Biodiversity Conservation Trust

Biodiversity Conservation Trust Ecological Monitoring Module Biodiversity Outcomes Report

Baseline | August 2022

CONTENTS

1 EXECUTIVE SUMMARY

Data from the Ecological Monitoring Module (EMM) will be most meaningful when it can measure improvement to biodiversity values over time, following 5-10 years' investment, active management and monitoring. Until then, the state of biodiversity at BCT agreement sites can be usefully compared to appropriate reference sites. Overall, the condition of biodiversity on BCT agreement sites compares well to reference sites, as outlined below.

Indicator	Summary outcome	Status
EMM implementation	Implementation of baseline monitoring is variable among regions but progressing well, with 100% of 1,469 Priority 1 sites planned for completion by spring 2023.	Good
Vegetation integrity	Vegetation integrity scores at BCT agreement sites are slightly lower than reference sites but are expected to increase in response to active management, relative to reference sites, over time.	Moderate
Species composition	Plant species richness at BCT agreement sites is generally at or above benchmark, and floristic value of grassy ecosystems at agreement sites is greater than similar reference sites.	Good
Ecosystem function	Tree size distribution at BCT agreement sites is within healthy range and soil function is slightly lower than reference sites (but at sites targeted for active management).	Moderate
Threatened species habitat	BCT agreement sites are protecting significantly more critical threatened species climate refuge habitat than typical sites in the landscape and are also protecting moderate-high condition koala habitat.	Good
Climate change risk	BCT agreement sites are at significantly lower risk of climate change impacts to biodiversity than reference sites.	Good
Landscape condition	BCT agreement sites are generally in higher condition than reference sites with respect to modelled state-wide indicators of landscape-scale biodiversity condition.	Good
Avoided loss	The protective value of BCT agreements has resulted in an estimated 9,000 hectares of avoided biodiversity loss.	Good

2 BACKGROUND AND CONTEXT

This report is the first to document evaluation of ecological outcomes of BCT programs under the Ecological Monitoring Module (EMM). It represents a baseline assessment; however, it does not report on a comprehensive baseline data set – data remain to be collected from a number of sites, particularly from unfunded conservation agreements secured via the Conservation Partners Program (CPP). Given the BCT context – ongoing implementation of programs that result in a continual increase in the number and area of sites under its administration – it is not meaningful to quantify a single 'baseline' state as typically defined. Over time, however, evaluation and reporting on ecological outcomes will shift from focusing predominantly on the *state* of biodiversity values to *change* in those values attributable to BCT investment. Demonstrating improvement in the ecological condition of BCT assets will be most meaningful following 5-10 years of implementation of the EMM.

The report, and the design and implementation of ecological monitoring informing it, are guided by the objectives, principles and strategic priorities outlined in the EMM framework document, approved by the BCT Board in November 2019. Figure 1 summarises and expands on this framework, demonstrating the links between corporate objectives, scientific questions, and monitoring.

The following guiding principles and assumptions underpin the analyses presented in the report:

1. Reporting on baseline data is not particularly insightful without some context for interpretation (i.e. a reference against which to evaluate), therefore, 'unprotected lands' and the public reserve estate have been used for comparing biodiversity values with BCT agreement sites;
2. Products developed under the *NSW Biodiversity Indicator Program* are considered valid surrogates for different components of biodiversity value at the state scale;
3. Vegetation condition benchmarks and predictive models of biodiversity change over time developed under the *NSW Biodiversity Assessment Method* (BAM) are considered fit-for-purpose (i.e. for quantifying a standardised measure of vegetation condition and estimating future biodiversity values, respectively); and
4. Best practice evaluation of conservation effectiveness should consider counterfactual scenarios – i.e. to determine the net benefits directly attributable to BCT investment.

Appendix 1 provides additional technical detail on each of the data sets and analyses presented in the report

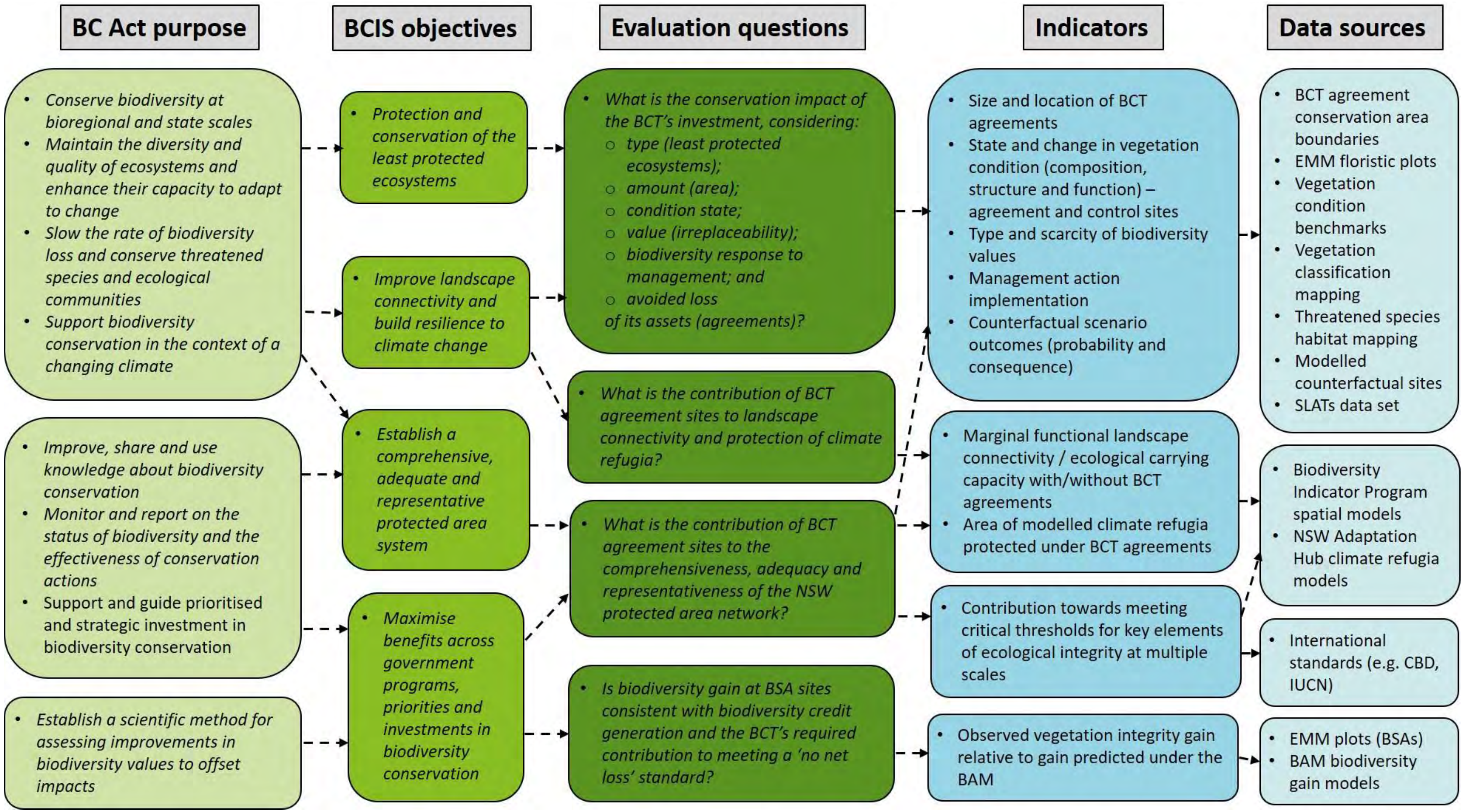


Figure 1: Outline of the framework for evaluating ecological outcomes, linking high level objectives to data requirements for reporting.

3 EMM IMPLEMENTATION PROGRESS

EMM implementation by BCT staff began in Spring 2020 with the establishment of baseline monitoring points (e.g. vegetation integrity plots). Despite some delays due to COVID restrictions and wet weather, data collection is on track for completion of all high priority sites by 2023 (Table 1).

Inclusion of monitoring plans aligned to the EMM was made a requirement of all new Biodiversity Stewardship Agreement (BSA) applications from 1 March 2021, with implementation of baseline monitoring required within 12 months of the start of active management. Therefore, given expected timeframes associated with application approval, agreement execution and fulfilling the Total Fund Deposit (TFD), EMM implementation at BSA sites is expected to begin by approximately 2023.

Table 1: EMM implementation to date and projected

BCT Region	Site priority	Complete	Autumn 2022	Spring 2022	2023	Total
Murray-Riverina	Priority 1	190	124	67	6	387
	Priority 2	0	6	15	21	42
	Total (plots)	190	130	82	27	429
	Cumulative priority 1 completion (%)	49	81	98	100	100
North Coast	Priority 1	70	5	5	0	80
	Priority 2	0	51	51	66	168
	Total (plots)	70	56	56	66	248
	Cumulative priority 1 completion (%)	88	94	100	100	100
Northern Inland	Priority 1	45	58	0	301	404
	Priority 2	0	0	0	27	27
	Total (plots)	45	58	0	328	431
	Cumulative priority 1 completion (%)	11	25	25	100	100
South East	Priority 1	114	0	87	0	201
	Priority 2	0	0	24	54	78
	Total (plots)	114	0	111	54	279
	Cumulative priority 1 completion (%)	57	57	100	100	100
Sydney-Hunter	Priority 1	62	48	24	150	284
	Priority 2	9	15	24	15	63

BCT Region	Site priority	Complete	Autumn 2022	Spring 2022	2023	Total
	Total (plots)	71	63	48	165	347
	Cumulative priority 1 completion (%)	22	39	47	100	100
Central West / West	Priority 1	50	93	54	176	373
	Priority 2	0	0	24	33	57
	Total (plots)	50	93	78	209	430
	Cumulative priority 1 completion (%)	13	38	53	100	100
State-wide total	Priority 1	469	280	237	483	1469
	Priority 2	71	120	138	389	718
	Total (plots)	540	400	375	872	2187
	Cumulative priority 1 completion (%)	32	51	67	100	100

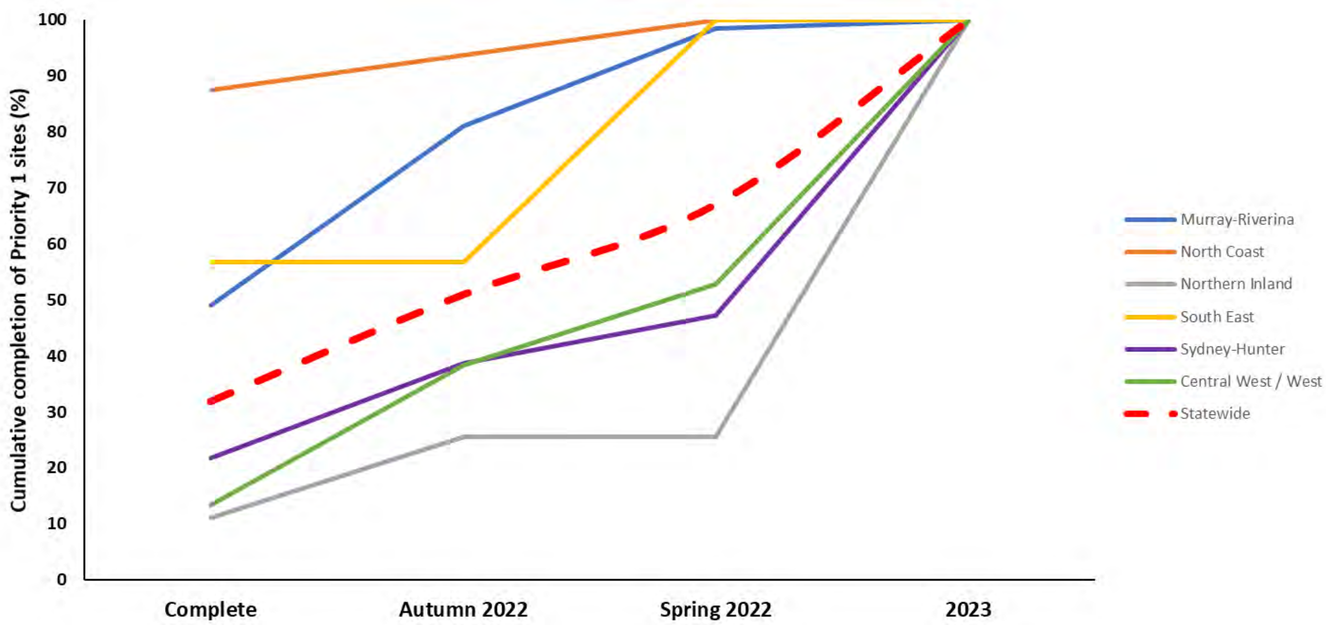


Figure 2: Projected EMM data collection activity at Priority 1 sites through to 2023, by BCT region

To maximise the efficiency of the EMM, collaborations are underway with various partners, for example, with:

- Natural Resources Commission Forest Monitoring and Improvement Program (aligning methods to enable data sharing)
- Australian National University, University of NSW and Charles Sturt University (student interns assisting data collection)
- NPWS Eco Health Program (aligning methods to enable data sharing)
- RMIT University – collaborating on the ‘Estimating counterfactuals for quantifying avoided loss’ research project
- Seven BCT-supported PhD projects collecting data and/or developing metrics, which will contribute to the EMM and program-level evaluation.

