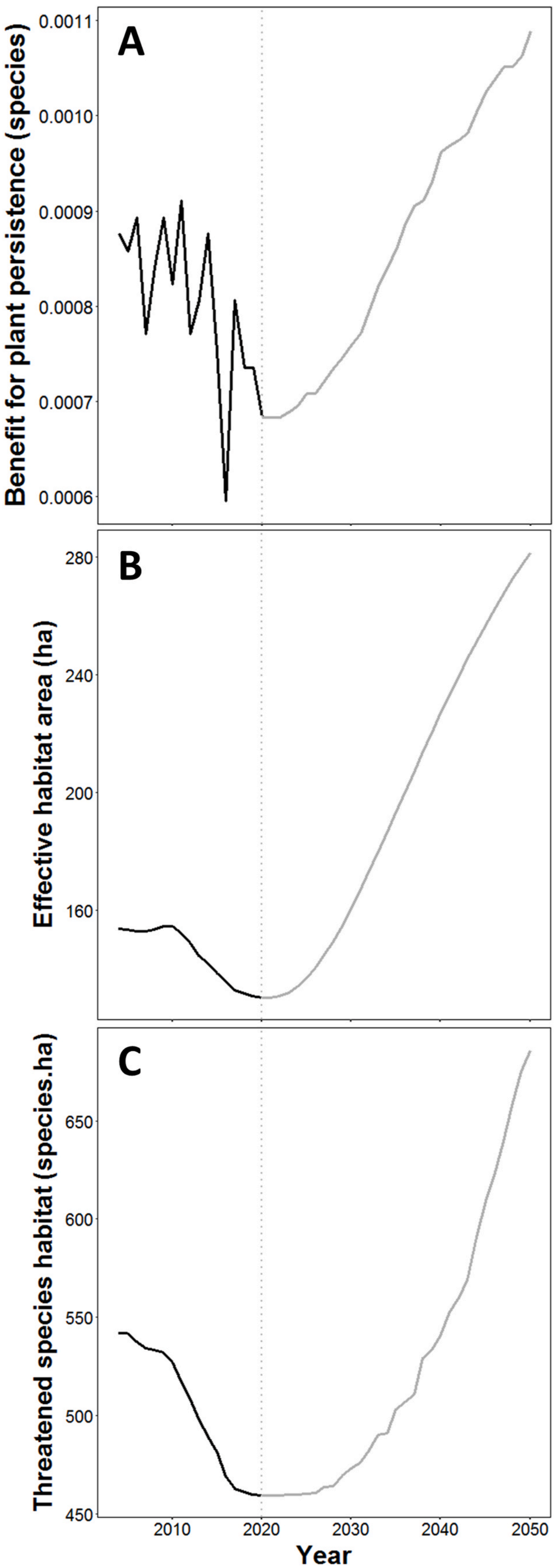

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Fig. 1. Biodiversity assessment results for one of the case-study farms (ShR2), for: **A.** the benefit of on-farm habitat for plant species persistence; **B.** the effective habitat area (a summary of ecosystem condition across the farm), and; **C.** threatened species habitat. The results for all the case-study farms are provided in Fig. S2. The vertical dotted line indicates the point of transition (2020) from analysis of the recent past (black line) to estimated future changes (grey line).

previously described indicators, the benefit for species persistence is a non-additive indicator, meaning that its derivation for a farm requires an analysis, rather than simple summation of component spatial grid cells. This analysis combines the ecosystem condition data (Appendix S1) with spatial layers of predicted compositional diversity patterns, accounting for areas both within and outside the farm boundary (Appendix S2). This indicator is an alternative expression of the Biodiversity Habitat Index (UNEP-WCMC, 2023), which is a Component Indicator under the United Nations Convention on Biological Diversity Kunming-Montreal Global Biodiversity Framework (CBD, 2022) and has been applied in a variety of biodiversity assessments (Allnutt et al., 2008; UNEP-WCMC, 2016; Di Marco et al., 2019; Mokany et al., 2022b). The spatial biodiversity models underlying this biodiversity indicator have been validated with compositional data from 118,509 plant community survey plots from across Australia (Mokany et al., 2022a) (Appendix S2).

All biodiversity indicators were derived using the web-based analytical platform LOOC-B (Landscape Options and Opportunities Calculator - for Biodiversity) (CSIRO, 2024). Analyses were implemented using a spatial file (GeoJSON) specifying the boundary of each farm, and were undertaken using the LOOC-B application programming interface (API) (CSIRO, 2024) called from the R statistical computing environment (R Core Team, 2024).

2.4. Estimating future benefits of revegetation actions

The biodiversity indicator values were estimated into the future for a 30-year period (2020–2050) under the scenario of revegetating approximately 10 % of the farm area. This simply required calculating each biodiversity indicator, as described above, but using estimated changes in ecosystem condition following revegetation of the proposed areas. Most of the case-study farms are located in areas where natural ecosystems are predominantly forest and woodland, in which case the revegetation action assessed was a diverse mixed native species restoration planting with concomitant exclusion of livestock grazing. For the four farms located in areas where natural ecosystems have sparse or no tree cover (farms: CaC1, CaC5, CaC6, CaC7), the revegetation action assessed was natural regeneration of the existing native vegetation following removal of all livestock grazing from the identified area.

To estimate expected changes in ecosystem condition into the future under the proposed revegetation actions, we applied response functions informed by best available data (Prober et al., 2025). The response functions estimate change in ecosystem condition over time based on the initial ecosystem condition and the implemented action (Appendix S3). The scenario analysis assumed that the restoration action was successful in achieving revegetation, and we did not assess uncertainty associated with the success of the restoration action or with the biodiversity benefits of the action. As with estimates of historical changes in the biodiversity indicators, the revegetation scenario for each farm was assessed using API calls to the LOOC-B analytical platform (CSIRO, 2024) with a spatial file (GeoJSON) specifying the boundary of the hypothetical revegetation action on each farm. The outputs from the scenario assessments were combined with the most recent observed results (2020) for each farm (reported above) to derive farm-scale biodiversity indicators for 2050, and their change from 2020–2050.