4 BASELINE BIODIVERSITY STATUS

4.1 EMM DESIGN

The EMM sampling design is based on *stratification groups* – these groups are based on geographical and biophysical characteristics such that biodiversity (generally vegetation, in this context) within each group is expected to vary naturally and respond to management and/or climate similarly. Stratification groups are defined as the unique combination of bioregion (IBRA) and Vegetation Class (Keith) (also known as *Regional Vegetation Classes*). These groups are useful for ensuring that monitoring is representative, for allowing data aggregation, and align with existing corporate data sets which support analysis and evaluation (e.g. vegetation condition benchmarks, state-wide vegetation class maps and floristic plot data). There are approximately 500 different potential stratification groups in NSW, however, BCT agreements currently occur in <200 groups, not all of which have been sampled under the EMM.

4.2 MEASURING VEGETATION INTEGRITY

Plot-based assessment of vegetation integrity (comprised of three elements of floristic condition: composition, structure and function) is the core of the EMM method. The method is based on the Biodiversity Assessment Method (BAM; DPIE 2020), allowing the calculation of a standardised *Vegetation Integrity* (VI) *Score*, while including additional measures which enhance the precision of the data set and its power to detect change over time.

Figure 3 reports on an aggregate assessment of vegetation integrity across all sites (plots) sampled so far under the EMM (100% funded Conservation Agreements delivered under the CMP; *N*=362). Each plot is representative of a *vegetation unit* within a BCT agreement site – i.e. a delineated area of consistent vegetation class and condition state. Figure 3 reports the mean vegetation integrity score, weighted by the area represented by each plot (i.e. it reflects both the area under agreement as well as respective condition). To provide some context, this metric is also reported for a sample of equivalent historical floristic survey plots on private land, matched for sample size and relative allocation to different stratification groups.

The indication from Figure 3 that BCT agreement sites are in lower condition than reference sites should be interpreted with caution – there is likely to be a bias in historical floristic surveys towards sites receiving conservation management, and therefore do not represent a true random sample of the broader landscape (e.g. cropped paddocks are generally not sampled). Figure 12, which presents a comprehensive landscape dataset, represents a more appropriate comparative assessment. In addition, monitoring intensity under the EMM is proportional to expected biodiversity change in response to management, therefore poorer quality sites subject to more intensive management are over-represented in the baseline data set. Finally, the data set presented here is comprised of funded agreements established under the CMP, which are more likely to be in degraded landscapes compared to unfunded agreement types which have yet to be sampled by the EMM. A more meaningful evaluation should also consider net improvement in ecological condition over time (see Figure 5), which the EMM (including a control site network) will provide in the coming years.

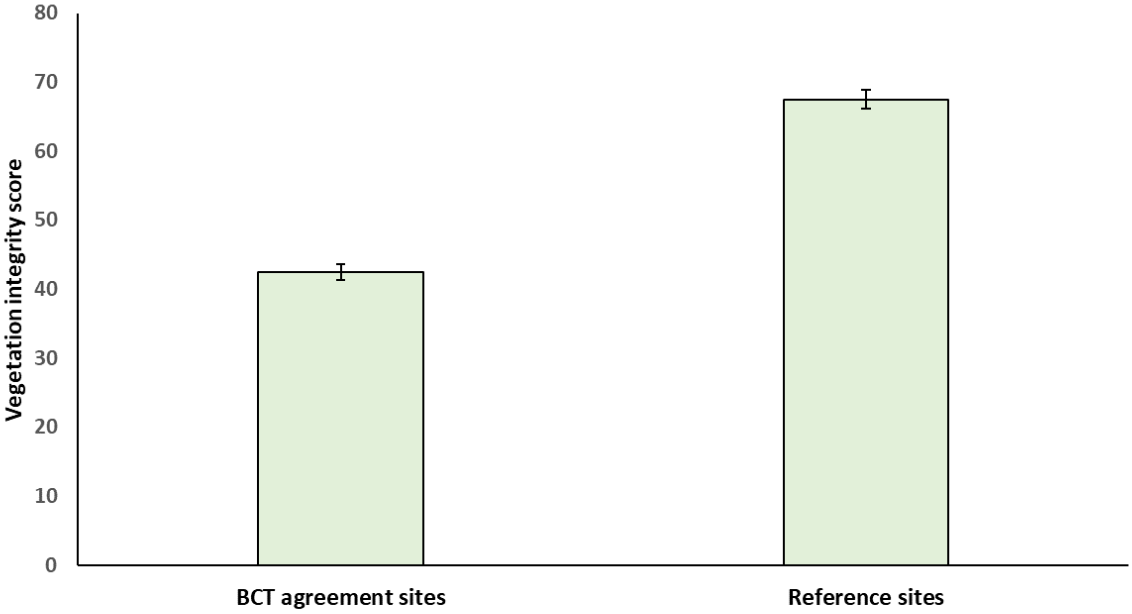


Figure 3: Mean vegetation integrity score (± standard error) for monitoring plots sampling BCT agreement sites and a sample of reference sites on private land matched for stratification group (N=362).

A fundamental indicator of biodiversity value is site-based species richness (i.e. *alpha diversity*). The collection of composition data under the EMM allows for quantification of plant species richness at each site (i.e. the total number of different plant species occurring), which compared to structure and function indices, is generally less susceptible to observer bias. Furthermore, plant species richness as a biodiversity indicator is also more stable (i.e. less sensitivity to variation in environmental conditions of short timeframes), making it a robust indicator of a site's general quality. Figure 4 shows plant species richness for all monitoring plots on BCT agreement sites, relative to respective benchmark values. The figure shows that for the majority of sites, species richness is above or within proximity of benchmark values to be considered 'good' condition.

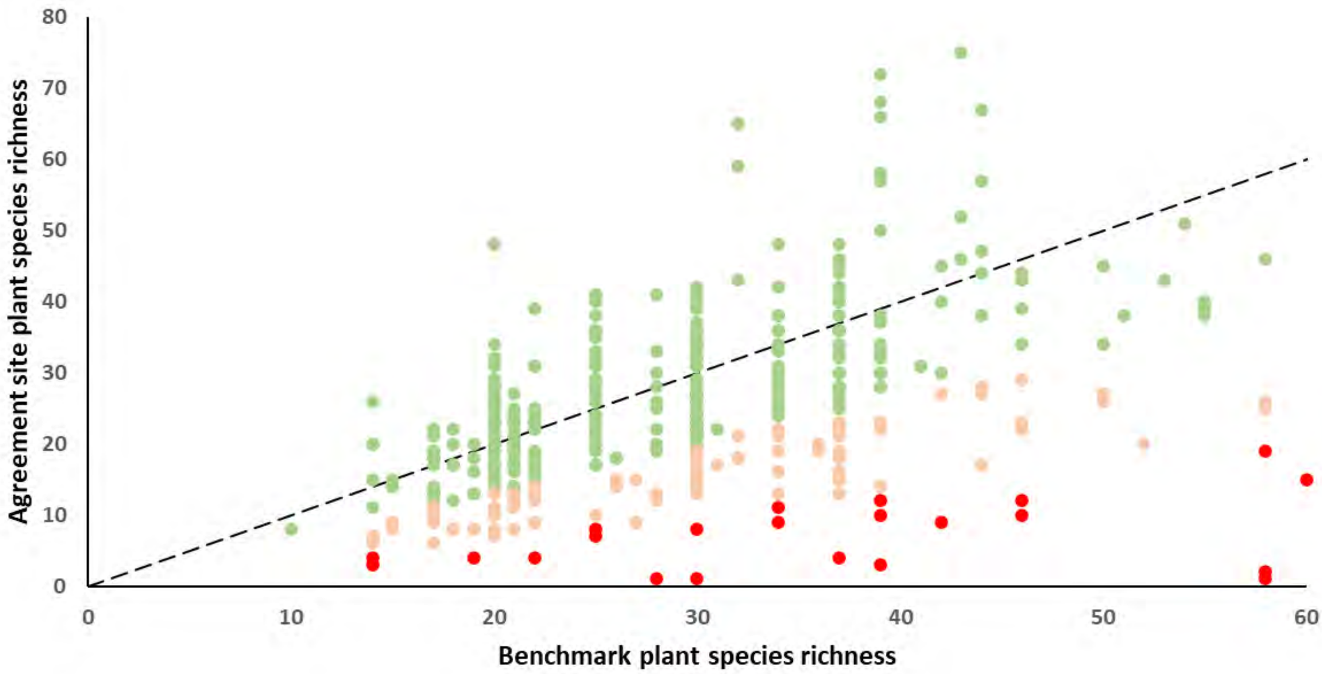


Figure 4: Plant species richness observed at BCT agreement sites, for each monitoring plot (y-axis), relative to benchmark value (x-axis). Circle colours represent plots evaluated as 'good' (>66% of benchmark; green), 'moderate' (33-66% of benchmark; pink) and 'poor' (<33% of benchmark; red). Broken black line represents benchmark equivalence.

4.3 PROJECTED BIODIVERSITY CHANGE

The critical measure of success, or return on investment, with respect to biodiversity values on BCT agreement sites, is the outcome relative to the likely outcome in the absence of BCT investment (counterfactual scenario). One element of this measure is the expected decline in vegetation condition over time in the absence of active management (e.g. of invasive pests and weeds). Models of these decline trajectories, as well as predicted condition gains in response to management, have been developed under the BAM, and can be used to predict future values. Figure 5 shows the predicted outcomes, in terms of vegetation integrity, for the sample of BCT agreement sites used in Figures 3 and 4. For comparison, an alternative model assumes no management or protection (a valid counterfactual scenario for a BCT agreement site), and for the agreement sites it assumes implementation of a standard suite of BCT management actions (e.g. pest and weed control), over a 20-year period.

The forecasted net benefit over this timeframe is approximately 12 vegetation integrity points, or a 23% improvement in biodiversity value, on average, per BCT agreement site.

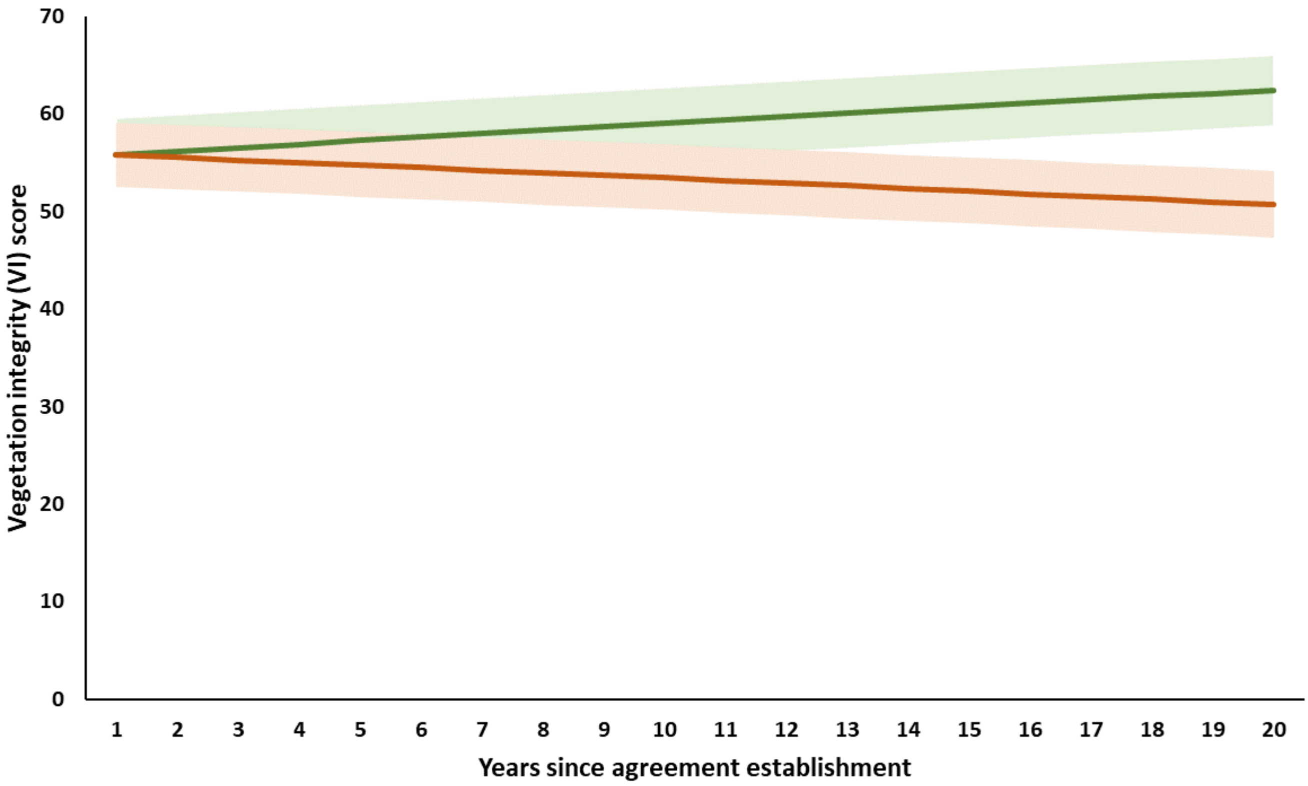


Figure 5: Projected change in vegetation integrity score over 20 years for a sample (N=120) of sites under BCT agreement (green line) and projected assuming no management or agreement protection (orange line) ±95% confidence intervals (green/red shading). The difference between the two scenarios becomes statistically significant by Year 8 (t=2.33, p=0.027).

4.4 ECOSYSTEM FUNCTION

4.4.1 Floristic Value

While species richness is a robust and accepted measure of ecosystem condition, species composition (i.e. *which* species are present) indices can provide more insight into ecosystem health, particularly when species' associations with function and disturbance are known. One such index is *Floristic Value Score* (FVS; Rehwinkel 2015), designed specifically for grassy ecosystems, which allocates species-specific score based on sensitivity to disturbance (e.g. grazing, fire). FVS, then, provides a useful metric with which to evaluate the ecological condition of sites with respect to current and historical management. FVS tools and supporting data sets have been developed for the BCT, covering the Riverina, South West Slopes, South East Highlands bioregions (as well as the Monaro subregion within SEH).

Figure 6 shows that BCT agreement sites are generally in better condition (greater floristic value) than comparative reference sites. This is a positive sign, particularly considering that many BCT agreements allow stock grazing within these ecosystems. More detailed analysis will provide insights into the relationship between floristic value and stock/total grazing pressure. For agreements under improved grazing management regimes (e.g. exclusion, reduced intensity), the expectation is for floristic value to improve over time, as more sensitive species will persist.

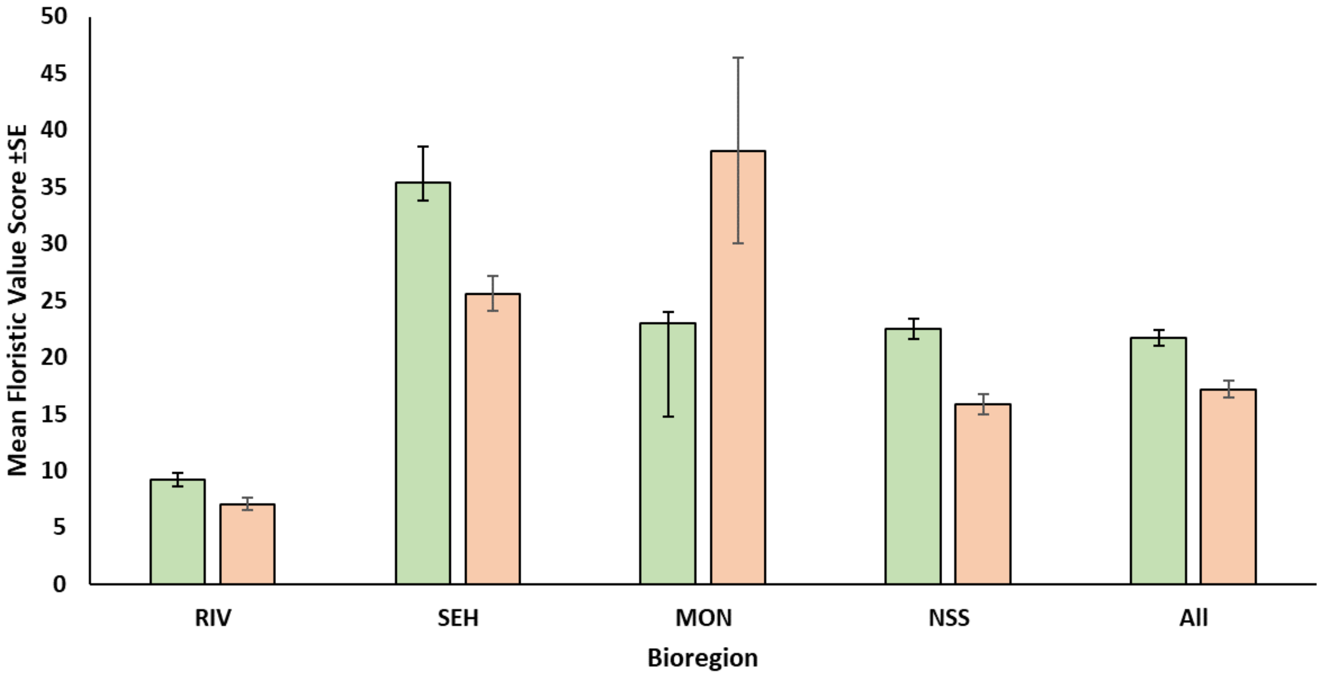


Figure 6: Floristic value score (± standard error) for monitoring plots on BCT agreement sites (green bars) and a matched sample of historical floristic survey sites (orange bars) (N=628).

4.4.2 Soil surface condition

Soil health and function are fundamental to ecosystem function. The EMM applies a component of Landscape Function Analysis (LFA) based on methods described by Tongway and Hindley (2004). This assessment focuses on understanding the movement and retention of nutrients on the soil surface, therefore is most useful when applied to systems and management regimes where these processes are most dynamic – i.e. agreement sites with a history of degradation (e.g. over-grazing) or at risk of degrading processes in the future.

Figure 7 shows soil surface condition values as well as the separated components making up this metric – *stability*, *infiltration* and *nutrient cycling*, for a sample of BCT agreement sites. For comparison, a sample of sites representative of background variation, from a research collaboration (D. Eldridge *pers comm.*) have been provided. As per the interpretation of vegetation integrity data, these results should be interpreted with caution, given that sites selected for soil surface condition assessment are generally historically degraded and subject to more intensive management change under a BCT agreement. A comprehensive evaluation of the value of BCT's investment in these sites will come from analysing change in these values over time, in response to management, at agreement and control sites.

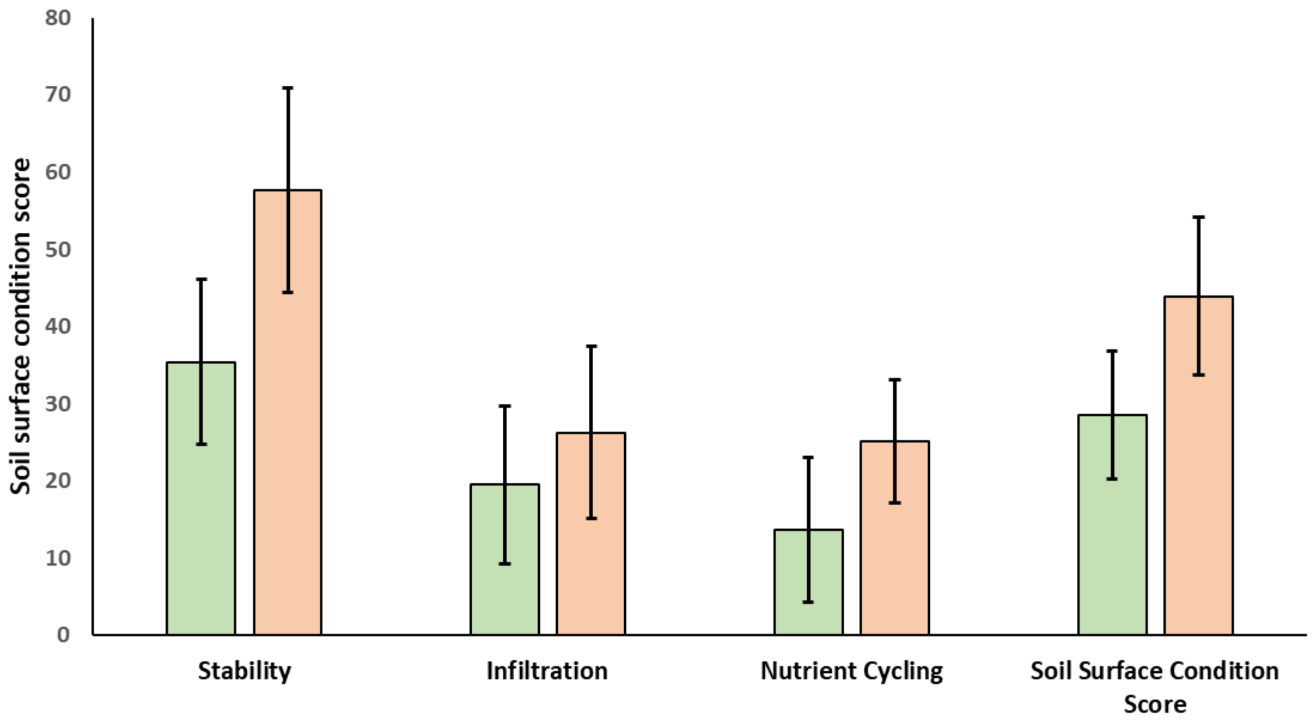


Figure 7: Mean soil surface condition score and constituent metrics (± 95% confidence interval) for a sample of BCT agreement (green bars) and reference (orange bars) sites (N=82).

Another important indicator of ecosystem (particularly forest) health and functionality is the size (age) distribution of tree species. While technically a measure of ecosystem structure, these data provide valuable information related to function, successional state and disturbance history. It is also a good indicator of current and future potential for faunal habitat provision – i.e. the presence of all age (size) cohorts indicates a continual supply of large (e.g. hollow-bearing) trees. As an indicator of ecosystem health (and disturbance impacts) the sample frequency distribution of stem size classes for BAM 'tree' growth form species was compared to a reference model based on approximately 2,300 validated plots (Bionet Flora Survey) and the scientific literature ('healthy' wooded systems can generally be described by a negative exponential function relating stem size and density [Enquist & Niklas 2001]).

Figure 8 shows that for the sample of plots where stem size density data have been collected, for two predominant vegetation formations, the frequency distribution of size (age) classes is generally consistent with expectations for a healthy system, based on reference data, with the exception of the 5-9cm class. This may be indicative of herbivore browsing impacts, however, more detailed analysis of species composition, complementary data on total grazing pressure, and a larger dataset, is required before solid conclusions can be drawn.