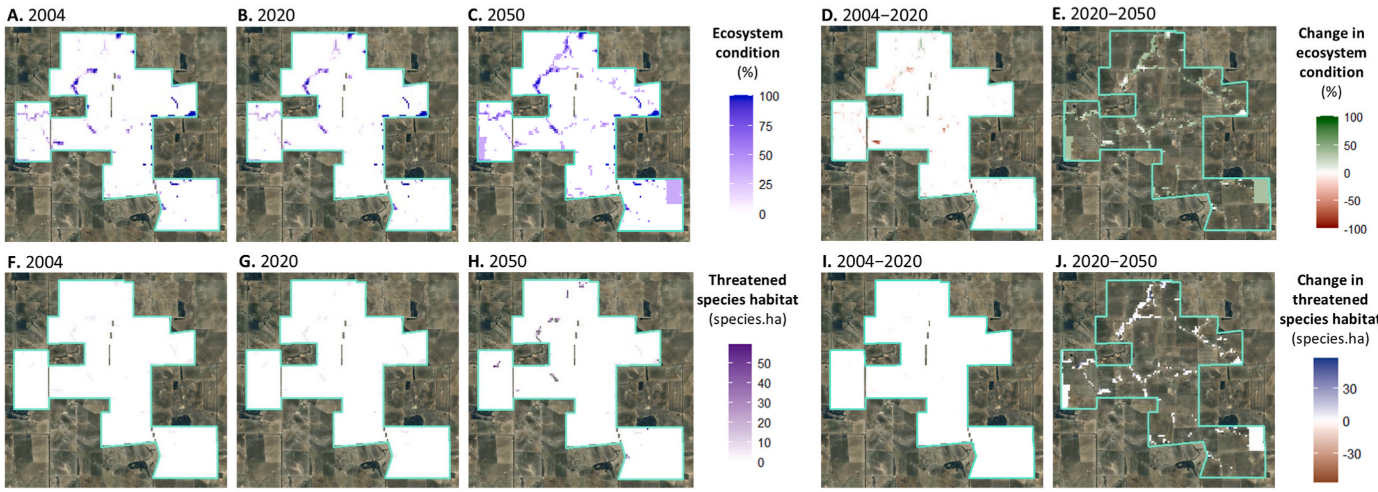

Fig. 2. Spatial biodiversity assessment results for one of the case-study farms (ShR2), for the ecosystem condition indicator (top row, A-E) and the threatened species habitat indicator (bottom row, F-J). Images show spatially explicit values for the years 2004 (A,F), 2020 (B,G) and 2050 (C,H), with the change from 2004 to 2020 (D, I) and 2020 to 2050 (E,J) also shown. The farm boundary is shown with an aqua line. The areas used in the revegetation scenario are shown in panels E and J, with no data shown for all other areas, for which there can be no change from 2020 to 2050 (see also Fig. S1). The mapped results for all the case-study farms are provided in Figs. S3 and S4.

3. Results

3.1. Historical changes in biodiversity

Over the recent historical period of the annual ecosystem condition data (2004–2020), most of the case-study farms experienced decreases in the three biodiversity indicators (Table S1, Fig. S2). This includes a decrease in effective habitat area for 11 farms, a decrease in threatened species habitat for 13 farms, and a decrease in benefit for species persistence for 9 farms (Table S1). Half of the farms (n = 7) had decreases in all three indicators over the historical period, with no farms having increases in all three indicators (Table S1). There were increases in the benefit for species persistence for 4 farms, effective habitat area for 3 farms and just 1 farm had an increase in the amount of threatened species habitat (Table S1, Fig. S2).

Given the start year of the historical period (2004) was relatively arbitrary, trends in the annual changes in the biodiversity indicators are also informative (Fig. 3, S2), with four farms having consistent declines over the time-series (e.g. ShR2; Fig. 1), and four of the farms showing consistent increases in the indicators over the most recent 5 years (2015–2020) (Fig. S2). Comparing the results for the historical period across the three biodiversity indicators, the effective habitat area and threatened species habitat indicators most commonly showed similar trends over time, while the nature of the temporal change in the benefit for species persistence indicator often differed from the other two indicators (Fig. S2). Averaged across the farms, the value of the threatened species habitat indicator relative to 2020 showed the greatest decline over the historical period (Fig. 3), though this was heavily influenced by a single farm with the lowest amount of threatened species habitat (ShR4), for which a unit change creates a larger relative change.

Mapping the data and indicators across each of the farms highlights which areas have the highest value for each biodiversity indicator in 2020, and which areas on each farm have changed most from 2004 to 2020 (Figs. S3 and S4). For example, for the ShR2 farm, most of the farm had low ecosystem condition in 2020, with patches of high ecosystem condition and threatened species habitat distributed along riparian areas and the borders of sown fields (Fig. 2B–G). From 2004 to 2020, there were areas across the farm that experienced increases, decreases and no change in ecosystem condition (Fig. 2D).

3.2. Estimated future changes in biodiversity

Under the revegetation scenario, all farm-scale biodiversity indicators increased for all farms from 2020–2050 (Fig. 3, Table S1, Fig. S2). When biodiversity indicator values were considered relative to their value in 2020, on average the three indicators increased from 2020 to 2050 across case-study farms, with the relative values in 2050 exceeding those in 2020 (Fig. 3). For 12 farms, the increase in biodiversity indicator values to 2050 under the revegetation scenario more than compensated for reductions over the historical period (2004—2020) for at least one indicator, with seven farms having all three biodiversity indicators achieving full recovery to 2004 levels under the revegetation scenario by 2050 (ShR1, ShR2, ShR3, ShR4, ShC2, ShC3, CaC4) (Table S1).

The magnitude of the expected change in the biodiversity indicators under the revegetation scenario was not directly related to either farm area or the average ecosystem condition at the commencement of the scenario in 2020 (Fig. 4). However, the largest increases for each indicator were predicted to occur in the farm covering the greatest area (CaC6 – 522,638 ha) (Fig. 4, Table S1). The projected change in each indicator to 2050 relative to the value in 2020 showed that farms with lower average ecosystem condition in 2020 tended to have the greatest relative increase in the biodiversity indicator values under the revegetation scenario (Fig. 5).