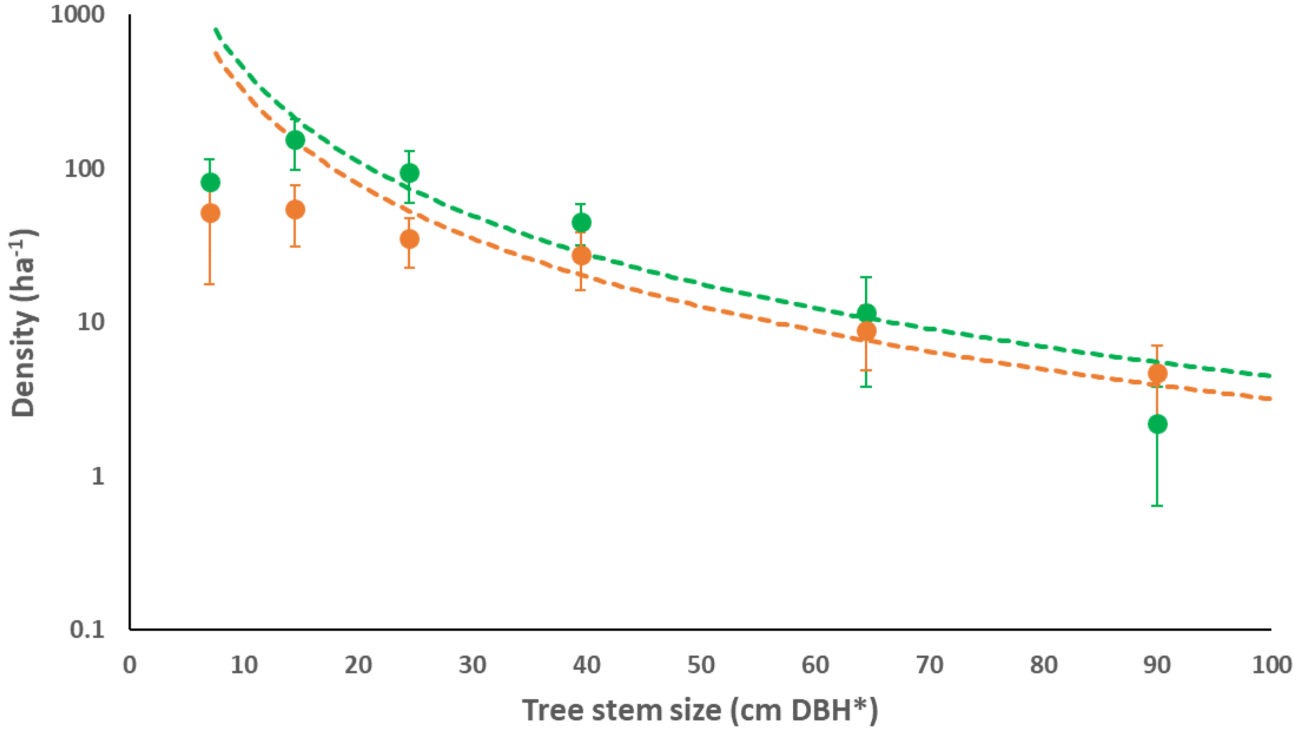


*Figure 8: Mean (±95% confidence interval) density (log scale) of tree stems at BCT agreement sites, within dry sclerophyll forest (green circles) and grass woodland (orange circles) vegetation formations, compared to a modelled distribution based on historical plot data from matching vegetation formations (green and orange broken lines respectively). *Diameter at breast height (1.3m) over bark.*

4.5 THREATENED SPECIES

Under the EMM, targeted monitoring of all important threatened species populations and/or their habitat is required on all BCT agreement sites. 'Important,' in this context, refers to BSA sites/species generating species credits, agreements established via a CMP conservation tender targeting a particular threatened species or other agreements encompassing SoS site-managed priority management sites (monitoring of these populations is generally undertaken via SoS program implementation).

To date, threatened species monitoring has been limited to funded CAs established via three CMP tenders targeting koala habitat on the North Coast (10) and Southern Highlands (7).

4.5.1 Koalas

Koala occupancy was assessed for the 17 targeted funded CAs using passive acoustic detectors (Audiomoth), which recorded male's bellowing during the breeding season. Koala presence was detected at 12 of the 17 sites (71%).

Condition of koala habitat was assessed by evaluating vegetation integrity (using method outlined above) for sites with modelled suitable koala habitat (NSW Koala Information Base). Figure 9 shows the distribution of condition by area of suitable koala habitat, which is approximately normally distributed, with a mean score of 46.47. Once a larger data set has been collected, future assessment of koala habitat condition will apply a similar analysis to that shown in Figure 8, focused on identified koala use trees.

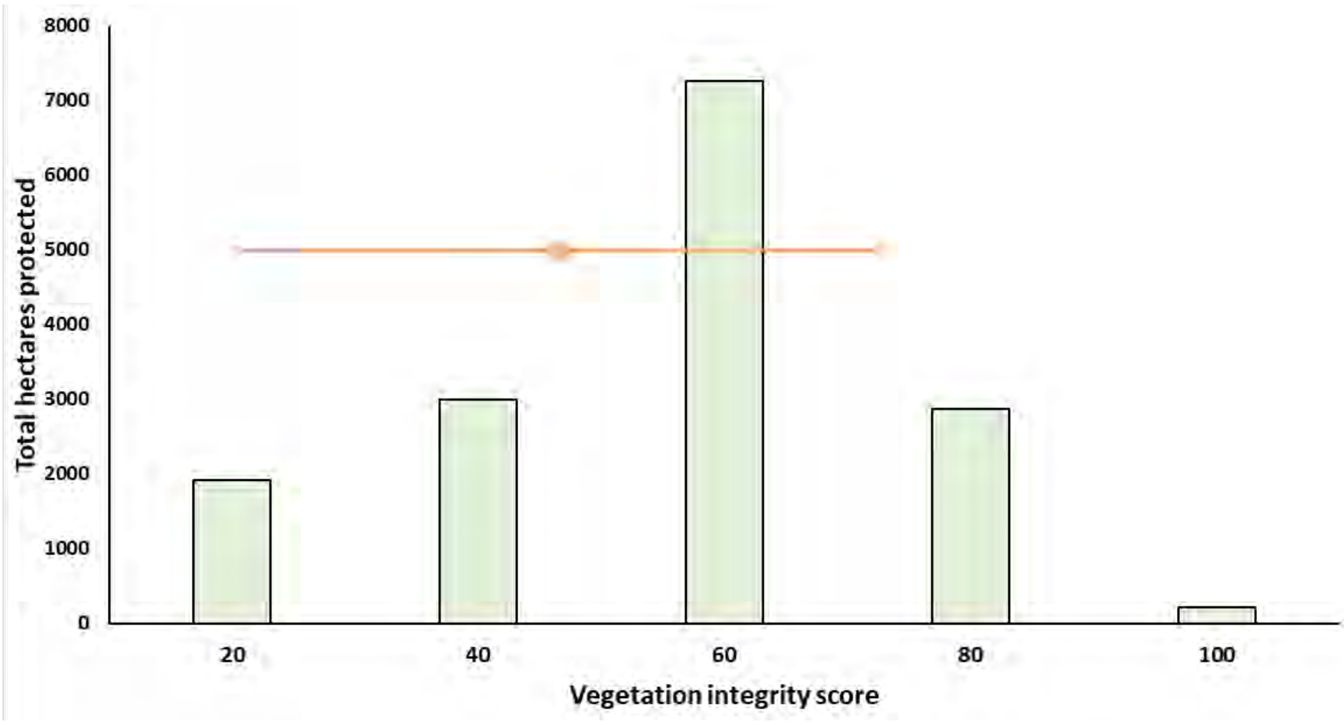


Figure 9: Distribution of koala habitat protected by BCT agreements, by vegetation condition and area (green bars) with mean (± standard error) shown by the orange circle.

4.5.2 Climate refugia for threatened species

Under the *Saving our Species* (SoS) program, spatial priorities for the protection and management of threatened species populations are made explicit for a subset of species in the *Site-managed* stream. These species are identified as priority assets under the BCIS and the BCT evaluates and reports on its contribution to protection of priority management sites for these species via regular KPI reporting. A second group of high priority threatened species under SoS – *Landscape species* – has less well-defined spatial priorities due to the nature of these species' ecology and distribution (widely dispersed, highly mobile).

Recent research conducted under SoS has applied a modelling technique, *Rapid Evaluation of Metapopulation Persistence* (REMP; Drielsma & Ferrier 2009) to habitat suitability under climate change models developed by the Adaptation NSW Bionode (Beaumont *et al.* 2019). This product quantifies, for each modelled species and for each 90m pixel in the landscape, the future value of the habitat in terms of its ability to support a viable population, under four different Global Climate Models (GCMs). A consensus model for each species quantifies the number of GCMs (0-4) at each pixel predicting population persistence (>threshold value) at that location in 2070.

Figure 10a shows a combined map representing this value summed across 49 SoS priority landscape species that have been modelled so far. The mapped value, therefore, represents an indicator of the value of each site as climate refugia for these threatened species. For example, a pixel with predicted suitable future habitat under all four models for one species is assigned a score of 4, for two species, 8, and for a single species where only two models predicted suitable future habitat, 2. Figure 10b shows that BCT agreement conservation areas are protecting, on average, land with approximately twice the value of the background unprotected landscape.

This product is in its infancy and will be improved over time, both as additional species are modelled, and the models are improved via various quality assurance and review steps.

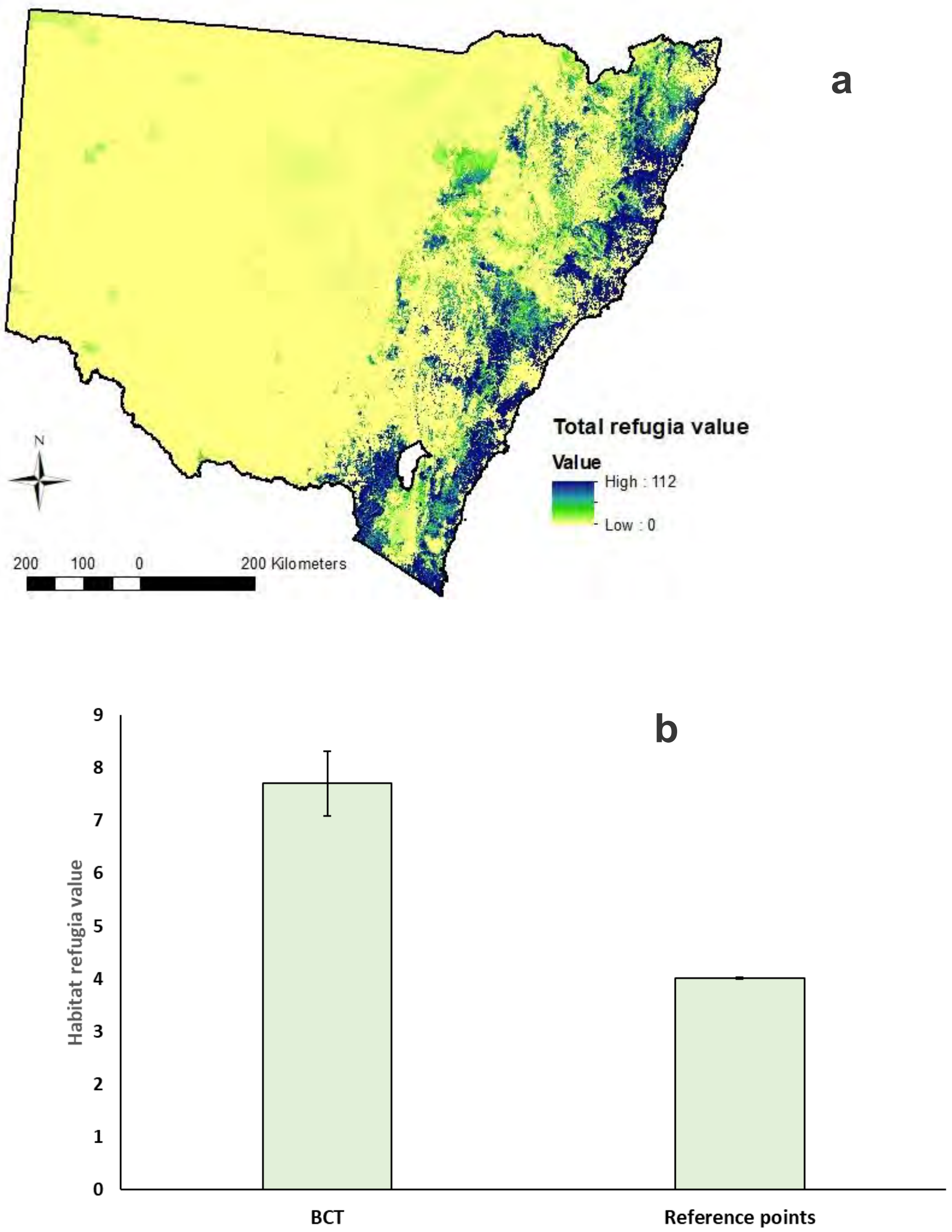


Figure 10: NSW map of REMP climate refugia – each 90m pixel value represents the sum of individual species scores (0-4) indicating habitat of sufficient suitability to support a viable population in 2070, based on each of 4 GCMs, for 49 species (i.e. theoretical range: 0-196) (a). Analysis of these values in relation to BCT agreement conservation areas and an equivalent (matched area within bioregion) sample of unprotected sites in the landscape. Chart shows mean (±95% confidence interval) summed refugia values.

5 LANDSCAPE SCALE VALUES

5.1 MULTIDIMENSIONAL VALUE

When attempting to quantify the total value of ecological assets protected under BCT agreements, biodiversity condition represents just one component. Another two key components are quantity (i.e. area) and pressure (i.e. risk of extirpation of a particular biodiversity value). A fundamental objective of the BCT is to strategically maximise the area protected of high condition examples of the most threatened landscapes. There are multiple ways to quantify these objectives – the BCIS does just this via the definition of *Priority Investment Areas* (PIAs). Figure 11 represents the aggregation of outcome measures for all three of these components, as they apply to ecological (vegetation) communities protected by BCT agreements; using VI score to represent condition and the proportion of each community estimated to be lost in NSW since 1750 as an indicator of pressure.

Figure 11 allows for visual assessment of the extent to which BCT investment in securing land is meeting all three of these objectives simultaneously – i.e. an optimal scenario would be represented by cells clustered in the top right corner of the plot, shaded dark blue.

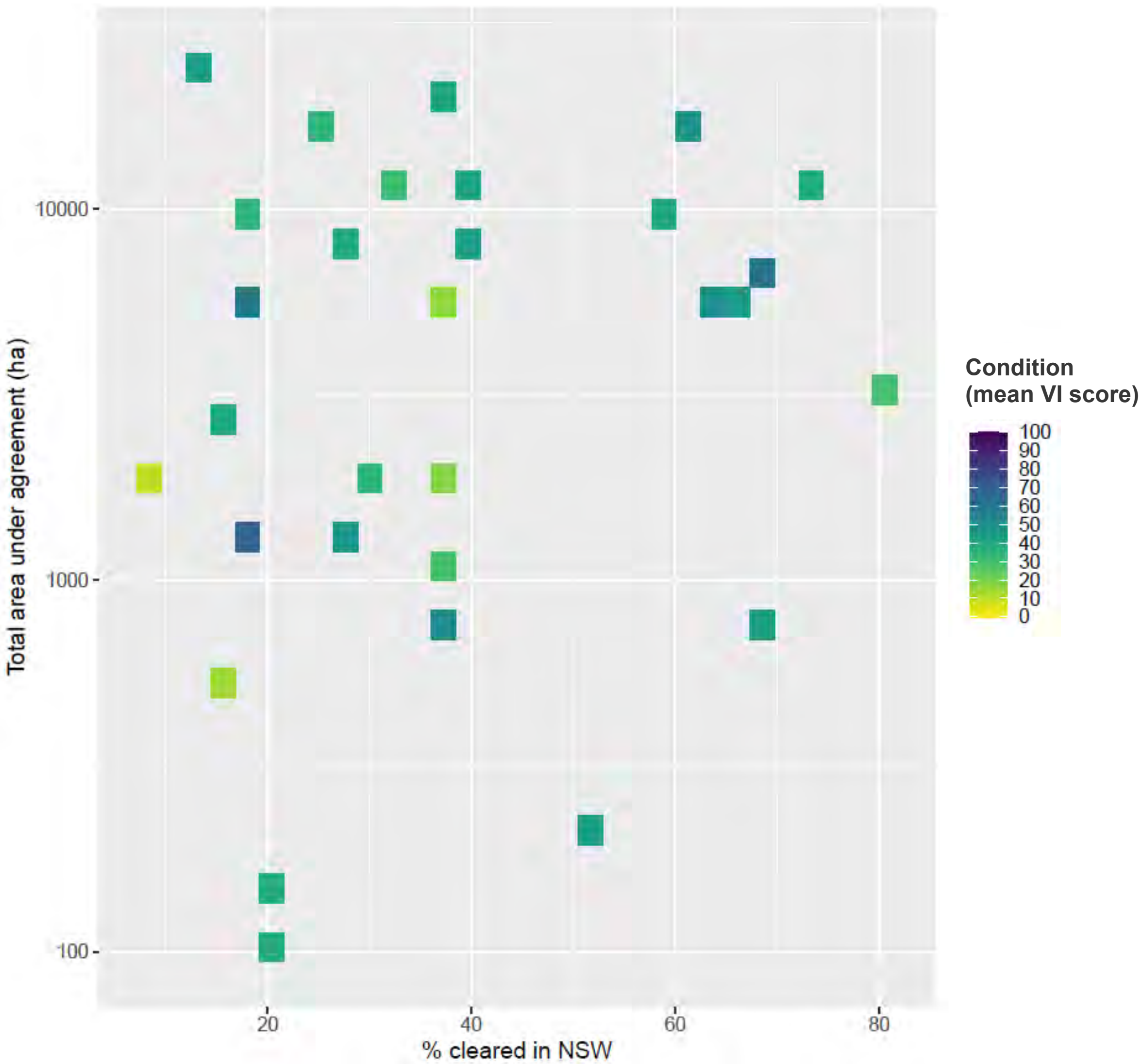


Figure 11: Total conservation area (log scale) covering ecological communities (vegetation class) under BCT agreement (on-title, offsets excluded), by proportion cleared in NSW since 1750, weighted by condition (vegetation integrity score).

5.2 COMPLEMENTARY STATE-WIDE DATA

To complement site-based biodiversity data collected under the EMM for evaluation and reporting of BCT outcomes, there are several high quality and relevant state-wide data sets developed by DPIE or collaborators. These data can be used to answer broad-scale questions about the aggregate value of biodiversity protected by BCT agreements, from different perspectives.

5.2.1 NSW Biodiversity Indicator Program

The Biodiversity Indicator Program (BIP) has developed a number of spatial models quantifying different indicators of biodiversity value at a fine scale (90m resolution) across all land area in NSW. These models can be interrogated to quantify relative values, not only for BCT agreement conservation areas, but the broader landscape, as a reference. NSW maps of all three models referred to below are presented in Appendix 2.

5.2.1.1 Ecological carrying capacity of terrestrial habitat

Ecological carrying capacity of terrestrial native vegetation (ECC) model accounts for how the generalised quality of habitats for biodiversity at each location and its connection with surrounding habitat enables biological movement such as foraging, dispersal and migration of fauna species. It is used to account for the capacity of a landscape to support its original complement of biodiversity comprised of interacting species, populations and ecosystems. ECC is defined as the ability of an area to maintain self-sustaining and interacting populations of all species naturally expected to occur there, given the habitat resources (such as food and water) and connections to other habitat needed for persistence (OEH & CSIRO 2019).

Figure 12a shows how modelled ECC varies across NSW and the part of this distribution protected by BCT agreement sites. BCT agreement conservation areas are currently protecting areas with higher ECC than typical state-wide, and when compared directly to a relevant control group – randomly selected matched area of unprotected lands – and standardising for variation in ECC within bioregion, BCT sites hold (statistically) significantly greater ECC than would be expected. This result is being driven, in particular, by the BCT targeting high quality sites within bioregions that are generally characterised by poorer quality sites (e.g. sheep-wheat belt).