4. Discussion

Halting and reversing biodiversity declines in agricultural landscapes is crucial in order to minimise species extinctions and achieve global biodiversity goals (CBD, 2022). Aligning with observed trends at national and global scales (IPBES et al., 2019; Murphy and van Leeuwen, 2021), most farms we examined had reductions in the three biodiversity indicators over the recent past (2004—2020; Figs. 1 and 3; Table S1). Recent change may often be relatively small compared to the larger biodiversity impacts during historical periods of agricultural development, however it represents ongoing and meaningful impacts of farm management on biodiversity. Monitoring biodiversity change past-to-present is crucial to understand the implications of past management decisions and to inform the need for future actions (Nicholson et al., 2019; Gonzalez et al., 2023).

Our study shows that on-farm revegetation actions have the potential to halt and reverse historical trends in biodiversity decline. Revegetation

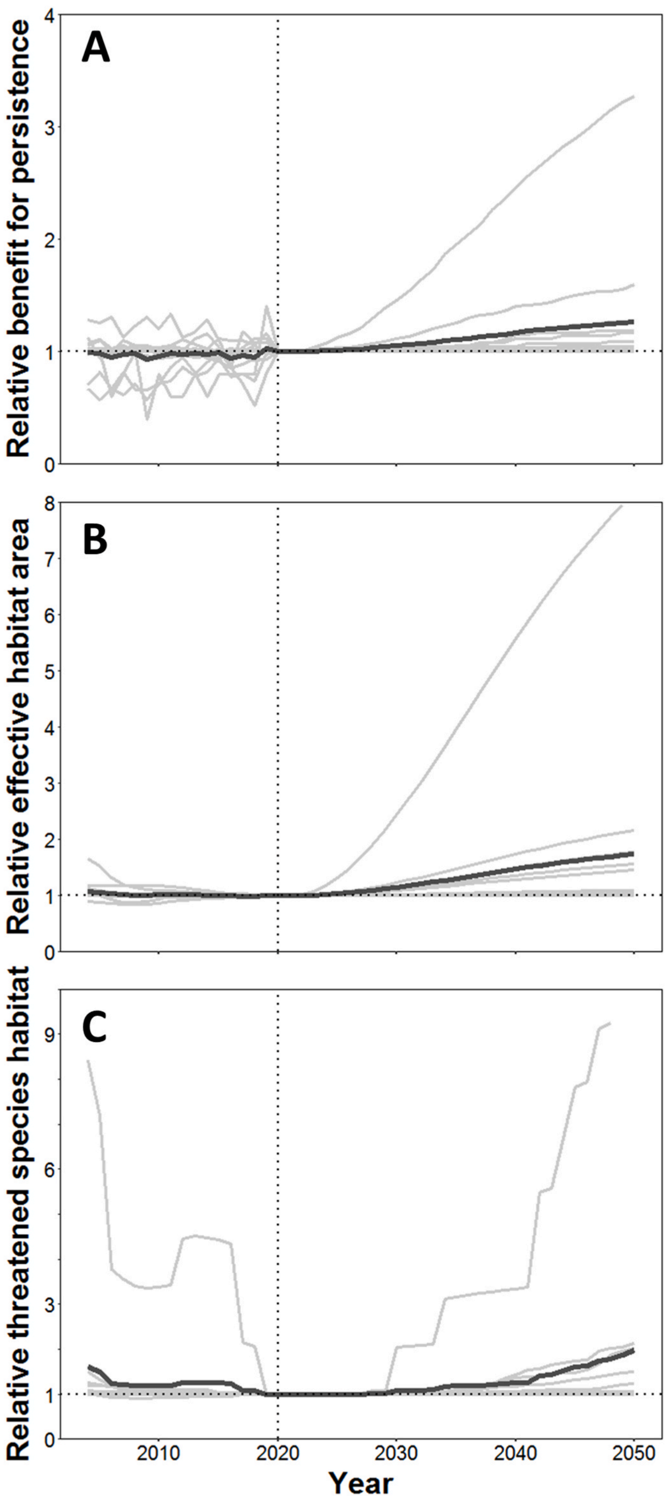

Fig. 3. The value for each biodiversity indicator relative to the value in 2020 (most recent observation). Each individual farm is displayed with a grey line, while the average across farms is shown with a black line. The relative indicator value is simply the indicator value for a farm in a given year divided by the indicator value for that farm in 2020.