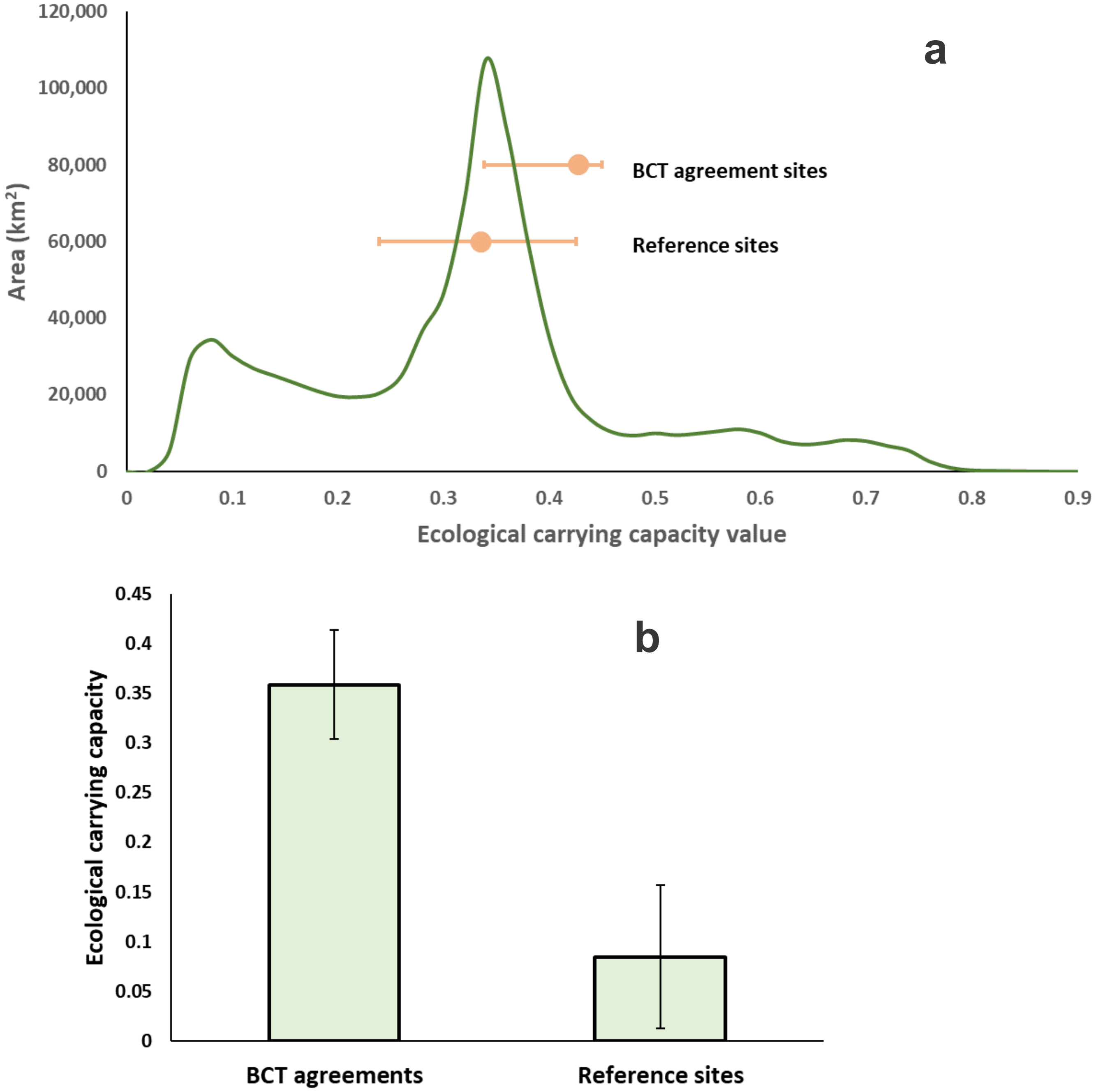


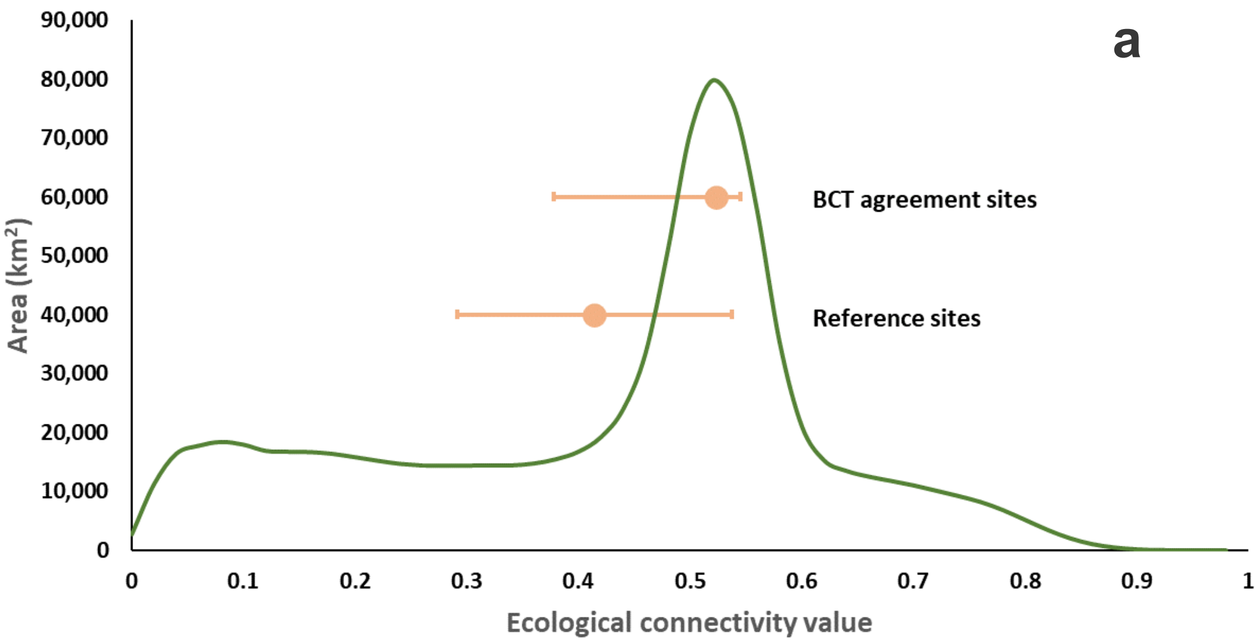
Figure 12: Distribution of ECC values by total area, for all of NSW (blue line) with area-weighted mean (±95% confidence interval) ECC value for BCT agreement (on-title, offsets excluded) sites and unprotected sites in the landscape (red circles; disregard y-axis position) (a). IBRA-standardised mean ECC value (±95% confidence interval) for BCT agreement sites and unprotected sites (t=3.33, p=0.003) (b).

5.2.1.2 Ecological connectivity of terrestrial habitat

Ecological connectivity of terrestrial native vegetation (EC) is the degree to which a landscape retains ecological functions and processes that enable biological movement (such as foraging, dispersal and migration) at a range of spatial scales. EC accounts for the generalised quality of habitats for biodiversity at each location, the fragmentation of habitat within its neighbourhood and how its position in the landscape contributes to connectivity among habitats across a region, for example, as part of a habitat corridor or as a stepping stone (OEH & CSIRO 2019).

EC is measured by combining two landscape aspects of connectivity: (i) neighbourhood context, which measures how well ecological processes can operate at a location and within its surrounding neighbourhood, and (ii) link value, which measures how well a location contributes to overall network connectivity and therefore to ecological processes operating between other locations. The resulting indicator of ecological connectivity ranges from 0 (minimum quality, disconnected habitat) to 1 (maximum quality, fully connected habitat) for an individual pixel in the landscape.

Figure 13a shows that BCT agreement sites have connectivity values generally aligned with what is typical for the wider NSW landscape. However, when controlling for bioregional effects, Figure 13b shows that, as per ECC, BCT conservation areas are protecting significantly higher quality sites than equivalent unprotected lands.



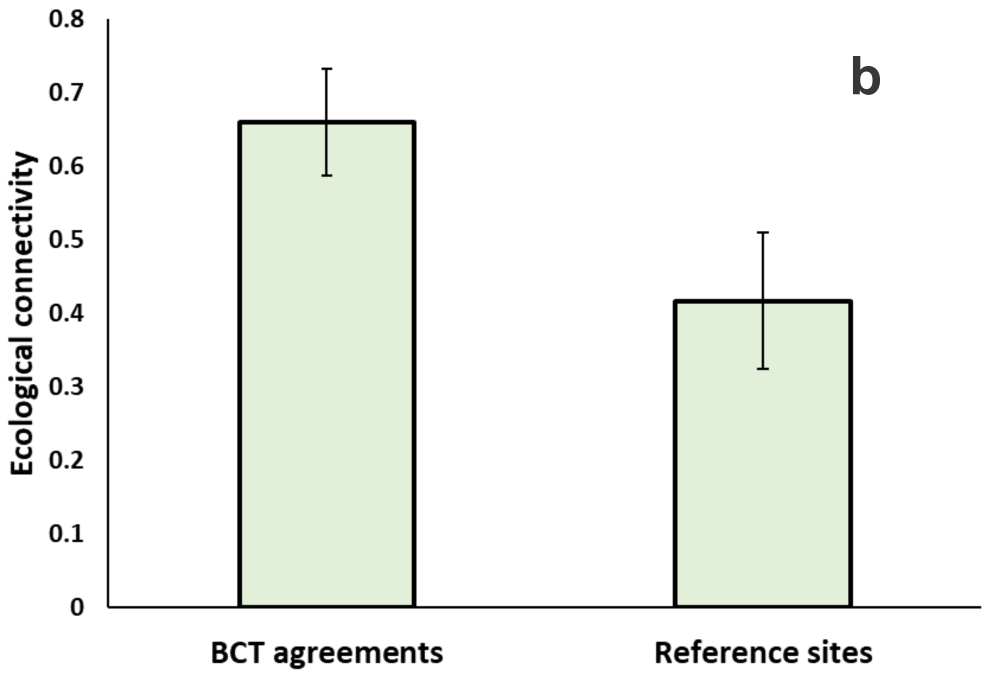


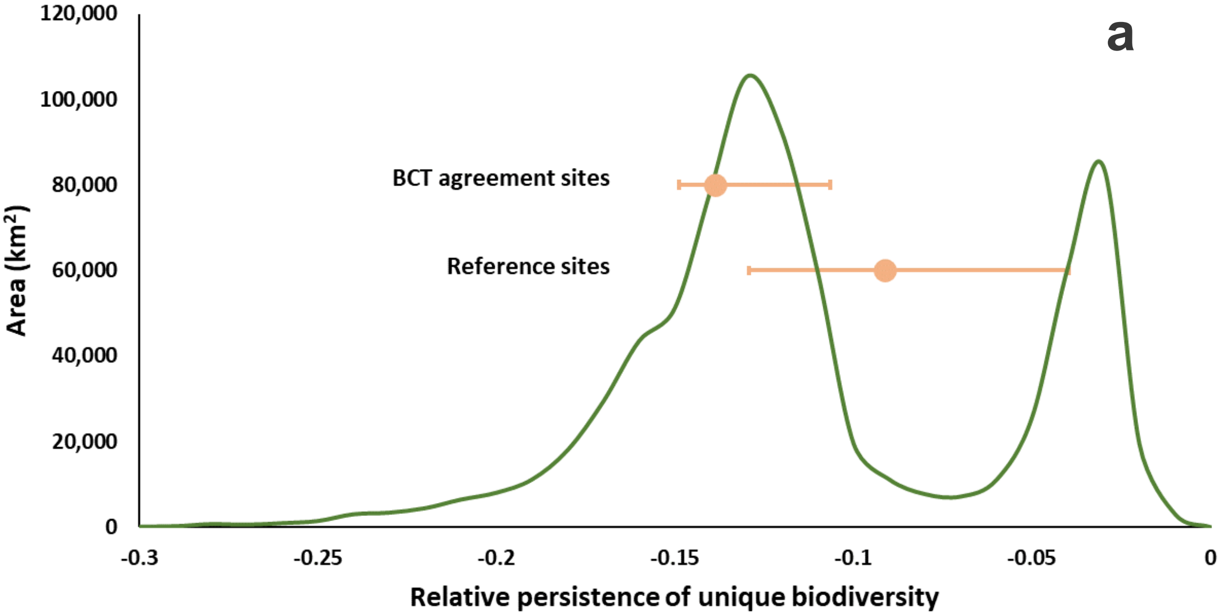
Figure 13: Distribution of ecological connectivity values by total area, for all of NSW (blue line) with area-weighted mean (±95% confidence interval) EC value for BCT agreement (on-title, offsets excluded) sites and unprotected sites in the landscape (red circles; disregard y-axis position) (a). IBRA-standardised mean EC value (±95% confidence interval) for BCT agreement sites and unprotected sites (t=6.42, p<0.001) (b).

5.2.1.3 Persistence of all ecosystems (including undiscovered species)

This indicator assesses the expected persistence of species diversity as a function of the proportion of habitat remaining in ecosystems given the remotely sensed change in the ecological condition and carrying capacity of habitat. Known and unknown species diversity is estimated using a Generalised Dissimilarity Model (GDM) – a statistical technique for analysing and predicting patterns of change in species composition between sites across whole regions (Ferrier et al. 2007). GDM employs best-available data from systematic surveys of species co-occurrences for a biological group (i.e. from Bionet sightings data), typically related by taxonomy, such as plants, mammals, reptiles, insects. These data are used to fit a statistical model relating the similarity in species composition between pairs of locations to mapped environmental predictors (climate, terrain, soil etc.). The compositional similarity in species between sites, or the proportion of species shared, varies from 1 (all species are shared) to 0 (all species are different).

Each pixel (90m) in the landscape is assigned a value reflecting its state-wide contribution to the amount of unique biodiversity projected to persist, for the biological group of interest, when the cell is viewed in isolation. It is calculated as the amount of biodiversity lost relative to the state-wide indicator immediately following hypothetical removal of all natural habitat in that pixel.

Figure 14a shows how this indicator varies across NSW (smaller negative values [closer to zero] represent higher biodiversity value). BCT agreement sites approximate a typical site from a state-wide perspective, however, Figure 14b shows that equivalent unprotected lands, when controlling for bioregional effects, have higher values than BCT agreements. This may be an artefact of the way the indicator is calculated and how the data have been summarised – i.e. larger BCT conservation areas in the west of the state may have smaller mean values which are (area-) weighted more, compared to single pixels sampled to generate the unprotected lands sample. Future iterations of this analysis should consider complementarity of site-based diversity in the context of a bioregion (as opposed to state-wide), which requires manipulation of the model by the custodians (BIP team).



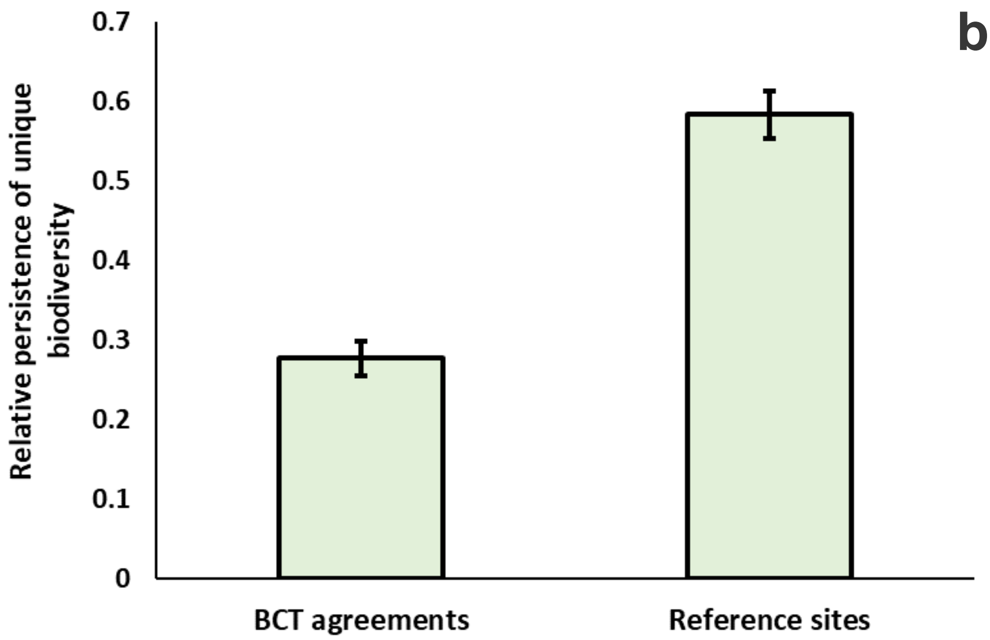
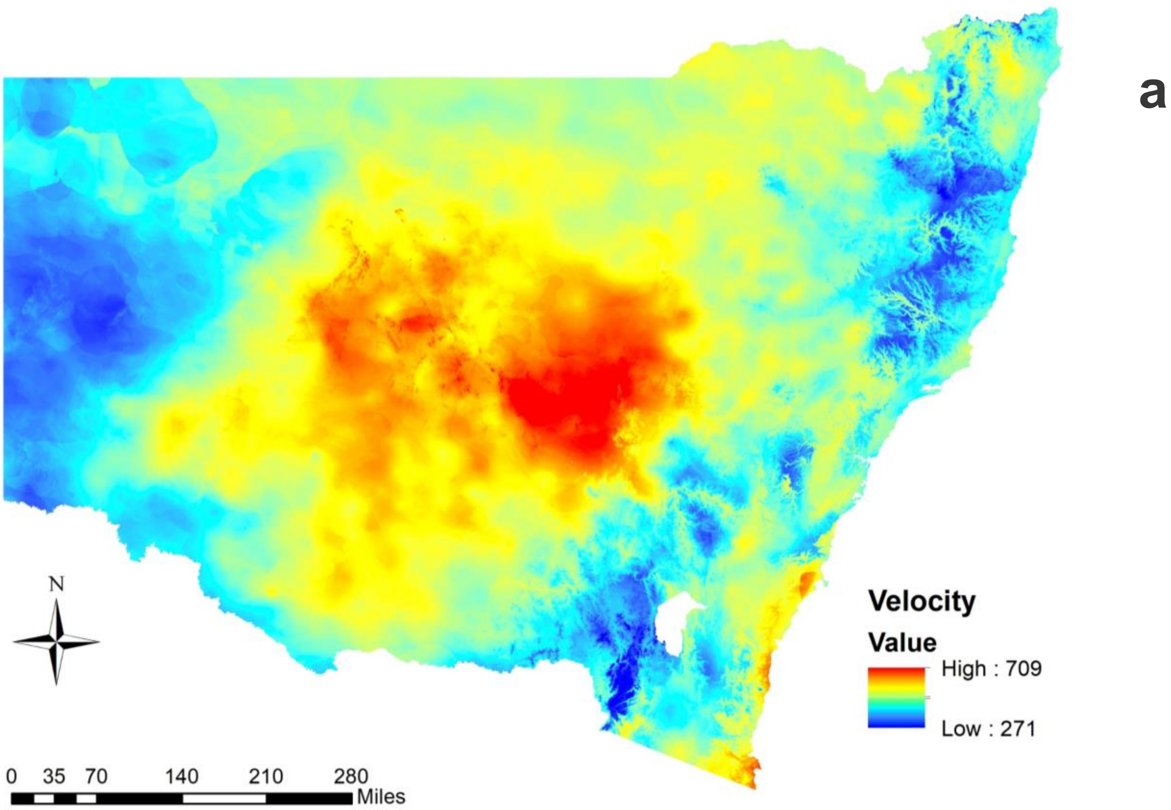


Figure 14: Distribution of modelled values for the persistence of unique biodiversity, by total area, for all of NSW (blue line) with area-weighted mean (±95% confidence interval) EC value for BCT agreement (on-title, offsets excluded) sites and unprotected sites in the landscape (red circles; disregard y-axis position) (a). IBRA-standardised mean value (±95% confidence interval) for BCT agreement sites and unprotected sites (t=10.23, p<0.001) (b).

6 CLIMATE CHANGE IMPACTS

Under the DPE Biodiversity Impacts and Adaptation Project several state-wide spatial products have been developed which can be used to assess climate risk to biodiversity assets protected by BCT agreements. One of these uses a GDM similar to that described in Section 4.2.1.3 and intersects down-scaled future climate scenarios with respect to a suite of different environmental variables (e.g. temperature, rainfall). The model then predicts impacts in terms of proportional change in species composition at each site between the present and 2070. This can be interpreted as the change in, or level of impact to, the climatic capacity of each location to continue supporting its existing composition of species.

Figure 15a shows how this modelled value varies across NSW, with the sheep-wheat belt at particularly high risk. Figure 15b shows that BCT agreement sites have significantly lower values than the landscape average for private lands across the state, while still being relatively high – with a predicted 44% change in species composition. This can be interpreted as a risk to ecosystems under BCT management, but also an opportunity for net biodiversity improvement, if management of these sits is targeted towards improved resilience.



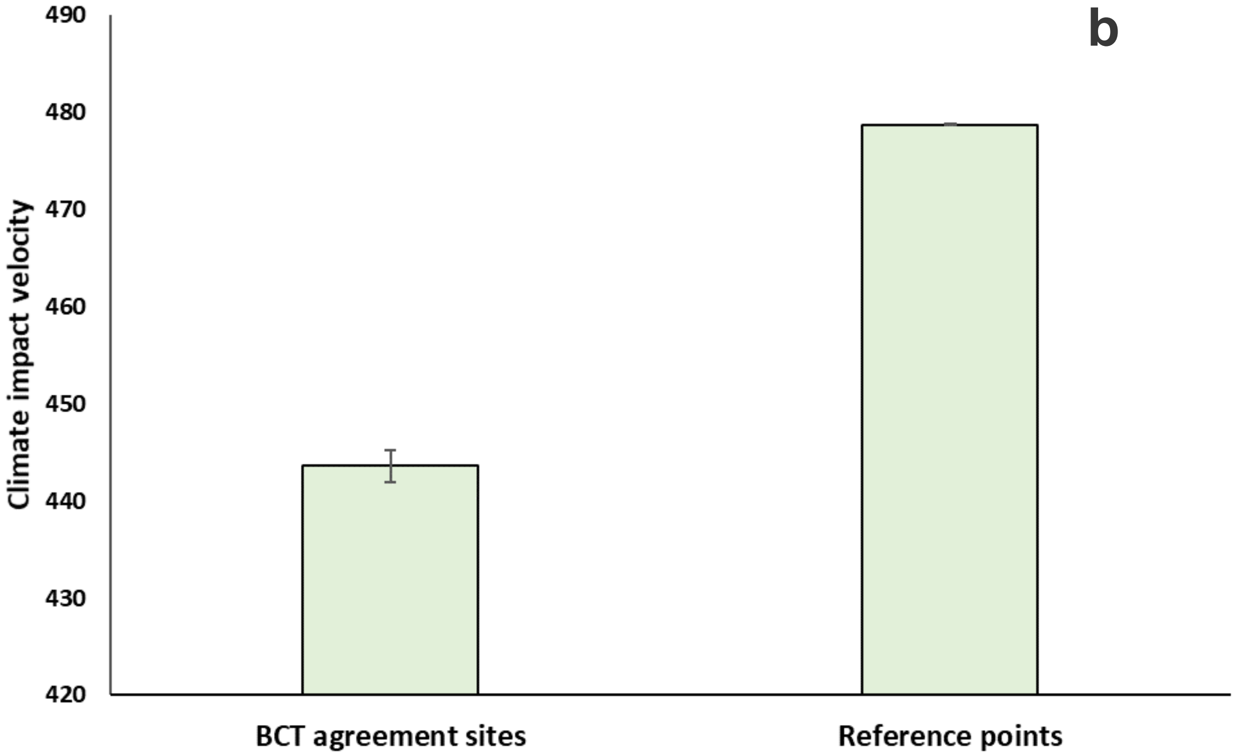


Figure 15: Predicted velocity of climate change impacts, as estimated proportional change in species composition per site (90m pixel). Map of predicted values for NSW (a) and mean (± standard error) values for BCT agreement sites and a matched sample of reference sites on private land.

7 QUANTIFYING AVOIDED LOSS VALUE

An additional consideration, crucial to rigorous evaluation of any investment in conservation – particularly for protected area networks – is counterfactual scenarios (Bull et al. 2020; Pressey et al. 2021). Counterfactual scenarios refer to the likely outcomes in the absence of intervention – i.e. in this context, understanding the likely outcome for biodiversity values on an agreement site, were the agreement not in place. The true value of any given BCT agreement site (in terms of conservation impact) should be quantified as the marginal difference in biodiversity value between the observed outcomes (e.g. site-based monitoring of vegetation integrity) and the appropriate counterfactual(s).

Achieving this typically requires a measure of avoided loss, which in the BCT context, comes primarily from two sources:

1. gradual decline in biodiversity condition due to a lack of active management (e.g. pest and weed control); and
2. risk of total loss or degradation of biodiversity due to anthropogenic disturbance (e.g. clearing native vegetation).

The first will be measured via site-based monitoring at control (or ‘business as usual’) sites, and the second is the focus of a current research project. This project, partnering with RMIT, uses satellite data on woody vegetation loss and various data sets likely to relate to clearing risk, to build a predictive model of likelihood of biodiversity loss which can also be used to match BCT agreement sites with equivalent ‘control’ sites in the landscape via desktop. These control sites can then be monitored remotely over time to assess actual loss of woody vegetation, which can be assumed to be a valid surrogate for avoided loss at matched agreement sites. Figure 16 shows a sample of a preliminary model output.

Based on results from the pilot project, focusing on two bioregions (South West Slopes and North Coast), and estimates applied to sites in other regions based on the available data, the cumulative avoided loss of biodiversity (avoided clearing of woody native vegetation) attributable to BCT agreements (*N=1267;* excludes offset and Wildlife Refuge sites) over their respective lives is **8,808 hectares**.

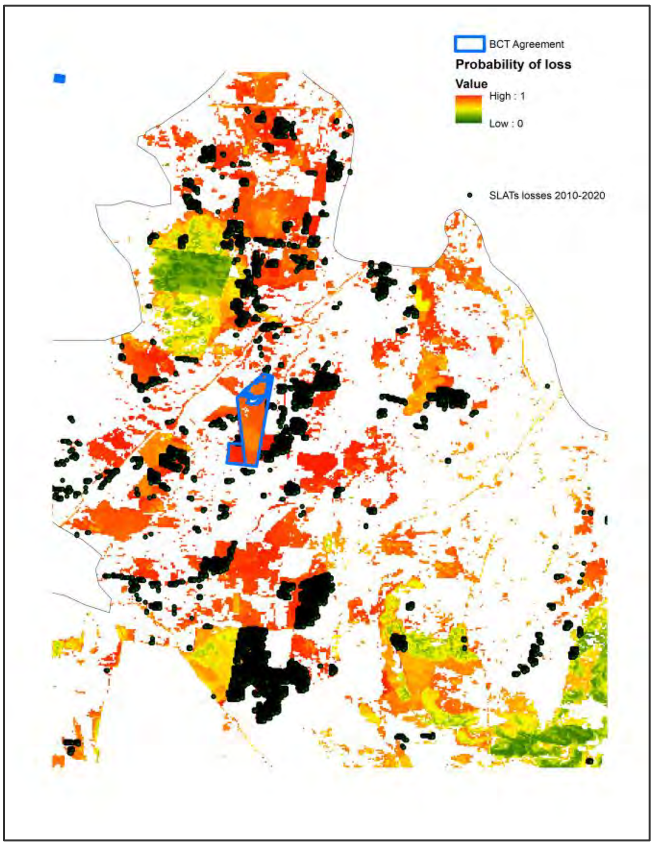


Figure 16: Mapped risk of biodiversity loss based on a predictive model of native vegetation clearing risk, used to quantity avoided loss for BCT agreement sites.

8 BIODIVERSITY CONDITION INDEX

A rigorous and useful indicator of ecological integrity – also one that aligns with the purpose of the *Biodiversity Conservation Act* with respect to a healthy, productive and resilient environment – should incorporate the critical elements of abundance, condition and diversity (Soto-Navarro *et al.* 2021; Nicholson *et al.* 2021). In this context, these elements should be interpreted as:

- *abundance* – area of ecological communities, size and distribution of species populations, both absolute, and relative to critical thresholds (e.g. species extinction, ecosystem collapse)
- *condition* – composition, structure and function of ecological communities relative to reference state, and viability of species populations, at multiple scales – i.e. patch condition and landscape connectivity
- *diversity* – variation at the three levels of biological organisation; ecosystems, species and genes (in particular, as it relates to the maintenance of adaptive capacity)

If the index (in line with other BCT KPIs), is also designed to provide a meaningful measure of return on investment, then it must incorporate calculation of the marginal value relative to appropriate counterfactuals, as opposed to simply the absolute outcome. It should also consider current, as well as future value, particularly with reference to contribution to climate adaptation.