acts to change the structure, function and composition of an area closer to a reference state, hence increasing the ecosystem condition of that area and improving the capacity to support biodiversity (Atkinson et al., 2022). The revegetation scenario indicated that substantial improvements in biodiversity are possible by 2050, although the magnitude of the projected gains varied markedly between the 14 case-study farms. Most farms (n = 12) had at least one biodiversity indicator that was estimated to be greater in 2050 under the revegetation scenario than the estimated value in 2004. However, by 2050 only half of the farms were estimated to have all three biodiversity indicators exceeding their 2004 values following revegetation of 10 % of farm area. These results highlight the magnitude of historical reductions in the biodiversity indicators, and support the basic premise that losses in habitat for biodiversity can be rapid but gains often take a long time to achieve and may only ever be partial (Mori and Isbell, 2024).

The estimated increases in the biodiversity indicators under the revegetation scenario were not consistently related to farm size or the average ecosystem condition across a farm at the start of the scenario (Fig. 4). Given that we applied the hypothetical revegetation action to a consistent fraction of each farm (10 % of farm area), larger farms had a larger area dedicated to revegetation. Hence, it may be expected that larger farms would obtain greater increases in biodiversity from revegetating 10 % of their farm area. However, in Australia, larger farms tend to be located in areas that are less intensively utilised for agriculture, with lower levels of historical vegetation modification and higher average ecosystem condition (Fig. S1). Greater benefits of revegetation in terms of increasing ecosystem condition are obtained when initial ecosystem condition values are low to intermediate (Appendix S3). In addition, the location of smaller more intensively used farms within regions where greater loss of habitat has occurred means that additional provision of habitat (through revegetation) in these regions has greater benefits for promoting species persistence and providing threatened species habitat than the same increases in habitat in less modified regions. This explains why some smaller farms with smaller revegetation areas achieved a comparable magnitude of estimated biodiversity benefits as larger farms that had a much greater area of revegetation (Fig. 4).

When the estimated gains from the revegetation scenario were placed in the context of the initial biodiversity indicator values (i.e. in 2020), farms with the lowest average ecosystem condition in 2020 were estimated to achieve the greatest relative increase in biodiversity indicator values (Fig. 5). Greater relative increases are obviously more easily achievable where the initial farm-scale biodiversity indicators are lower. Larger farms that have higher average ecosystem condition may still be able to make substantial improvements in biodiversity through revegetation actions, though may be better focussed on management that maintains and enhances existing native vegetation (Haslem et al., 2024). Even for smaller farms, our results highlight that retaining existing native vegetation is critical in supporting biodiversity; revegetation is often difficult, costly, time-consuming, and has limits in its capacity to compensate for loss of high quality native vegetation (Simmonds et al., 2023).

The specific areas of each farm that were identified as part of the revegetation scenario also contribute to variation between farms in the projected biodiversity outcomes. This study relied on farmers identifying specific farm areas that they would be most likely to implement such a revegetation action on, generally adjacent to current vegetation or poorer pasture producing land. Hence, we applied a single 'most likely' spatial revegetation scenario, rather than implement a large number of alternative configuration scenarios for each farm. This is relevant because the spatial configuration of the revegetation action influences the projected biodiversity outcomes. Hence our analyses indicate the projected biodiversity outcomes from the revegetation action most likely to be implemented by the farmers, not the maximum possible outcomes.

Our study highlights the benefits of considering more than one biodiversity indicator in assessing change over time. While all three biodiversity indicators applied here use a habitat-based approach and include a time series of ecosystem condition as a key input, they provide a complementary picture of biodiversity change (Fig. 1, S2). While the effective habitat area indicator simply reports on the total area of condition weighted habitat being provided for biodiversity, the threatened

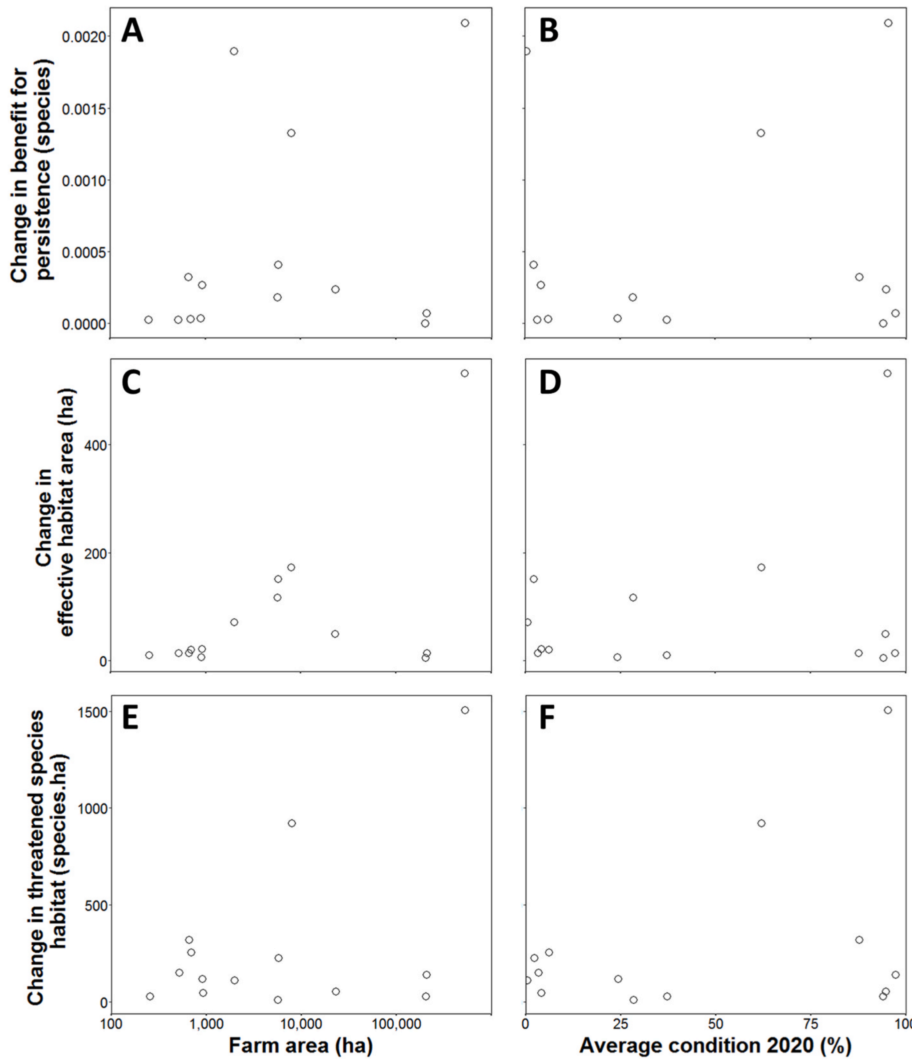

Fig. 4. The change in each biodiversity indicator (2020–2050) for each farm under the revegetation scenario in relation to: farm area (**A**, **C**, **E**), and; average ecosystem condition across the farm in 2020 (**B**, **D**, **F**). The change in an indicator for a farm is simply the indicator value for the farm in 2050 minus the indicator value for the farm in 2020. Note that farm area is depicted on a $\log_{10}$ scale.

species habitat indicator accounts for where the highest quality habitat is provided relative to the areas where nationally listed threatened species are most likely to occur. Trends in these two indicators for the case-study farms are more similar, compared to the indicator reporting the benefit of on-farm habitat for species persistence (Fig. S2). The species persistence indicator accounts for the availability of habitat in the surrounding region, hence even if there is no change in ecosystem condition on a farm, this indicator can increase when habitat loss occurs in the surrounding region, which makes the habitat occurring on the farm even more important for supporting the ongoing persistence of species (Prober and Smith, 2009). Revegetated areas that are well connected to areas of existing habitat in the surrounding landscape are likely to result in greater improvements in biodiversity (Correa Ayram et al., 2016). While the estimated benefits of on farm revegetation actions for species persistence were often numerically small (Figs. 1A and 4A,B, Table S1), all increases in habitat availability play a part in supporting ongoing species persistence and avoiding further extinctions, with the differences between farms enabling a direct comparison of the benefits of the proposed revegetation actions for species persistence. The trend in the indicator over time is just as important as the magnitude of the indicator value.