8.1 AGGREGATE ECOSYSTEM INTEGRITY VALUE

KPI = *area protected under agreement * vegetation integrity score * irreplaceability * avoided loss weighting*

Element	Data source	Calculation Details
area	BCT agreements layer	Total area of all on-title agreements excluding offset sites (ha)
vegetation integrity score	EMM floristic data	Mean vegetation integrity score across all conservation areas, assigning mean score by stratification group to unsampled sites (*0.01)
irreplaceability	Vegetation classification mapping (pre-European and current)	Proportion of relevant vegetation class lost in NSW since 1750
avoided loss	Counterfactual project (RMIT partnership)	Mean cumulative proportion of woody vegetation loss estimated to have been avoided over the life of the agreement.
Q4 2022 KPI value: 823		

This value can be interpreted as equivalent to hectares of benchmark (pristine) vegetation, of which 100% of its extent outside of conservation areas in NSW has been lost, and which would have had a 100% probability of being lost were it not under agreement (i.e. 100% avoided loss value).

9 PROSPECTIVE ANALYSES AND REPORTING

The EMM has collected and will increasingly collect large volumes of different types of data, capable of informing a variety of analyses at different scales to answer a variety of ecological questions. This report is not intended to be exhaustive with respect to these potential analyses, rather it provides a high-level summary of the key data sets and analyses at the program/state scale.

As various research collaborations and partnerships (e.g. PhD projects supported by the BCT) deliver outcomes of the next 12-24 months, future versions of this report will include analysis and evaluation using additional data sets and metrics, including:

- soil chemistry and microbial biodiversity;
- different derived characteristics of species composition (i.e. beyond richness), such as functional and phylogenetic diversity;
- more comprehensive assessment of threatened species habitat condition and suitability;
- comprehensive assessment of avoided loss values at a state-wide scale; and
- distribution and abundance of fauna and their habitats on BCT agreement sites.

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APPENDIX 1: TECHNICAL SPECIFICATIONS – DATA AND ANALYSES

Figure / Table	Data source	Analysis	Reference(s)
Figure 3	EMM vegetation integrity plots; BAM vegetation condition benchmarks cover and richness raw data (https://datasets.seed.nsw.gov.au/dataset/vegetation-condition-benchmarks-cover-and-richness-raw-data-v1-2)	Reference sites - modified VI score calculated as the geometric mean of structure and composition condition scores (function attribute data not available)	Somerville *et al.* (2019)
Figure 4	EMM vegetation integrity plots; BAM vegetation condition benchmarks cover and richness raw data (https://datasets.seed.nsw.gov.au/dataset/vegetation-condition-benchmarks-cover-and-richness-raw-data-v1-2)	Sum of growth form group composition data (richness)	Somerville *et al.* (2019)
Figure 5	EMM vegetation integrity plots	Predicted gain in VI over time under management and decline in VI over time without management based on relevant BAM equations	EMM; DPIE (2020)
Figure 6	EMM vegetation integrity plots and Bionet Flora Survey plots (species observation data)	FVS calculated using method and bespoke tool developed by R. Rehwinkel, for target bioregions. Taxonomy follows NSW Bionet.	Rehwinkel (2015)

Figure 7	EMM soil surface condition quadrats; UNSW soil study plots (D. Eldridge)	Soil surface condition score and constituent metrics calculated as per LFA method by Tongway and Hindley (2004)	Tongway and Hindley (2004)
Figure 8	BAM vegetation condition benchmarks stems raw data (https://datasets.seed.nsw.gov.au/dataset/vegetation-condition-benchmarks-stems-raw-data-v1-2)	Models for comparison built using BAM benchmark stems raw data for two relevant vegetation formations, assuming a negative exponential (2) function, based on Enquist & Niklas (2001).	Capararo *et al.* (2019)
Figure 9	EMM vegetation integrity plots; modelled koala habitat suitability from NSW Koala Habitat Information Base (KHIB)	EMM vegetation integrity plots intersected with 'suitable' koala habitat. Habitat suitability model predicts the spatial distribution of potential koala habitat across NSW using 7 regional models containing a value between 0 and 1 (with 1 the highest probability). A statewide layer was developed by combining the 7 regional models into one model within ArcPro by reclassifying the grids were cell values >0.35.	Koala habitat information base (https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Animals-and-plants/Threatened-species/koala-habitat-information-base-technical-guide-190534.pdf)
Figure 10	Habitat suitability for threatened species under future climates (SoS)	Consensus models (value of 0-4 dependent on number of GCMs above threshold for 2070 suitability) summed across 49 species (SoS *Landscape species*)	Beaumont *et al.* (2019); Drielsma & Ferrier (2009)
Figure 11	Condition – EMM vegetation integrity plots; Fractional loss – ENSW	Fractional loss (% cleared since 1750) estimated for vegetation classes outside the ENSW mapped area using NSW	ENSW PCT mapping

	PCT mapping (1750 and current); Area – BCT agreements layer	SVTM and *nibble* tool (ArcGIS) assigning Keith Class to 'cleared' pixels via nearest neighbour to generate estimated 1750 data set	(DPIE 2020); NSW SVTM
Figure 12	Biodiversity Indicator Program (https://datasets.seed.nsw.gov.au/dataset/ecological-carrying-capacity-of-terrestrial-habitat)	Summary value for BCT agreement sites was calculated by first assigning a value for each site equal to the mean of all intersecting pixels. A weighted (BCT agreement site area) mean was then calculated for each bioregion, which was then standardised using the normal cumulative distribution function with mean and standard deviation taken from the full distribution of model values for the respective bioregion. Finally, bioregions were aggregated via an arithmetic mean and 95% confidence interval (incorporating dis-aggregated variances). Summary value for background 'unprotected' lands was calculated by randomly selecting pixels with a summed area equivalent to the total area of agreement sites within each bioregion. The mean value of these pixels for each bioregion was standardised using the same method as above, and then combined as above.	OEH & CSIRO (2019)
Figure 13	Biodiversity Indicator Program (https://datasets.seed.nsw.gov.au/dataset/ecological-connectivity-of-terrestrial-habitat)	As above, for ecological connectivity of terrestrial habitat layer.	OEH & CSIRO (2019)
Figure 14	Biodiversity Indicator Program (https://datasets.seed.nsw.gov.au/dataset/persistence-of-ecosystems-vascular-plants)	As above, for persistence of ecosystems (including undiscovered species) layer.	OEH & CSIRO (2019)

Figure 15	Modelled climate impact on future species composition from DPE Biodiversity Impacts and Adaptation Project (Stage 2)	Modelled capacity for the landscape to support current species composition, measured as predicted change in species composition 2000-2070 via a generalised dissimilarity model (i.e. velocity of change)	Biodiversity Impacts and Adaptation Project (Stage II) NSW and ACT Regional Climate Modelling Project (2016)
Figure 16	BCT-RMIT research partnership project: Estimating counterfactuals to quantify avoid loss	Preliminary output data based on spatial model focused on NSW South West Slopes case study region. Model outputs estimate avoided loss associated with each agreement site by matching agreement sites with a group of 'control' sites in the landscape, then quantifying woody vegetation loss across those control sites over a specified timeframe, using available satellite data (i.e. SLATS).	Full data set not yet available.

APPENDIX 2: NSW BIODIVERSITY INDICATOR PROGRAM PRODUCTS – NSW MAPS

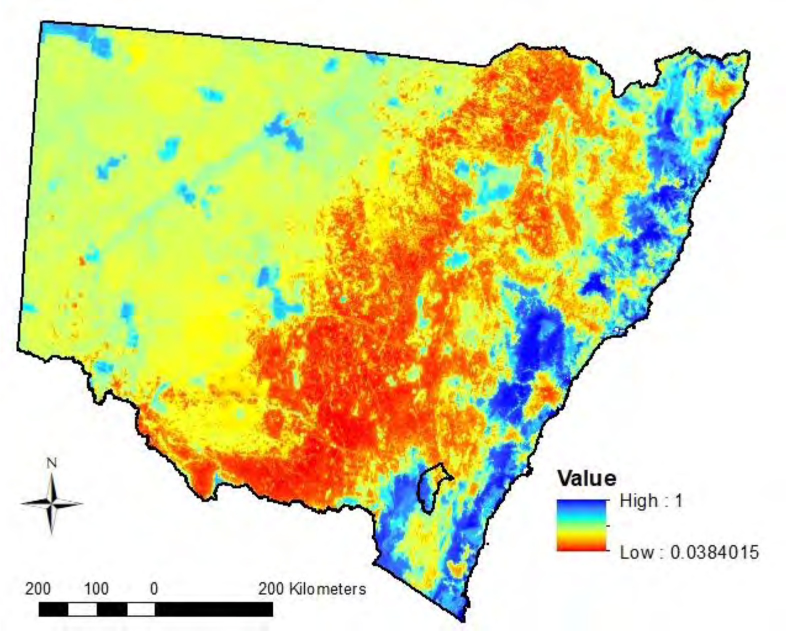

Figure A: Mapped Ecological Carrying Capacity of Terrestrial Habitat for NSW

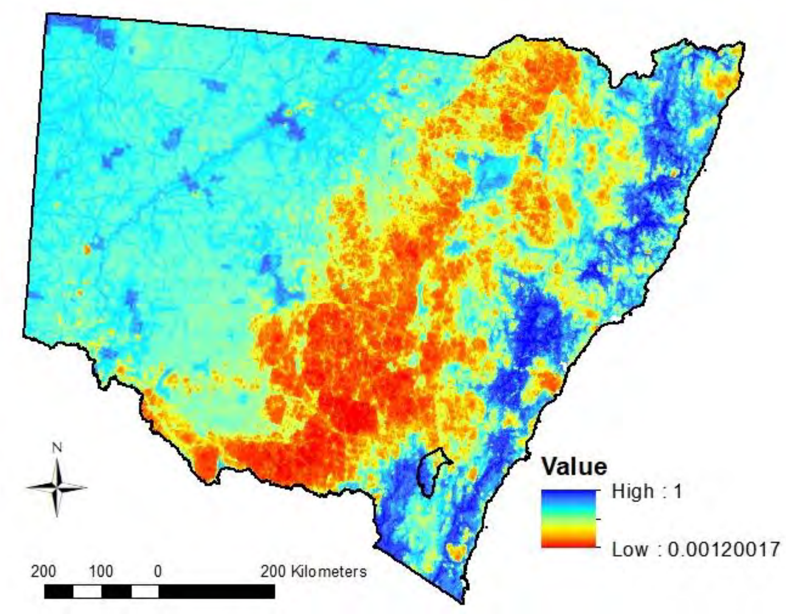

Figure B: Mapped Ecological Connectivity of Terrestrial Habitat for NSW

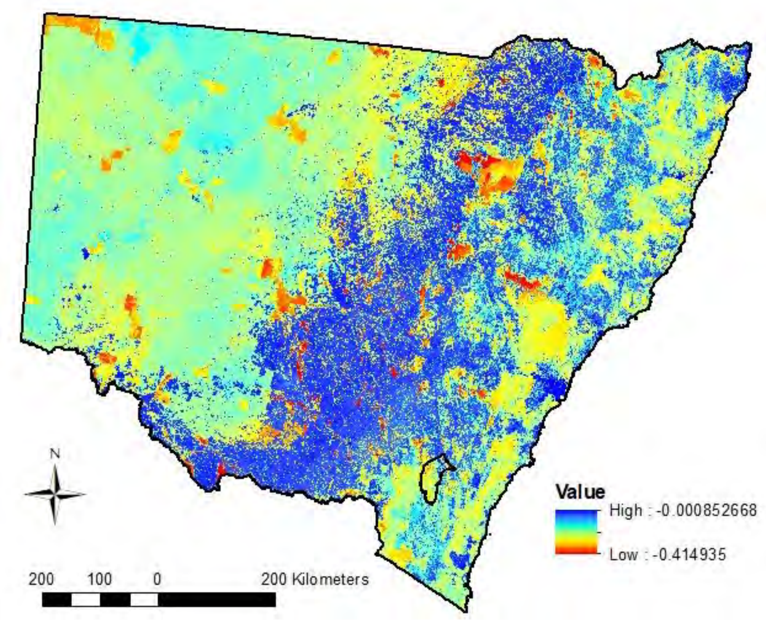

Figure C: Mapped persistence of all ecosystems (including undiscovered species) for NSW