The habitat-based assessment applied here to quantify past and possible future changes in biodiversity on farms has a range of benefits. First, it provides consistent metrics, enabling direct comparison of recent changes across different farms and identification of which revegetation actions on which farms are likely to lead to the greatest benefits for biodiversity. Such information could help inform prioritisation of conservation funds for revegetation (Mappin et al., 2022). The habitat-based approach also enables seamless consideration of potential future improvements in the context of historical changes in the biodiversity indicators, a capability which is crucial for farms or agricultural businesses interested in pursuing nature-positive goals (zu Ermgassen et al., 2022). Furthermore, these habitat-based assessment methods are fast, efficient, low-cost and highly scalable, aligning with existing frameworks for ecosystem accounting (United Nations et al., 2021) and farm-scale natural capital assessment (Ogilvy et al., 2022). Within Australia, the same biodiversity analyses are able to be undertaken for any farm via the LOOC-B web application (CSIRO, 2024), helping to remove barriers to farmers demonstrating the biodiversity benefits of their vegetation management actions. A habitat-based approach complements on-ground data on species abundances across a farm and properly recognises the important role played in habitat management, even if external factors result in lower than expected utilisation of that habitat by native species.

While our analyses estimate the likely biodiversity consequences of revegetating 10 % of farm area, the likelihood of farmers implementing

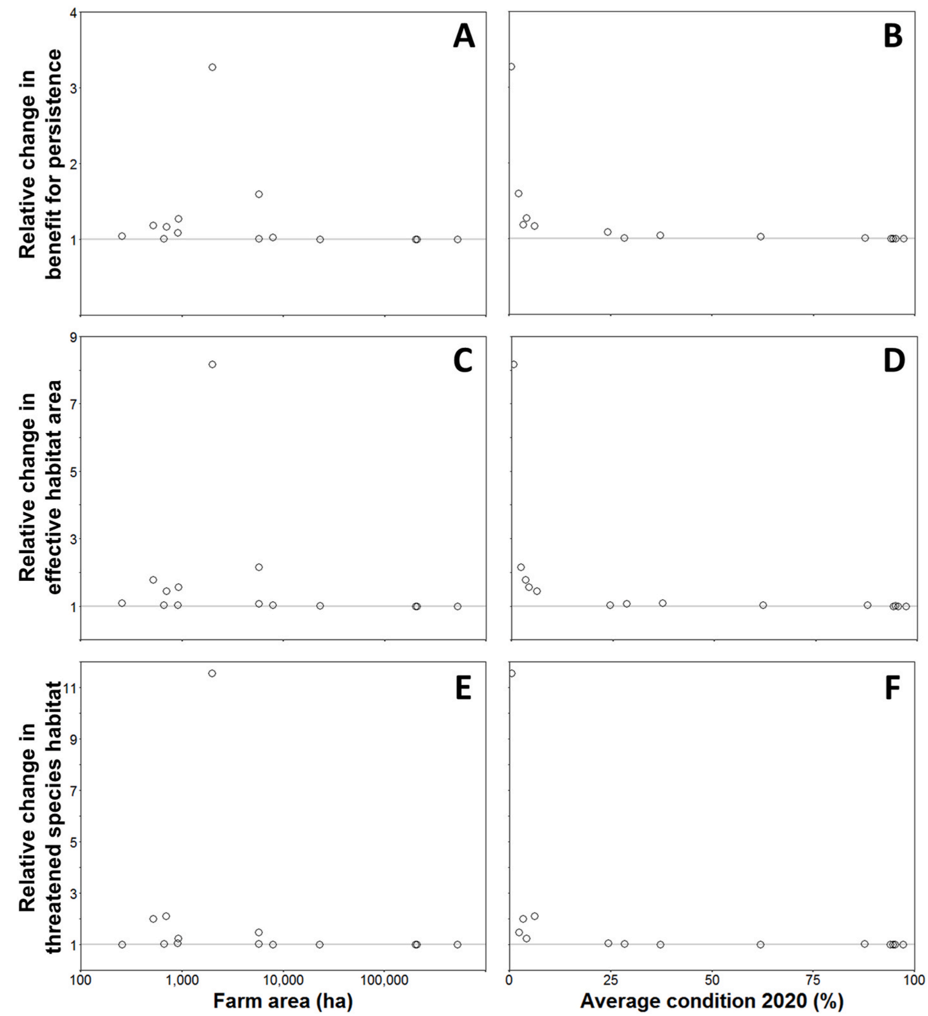

Fig. 5. The relative change in each biodiversity indicator (2020–2050) for each farm under the revegetation scenario in relation to: farm area (**A**, **C**, **E**), and; average ecosystem condition across the farm in 2020 (**B**, **D**, **F**). The relative change in an indicator for a farm is simply the indicator value for the farm in 2050 divided by the indicator value for the farm in 2020. Note that farm area is depicted on a $\log_{10}$ scale.

this scenario would depend on a range of other factors. These include the consequences of the revegetation actions on agricultural production, profit, financial benefits from carbon storage and the consequences for other ecosystem services (O'Grady et al., 2024). An assessment of these broader consequences of the revegetation scenario are reported elsewhere (Bhattarai et al., 2025), and are beyond the scope of the present study. Generally, best available estimates of current financial returns for the additional carbon and biodiversity on farms indicate lower total financial returns as a consequence of the 10 % revegetation scenario (Bhattarai et al., 2025). Such revegetation actions would therefore need to provide other, non-monetary benefits to the farmers (Haslem et al., 2024), or require additional market-based mechanisms that return greater financial returns than those currently available (Luxton et al., 2024).

It is important to note that the biodiversity assessment and associated data applied here have a variety of inherent assumptions and limitations. The assessment relies on estimates of ecosystem condition derived from space-borne remote sensing data (Landsat) at ≈30 m spatial resolution, so may not detect very narrow strips of native vegetation. In addition, the ecosystem condition data do not account for important factors that are difficult to detect from space-borne remote sensing, including understory vegetation composition and structure, or alien invasive plant and animal species. Further research to improve methods for estimating ecosystem condition over time using remotely-sensed data will be valuable in enhancing the accuracy of farm-scale biodiversity assessments.

Our scenario assessment method relies on reasonably accurate assessment of the most recent ecosystem condition for an area, and applies forecasting functions (Appendix S3) that generalise expected future outcomes based on relatively sparse available published data on observed impacts of different actions on biodiversity. There may be substantial variation in the actual response of ecosystem condition at a given location to the implementation of a revegetation action, due to differences in the history of a site (e.g. weed invasion), local factors (e.g. soil attributes), the regional context (amount and configuration of surrounding habitat), or major climatic or disturbance events (e.g. drought, fire). Our assessment did not consider uncertainty in the future projections of the biodiversity indicators due to these and other factors, but rather derived a single best estimate of expected change under revegetation. Future use of these approaches should focus on development of rigorous methods to estimate the uncertainty associated with the forecasted changes under proposed actions. Additional field studies of the observed biodiversity outcomes of revegetation actions in different contexts are also vital to improve the accuracy of estimates of future ecosystem condition (Appendix S3).

A variety of socio-economic factors continue to promote increasing agricultural intensification at the expense of biodiversity (Heagney et al., 2021). Improving the information available on the consequences of vegetation management actions at the farm scale provides an important component necessary in reversing trends in biodiversity decline. Coupling these advances in ecological information with appropriate policies and programs can support farmers to be part of the solution in averting the current species extinction crisis.

CRediT authorship contribution statement

Karel Mokany: Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Hugh M. Burley:** Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis, Data curation. **Chris Ware:** Writing – original draft, Software, Data curation. **Katherine M. Giljohann:** Writing – original draft, Data curation. **Anthony P. O'Grady:** Writing – original draft, Resources, Project administration, Funding acquisition. **Karen M. Christie-Whitehead:** Writing – original draft, Resources, Project administration, Funding acquisition, Conceptualization. **Matthew T. Harrison:** Writing – original draft, Resources, Project administration, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: All authors reports financial support was provided by Meat and Livestock Australia. All authors reports financial support was provided by Australian Wool Innovation Ltd. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2025.125174.

Data availability

Where possible, the source data for this study are cited and available. Several datasets applied have licenses which restrict our capacity to provide access to them.

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